Haywood County

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LANDFILL NO. 6
CLOSURE PLAN FOR
AREAS F, G, AND H
CANTON, NORTH CAROLINA

CHAMPION INTERNATIONAL CORP.

CANTON, NORTH CAROLINA

SEPTEMBER 12, 1997

Prepared by

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SPECIFICATIONS

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SECTION 02731

GEOTEXTILES

1. GENERAL

1.1 RELATED DOCUMENTS

Drawings and general provisions of Contract, including General and Supplementary Conditions and Division-1 Specification sections, apply to work of section.

1.2 DESCRIPTION OF WORK

Extent of geotextile work is indicated on drawings and schedules, and by requirements of this section.

1.3 QUALIFICATIONS AND WARRANTIES

1.3.1 Manufacturer's Qualifications: Firms regularly engaged in manufacture of products of types, materials, and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years.

1.3.2 Installer's Qualifications: Firms regularly engaged in installation of products of types, materials, and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years.

1.4 QUALITY CONTROL DOCUMENTATION

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

1. Written certification that minimum average roll values given in the specification are guaranteed by the Manufacturer.

2. 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.

3. 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 testes. 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. Apparent Opening Size

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 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

1.4.2 Product Review: The Owner's Representative 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.

2. PRODUCTS

2.1 GEOTEXTILE:

2.1.1 General: Provide geotextiles as indicated on Drawings.

2.1.2 Woven Geotextile: The geotextile used in construction of riprap ditches and/or riprap spillways shall be Mirafi 700X, Amoco 1199, as manufactured by Nicolon Mirafi group and

Amoco Fabrics and Fibers Company, respectively, or an approved equal except as shown on the contract drawings.

Test Method	Minimum Permissible Value
Puncture (ASTM D 4833-88)	135 lb
Trapezoidal tear strength (ASTM D-4533)	100x60 lbs
Grab tensile/elongation (ASTM D-4632-91)	370x250/15%
Mullen burst strength (ASTM D-3786)	480 psi
Apparent open size (AOS) (ASTM D-4751)	70 U.S. Standard sieve
Permittivity (ASTM D-4491-92)	18 gal/min/ft^2

2.1.3 Non-Woven Geotextile: 6 oz/sy - The geotextile attached to each side of the geonet for Areas F and G shall be Amoco 4506, or meet the minimum requirements listed below:

PROPERTY	TEST PROCEDURE	MINIMUM VALUE[1]
Weight	ASTM D 5261	6 oz/sy
Grab Strength	ASTM D 4632	150 lbs
Tear Strength	ASTM D 4533	65 lbs
Mullen Burst	ASTM D 3786	350 psi
Puncture Resistance	ASTM D 4833	90 lbs
AOS	ASTM D 4751	70 U.S Sieve

(1) Values in weaker principle direction. All minimum values represent minimum average roll values (i.e. test results from any sampled roll in a lot, tested in accordance with ASTM D 4759-88 shall meet or exceed the minimum values listed.)

2.1.4 Non-Woven Geotextile: 8 oz/sy - The geotextile attached to each side of the geonet for Area H shall be Amoco 4508, or meet the minimum requirements listed below:

PROPERTY	TEST PROCEDURE	MINIMUM VALUE[1]
Weight	ASTM D 5261	8 oz/sy
Grab Strength	ASTM D 4632	203 lbs
Tear Strength	ASTM D 4533	80 lbs
Mullen Burst	ASTM D 3786	450 psi
Puncture Resistance	ASTM D 4833	130 lbs
AOS	ASTM D 4751	100 U.S Sieve

3.0 QUALITY ASSURANCE

3.1 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 Owner's Representative 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 assure 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 assure that no potentially harmful foreign objects, such as needles, are present.

3.2 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 inches (75 mm) prior to seaming. In general, no horizontal seams shall be allowed on sideslopes (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 Owner's Representative.

The Installer shall pay particular attention at seams to assure 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.

3.3 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 percent 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 Owner's Representative shall observe any repair and report any noncompliance with the above requirements in writing to the Project Manager.

3.4 GEOTEXTILE PROTECTION

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

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 Owner's Representative, all lifts of soil material shall be in conformance with the guidelines given in Section 02200 and 02771-4.7.1.

END OF SECTION

SECTION 02741

GEONETS

1. GENERAL

1.1 RELATED DOCUMENTS

Drawings and general provisions of Contract, including General and Supplementary Conditions and Division-1 Specification sections, apply to work of section.

1.2 DESCRIPTION OF WORK

Extent of geonet work is indicated on drawings and schedules, and by requirements of this section.

1.3 QUALIFICATIONS AND WARRANTIES

1.3.1 Manufacturer's Qualifications: Firms regularly engaged in manufacture of products of types, materials, and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years.

1.3.2 Installer's Qualifications: Firms regularly engaged in installation of products of types, materials, and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years.

1.4 QUALITY CONTROL DOCUMENTATION

1.4.1 Product Data: 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 specifications.

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 percent 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 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 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. Tensile strength
    c. Transmissivity
    d. Carbon black content

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

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

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

The Owner's Representative shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Owner's Representative 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 specifications.

2. PRODUCTS

2.1 GEONET

2.1.1 General: Provide geonet as indicated on Drawings.

2.1.2 Geonet: The geonet within the drainage system shall be GSE Fabrinet or meet the minimum requirements listed below:

Property	Qualifier	Test Method	Spec. Value	Unit
Density	Minimum	ASTM D 1505	0.93	g/cc
Carbon Black	Range	ASTM D 1603	2 - 3	percentage
Tensile Strength	Minimum	ASTM D 751	50 MD/25XD	ppi
Transmissivity	Minimum	ASTM D 4716	$3x10^{-4}$ *	cm/sec

Notes:

MD machine direction
XD transverse direction
* At 0.02 hydraulic gradient, 20,000 psf compressive load

3. QUALITY ASSURANCE

3.1 GEONET DEPLOYMENT

During shipment and storage, the geonet shall be protected from inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions.

The Owner's Representative 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 geonet in such a manner as to assure they are not damaged in any way, and the following shall be complied with:

1. On slopes, the geonet shall be securely anchored and then rolled down the slope in such a manner as to continually keep the geonet sheet in tension.

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. Geonets shall be cut using a 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 geonets.

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

5. During placement of geonets, care shall be taken not to entrap, in or beneath the geonet, 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 geonet shall be carried out over the entire surface, after installation, to assure that no potentially harmful foreign objects are present.

The independent laboratory shall note any noncompliance and report it to the Project Manager.

3.2 SEAMING PROCEDURES

Geonets shall be overlapped a minimum of 4 inches (75 mm) prior to tying. In general, no horizontal seams shall be allowed on sideslopes (i.e. seams shall be along, not across, the slope), except as part of a patch.

3.3 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 inches (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 feet (1.5 m) along the slope, every 6 inches (0.15 m) in the anchor trench, and every 6 inches (0.15 m) along end-to-end seams on the base of the landfill.

5. In general, no horizontal seams shall be allowed on sideslopes.

The Owner's Representative shall note any noncompliance and report it to the Project Manager.

3.4 DEFECTS AND REPAIRS

Any holes or tears in the geonet shall be repaired by placing a patch extending 1 foot (0.3 m) beyond the edges of the hole or tear. The patch shall be secured to the original geonet by tying every 6 inches (0.15 m). Tying devices shall be as indicated in Section 3.4. If the hole or tear width across the roll is more than 50 percent 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 3.4.

2. On sideslopes, the damaged geonet shall be removed and replaced.

3.5 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 assure:

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 02200 and 02771-4.7.1.

Any noncompliance shall be noted by the Owner's Representative and reported to the Project Manager.

END OF SECTION

SECTION 02771

GEOMEMBRANE LINER (POLYVINYL CHLORIDE (PVC))

1. GENERAL

1.1 RELATED DOCUMENTS

Drawings and general provisions of Contract, including General and Supplementary Conditions and Division-1 Specification sections, apply to work of section.

1.2 DESCRIPTION OF WORK

Extent of flexible membrane lining work is shown on drawings.

Refer to other Division-2 sections for earthwork related to lining work.

