CONSTRUCTION QUALITY PLAN

FOR THE INSTALLATION OF HDPE GEOMEMBRANE
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SECTION A – CONSTRUCTION QUALITY CONTROL

This manual addresses the Quality Control Program developed and utilised by Ecotech Installation Personnel to assure the quality of workmanship and the installation integrity of HDPE and LLDPE geomembranes. Ecotech recognises that careful and specific documentation of the installation is required to substantiate this Quality Control Program.

A. MANUFACTURING QUALITY CONTROL

1. HDPE and LLDPE Geomembrane Quality Control

1.1 The manufacture standard quality control specifications are documented in Section E Appendix 3. Site specific requirements, if any, are documented in Section D.

1.2 The geomembrane shall consist of quality resins designed and manufactured specifically for the purpose of this work, as satisfactorily demonstrated by prior use. The geomembrane shall be high density polyethylene (HDPE) or linear low density polyethylene (LLDPE). The geomembrane liner will be manufactured from first quality resins containing no plasticizers, fillers, recycled polymers, or extenders. Carbon black is normally added to provide ultraviolet resistance, and other additives to provide thermal stability. If a color other than black is specified then color concentrates and other ultraviolet inhibitors will be added in place of carbon black.

1.3 The geomembrane shall be manufactured as a continuous sheet approximately 8 meters wide. The roll length shall be maximized to provide the largest manageable sheet for the fewest field seams. All rolls shall be identified with a unique roll number printed on a label affixed to the inside and outside of the roll showing manufacturer, thickness, and material type (HDPE or LLDPE).

1.4 The geomembrane shall be either smooth-surface or textured-surface material. Textured-surface geomembrane shall be manufactured so that the surface irregularities are on one side or both sides of the sheet.

2. Raw Materials

2.1 The resin shall be designed and manufactured specifically for the intended purpose. Tests shall be performed by the resin manufacturer and results provided to Ecotech. When the resin is delivered, it shall be tested to verify that it meets the required specification.

2.2 Test results shall be recorded on the relevant form.

2.3 The resin shall be a standard product or an approved equal.
3. **Geomembrane Testing**

3.1 Geomembrane is tested at the frequencies indicated on Ecotech’s standard material specification sheets (Section E) unless modified by site-specific project requirements (Section D).

3.2 Test results are recorded on the relevant form. Test results shall refer to the relevant roll number.

4. **Extrusion Rod**

4.1 Extrusion rod is tested at the frequencies indicated on Polytex’s standard material specification sheets (Section E) unless modified by site-specific project requirements (Section D).

4.2 Test results shall be recorded on the relevant form.

5. **Storage and Handling**

5.1 Rolls of material are handled with equipment that will not damage the membrane. Fabric straps are attached to the rolls of material to be used for unloading at the job site.

5.2 The storage area shall be reasonably flat and free of sharp rocks or other objects that could damage the material.

B. **Delivery, Storage and Handling**

1. Prior to unloading, the handling equipment is inspected to verify that it will not damage the material. Fabric straps or other approved apparatus are used for handling of material.

2. Rolls must be examined upon unloading to insure that there is no damage to the material and to assure that the correct material for the job has been received.

3. The storage area must be secure to prevent vandalism and thefts and must be such that rolls are not likely to be damaged by passing vehicles. The storage area shall be such that continuous contact with water is minimized. The storage area shall be smooth, flat and free of rocks or other objects that could cut or puncture the liner. Rolls of geomembrane do not need protection from normal weather conditions.

C. **On-site Material Inspection**

1. Identification labels on material rolls shall be inspected and roll numbers recorded for future documentation. The roll number is unique and shall be used to identify the roll in
QC testing and to determine which panels are cut from an individual roll.

D. Panel Identification and Layout

1. As part of the initial job planning a panel layout drawing shall be prepared that shows how rolls of liner material may be assembled and joined to form the finished liner. Each panel of liner shall be assigned a number for future reference. This panel identification number shall be related on the QC Panel Placement Form to a manufacturing roll number that identifies the resin type, batch number, and date of manufacture.

2. 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 slope, not less than 2.0 m from the toe of the slope.

3. Proposed Panel Layout Drawings are intended as a guideline, during Project Planning, to indicate the basic layout concepts and allow for feedback between the Owner, Liner Installer, Engineer, etc. Actual finished Panel Layout (i.e. “As-Built”) may differ from the proposed panel layout due to field evaluations of actual site conditions. Such conditions may include considerations for construction coordination between contractors, weather (i.e. wind direction), minimization of field seaming and miscellaneous other factors.

4. Ecotech will attempt 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 Ecotech and/or third party Q.A Consultant as determined on a site specific basis.

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

6. The geomembrane shall be installed to the limits shown on the project Drawings and as shown on the approved panel layout drawings.

E. Equipment

1. **Welding Equipment**: EcoTech will provide welding equipment showing extrudate temperature (extrusion welder), wedge temperature (wedge welder) or nozzle temperature (hot air). Sufficient equipment will be available to avoid delaying work, and shall be powered by a power source capable of providing constant voltage under a combined-line load. Generators with rubber tires are allowed on the geomembrane. Prior to placement on the geomembrane, tires should be inspected to assure that there are no sharp objects adhered to them that could result in damage to the geomembrane. Scrap membrane should be placed under the generator to ensure that any spilled fluids will not come into contact with the geomembrane.
2. **Punch Press:** EcoTech shall provide a punch press for the on-site preparation of specimens for testing.

3. **Field Tensiometer:** EcoTech will provide a tensiometer for on-site shear and peel testing of geomembrane seams. The tensiometer shall be in good working order, built to ASTM specs, and calibrated within one year. The tensiometer shall be motor driven and capable of a 50mm/min jaw separation rate. It shall be capable of measuring the force exerted between the jaws and have a digital readout.

4. **Vacuum Box:** EcoTech will provide a vacuum box for on-site testing of geomembrane seams. The vacuum box shall have a transparent viewing window on top and a soft closed-cell neoprene gasket attached to the bottom. The housing shall be rigid and equipped with a bleed valve and vacuum gauge. A separate vacuum source shall be connected to the vacuum box. The equipment shall be capable of inducing and holding a vacuum of 35 kPa.

5. **Gauge and Air Pump:** The Geomembrane Contractor shall provide an air pump capable of achieving a minimum of 240 kPa. Gauges must be capable of registering at least 240 kPa.

6. **Miscellaneous Equipment:** Small tools will include hook blade utility knives, scissors with rounded points and silicone or rubber rollers. Step up transformer per generator will be used to assure constant voltage to the welding equipment as necessary.

### F. Subgrade Preparation

1. The subgrade is prepared by the Owner or by the Earthwork Contractor according to the project specifications. Site specific requirements, if any, are documented in Section D. The surface must be smooth, with no rapid changes of grade such as steps or settlement next to concrete structures. All slopes and surfaces must be compacted to ensure the integrity of the membrane. While the geomembrane is designed to withstand some differential settlement, an analysis of these areas must be made by the engineer to ensure that the stresses on the membrane are acceptable.

2. The surface of the subgrade must be free of sharp rocks, penetrating debris or other appurtenances that could damage the membrane. Typically, finished subgrade is achieved using a smooth steel drum roller or other method as approved by the Project Engineer. Under certain conditions a cushion geotextile can be evaluated and approved for use by the Project Engineer, to provide protection for the geomembrane.

3. After acceptance by the Owner’s Representative, Ecotech Project Supervisor shall perform a visual inspection of the subgrade surface to determine that it is suitable to be lined. Ecotech Project Supervisor will provide the Owner's and/or Contractor's Representatives with a written acceptance of the surface to be lined prior to commencing installation. This acceptance will be limited to an amount of area that Ecotech is capable of lining during a particular work shift. Subsequent repairs to the subgrade and the surface shall remain the responsibility of the Contractor. An example of Ecotech Subgrade Surface Acceptance form is included in Appendix 1.
G. **Anchoring**

1. The membrane is to be anchored as shown on the plans and approved drawings. The anchor trench is excavated by the Owner or by the Earthworks Contractor as shown on the approved contract drawings. Attention must be paid to the stability of the soil being excavated. Excavation of trenches should be coordinated with the geomembrane installation to avoid excessive exposure to weathering prior to installation. Trenches that collapse, deteriorate, or become saturated, may require rework by the contractor.

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

3. Upon placement of geomembrane panels, the anchor trench must be partially backfilled by the contractor immediately to prevent panel slippage, wind uplift or blowout that could result in liner damage. If immediate backfilling of trenches is not possible, sandbag loading should be used to provide temporary ballast. Final backfilling and compaction, by the Owner or Earthworks Contractor should commence only after the geomembrane has had time to dissipate manufacturing orientation and settle into its final position. Final backfilling of the anchor trench shall be completed per the specification.

H. **Deployment**

1. Geomembrane panels shall be unrolled using methods that will not damage, stretch, or crimp the geomembrane and shall protect the underlying subsurface from damage. The methods used shall minimize wrinkles. If necessary a smooth piece of geomembrane may be used as a rub sheet to facilitate deployment of geosynthetic layers. The rub sheet does not need to run the entire length of the slope, only the top crest and first few feet of the slope need to be covered to facilitate deployment. Ballast that will not damage the geomembrane shall be used to prevent uplift due to wind.

2. Panels shall be oriented perpendicular to the line of the slope crest (i.e., down and not across slope). If panels must be placed across slopes then they shall be shingled such that the upper panel is overlapped above the lower panel. For slopes steeper than 10:1, cross seams parallel to the crest or toe will be located at least 60cm from the crest or the toe of slope. Cross seams on slopes should be minimized, but are acceptable when staggered throughout the slope.

3. Each panel deployed shall be assigned a simple and logical identifying code consistent with the submitted panel layout drawings. No more panels shall be deployed in one day than can be welded during that same day. Tack welding may be acceptable as a temporary measure. However, when possible tack welded panels shall not be left overnight.
4. Personnel walking on the geomembrane shall not wear types of shoes that could damage the geomembrane. Smoking shall not be permitted on the geomembrane.

5. Vehicular traffic on the geomembrane shall be minimized. Equipment shall not damage the geomembrane by handling, trafficking, leakage of hydrocarbons, or any other means. The geomembrane surface shall not be used as a work area, for preparing patches, storing tools and supplies, or other uses. A protective cover may be spread out as a work surface.

6. EcoTech uses low ground pressure devices such as ATV's and tractors to help facilitate deployment over other geosynthetic layers and to reduce the potential for strain related injuries among its field personnel. Low ground pressure devices are machines with less than 50 kN/sqm per wheel when carrying a driver weighing approximately 70 kgs. The typical specification for equipment working directly over the geosynthetics placing cover material is 50 kN/sqm. Using low ground pressure machines also results in a safer work environment.

7. ATVs are not operated: 1) at excessive speeds, 2) in tight turning circles, 3) under extreme breaking and accelerating conditions, 4) with dirty tires, and 5) over wrinkles, that might damage the geomembrane.

8. Sufficient material shall be provided to allow for geomembrane shrinkage and contraction and to avoid bridging. EcoTech Project Supervisor shall determine the amount of additional geomembrane required for compensation based on the weather conditions during installation.

I. Panel Placement

1. When possible the geomembrane should be deployed according to the previously approved panel layout drawing, when such drawings are available. Site conditions such as wind and requirements of the owner or earthwork contractor may require changes to the panel layout sequence. The installation should be started at the highest elevation so that any rainfall runs off to the lower part of the impoundment, thus preventing water from getting under the geomembrane. When possible liner should also begin at the “upwind” side to minimize wind lift. When in position, panels shall be visually inspected to identify, and to allow for subsequent repair, any damage that may have occurred during handling or installation.

2. Geomembrane rolls are unrolled using a front-end loader, a forklift or and excavator, with specially designed lifting apparatus attached to the bucket or forks of the equipment. This enables the panels to be placed in position without heavy equipment running on the material. Panels are deployed to allow a minimum overlap of ten centimeters. When possible, final overlap should be oriented to create a “shingle effect” in the down slope/grade direction.
J. Preparation for HDPE or LLDPE Seaming

Ecotech relies on the experience of the Project Supervisors and the results of test seams to determine seaming restrictions by weather. Many factors, such as the geomembrane temperature, humidity, wind, precipitation, etc., can affect the integrity of field seams and must be taken into account when deciding whether or not seaming should proceed.

Test seams, as described below are required prior to daily production seaming to determine if the weather conditions will affect Ecotech ability to produce quality seams. Additional non-destructive and destructive testing of production seams substantiate the decision made by the Project Supervisor to seam on any given day.