1.3 QUALITY ASSURANCE, QUALIFICATIONS, AND WARRANTIES

1.3.1 Manufacturer's Experience: The manufacturer supplying the membrane shall satisfactorily demonstrate previous experience by letter of certification. Certification shall indicate that the manufacturer has produced, and has in service in similar applications for a period of not less than one (1) year, at least two (2) million sq ft of PVC material meeting these Specifications.

1.3.2 Installer's Experience: The Installer proposing to install the lining shall satisfactorily demonstrate previous experience by letter of certification. Certification shall indicate the Installer's successful past installation of at least 2,000,000 sq ft of PVC geomembrane.

Installation shall be performed under the direction of a single installation supervisor who shall remain on site and be in responsible charge throughout the liner installation, including subgrade acceptance, liner layout, seaming, testing and repairs, and all other activities contracted for with the Installer. The installation supervisor shall have supervised the installation of at least 2,000,000 sf of PVC geomembrane. Actual seaming shall be performed under the direction of a master seamer who may be the same person as the installation supervisor, and who has a minimum of 1,000,000 sf PVC geomembrane seaming experience using the same type of seaming apparatus as that specified in this project. The installation supervisor or master seamer must be on site whenever seaming is being performed.

1.3.3 Manufacturer's Guarantee: The manufacturer of the membrane liner shall enter into agreement with the Owner guaranteeing the membrane as follows:

The manufacturer warrants the PVC liner which is manufactured, sold as first quality, and installed with technical assistance and/or by an approved installation contractor to be (1) furnished free of manufacturing defects in workmanship or material for a period of one year from the time of delivery with the basis for judgment of defects being the applicable product specifications in effect at the time the order was placed unless modified by mutual written agreement; (2) shall not develop cracks/holes which go completely through the membrane due to the effects of normal service for a period of twenty (20) years from the date of delivery. "Normal service" does not include physical damage caused by acts of God, casualty, or catastrophe such as (but not limited to) earthquakes, fire, explosion, floods, lightning, piercing hail, tornadoes, corrosive air pollution, mechanical abuse by machinery, equipment, people or animals, or excessive flexures, pressures or stress from any source other than faulty installation, and (3) immune to chemical attack and degradation by chemicals, specified in the manufacturer's literature, as compatible with, and as not having an adverse effect on the membrane; and (4) immune to chemicals tested by the manufacturer for the Owner.

Should defects or weathering degradation within the scope of the above warranty occur, the manufacturer shall refund to the purchaser-user the pro-rata part for the unexpired term of the warranty of the purchaser-user's original cost of such product, or will supply repair or replacement materials at the then-current price. In the event the manufacturer supplies repair or replacement materials, against the then-current price, the manufacturer will credit the lesser of (1) the pro-rata part of the original sales price of the material so repaired or replaced for the unelapsed period of the warranty, or (2) the pro-rata part of the then-current price of the material so repaired or replaced to the unelapsed period of the warranty. The warranty shall continue in effect on the repaired or replaced material for the unelapsed term of the original warranty. To enable the manufacturer's technical staff to properly determine the cause of any alleged defect and to take appropriate steps to effect timely corrective measures if such defect is within the warranty, any claim for alleged breach of warranty will be made and presented in writing to manufacturer and the installing Contractor within thirty (30) days after the alleged defect was first noticed.

1.4 QUALITY CONTROL DOCUMENTATION

1.4.1 Product Data: Prior to the installation of any geomembrane, the manufacturer, fabricator, or installer shall provide the Owner's Representative with the following information:

1. Copies of the quality control certificates issued by the resin supplier.

2. Reports on quality control tests conducted by the Manufacturer to verify that the geomembrane manufactured for the project meets the project specifications.

3. A list of the materials which comprise the geomembrane, expressed in the following categories as percent by weight: polyvinyl chloride resin, plasticizer(s), fillers, and additives.

4. Reports on quality control tests conducted by the fabricator to verify that the geomembrane fabricated for the project meets the project specifications.

5. Written certification that minimum values given in the specification are guaranteed by the manufacturer or fabricator.

6. 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. Thickness
   c. Tensile properties

   These quality control tests shall be performed in accordance with the test methods specified in the specifications.

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

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

The Fabricator shall identify all panels of geomembrane with the following:

1. Fabricator's name
2. Product identification
3. Thickness
4. Roll numbers included in the panel
5. Panel dimensions and placement identifier

1.4.2 Product Review: The Owner's Representative 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 for all rolls and panels, and that each certificate identifies the rolls related to it.

4. Panel packages are appropriately labeled.

5. Certified minimum properties meet the specifications.

2. PRODUCTS

2.1 POLYVINYL CHLORIDE (PVC) MEMBRANE

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

2.1.2 Physical Characteristics: The PVC materials shall have the following physical characteristics:

Property	Qualifier	Test Method	Spec Value	Unit
PVC GEOMEMBRANE PROPERTIES				
Thickness	Nominal	-	40	mils
Thickness	minimum	ASTM D 1593, (para.8.1.3)	38	mils
Specific Gravity	minimum	ASTM D 792 Method A	1.2	g/cc
Tensile Properties				
Break strength	minimum	ASTM D 882 Method A or B	92	lbs/in.
Break elongation	minimum	ASTM D 882 Method A or B	350	percent
Modulus @ 100% Elongation	minimum	ASTM D 882 Method A or B	36	lbs/in.
Tear Resistance	minimum	ASTM D 1004, Die C	10	lbs
Low Temperature	maximum	ASTM D 1790	-29	degrees C
Dimensional Stability	maximum change	ASTM D 1204[2]	5	percent
Water Extraction	maximum	ASTM D 3083[1]	-0.35	percent
Volatile Loss	maximum	ASTM D 1203 Method A	0.5	percent
Resistance to Soil Burial				
Break	maximum	ASTM D 3083[1]	5	percent
Elongation @ Break	maximum	ASTM D 3083[1]	20	percent
Modulus @ 100% Elongation	maximum	ASTM D 3083[1]	20	percent
Hydrostatic Resistance	minimum	ASTM D 751 Method A	82	lbs/sq in.
PVC SEAM PROPERTIES				
Thickness	minimum	-	38	mils
Bonded Seam Strength	minimum	ASTM D 3083[1,3]	74	lbs/in.
Peel Adhesion				
Hot Wedge	minimum	ASTM D 3083[1,3]	10	lbs/in.
Solvent	minimum	ASTM D 3083[1,3]	10	lbs/in.

Notes:
1. As modified in Annex A.
2. 100°C for 15 minutes.
3. 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.

The geomembrane shall be produced as to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter, and shall not have striations, roughness, pinholes or bubbles on the surface.

2.1.3 Documentation: Prior to delivery of the geomembrane to the job site, the Installer shall be required to provide the Owner with a written certification that the product delivered was extruded from the specified resin. The manufacturer shall provide quality control certificates for each batch of resin and each shift's production of geomembrane, and shall follow the quality control testing program as described in Section 1.4. These quality control certificates shall be signed by responsible parties employed by the Manufacturer, and shall be supplied to the Owner. No geomembrane will be permitted to be delivered until the Owner has in his possession such certification.

2.1.4 Panel and Roll Identification: Each panel and roll shall have permanently affixed the following information: name of manufacturer/fabricator; date of manufacture/fabrication; resin batch code; thickness of the material; roll number(s); roll length; and roll width.

2.2 MISCELLANEOUS MATERIALS

2.2.1 Pipe Boots, Vents, and Patches: All such devices shall be of the same material as the lining or a compatible approved equal.

2.2.2 Mechanical Fastenings: Mechanical fastenings shall be of the material, size, and type as detailed on the plans or approved shop drawings.

3. QUALITY ASSURANCE

3.1 CONFORMANCE TESTING

Upon delivery of the panels of geomembrane, the Owner's Representative shall assure that one (1) conformance test sample is obtained from the geomembrane. The sample shall then be forwarded to an independent laboratory for testing to assure conformance to the specifications.

The following conformance tests shall be conducted:

1. Density
2. Thickness
3. Tensile characteristics

These conformance tests shall be performance in accordance with the test methods specified in the specifications.

3.1.1 Sampling Procedures: The panel to be sampled shall be selected by the Owner's Representative. The sample shall be

taken across the entire width of a roll and shall not include the first 3 feet (1 m). Unless otherwise specified, samples shall be 3 feet (1 m) long by the roll width. The Owner's Representative shall mark the machine direction on the sample with an arrow.