1. The seam numbering system shall be compatible with the panel coding system.
2. 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. The EcoTech Project Supervisor will provide direct supervision of the seaming operations to verify proper welding procedures are followed. During welding operations, at least one Senior Technician shall be present and shall provide supervision over other welders.
3. 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 QC Panel Seaming Form as presented in Appendix 1.
4. The surface of the geomembrane shall be wiped with a clean cloth to remove moisture, dust, dirt, debris, or other foreign material. Solvents or adhesives shall not be used. Panels shall overlap by a minimum of ten centimeters for all welds.
5. Fishmouths or wrinkles at seam overlaps shall be cut to achieve a flat overlap. The cut fishmouths or wrinkles shall be welded where the overlap is more than 10cm. When there is less than 10cm overlap, an oval or round patch extending a minimum of three inches beyond the cut in each direction shall be used.
6. Seams shall be welded only when ambient temperature is between 0°C and 44°C as measured 20cm above the geomembrane surface unless other limits are approved, in writing, by the Engineer (see Section D for site-specific requirements, if any). For temperatures below 0°C, the following procedures shall be utilized:
   1. When the weather is clear and sunny with gentle winds (16 km/s or less) wedge welding can normally be performed at an ambient temperature between -10°C and 0°C (liner temperature is usually warmer than ambient due to the sun) without additional provisions other than adjusting the welding machine. Welding temperatures and machine speeds are adjusted to compensate for cloudy weather and higher winds.
   2. For temperatures between -15°C and -10°C some means of preheating the liner other than that provided by the welding machine is needed.
Types of preheating (space heaters, temporary shelters and combinations of the two) will be determined by the individual job conditions.

3. The following variables are measured and recorded:
   - Liner Temperature (surface contact thermometer)
   - Ambient Temperature (20cm above liner)
   - Wedge Temperature During Welding
   - Wedge Speed
   - Temperature Set Point of Wedge
   - The wedge temperature during welding must be monitored by the machine operator to insure temperature consistency.
   - No welding can take place when it is snowing, sleeting, or raining. Snow and ice must be removed from the liner prior to welding. Snow removal is the responsibility of the owner or contractor.

K. Trial welds

1. Trial welds shall be performed on geomembrane samples to verify welding equipment operations and performance of seaming methods and conditions. Minimum of two trial welds per day or shift per welding apparatus will be made, one made prior to the start of work and one completed mid shift. Additional trial welds shall be made as necessary when air temperature changes by more than 10°C or winds change by more than 15 km/h or in accordance with site-specific requirements, if any (see Section D). Welds shall be made under the same surface and environmental conditions as the production welds (i.e., in contact with geomembrane subsurface and similar ambient temperature).

2. Samples shall be at least 1.20m long and 0.30m wide with the seam centered lengthwise.

3. Cut three (3) 25 mm wide specimens, one (1) from the middle of the seam and 300 mm from each end of the test seam using a 25 mm die cutter. The specimens shall then be tested in peel using a field tensionmeter.

4. In order for a trial weld to be considered acceptable, all three specimens must meet the following criteria:
   a) Exhibit Film Tearing Bond (FTB).
   b) Meet or exceed the minimum peel strength values listed in the Material Specification Sheet. If any specimen fails, 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.
5. A trial weld specimen is considered to pass when the peel test results meet or exceed the project specifications. For double-wedge welding, both welds shall be individually tested and both shall be required to pass in peel.

6. The trial seam tests must pass before welding on the geomembrane starts. If repeat tests performed utilising 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.

7. Remaining samples shall be retained for future testing. The primary method of welding shall be wedge welding; extrusion welding shall be used for repairs and detailing.

8. Trial Weld Documentation: CQC Co-ordinator 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. All trial weld records shall be maintained on Ecotech Trial Weld Form as exhibited in Appendix 1. Ecotech Project Supervisor will give final approval to proceed with welding after observing trial welds.

L. Welding Procedures

Two types of geomembrane welding methods are acceptable; primary (fusion or wedge welding) for panels connection and secondary (extrusion welding) for repairs and detailing. The seaming shall be a continuous operation along the entire seam with a minimum number of interruptions along any given seam. The seaming shall be a continuous operation along the entire seam with a minimum number of interruptions along any given seam. At least one operable spare welding unit for each seaming method shall be on site at all times. Artificially induced cooling of welded seams shall not be allowed.

1. Fusion (Wedge) Welding:

- Fusion (wedge) welding utilizes a metallic wedge heated to the required temperature and guided between the lapped edges of adjacent panels. The welding machine is aligned and set to the required temperature (typically 325°C to 400°C depending on the material thickness and site conditions), and the machine travel speed is set to the required setting for the applicable material thickness. The wedge heats the area of the two panels to be joined to the required temperature. Rollers immediately following the wedge exert the required pressure on the heated area to obtain fusion between the adjoining panels.

- Welding apparatus shall be automated, vehicular-mounted, and equipped with devices giving applicable temperatures and pressures.

- As the welding progresses, the welding operator takes care to assure correct machine speed and alignment.
2. Extrusion Welding:

- Adjacent panels shall be tack bonded together using procedures that do not damage the geomembrane, allow required tests to be performed, and are not detrimental to final seaming. Welding apparatus shall be free of heat-degraded extrudate before welding. The geomembrane surface shall be abraded to a maximum ¼ inch, 5mm beyond the weld bead area, using a disc grinder, or equivalent, not more than ½ hour before welding. The top edges of geomembrane 1.5mm or greater shall be beveled 45° using a hand held grinder. The ends of all seams, which are more than five minutes old, shall be ground when restarting the weld. Grinding depth shall not exceed ten percent of the liner thickness.
- Extrusion welding entails placing a hot extrudate on top of the preheated lap of two adjoining panels while simultaneously applying pressure, and utilizes a welding rod made from the same type of resin as the membrane. The welding rod is melted inside the extrusion welding machine to form the hot extrudate. Preheating of the sheet in the weld area is performed by the extrusion welding machine.
- The Teflon shoe (that determines the profile of the molten extrudate) is checked for correct dimensions. The temperature controllers are then set to appropriate temperatures and the machines are allowed to heat to the temperature set point.
- When the seam area is prepared, the welding machine is positioned so the nozzle and the shoe are flat on the seam. As the machine is moved forward, care is taken to assure that the point of the preheat nozzle is centered on the edge of the top sheet and is as close to the sheet as possible.
- As the welding progresses, the welding operator takes care to assure correct machine speed and alignment.

3. Hot Air Seaming:

- Hot air seaming utilizes a resistance heater, blower and temperature controller to force hot air between the lapped edges of the adjoining geomembranes. The hot air melts the opposing sheet surfaces. Pressure is immediately applied to bond the two sheets.
- Hot air seaming is commonly used for repairs and detailing tasks.

4. Seaming Documentation

- All seaming operations will be documented by the CQC co-ordinator 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 set temperature. CQC Co-ordinator or Assistant will record date, time, seam number, Technician ID, machine ID, set temperature, speed, and weather conditions on the QC Panel Seaming Form (See Appendix 1).
• Welding Technicians will periodically check operating temperature and speed and mark the information along the seam.

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

M. Seam Inspection and Repair

• After welding, a close visual inspection of the seam is made. This is done as soon as possible after the weld has been completed. The inspection is to include weld alignment. For extrusion welding, the weld thickness and profile is inspected.

• Defective areas are marked and repaired then the repairs are inspected and approved. This inspection/repair process is carried out in a systematic manner as soon as possible to ensure that no defective area goes unrepaired.
SECTION B – INSTALLATION QUALITY ASSURANCE

A. Conformance Testing (By CQA Consultant)

When conformance testing of the geomembrane material is required and the samples have not been taken in the plant, samples shall be obtained in the field at a frequency defined in the project specifications. The CQA Consultant shall obtain samples and forward them to their laboratory. Care shall be taken not to damage the geomembrane during sampling. The sample shall be cut 1.00m long (excluding the first meter of the roll) by width of roll. The machine direction shall be marked on the samples with an arrow.

B. Non-Destructive Testing

Non-destructively test all field seams over their full length using vacuum box testing, air pressure testing for fusion (wedge) welded seams only, or spark testing. Generally non-destructive testing is carried out as the seaming progresses.

Air pressure, vaccum box, and spark testing methods apply only to seam. Ecotech personnel shall continuously visualy examine the geomembrane panels for the presence of other penetrating and non penetrating defects and shall continuously feel for protuberences when walking on the geomembrane.

EcoTech standard testing parameters and requirements are documented in Section C. Site-specific requirements, if any, are documented in Section D.

1. Vacuum box testing

Vacuum box testing shall conform to the following requirements:

- The equipment shall include two vacuum box assemblies consisting of the following: a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, a vacuum gauge, a vacuum device equipped with pressure control, a rubber pressure/vacuum hose with fittings and connections, a soapy solution and an applicator.

- Testing shall conform to the following procedure: Brush soapy solution on seam. Place vacuum box over the wetted area. Ensure that a leak-tight seal is created. Apply a vacuum of approximately 35kPa. Examine the geomembrane through the
viewing window for the presence of soap bubbles for not less than ten seconds. All areas where soap bubbles appear shall be marked and repaired as described in this section.

- Vacuum box testing will be performed by qualified construction personnel with frequent supervision by the CQC Co-ordinator.
- Overlap must be trimmed prior to vacuum boxing all seams.
- Special attention shall be exercised when vacuum testing "T" seams or patch intersections with seams.
- Vacuum testing crew will use Mean Streak permanent markers to write on liner indicating tester’s initials, date, and pass/fail designation on all areas tested.
- Records of vacuum testing will be maintained by the CQC Co-ordinator or testing crew on QC Non-Destructive Testing Form or Repair Report Form as exhibited in Appendix 1.

2. Air pressure testing

For fusion (wedge) welded seam with an enclosed space, shall conform to the following requirements:

- The equipment shall consist of the following: an air pump (manual or motor driven) equipped with pressure gauge capable of achieving pressure over 170kPa, a rubber hose with fittings and connections, a sharp hollow needle and a pressure gauge. Sufficient cushioning (i.e. rubsheet, wheels, padding, etc.) should be provided under the air pump equipment to protect the geomembrane.

- Testing shall conform to the following procedure:
  
  Seal both ends of the seam to be tested. Insert needle into the channel created by the double-wedge weld. Energize the air pump to a minimum pressure as indicated in Section C, close the valve, and sustain the pressure for at least five minutes. If pressure loss exceeds the allowable drop or does not stabilize, locate faulty area and repair as described in this section.

  After test completion, the air channel at the opposite end of the seam from the air insertion point should be punctured to release the air. This will assure there is no channel blockage and that the seam has been tested along its entire length. If blockage is present, locate and test seam on both sides of blockage. Remove needle and repair penetration holes by extrusion welding as necessary.

- 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 Co-ordinator on the QC Non-Destructive Testing Form as exhibited in Appendix 1.

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

  o Check seam end seals and retest seams.
o If a seam does not maintain the specified pressure, the seam should be visually inspected to localise the flaw. If this method is unsuccessful, cut one 25 mm sample from each end of the seam.

o Perform destructive peel tests on the samples using the field tensionmeter.

o If all samples pass destructive testing, remove the overlap left by the wedge welder and vacuum test the entire length of seam.
  • If a leak is located by the vacuum test, repair by extrusion fillet welding. Test the repair by vacuum testing.
  • If no leak is discovered by vacuum testing, the seam will be considered as passing non-destructive testing.

o If one or more specimens fail the peel tests, additional samples will be taken.

3. Spark testing

Spark testing shall be used for those extrusion seams that are unable to be tested by a vacuum box.

• The spark test method consists of placing 24 gauge copper wire at the edge or just under the top sheet overlap of the two sheets, prior to extrusion welding. After welding, a spark detector operating between 10 and 30 kVA is run along the weld. If any pinholes are present, a circuit will be completed through the copper wire and the spark detector. Sparks will be observed jumping from the probe to the seam this will indicate a failure. The spark test is typically used for extrusion welded seams where there is no hazard anticipated from a spark and where there is no chance of creating a vacuum seal.

• There is no immediate danger to human or animal life if a circuit is made through the spark detector. However, the spark detector should not be used in the presence of water or excessive moisture.

• The spark testing crew will use mean streak permanent markers to write on liner indicating testers initials, date and pass/fail designation on all areas tested.

• Records of spark testing will be maintained by the C.Q.C. co-ordinator or tester crew on QC Non-Destructive Testing Form or Repair Report Form as exhibited in Appendix 1.

C. Destructive Testing

• As the welding of the geomembrane progresses, test samples shall be cut from the finished liner. Defective areas identified by visual inspection such as appearance of excessive heating, contamination, offset weld, etc. should be marked for subsequent repair. The Owner’s representative or QA/QC consultant shall determine the location of the destructive samples (see Section C for
standard frequency or Section D for site-specific frequency, if any). When reasonable, destructive samples should be taken at the beginning or end of a seam, preferably from areas that will be buried in the trench. Based upon successful test results and Engineer’s approval the frequency of testing may be decreased (see Section D for site-specific requirements, if any). It is in the Owner’s interest to minimize the number of destructive holes in the liner.

- Both destructive and trial weld samples shall be labeled with the following information:
  
  a) destructive or trial weld sample  
  b) job name and number  
  c) date sample was welded  
  d) membrane thickness  
  e) sample or seam number, if applicable  
  f) welder’s name  
  g) welding machine number  
  h) ambient temperature at time of welding

- Laboratory Testing (performed by the CQA laboratory): Samples shall be tested in peel and shear. Minimum acceptable strength to be obtained for these tests shall be in compliance with EcoTech’s standard testing values (see Section C). If the project specifications are not in agreement, special considerations will be made between EcoTech and the CQA consultant/Owner’s representative in order to agree upon destructive values for each individual project (See Section D).