3.1.2 Test Results. All conformance test results shall be reviewed and accepted or rejected by the Owner's Representative prior to the deployment of the geomembrane.

The Owner's Representative shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The Owner's Representative shall be responsible for checking that all test results meet or exceed the property values listed in Section 2.1.2.

4. EXECUTION

4.1 SUBGRADE PREPARATION

4.1.1 Surface Preparation: The earthwork contractor shall be responsible for preparing the supporting soil for geomembrane placement. The Owner's Representative shall coordinate the work of the earthwork contractor and the Installer so that the requirements of the specification are met.

Before the geomembrane installation begins, the Owner's Representative shall verify that:

1. 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.

2. The surface of the supporting soil does not contain stones which may be damaging to the geomembrane.

3. There is no area excessively softened by high water content.

4. 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 shall be given by the Installer to the Owner's Representative prior to commencement of geomembrane deployment in the area under consideration.

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.

4.2 GEOMEMBRANE DEPLOYMENT

4.2.1 Panel Nomenclature: A field panel is defined as a unit of geomembrane which is to be seamed in the field.

It shall be the responsibility of the Installer/Fabricator to assure that each field panel is given an identification code (number or letter-number) consistent with the approved layout plan. This field panel identification code shall be as simple and logical as possible. The Installer/Fabricator 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 Owner's Representative shall verify that field panels are installed at the locations indicated on the Installer's layout plan, as approved by the Owner's Representative.

4.2.2 Panel Deployment Procedure: The Owner's Representative shall review the panel deployment progress of the Installer (keeping in mind issues relating to wind, rain, and other site-specific conditions). The Owner's Representative shall verify that the condition of the supporting soil does not change detrimentally during installation.

The Owner's Representative shall record the identification code, location, and date of installation of each field panel.

4.2.3 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 Owner's Representative. 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 Owner's Representative shall verify that the above conditions are fulfilled. Ambient temperature shall be measured by the Owner's Representative in the area in which the panels are to be deployed. The Owner's Representative shall inform the Installer of any weather related problems which may not allow geomembrane placement to proceed.

4.2.4 Method of Deployment: Before the geomembrane is handled on site, the Owner's Representative 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 Owner's Representative shall observe and verify that the Installer's personnel handle the geomembrane with care.

The Owner's Representative 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. All personnel do not smoke or wear damaging shoes while working on the geomembrane, or engage in other activities which could damage the geomembrane.

4. The method used to unroll the panels does not cause excessive scratches or crimps in the geomembrane and does not damage the supporting soil.

5. The method used to place the panels minimized wrinkles (especially differential wrinkles between adjacent panels).

6. 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 minimize risk of wind flow under the panels.

7. 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 Owner's Representative shall inform the Installer if the above conditions are not fulfilled.

4.2.5 Damage and Defects: Upon delivery to the site, the Owner's Representative shall conduct a surface observation of all panels for defects and for damage. This inspection shall be conducted without unfolding panels unless defects or damages are found or suspected. The Owner's Representative shall advise the Installer, in writing, of any panels or portions of panels which should be rejected and removed from the site because they have severe flaws, and/or minor repairable flaws.

The Owner's Representative shall inspect each panel, after placement and prior to seaming, for damage and/or defects. The Owner's Representative shall advise the Installer 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 Owner's Representative. Repairs shall be made using procedures described in Section 4.6.

4.2.6 Writing on the Liner: To avoid confusion, the Installer and the Owner's Representative 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.

4.3 FIELD SEAMING

4.3.1 Seam Layout: Before installation begins, the Installer must provide the Owner's Representative with a panel layout drawing, i.e. a drawing of the facility to be lined showing all expected seams. The Owner's Representative 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 Owner's Representative. In addition, panels not specifically shown on the panel layout drawing may not be used without the Owner's Representative'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 feet (1.5 m) from the toe of the slope, or areas of potential stress concentrations, unless otherwise authorized by the Owner's Representative.

A seam numbering system compatible with the panel numbering system shall be used by the Owner's Representative.

4.3.2 Accepted Seaming Methods: Hot-wedge welding will be the preferred method of seaming panels. Solvent welding will be allowed on patches, pipe boots, and in specialty areas. Proposed alternate processes shall be documented and submitted by the Installer to the Owner's Representative for approval.

4.3.2.1 Seaming Process: The Owner's Representative shall log ambient, seaming apparatus, and geomembrane surface temperatures at appropriate intervals and report any noncompliances to the Installer.

The Owner's Representative 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. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.

4. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.

5. The geomembrane is protected from damage in heavily trafficked areas.

6. 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.

7. In general, the geomembrane panels are aligned to have a nominal overlap of 5 inches (125 mm) for fusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.

4.3.3 Seam Preparation: The Owner's Representative 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 Owner's Representative must assure 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 Owner's Representative shall also verify that seams are aligned with the fewest possible number of wrinkles and "fishmouths".

4.3.4 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. Trial seams shall be made under the same conditions as actual seams.

The trial seam sample shall be at least 5 feet (1.0 m) long by 1 foot (0.3 m) wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as indicated in Section 4.3.2.

Two specimens shall be cut from the sample with a 1 inch (25 mm) wide die. The specimens shall be cut by the Installer at locations selected randomly along the trial seam sample by the Owner's Representative. 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. 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 Owner's Representative shall observe all trial seam procedures.

4.3.5 General Seaming Procedures: During general seaming, the Owner's Representative 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 ficiencies are corrected and two consecutive successful trial welds are achieved. The Owner's Representative shall observe all trial seam procedures.

4.3.5 General Seaming Procedures: During general seaming, the Owner's Representative 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 inches (150 mm) beyond the cut in all directions.

4. Seaming shall e Owner's Representative shall verify that these weather conditions are fulfilled and notify the Installer in writing if they are not. Ambient temperature shall be measured by the Owner's Representative in the area in which the panels are to be placed and decide if the installation is to be stopped or special procedures used.

4.3.6.2 Cold Weather Conditions: To assure 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 Owner's Representative 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 Owner's Representative, if the Installer demonstrates to the Owner's Representative's satisfaction that welds of equivalent quality may be obtained without preheating at the expected temperature of installation.

3. If preheating is required, the Owner's Representative shall inspect all areas of geomembrane that have been preheated by a hot air device prior to seaming, to assure 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 Owner's Representative.

6. Additional destructive tests (as described in Section 4.5) shall be taken at an interval between 500 feet and 250 feet of seam length, at the discretion of the Owner's Representative.

7. Sheet grinding may be performed before preheating, if applicable.

8. Trial seaming, as described in Section 4.3.4, 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.

4.3.6.3 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 Owner's Representative that geomembrane seam quality is not compromised.

Trial seaming, as described in Section 4.3.4, shall be conducted under the same ambient temperature conditions as the actual seams.

At the option of the Owner's Representative, additional destructive tests (as described in Section 4.5) may be required for any suspect areas.

4.4 NONDESTRUCTIVE SEAM TESTING

4.4.1 Concept: The Installer shall nondestructively test all field seams over their full length using an air lance, air pressure test (for double fusion seams only), or other approved method. Air pressure testing is described in Section 4.4.3. 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 Owner's Representative 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 of any required repairs.

4.4.3 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 20 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 20 and 30 psi (160 and 200 kPa), close valve, allow 2 minutes for pressure to stabilize, and sustain pressure for at least 2 minutes.

e. If loss of pressure exceeds 4 psi (30 kPa) or does not stabilize, locate faulty area and repair in accordance with Section 4.6.

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.

4.4.4 Test Failure Procedures: The Installer shall complete any required repairs in accordance with Section 4.6. For repairs, the Owner's Representative 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.

4.5 DESTRUCTIVE SEAM TESTING

4.5.1 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.

4.5.2 Location and Frequency: The Owner's Representative 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 feet (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 Owner's Representative'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.

4.5.3 Sampling Procedures: Samples shall be cut by the Installer at locations chosen by the Owner's Representative as the seaming progresses so that laboratory test results are available before the geomembrane is covered by another material. The Owner's Representative 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 4.6. The continuity of the new seams in the repaired area shall be tested according to Section 4.4.

4.5.4 Sample Dimensions: The sample for testing shall be 12 inches (0.3 m) wide by 42 inches (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 inches x 12 inches (0.3 m x 0.3 m).

2. One portion for field laboratory testing, 12 inches x 18 inches (0.3 m x 0.5 m) and

3. One portion to the Owner's Representative for archive storage, 12 inches x 12 inches (0.3 m x 0.3 m).

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

4.5.5 Field Laboratory Testing: The coupons, 1 inch (25 mm) wide strips, shall be tested in the field using a tensiometer for peel, shear, and thickness, and shall not fail according to the criteria in Section 2.1.3. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. If it fails, the seam should be repaired in accordance with Section 4.6. Final judgment regarding seam acceptability, based on the failure criteria, rests with the Owner's Representative.

The Owner's Representative shall witness all field tests and mark all samples and portions with their number. The Owner's

Representative 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.

4.5.6 Destructive Test Failure Procedures: The following procedures shall apply whenever a sample fails a destructive test. 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 feet (3 m) minimum from the point of the failed test in each direction) and take a sample with a 1 inch (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 field 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 field laboratory destructive tests have been taken. Passing laboratory destructive tests of trial seam samples taken as indicated in Section 4.3.4 may be used as a boundary for the failing seam. In cases exceeding 150 feet (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 4.6.

The Owner's Representative shall document all actions taken in conjunction with destructive test failures.

4.6 DEFECTS AND REPAIRS

4.6.1 Identification: All seams and non-seam areas of the geomembrane shall be examined by the Owner's Representative 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.

4.6.2 Evaluation. Each suspect location both in seam and non-seam areas shall be nondestructively tested using the methods described in Section 4.5 as appropriate. Each location which fails the nondestructive testing shall be marked by the Owner's Representative 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.

4.6.3 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 Installer and Owner's Representative.

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 Owner's Representative and shall not exceed 50 feet (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 manual.

   d. Patches or caps shall extend at least 6 inches (150 mm) beyond the edge of the defect, and all corners of patches shall be rounded with a radius of approximately 3 inches (75 mm).

4.6.4 Repair Verification: Each repair shall be numbered and logged. Each repair shall be nondestructively tested using the methods described in Section 4.5 as appropriate. Repairs which pass the nondestructive test shall be taken as an indication of an adequate repair. Repairs more than 150 feet long may be of sufficient extent to require destructive test sampling, at the

discretion of the Owner's Representative. Failed tests indicate that the repair shall be redone and retested until a passing test results. The Owner's Representative shall observe all nondestructive testing of repairs and shall record the number of each repair, date, and test outcome.

4.6.5 Large Wrinkles: When seaming of the geomembrane is completed, and prior to placing overlying materials, the Owner's Representative shall indicate to the Installer 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 onto itself. This is generally the case for a wrinkle that extends 12 inches 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 Owner's Representative to assure that wrinkle formation is minimized.

4.7 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.

4.7.1 Soils: A copy of the specifications prepared by the Designer for placement of soils shall be given to the Owner's Representative. The Owner's Representative 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. Equipment used for placing soil shall not be driven directly on the geomembrane.

4. A minimum thickness of 9 inches of soil is specified between a light dozer (ground pressure of 5 psi (35 kPa) or lighter) and the geomembrane.

5. In any areas travresed by any vehicles other than low ground pressure vehicles approved by the Owner's Representative, the soil layer shall have a minimum thickness of 3 feet (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 Owner's Representative shall measure soil thickness and verify that the required thicknesses are present. The Owner's Representative 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 Owner's Representative shall inform the Contractor if the above conditions are not fulfilled.

END OF SECTION

APPENDIX C

CALCULATIONS

COVER SLOPE STABILITY

STABILITY OF COVER SOIL ABOVE A GEOMEMBRANE

PROJECT: CHAMPION LANDFILL CLOSURE PROJ. #: 97044
BY: GUY COTE

Problem: Determine factor-of-safety for given design parameters

Length of slope - $L := 220 \cdot ft$

Thickness of cover - $H := 1.5 \cdot ft$

Unit weight of soil(buoyant) - $\gamma := (120 - 62.4) \cdot \frac{lb}{ft^3}$

Sideslope angle - $\omega := 7.0 \cdot deg$

Friction angle of soil-to-geotextile - $\phi := 32 \cdot deg$

Friction angle of geotextile-to-geomembrane - $\delta := 21 \cdot deg$

Adhesion of soil-to-geomembrane - $CA := 0 \cdot \frac{lb}{ft^2}$

Cohesion of soil-to-soil - $C := 0 \cdot \frac{lb}{ft^2}$

Solution:

$a := .5 \cdot \gamma \cdot L \cdot H \cdot \sin(2 \cdot \omega)^2$

$a = 556 \cdot lb \cdot ft^{-1}$

$b := -\left(\gamma \cdot L \cdot H \cdot \cos(\omega)^2 \cdot \tan(\delta) \cdot \sin(2 \cdot \omega) + CA \cdot L \cdot \cos(\omega) \cdot \sin(2 \cdot \omega) + \gamma \cdot L \cdot H \cdot \sin(\omega)^2 \cdot \tan(\phi) \cdot \sin(2 \cdot \omega) \ldots \right.$
$\left. + 2 \cdot C \cdot H \cdot \cos(\omega) + \gamma \cdot H^2 \cdot \tan(\phi) \right)$

$b = -1.863 \cdot 10^3 \cdot lb \cdot ft^{-1}$

$c := (\gamma \cdot L \cdot H \cdot \cos(\omega) \cdot \tan(\delta) + CA \cdot L) \cdot (\tan(\phi) \cdot \sin(\omega) \cdot \sin(2 \cdot \omega))$

$c = 133 \cdot lb \cdot ft^{-1}$

$FS := \frac{-b + \sqrt{(b^2 - 4 \cdot a \cdot c)}}{(2 \cdot a)}$

$FS = 3.3$

Results: FS > 1, cover design is acceptable

REFERENCE: United States Environmental Protection Agency, "Design and Construction of RCRA/CERCLA Final Covers", EPA/625/4-91/025

Model #1: Stability of Cover Soil Above a Geomembrane

Consider a cover soil (usually a permeable soil like gravel, sand or silt) placed directly on a geomembrane at a slope angle of "ω". Two discrete zones can be visualized as seen in Figure 3. Here one sees a small passive wedge resisting a long, thin active wedge extending the length of the slope. It is assumed that the cover soil is a uniform thickness and constant unit weight. At the top of the slope, or at an intermediate berm, a tension crack in the cover soil is considered to occur thereby breaking communication with additional cover soil at higher elevations.

Resisting the tendency for the cover soil to slide is the adhesion and/or interface friction of the cover soil to the specific type of underlying geomembrane. The values of "c_a" and "δ" must be obtained from a simulated laboratory direct shear test as described earlier. Note that the passive wedge is assumed to move on the underlying cover soil so that the shear parameters "c" and "ϕ", which come from soil-to-soil friction tests, will also be required.