- At least five specimens shall be tested by each test method. Specimens from each sample shall be selected alternately for testing (i.e., peel, shear, peel, and shear). For double wedge seam samples, both welds shall be tested in peel. Test results shall be provided verbally within 24 hours after receiving samples, and in written form within seven days.

- Whenever a sample fails a destructive test, whether that test is conducted by the CQA laboratory, EcoTech’s laboratory or the field tensiometer, the seam shall be reconstructed between the nearest passing destructive tests location on each side of the failed. For reconstructed seams exceeding 200m, a sample taken from within the reconstructed seam shall also pass destructive testing.

- Prior to the geomembrane being covered by the next layer of geosynthetics or soil, seams shall exhibit passing results in laboratory testing.

- Immediately repair all holes in the geomembrane resulting from destructive samples. The continuity of the repair shall be vacuum tested in accordance with this section.

- All destructive seams shall be numbered and recorded on QC Destructive Test Form as exhibited in Appendix 1
D. **Defects and Repairs**

- The geomembrane shall be examined for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. The geomembrane surface shall be clean at the time of examination. Each suspect location shall be repaired and non-destructively tested. Geomembrane shall not be covered at locations that have not been repaired.
- Damaged geomembrane shall be removed and replaced with acceptable geomembrane if damage cannot be satisfactorily repaired.
- Any portion of the geomembrane exhibiting a flaw or failing a destructive or non-destructive test shall be repaired. Procedures available include:
  - Patching used to repair large holes (over 1cm diameter) and tears (over 30cm long), and contamination by foreign matter.
  - Abrading and re-welding: used to repair small extrusion seam sections (less than 30cm long).
  - Spot welding: used to repair small tears (less than 5 long), pinholes, or other minor, localized flaws.
  - Capping used to repair large lengths of failed seams.
  - Extrude overlap along the lengths of failed fusion welded seams
  - Removing the unsatisfactory material or seam and replacing with new material.
- Patches or caps shall extend at least 15cm beyond the edge of the defect, and all corners of material to be patched and these shall be rounded to a radius of at least 15cm. The geomembrane below caps shall be cut to avoid water or gas collection between the two sheets.
- Repairs shall be non-destructively tested using methods specified in this section.

E. **DOCUMENTATION**

An effective CQA plan depends largely on recognition of all construction activities that should 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 CQA Consultant will ensure that all quality assurance requirements have been addressed and satisfied.

The CQA Consultant will provide the Project Manager with written comments, data sheets, and logs to verify that all monitoring activities have been carried out. The CQA Site Manager will maintain, at the job site, a complete file of plans and specifications, the CQA plan, checklists, standard test procedures, daily logs, and other pertinent documents.

1. **Daily Recordkeeping**

   Standard reporting procedures will include preparation of daily reports which, at a minimum, will consist of: (a) field notes, including memoranda of meetings and/or
discussions with the Earthwork Contractor and Ecotech; (b) observation logs, and testing data sheets; and (c) construction problem and solution data sheets. This information will be regularly submitted to, and reviewed by, the Project Manager.

a) Observation Logs and Testing Data Sheets

Observation logs and testing data sheets will be prepared daily. At a minimum, these logs and data sheets will include the following information:

- an identifying log/sheet number for cross-referencing and document control;
- date, client name, project name, location, and other identification;
- data on weather conditions;
- a Site Plan showing all active work areas and test locations;
- descriptions and locations of ongoing construction;
- equipment and personnel in each work area, including those of all geomembrane related subcontractors;
- descriptions and specific locations of areas, or units, of work being tested and/or observed and documented;
- locations where tests were done and samples were taken;
- a summary of test results;
- calibrations of test equipment, and actions taken as a result of any nonconformance;
- off-site materials received, including quality verification documentation;
- decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of nonconformance; and
- signatures of the CQA Site Supervisor and the CQA Monitors.

These logs must show all non-complying test results (trial seams, field destructive tests, air pressure tests, etc.).

A comprehensive set of CQA Logs would be as follows:

- Manufacturer/Ecotech Compliance Agreement
- Certification and Test results of Raw Materials from Raw Materials Supplier
- Certification and Test results of Raw Materials from Membrane Manufacturer
- Roll Test Data Reports for Each Roll of Material
- HDPE Welding rod Test Reports
- Daily personnel attendance list
- Material inventory
- Conformance testing
- Subgrade acceptance
- Material deployment
- Trial seaming
- Production seaming
- Repairs
- Nondestructive testing
- Destructive testing
- Laboratory test results
- Problems and solutions
- Daily report

These documents must provide full traceability of men, seaming machines, machine settings, materials, weather, and test results, in the event of in-service operational problems.

The CQA Manager will incorporate all of these logs in the CQA Final Report.
F. **Independent Testing**

The Client at his own discretion and cost may require the Installer to extract random samples of sheet from each roll and from welded seams to qualify the Manufacturers and Installers test results. Samples shall be kept to a minimum and the following frequency of samples shall apply:

- Material samples = 1 – sample per roll
- Weld Samples from Site – 1 sample for every 300 metres, of seam.

All subsequent independent tests shall be undertaken by an approved testing authority experienced in the testing and evaluation of HDPE Flexible Membrane liners. The tests and results shall be subject to review and/or confirmation by the Membrane Manufacturer.

- Roll identification and dimensions
  - Roll number
  - Production Date
  - Area of Sheet on Roll
  - Roll Length
  - Roll Width
  - Roll Weight

- Resin lot information
  - Batch Number
  - Resin Type
  - Resin Test Results – ASTM
    - Density D792
    - Moisture D570
    - Brittleness D746
    - Melt Index D1238
    - O.I.T. D3895

G. **Geomembrane Acceptance**

EcoTech shall retain all ownership and responsibility for the geomembrane until final commissioning. Owner will accept the geomembrane installation when the installation is complete and verification of the adequacy of all field seams and repairs, including associated testing, is complete.
Geomembrane Welding & Installation

1. Inspect Subgrade
2. Inspect Rolls
3. Test Startup Samples
4. Meet Specifications?
   - No: Reset Welder
   - Yes: Test Welds
5. Test Welds
6. Destructive Testing
7. Non-Destructive Testing
   - Spark/Air Pressure/Vacuum
   - Tensile Peel & Shear
8. Meet Specifications?
   - No: Repair
   - Yes: Visual Inspection
9. Visual Inspection
10. Quality Approval!
SECTION C- INSTALLATION QUALITY CONTROL AND QUALITY ASSURANCE REQUIREMENTS

This section contains EcoTech’s standard values for seam quality and non-destructive testing parameters. EcoTech will install material as per the following requirements unless superseded by site-specific project requirements (see Section D).