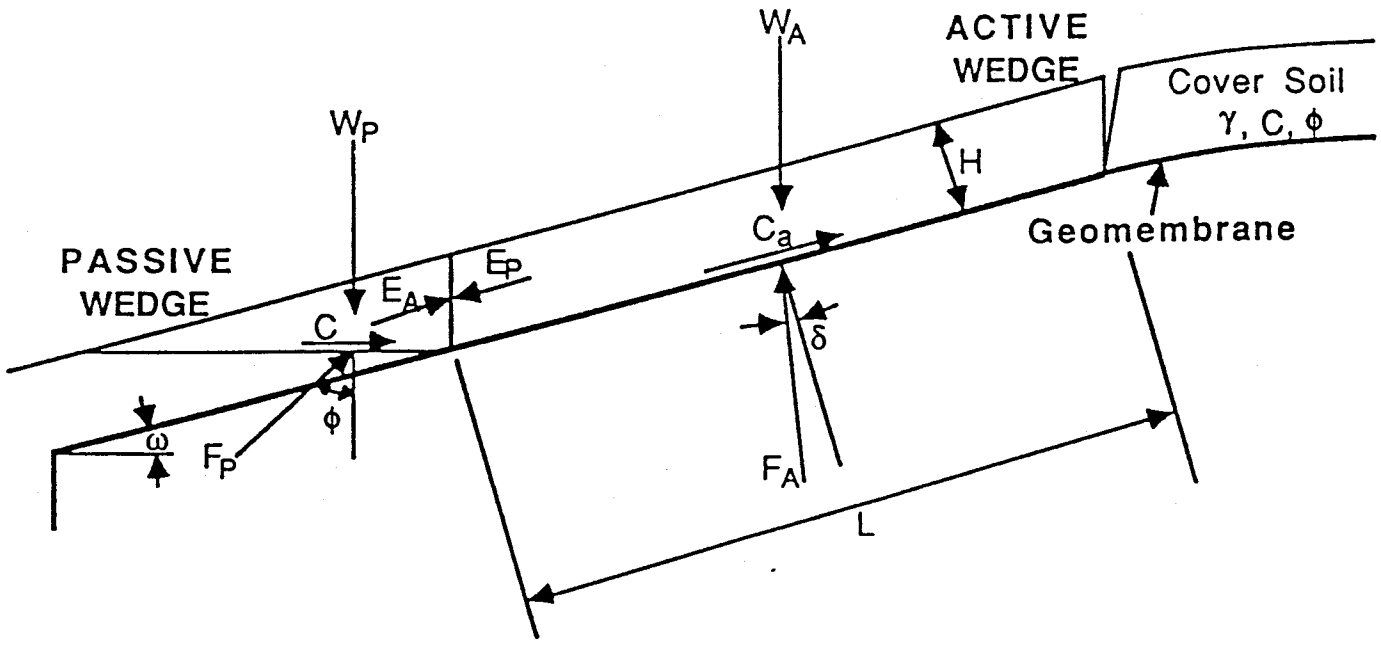

Figure 3 - Cross Section of Cover Soil on a Geomembrane Illustrating the Various Forces Involved on the Active and Passive Wedges

By taking free bodies of the passive and active wedges with the appropriate forces being applied, the following formulation for the stability factor-of-safety results, see Equation 3. Note that the equation is not an explicit solution for the factor-of-safety (FS), and must be solved indirectly. The complete development of the equation is given in Appendix "A".

$$(FS)^2 [0.5\,\gamma\, LH \sin^2(2\,\omega)] - (FS) [\gamma\, LH \cos^2\omega \tan\delta \sin(2\,\omega) + c_a L \cos\omega \sin(2\,\omega) + \gamma\, LH \sin^2\omega \tan\phi \sin(2\,\omega) + 2\,c\,H \cos\omega + \gamma H^2 \tan\phi] + [(\gamma LH \cos\omega \tan\delta + c_a L)(\tan\phi \sin\omega \sin(2\,\omega)] = 0 \quad (3)$$

Using $ax^2 + bx + c = 0$, where

$$a = 0.5\,\gamma\, LH \sin^2 2\omega$$

$$b = -[\gamma\, LH \cos^2\omega \tan\delta \sin(2\omega) + c_a L \cos\omega \sin(2\,\omega) + \gamma\, LH \sin^2\omega \tan\phi \sin(2\omega) + 2cH \cos\omega + \gamma\, H^2 \tan\phi]$$

$$c = (\gamma\, LH \cos\omega \tan\delta + c_a L)(\tan\phi \sin\omega \sin(2\omega))$$

the resulting factor-of-safety is as follows:

$$FS = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad (4)$$

When the calculated factor-of-safety value falls below 1.0, a stability failure of the cover soil sliding on the geomembrane is to be anticipated. However, it should be recognized that seepage forces, seismic forces and construction placement forces have not been considered in this analysis and all of these phenomena tend to lower the factor-of-safety. Thus a value of greater than 1.0 should be targeted as being the minimum acceptable factor-of-safety. An example problem illustrating the use of the above equations follows:

Example Problem: Given a soil cover soil slope of $\omega = 18.4°$ (i.e., 3 to 1), $L = 300$ ft., $H = 3.0$ ft, $\gamma = 120$ lb/ft^3, $c = 300$ lb/ft^2, $c_a = 0$, $\phi = 32°$, $\delta = 14°$, determine the resulting factor-of-safety

Solution:

$$a = 0.5\,(120)\,(300)\,(3) \sin^2(36.8°)$$

$$= 19{,}400 \text{ lb/ft}$$

$$b = -[(120)\,(300)\,(3) \cos^2(18.4°) \tan(14°) \sin(36.8°) + 0 + (120)\,(300)\,(3) \sin^2(18.4°) \tan(32°) \sin(36.8°) + 2\,(300)\,(3) \cos(18.4°) + 120\,(9) \tan(32°)]$$

United States
Environmental Protection
Agency

Office of
Research and Development
Washington, DC 20460

EPA/625/4-91/025
May 1991

EPA

Seminar Publication

Design and Construction of RCRA/CERCLA Final Covers

TABLE 5.5 FRICTION VALUES AND EFFICIENCIES (IN PARENTHESES) FOR (a) SOIL-TO-GEOMEMBRANE, (b) GEOMEMBRANE-TO-GEOTEXTILE, AND (c) SOIL-TO-GEOTEXTILE COMBINATIONS*

(a) Soil-to-geomembrane friction angles

Geomembrane	Soil types		
	Concrete sand ($\phi = 30°$)	Ottawa sand ($\phi = 28°$)	Mica schist sand ($\phi = 26°$)
EPDM	24° (0.77)	20° (0.68)	24° (0.91)
PVC			
rough	27° (0.88)	—	25° (0.96)
smooth	25° (0.81)	—	21° (0.79)
CSPE	25° (0.81)	21° (0.72)	23° (0.87)
HDPE	18° (0.56)	18° (0.61)	17° (0.63)

(b) Geomembrane-to-geotextile friction angle

Geotextile	Geomembrane				
		PVC			
	EPDM	Rough	Smooth	CSPE	HDPE
nonwoven, needle-punched	23°	23°	21°	15°	8°
nonwoven, melt-bonded	18°	20°	18°	21°	11°
woven, monofilament	17°	11°	10°	9°	6°
woven, slit film	21°	28°	24°	13°	10°

(c) Soil-to-geotextile friction angle

Geotextile	Soil types		
	Concrete sand ($\phi = 30°$)	Ottawa sand ($\phi = 28°$)	Mica schist sand ($\phi = 26°$)
nonwoven, needle-punched	30° (1.00)	26° (0.92)	25° (0.96)
nonwoven, melt-bonded	26° (0.84)	—	—
woven, monofilament	26° (0.84)	—	—
woven, slit film	24° (0.77)	24° (0.84)	23° (0.87)

Source: After Martin, et al. [8]

*Efficiency values in parentheses are based on the relationship $E = (\tan \delta)/(\tan \phi)$

on smooth geotextiles giving the lowest friction values. For reference purposes, Part c of Table 5.5 gives the soil-to-geotextile friction values that are necessary for slope design of lined slopes with geotextiles under or over the liner.

The frictional behavior of geomembranes placed on clay soils is of considerable importance in the composite liners of waste landfills. Current requirements are for the

STORMWATER CALCULATIONS

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : Champion Landfill No. 6 User: ghc Date: 08-28-97
County : Haywood State: NC Checked: ____ Date: _____
Subtitle: Area F
Subarea : A

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
	Acres (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Open space (Lawns,parks etc.)				
Good condition; grass cover > 75%	-	-	2.4(74)	-
Total Area (by Hydrologic Soil Group)			2.4	
			====	

SUBAREA: A TOTAL DRAINAGE AREA: 2.4 Acres WEIGHTED CURVE NUMBER: 74

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : Champion Landfill No. 6 User: ghc Date: 08-28-97
County : Haywood State: NC Checked: ____ Date: _____
Subtitle: Area F
Subarea : B

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
	Acres (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Open space (Lawns,parks etc.)				
Good condition; grass cover > 75%	-	-	2.4(74)	-
Total Area (by Hydrologic Soil Group)			2.4	

SUBAREA: B TOTAL DRAINAGE AREA: 2.4 Acres WEIGHTED CURVE NUMBER: 74

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : Champion Landfill No. 6 User: ghc Date: 08-28-97
County : Haywood State: NC Checked: ____ Date: _____
Subtitle: Area F

Subarea #1 - A

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	3.8	110	.07	F					0.143
Shallow Concent'd		360	.01	U					0.062
Open Channel		500	.04		.04	3	6.3		0.031
								Time of Concentration =	0.24*
									=====