1. **Air Pressure Testing**

   Non destructive air pressure testing of fusion welded seams shall conform to the following parameters:

   **INITIAL PRESSURE SCHEDULE**

<table>
<thead>
<tr>
<th>MATERIAL (mm)</th>
<th>MIN.kPa</th>
<th>MAX.kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 mm</td>
<td>165</td>
<td>205</td>
</tr>
<tr>
<td>1.5 mm</td>
<td>185</td>
<td>240</td>
</tr>
<tr>
<td>2.0 mm</td>
<td>205</td>
<td>240</td>
</tr>
<tr>
<td>2.5 mm</td>
<td>205</td>
<td>240</td>
</tr>
</tbody>
</table>

   **MAXIMUM PERMISSIBLE PRESSURE DIFFERENTIAL AFTER 5 MINUTES - HDPE**

<table>
<thead>
<tr>
<th>MATERIAL (mm)</th>
<th>PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 mm</td>
<td>30 kPa</td>
</tr>
<tr>
<td>1.5 mm</td>
<td>20 kPa</td>
</tr>
<tr>
<td>2.0 mm</td>
<td>15 kPa</td>
</tr>
<tr>
<td>2.5 mm</td>
<td>15 kPa</td>
</tr>
</tbody>
</table>

2. **Destructive Testing**

   Destructive test samples shall be marked and cut out randomly at a minimum average frequency of one (1) test location every 200 m of seam length.

   - Location of destructive samples will be selected by CQC Co-ordinator (or third party QA), with samples cut by Ecotech Construction Personnel.

   - Destructive samples should be taken and tested as soon as possible after the seams are welded (the same day), in order to detect possible problems in a timely manner.

   - CQC Co-ordinator will observe all destructive testing and record date, time, seam number, location, and test results on QC Destructive Testing Form as contained in Appendix 1.
• All destructive test locations with pass/fail designation will be marked on liner with permanent Mean Streak markers.

• Sample Size
  
  o The sample should be 300 mm wide with a seam 500 mm long centred length-wise 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.
  
  o A 25 mm specimen shall be cut from each end of the test seam for field testing.
  
  o The two (2) 25 mm wide specimens shall be tested in the field in a tensionmeter for peel. If any field specimen fails to pass, it will be assumed the sample fails destructive testing.

3. HDPE Minimum Acceptable Strength

<table>
<thead>
<tr>
<th>Geomembrane Nominal Thickness</th>
<th>30 mils</th>
<th>40 mils</th>
<th>50 mils</th>
<th>60 mils</th>
<th>80 mils</th>
<th>100 mils</th>
<th>120 mils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Wedge Seams&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength&lt;sup&gt;2&lt;/sup&gt;, lb/in.</td>
<td>57</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>160</td>
<td>200</td>
<td>240</td>
</tr>
<tr>
<td>shear elongation at break&lt;sup&gt;3&lt;/sup&gt;, %</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>peel strength&lt;sup&gt;3&lt;/sup&gt;, lb/in.</td>
<td>39</td>
<td>52</td>
<td>65</td>
<td>78</td>
<td>104</td>
<td>130</td>
<td>156</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Extrusion Fillet Seams</td>
<td></td>
<td></td>
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<td>104</td>
<td>130</td>
<td>156</td>
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<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

Notes for Tables 1(a) and 1(b):
1. Also for hot air and ultrasonic welding methods.
2. Value listed for shear and peel strengths are for 4 out of 5 test specimens; the 5<sup>th</sup> specimen can be as low as 80% of the listed values.
3. Elongation measurements should be omitted for field testing.

<table>
<thead>
<tr>
<th>Geomembrane Nominal Thickness</th>
<th>0.75 mm</th>
<th>1.0 mm</th>
<th>1.25 mm</th>
<th>1.5 mm</th>
<th>2.0 mm</th>
<th>2.5 mm</th>
<th>3.0 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Wedge Seams&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength&lt;sup&gt;2&lt;/sup&gt;, N/25 mm</td>
<td>250</td>
<td>350</td>
<td>440</td>
<td>525</td>
<td>700</td>
<td>875</td>
<td>1050</td>
</tr>
<tr>
<td>shear elongation at break&lt;sup&gt;3&lt;/sup&gt;, %</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>peel strength&lt;sup&gt;3&lt;/sup&gt;, N/25 mm</td>
<td>170</td>
<td>225</td>
<td>285</td>
<td>340</td>
<td>455</td>
<td>570</td>
<td>680</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
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</tr>
<tr>
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<td>25</td>
<td>25</td>
<td>25</td>
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<td>25</td>
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</tbody>
</table>
 SECTION D - SITE-SPECIFIC REQUIREMENTS

This section contains site-specific project requirements (if any) including material specifications, seam quality criteria and non-destructive testing and welding parameters.

These requirements supersede EcoTech’s standard requirements found in Section C.

Documents included in this section area as follows:

1. Method Statement and Site Organisation for Waimakariri Irrigation Storage Ponds
GEOMEMBRANE 1.5mm smooth HDPE INSTALLATION

- WAIMAKARIRI IRRIGATION STORAGE PONDS
1. **Scope**

This method statement covers the works to be carried out by ECOTECH at the Waimakariri Irrigation Storage ponds. The work essentially comprises:-

- Unloading containers of liner, supply to the deployment areas
- Deployment of lining materials with placement of temporary and permanent ballast
- Seaming and testing of lining materials
- Quality controls and records

2. **Supporting documentation**

This method statement should be read in conjunction with the following supporting documentation:

- Project Specification and Condition of the Contract
- Project Drawings
- Ressource Consent Conditions
- Building Consent Conditions
- Health and safety policy of Rooney Group.
- Ecotech Risk assessments.
- Ecotech Construction Quality Assurance Plan.

3. **Site organisation**

Works carried out by Ecotech are under the control of the Ecotech Project Supervisor. The Project supervisor will liaise with and take instructions from the Ecotech Project Manager. Overall control of operations on site is under the control of Rooney Earthmoving Ltd Management teams. The organisation of Ecotech staff is indicated in the organograms which follows:

3.1 **Description of the Parties**

These descriptions should be modified to suit the specific project organization. Insert individual or company names where indicated.

3.1.1 Owner
The Owner owns, and is responsible for, the facility. The Owner is Waimakariri Irrigation Limited.

3.1.2 Operator
The Operator is responsible to the Owner for the operation of the facility. The Operator may be the Owner. The Operator is Waimakariri Irrigation Limited.

3.1.3 Project Manager
The Project Manager is the official representative of the Owner or Operator. In this CQA Plan, the term "Project Manager" will apply equally to "Construction Coordinator" or "Owner's Representative", i.e. the individual in charge of field activities. The Project Manager is [to be confirmed].