Subarea #2 - B

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	3.8	220	.12	F					0.200
Open Channel		370	.02		.04	3	6.3		0.032
								Time of Concentration =	0.23*
									=====

--- Sheet Flow Surface Codes ---

A Smooth Surface	F Grass, Dense	--- Shallow Concentrated ---
B Fallow (No Res.)	G Grass, Burmuda	--- Surface Codes ---
C Cultivated < 20 % Res.	H Woods, Light	P Paved
D Cultivated > 20 % Res.	I Woods, Dense	U Unpaved
E Grass-Range, Short	J Range, Natural	

* - Generated for use by TABULAR method

TABULAR HYDROGRAPH METHOD Version 2.00

Project : Champion Landfill No. 6 User: ghc Date: 08-28-97
County : Haywood State: NC Checked: ____ Date: _____
Subtitle: Area F

Total watershed area: 0.008 sq mi Rainfall type: II Frequency: 100 years

	Subareas	
	A	B
Area(sq mi)	0.00*	0.00*
Rainfall(in)	8.0	8.0
Curve number	74*	74*
Runoff(in)	4.93	4.93
Tc (hrs)	0.24*	0.23*
(Used)	0.20	0.20
TimeToOutlet	0.00	0.00
Ia/P	0.09	0.09
(Used)	0.10	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) A	B
11.0	0	0	0
11.3	2	1	1
11.6	2	1	1
11.9	8	4	4
12.0	14	7	7
12.1	28	14	14
12.2	30P	15P	15P
12.3	18	9	9
12.4	10	5	5
12.5	6	3	3
12.6	4	2	2
12.7	4	2	2
12.8	4	2	2
13.0	2	1	1
13.2	2	1	1
13.4	2	1	1
13.6	2	1	1
13.8	2	1	1
14.0	2	1	1
14.3	2	1	1
14.6	2	1	1
15.0	2	1	1
15.5	0	0	0
16.0	0	0	0
16.5	0	0	0
17.0	0	0	0
17.5	0	0	0

18.0	0	0	0
19.0	0	0	0
20.0	0	0	0
22.0	0	0	0
26.0	0	0	0

P - Peak Flow * - value(s) provided from TR-55 system routines

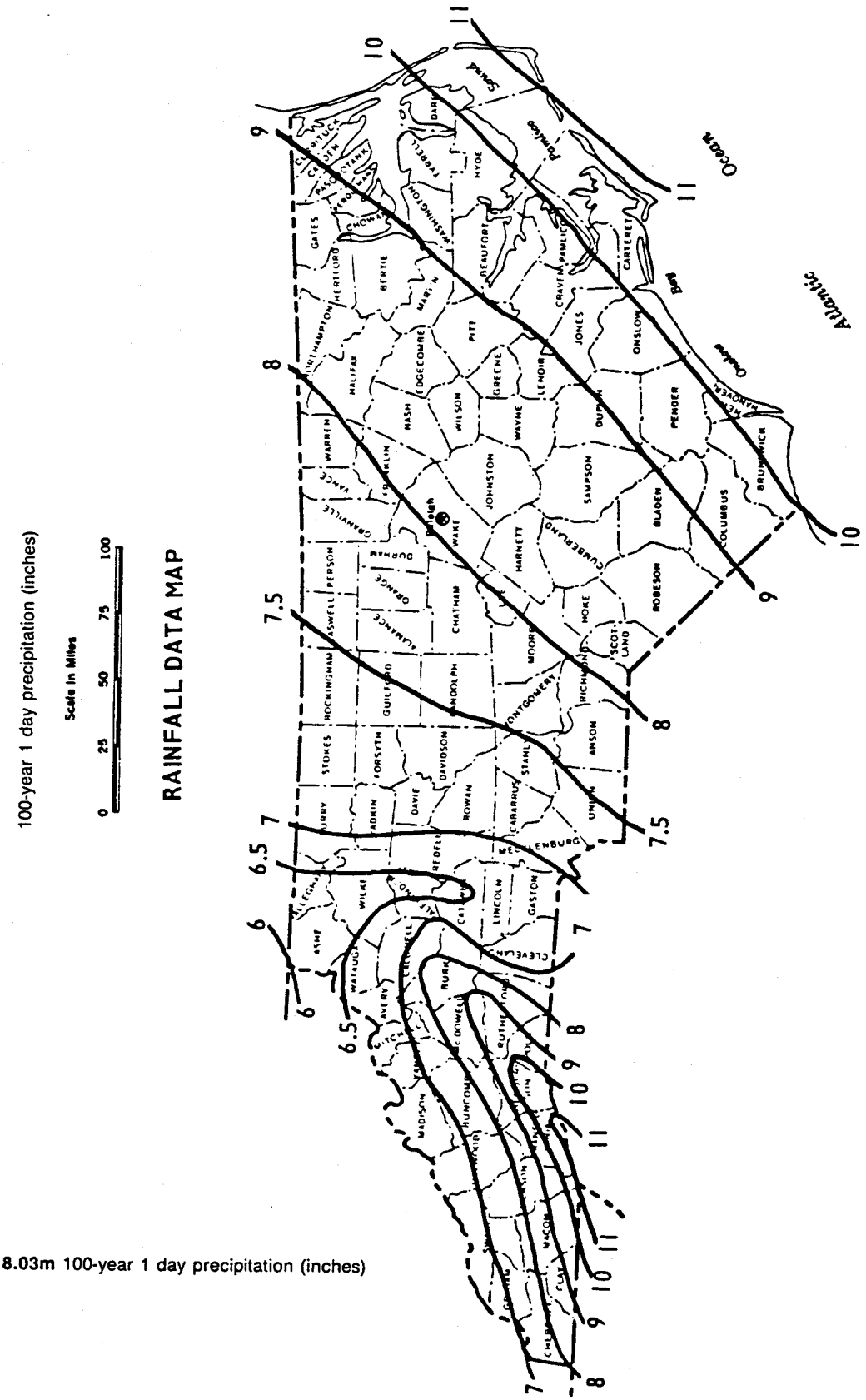

Figure 8.03m 100-year 1 day precipitation (inches)