3.1.4 Design Engineer (Engineer)
The Engineer is responsible for the design, drawings, plans, and specifications for the HDPE geomembrane and related geosynthetics. In this CQA Plan, the term "Engineer" will refer specifically to the Engineer responsible for the design. The Engineer is Damwatch Services Ltd.
3.1.5 General Contractor/Earthwork Contractor
The General Contractor (or the Earthwork Contractor) is responsible for the preparation of the soils relating to the lining system. The General Contractor prepares the subgrade on which the geosynthetics are placed, and the trench in which the geomembrane is anchored. He places the soil cover on top of the geosynthetics, and may place geosynthetics other than the geomembrane. The General Contractor is Rooney Earthmoving Ltd.

3.1.6 Resin Supplier
The Resin Supplier produces the raw resin for the Geomembrane Manufacturer. The Resin Supplier are [to be confirmed].

3.1.7 Geomembrane Manufacturer (Manufacturer)
The Geomembrane Manufacturer, or Manufacturer, is responsible for the production of the geomembrane, and, maybe, some prefabricated appurtenance components. The Manufacturer is [to be confirmed].

3.1.8 Geomembrane Installer (Installer)
The Geomembrane Installer (Installer) is responsible for field handling, storing, placing, seaming, ballasting (loading against wind), and other aspects of the geomembrane (and, perhaps, other geosynthetics) installation. The Installer is responsible for transportation of these materials from the main storage area to the site. The Installer is Ecotech.

The Installer’s Project Manager is [to be confirmed].
The Installer’s Site Supervisor is [to be confirmed].
The Installer’s Quality Control Representative is [to be confirmed].

3.1.11 Construction Quality Assurance Consultant
The CQA Consultant is a party, independent from the Owner, Operator, Manufacturer, Installer, and General Contractor, that is responsible for observing and documenting activities, and providing advice related to the CQA of the production, installation, testing, repair, and covering of the geomembrane lining system. The CQA Consultant is also responsible for issuing a final CQA report. The geosynthetics CQA Consultant is Damwatch Services Limited.

The CQA Project Manager is [to be confirmed].
The CQA Site Superintendent is [to be confirmed].

3.1.12 Construction Quality Assurance Laboratory
The CQA Laboratory is a party, independent from the Owner, Operator, Manufacturer, Installer, and General Contractor, that is responsible for conducting tests on samples of geomembrane taken from the Manufacturer’s plant or from the site and on seam samples taken from the site. The CQA Laboratory may be a division of the CQA Consultant. The CQA Laboratory is [to be confirmed].
3.2 Ecotech – Site Organisation Chart

The Ecotech Project Manager will be in charge of the overall project including but not limited to:

- Liaise with Client and Project Engineer and attend progress meeting.
- Organise and supervise the delivery of the material to the job. Verify the delivery documents accordingly to the goods delivered.
- Monitor the consumption of the material.
- Ensure that the material comply with the specifications.
- Organise the sequence of the work closely with the Project Supervisor and the earthwork contractor.
- Responsible for the ressources deployment in order to comply with the contractual completion date. Implement the production outputs.
- Monitor the quality of the works and analyse the QAQC the documentation. Ensure that the works comply with the QAQC plan.
- Responsible for maintaining high HSE standards on site. Carry out new employees, induction accordingly to Ecotech HSE plan. Conduct Too Box Meetings once a week.
- Organise with the Workshop Manager any maintenance, services of equipment as well as lifting devices and electric tools controles.

The Ecotech Project Supervisor will be in charge of the installation works including but not limited to:

- Report to the Project Manager
- Ensure that the HSE standards are in place anytime and ensure that every employee is conforming to the Company HS Policy. Participate to Toolbox talks.
- Responsible for the training of the new employees and the organisation of the crews.
- Responsible for the subgrade quality acceptance prior to deployment.
- Responsible for the deployment of the liner accordingly to the QAQC plan. Ensure that the liner is correctly ballasted and safe from wind up lift at any time closely with the earthwork contractor.
- Ensure that the works are carried out as per the QAQC Plan and the Method statement. Monitor the quality of the seams closely with the QAQC officer. Report any non conformity to the Project Manager.
- Ensure that the equipment is used, cleaned and stored properly after each working day. Manage the spare parts stock. Ensure that the equipment used is certified. Report to the Project Manager any defect or non compliance of the equipment.
- Fill out daily construction sheets showing resources, quantities installed, location, weather, delays, events... (journal) A folder is to be made for each pond.

The **Ecotech QAQC Officer** will be responsible of carrying out all necessary tests on the liner as per the QAQC Plan including but not limited to the following:

- Report to the Project Manager
- Carry out trial welds tests, non destructive and destructive tests and fill out the QC forms. Notify the Project Supervisor of any non-complyant results
- Monitor the placement of the panels and the seams location by filling out the required QAQC forms.
- Measure on a daily basis the quantity of liner installed, prepare a daily draft.
- Ensure that the testing devices are always in good condition and calibrated. Report to the Project Manager any defect or non compliance of the testing equipment.
- Responsible for the survey of the area covered before permanent ballast is installed.

4. **Organisation of the lining works**

   a) **Site Setup**

Before lining installation commences a number of set-up/preparation tasks will take place,

- Induction to all Ecotech employees and plant drivers (provided) with regard to the HSE plan, QAQC Plan and method of installation.
- Prepare safe acces to ponds bases to crew and equipment as well as trucks that will deliver the containers of liner. Ensure thoses accesses are correctly maintained all along the material delivery phase.
- Identify and move lining materials into small stockpiles around the site.
- Fill adequate number of sandbags and deposit around the site.

Welfare facilities, site office and material storage areas are to be provided by the Earthwork Contractor. Ecotech will provide a storage unit for their own tools and equipment.

The site will be kept clean at all times. Cores, wrappers and scrap materials will be gathered each day and stockpiled in an approved area for disposal.

The First Aid cabinet shall be positioned in the company vehicles and will be appropriate for the type of work. An update list of current First Aiders will be posted on Site noticeboard. It is the responsibility of all staff to be aware of the current First Aiders.

   b) **Method of installation**

The anchor trench will be excavated as required and controlled by the Ecotech Project Supervisor; the excavated material will be placed on the bench to be used to lock the liner inside the trench.
When the sub-grade is trimmed and rolled the Ecotech Project Supervisor will proceed to an inspection and issue a “Sub-grade acceptance certificate” for the agreed area which will be signed by him and the CQA Engineer.

The roll of liner is hung on the spreader beam and transported to the deployment area using a front loader. All spreader beams will be attached to a certified lifting point on the excavator/loader using a set of tested and certified chains.