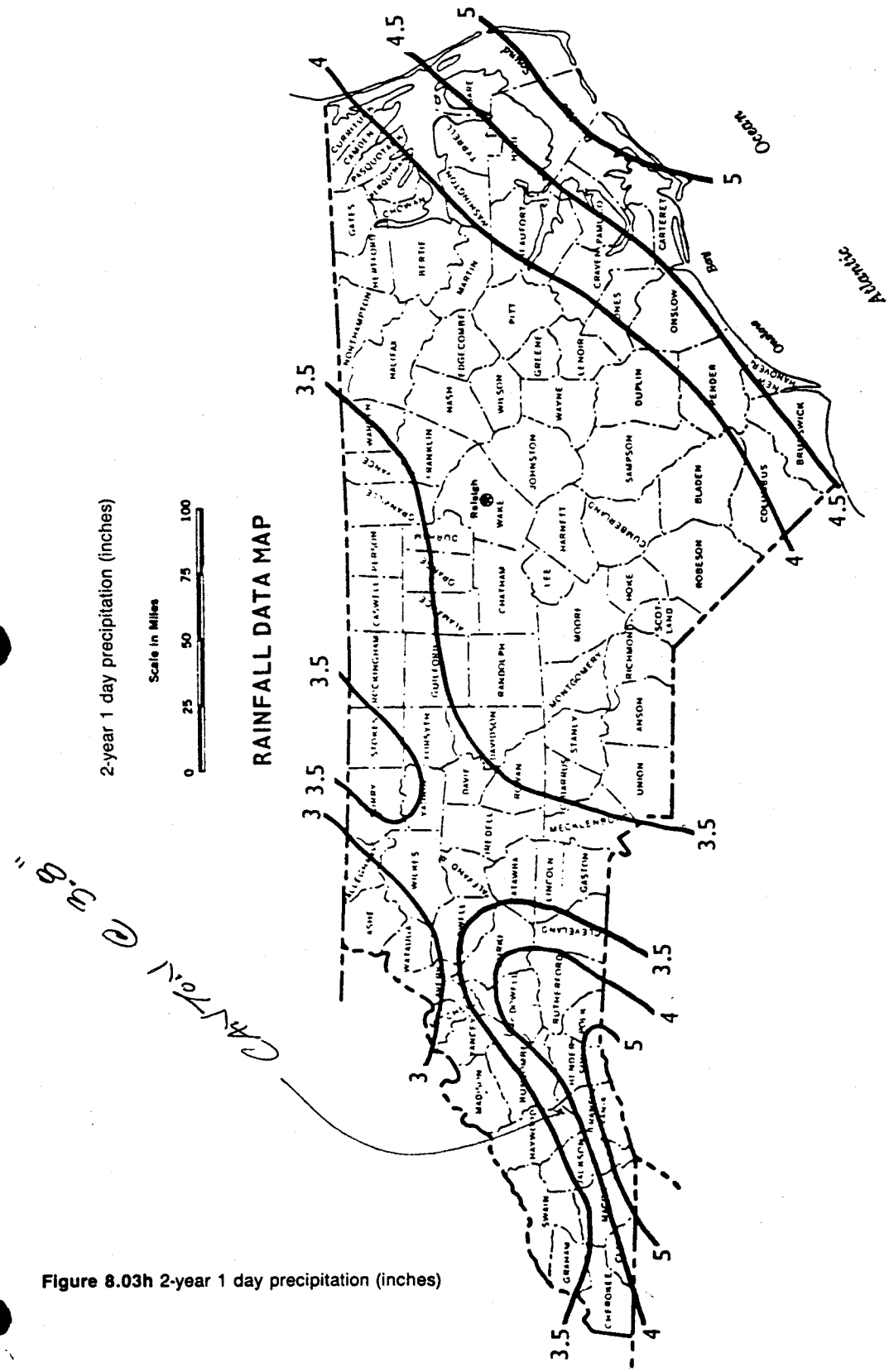

Figure 8.03h 2-year 1 day precipitation (inches)

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : CHAMPION - LANDFILL NO. 6 User: ghc Date: 08-21-97
County : HAYWOOD State: NC Checked: ____ Date: _____
Subtitle: FINAL GRADE - G
Subarea : A

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
	Acres (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Open space (Lawns,parks etc.)				
Good condition; grass cover > 75%	-	-	1.8(74)	-
Total Area (by Hydrologic Soil Group)			1.8	

SUBAREA: A TOTAL DRAINAGE AREA: 1.8 Acres WEIGHTED CURVE NUMBER: 74*

* - Generated for use by GRAPHIC method

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : CHAMPION - LANDFILL NO. 6 User: ghc Date: 08-21-97
County : HAYWOOD State: NC Checked: ____ Date: _____
Subtitle: FINAL GRADE - G

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	3.8	160	.06	F					0.205
Shallow Concent'd		500	.076	U					0.031
								Time of Concentration =	0.24*

--- Sheet Flow Surface Codes ---

A Smooth Surface	F Grass, Dense	--- Shallow Concentrated ---
B Fallow (No Res.)	G Grass, Burmuda	--- Surface Codes ---
C Cultivated < 20 % Res.	H Woods, Light	P Paved
D Cultivated > 20 % Res.	I Woods, Dense	U Unpaved
E Grass-Range, Short	J Range, Natural	

* - Generated for use by GRAPHIC method

GRAPHICAL PEAK DISCHARGE METHOD Version 2.00

Project : CHAMPION - LANDFILL NO. 6 User: ghc Date: 08-21-97
County : HAYWOOD State: NC Checked: ____ Date: _____
Subtitle: FINAL GRADE - G

Data: Drainage Area : 1.8 * Acres
Runoff Curve Number : 74 *
Time of Concentration: 0.24 * Hours
Rainfall Type : II
Pond and Swamp Area : NONE

Storm Number	1	2	3
Frequency (yrs)	10	25	100
24-Hr Rainfall (in)	6	7	8
Ia/P Ratio	0.12	0.10	0.09
Used	0.12	0.10	0.10
Runoff (in)	3.18	4.04	4.93
Unit Peak Discharge (cfs/acre/in)	1.148	1.162	1.162
Pond and Swamp Factor 0.0% Ponds Used	1.00	1.00	1.00
Peak Discharge (cfs)	7	8	10

* - Value(s) provided from TR-55 system routines

RUNOFF CURVE NUMBER COMPUTATION Version 2.00

Project : CHAMPION - LANDFILL NO. 6 User: ghc Date: 08-21-97
County : HAYWOOD State: NC Checked: ____ Date: _____
Subtitle: Area H
Subarea : A

COVER DESCRIPTION	Hydrologic Soil Group A	B	C	D
	Acres (CN)			
FULLY DEVELOPED URBAN AREAS (Veg Estab.)				
Open space (Lawns,parks etc.)				
Good condition; grass cover > 75%	-	-	3.5(74)	-
Streets and roads				
Gravel (w/ right-of-way)	-	2.2(85)	-	-
Total Area (by Hydrologic Soil Group)		2.2	3.5	

SUBAREA: A TOTAL DRAINAGE AREA: 5.7 Acres WEIGHTED CURVE NUMBER: 78*

* - Generated for use by GRAPHIC method

TIME OF CONCENTRATION AND TRAVEL TIME Version 2.00

Project : CHAMPION - LANDFILL NO. 6 User: ghc Date: 08-21-97
County : HAYWOOD State: NC Checked: ____ Date: _____
Subtitle: Area H

Flow Type	2 year rain	Length (ft)	Slope (ft/ft)	Surface code	n	Area (sq/ft)	Wp (ft)	Velocity (ft/sec)	Time (hr)
Sheet	3.8	270	.05	F					0.335
Shallow Concent'd		1020	.02	U					0.124
								Time of Concentration =	0.46*

--- Sheet Flow Surface Codes ---

A Smooth Surface
B Fallow (No Res.)
C Cultivated < 20 % Res.
D Cultivated > 20 % Res.
E Grass-Range, Short
F Grass, Dense
G Grass, Burmuda
H Woods, Light
I Woods, Dense
J Range, Natural

--- Shallow Concentrated --- Surface Codes ---

P Paved
U Unpaved

* - Generated for use by GRAPHIC method

GRAPHICAL PEAK DISCHARGE METHOD Version 2.00

Project : CHAMPION - LANDFILL NO. 6 User: ghc Date: 08-21-97
County : HAYWOOD State: NC Checked: ____ Date: _____
Subtitle: Area H

Data: Drainage Area : 5.7 * Acres
Runoff Curve Number : 78 *
Time of Concentration: 0.46 * Hours
Rainfall Type : II
Pond and Swamp Area : NONE

Storm Number	1	2	3
Frequency (yrs)	10	25	100
24-Hr Rainfall (in)	6	7	8
Ia/P Ratio	0.09	0.08	0.07
Used	0.10	0.10	0.10
Runoff (in)	3.58	4.47	5.39
Unit Peak Discharge (cfs/acre/in)	0.863	0.863	0.863
Pond and Swamp Factor 0.0% Ponds Used	1.00	1.00	1.00
Peak Discharge (cfs)	18	22	27

* - Value(s) provided from TR-55 system routines

LANDOWNER Champion ADDRESS Canton, NC

PROJECT Area H Culvert BY [illegible] DATE __/__/__

********** IMPUTS FOR CURCULAR CULVERT ANALYSIS **********

MANNINGS COEFFICIENT PVC=.009 R/C=.013 CMP<=.025		N=	.013
CULVERT DIAMETER	(FT)	D=	2.5
HEADWATER ABOVE UPSTREAM ENTRANCE INVERT	(FT)	DE=	4
TAILWATER ABOVE OUTLET INVERT => 0	(FT)	DO=	0
LENGTH OF CULVERT PIPE	(FT)	LP=	50
DROP ALONG CULVERT LENGTH (INVERT TO INVERT)	(FT)	PD=	.5
ENTRANCE LOSS COEFFICIENT		KE=	.8

30" OK

********** CULVERT OUTLET CONTROL (PRESSURE FLOW) EXISTS **********

CULVERT CAPACITY **********	(CFS)	Q=	42.44
PIPE VELOCITY	(FPS)	V=	8.649999
NEUTRAL SLOPE	(FT/FT)	SN=	.0107
ACTUAL SLOPE ON CULVERT PIPE	(FT/FT)	SO=	.01

DO YOU WANT TO CHANGE A VARIABLE Y/N ?

LANDOWNER _____ ADDRESS _____

PROJECT _____ BY _____ DATE ___/___/___

********** IMPUTS FOR CURCULAR CULVERT ANALYSIS **********

MANNINGS COEFFICIENT PVC=.009 R/C=.013 CMP<=.025		N=	.013
CULVERT DIAMETER	(FT)	D=	2.5
HEADWATER ABOVE UPSTREAM ENTRANCE INVERT	(FT)	DE=	4
TAILWATER ABOVE OUTLET INVERT => 0	(FT)	DO=	0
LENGTH OF CULVERT PIPE	(FT)	LP=	50
DROP ALONG CULVERT LENGTH (INVERT TO INVERT)	(FT)	PD=	.5
ENTRANCE LOSS COEFFICIENT		KE=	.8

********** CULVERT OUTLET CONTROL (PRESSURE FLOW) EXISTS **********

CULVERT CAPACITY **********	(CFS)	Q=	42.44
PIPE VELOCITY	(FPS)	V=	8.649999
NEUTRAL SLOPE	(FT/FT)	SN=	.0107
ACTUAL SLOPE ON CULVERT PIPE	(FT/FT)	SO=	.01

DO YOU WANT TO CHANGE A VARIABLE Y/N ?

RIP RAP CHANNEL DESIGN FOR H OUTLET

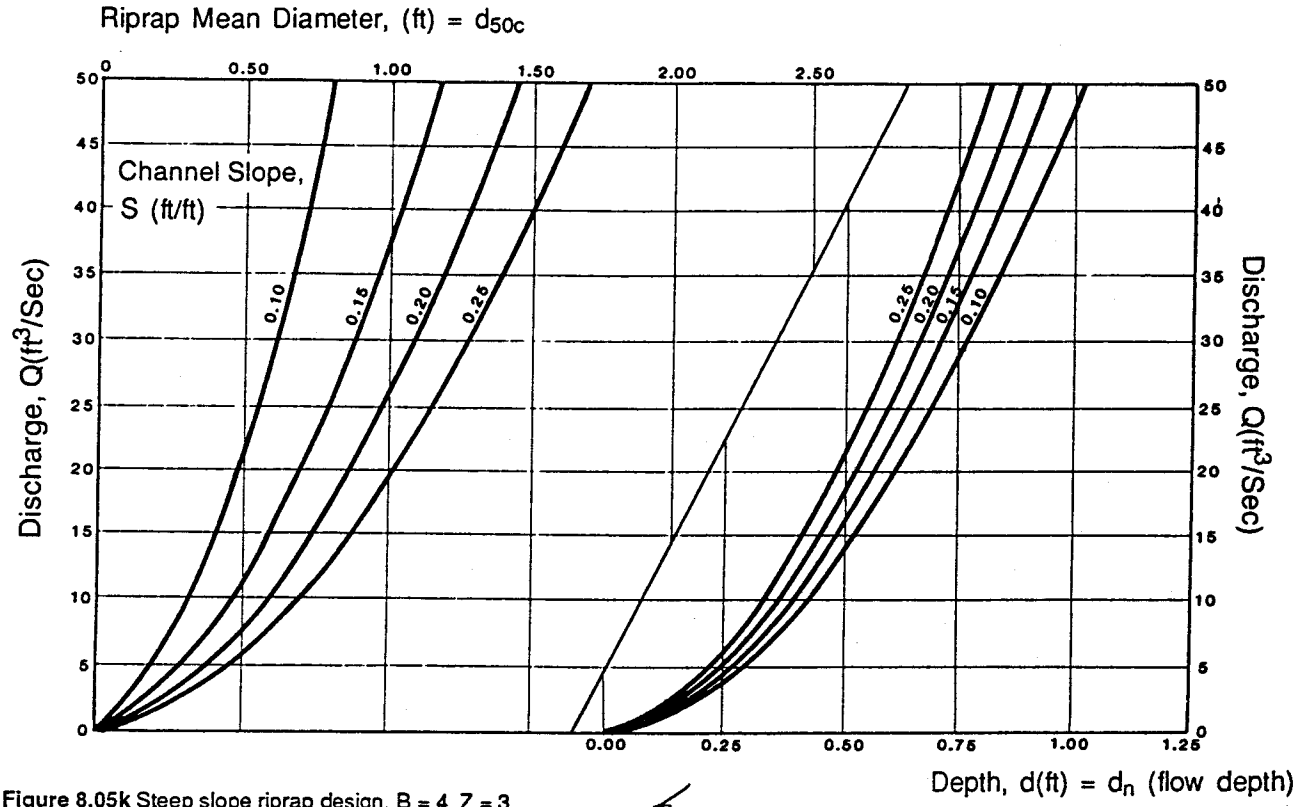

Figure 8.05k Steep slope riprap design, B = 4, Z = 3.

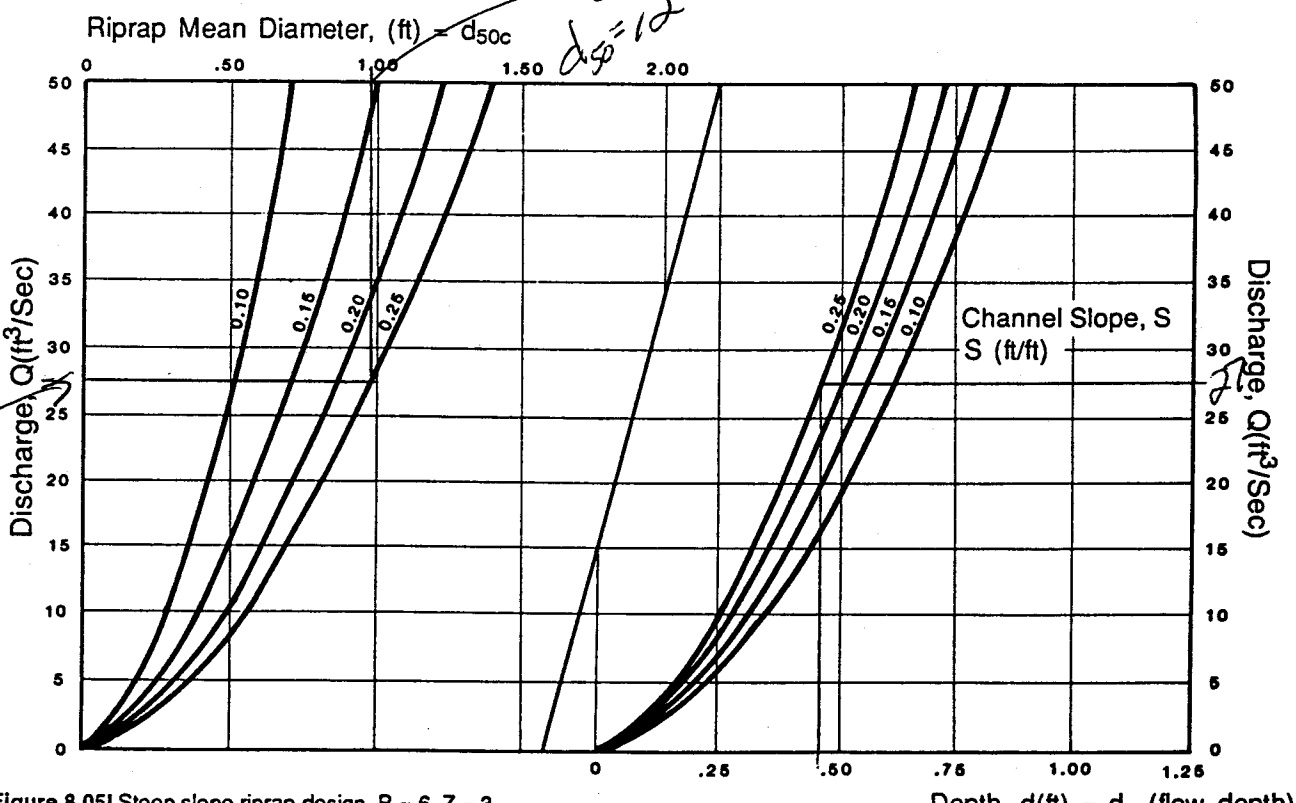

Figure 8.05l Steep slope riprap design, B = 6, Z = 3.

Drawings "Under Seperate Cover"