The deployment will be performed using 2 methods. The liner can either be pulled from the top of to the bottom the slope including 35m on the floor, the excavator remains still; or layed onto the ground from the top to the bottom of the slope as the excavator drives down. This second solution can generate some further ground repairs after the excavator tracked down. In some circumstances, it is preferable to pull the membrane off the roll but it exposes the liner to the wind. It is necessary to gauge the wind speed and direction before deploying each panel.

The Project Supervisor will be responsible of the choice of the method accordingly to the weather conditions, wind speed and ground conditions.

The panels will be singled (where possible) in the wind direction to allow the wind pass over the top helping to reduce the risk of wind uplift.

On a daily basis as the work progresses, the temporary leading edge of the liner will be ballasted with sandbags to prevent uplift of the membrane in the wind.

On slope areas sandbags attached to a rope line will be deployed where necessary. When wind is constant and deployment is taking place lines will be installed on each individual panel.

The leading edge of exposed materials has to be kept to a minimum.

The welding and testing will be carried out in compliance with the QAQC Plan, it will also comply with the site-specific specification and drawings, if any.

The sandbags will be removed and used on the next area when backfill and compaction of the anchor trench will be completed as well as the 100mm layer of silt on the floor.
CERTIFICATE OF ACCEPTANCE
OF SOIL SUBGRADE SURFACE

PROJECT NAME: ____________________________________________________________

PROJECT NUMBER: _________________________________________________________

OWNER: ___________________________________________________________________

LOCATION: ________________________________________________________________

I the undersigned, a duly appointed representative of EcoTech, have visually observed the soil subgrade surface described below and found it to be an acceptable surface on which to install geomembrane.

This certification is based on observations of the surface of the subgrade only. No subterranean inspections or tests have been performed by EcoTech, and EcoTech makes no representations or warranties regarding conditions which may exist below the surface of the subgrade. EcoTech accepts no responsibility for conformance of the subgrade to this project’s specifications.

Area being accepted: _________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

EcoTech REPRESENTATIVE:

DATE: ___________________________________________________________________

SIGNATURE: ______________________________________________________________

NAME: ___________________________________________________________________

TITLE: ___________________________________________________________________

OWNER REPRESENTATIVE:

DATE: ___________________________________________________________________

SIGNATURE: ______________________________________________________________

NAME: ___________________________________________________________________

TITLE: ___________________________________________________________________

COMPANY: __________________________________________________________________
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<td>Resin Manufacturers</td>
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<td>3</td>
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This manual is conforming to the ISO 9001 standard. This manual is confidential and assigned to the above mentioned person. It shall not be copied, nor lends without Solmax International Inc. President's authorization.
Solmax International Inc. has applied, since its opening, a quality control program acknowledged by the industry. However, with our company’s growth and the current competition in the environmental industry, we must be constantly able to retrace the realization history and ensure a superior quality level for all the projects we realize.

**PROGRAM SCOPE**

The present manual was developed and implemented by Solmax International Inc., in order to describe the plant quality control procedures. This manual describes the general lines of all the quality control procedures, from the resin selection (including the reception and the storage) to the roll manufacturing (including the identification, the flaws of the material, the manipulation and the storage).

Solmax International Inc. has implemented a high quality level for geomembranes. Its quality control program is considered as one of the most rigid in the industry. This complete and detailed program allows a rapid and precise detection of any nonconformities, in the execution or of all the material. This also allows Solmax’s personnel to identify the causes and the extent of the nonconformity, and to take all necessary corrective actions to prevent its reoccurrence. In addition, to ensure that we meet the standards and specifications, these well-defined quality control procedures allow an excellent traceability.

**QUALITY CONTROL STRUCTURE**

Solmax International’s laboratory is staffed 24 hours a day, 365 days a year. This minimizes the possible occurrence of substandard material being shipped prior to identification of the problem.

In Varennes (Canada) the QC personnel reports to the production manager, whom reports to the Vice-President Quality, Operation & Technical Services

In Malaysia the QC personnel reports to the plant manager, whom reports to the board of directors.
Solmax uses resin from internationally recognized resin manufacturers. The resin is shipped to the Solmax facility by railcar (capacity of approximately 180,000 lbs of resin pellets) by container or by box. Each transport is then given a batch number to ease identification and traceability of raw materials. The incoming resin used by Solmax is continually monitored by Solmax’s Quality Control Department. A rigorous set of tests are performed on the incoming resin before we approve it for manufacturing.

**GENERAL FLOW CHART**

Solmax uses resin from internationally recognized resin manufacturers. The resin is shipped to the Solmax facility by railcar (capacity of approximately 180,000 lbs of resin pellets) by container or by box. Each transport is then given a batch number to ease identification and traceability of raw materials. The incoming resin used by Solmax is continually monitored by Solmax’s Quality Control Department. A rigorous set of tests are performed on the incoming resin before we approve it for manufacturing.

**RESIN RECEPTION**
- By train or truck

**SAMPLING**
- On each delivery for quality control

**L Meyer to Solmax**
- Laboratory Testing
  - Density ASTM D-1505
  - Melt Index ASTM D-1278 (condition E & F)

**RESIN PUMPING**
- In the silos for production uses

**RESIN PUMPING**
- In the silos for production uses

**GEOMEMBRANE PRODUCTION**
- Verification of production parameters and thickness characteristics
- Visual inspection of the final product

**GEOMEMBRANE SAMPLING**
- A sample (30cm per roll width) is to be removed from each roll and allowed to acclimatize to standard laboratory conditions for testing

**NON-COMPLIANT PRODUCT**
- The roll is identified as non-compliant and re-evaluated by the technical department
- The roll might be reclassified or downgraded

**LABORATORY TESTING**
- Each roll is controlled in accordance with the test methods and frequencies specified on the technical datasheet

**ROLL WRAPPING**
- Upon approval of a laboratory technician, the roll is identified with 3 labels and then placed in the designated area, until delivery to the client

**Does the roll meet the specifications?**
- Yes
- No

**Does the product pass the visual inspection?**
- Yes
- No

**Return of the resin to the supplier**
RAW MATERIAL QUALITY CONTROL
POLYETHYLENE GEOMEMBRANE MANUFACTURING
RAW MATERIAL QUALITY CONTROL

RESIN MANUFACTURERS

The resin manufacturers need to provide quality control data documentation to Solmax, for each lot, confirming that the raw material test results comply with Solmax specifications for the following properties:

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>ASTM D 1505 / D 792</td>
</tr>
<tr>
<td>Melt Index</td>
<td>ASTM D 1238 Condition E</td>
</tr>
<tr>
<td>Oxidative Induction Time (OIT)</td>
<td>ASTM D 3895</td>
</tr>
</tbody>
</table>

The carbon black content is applicable if the resin is preblended (Carbon Black Content specification ASTM D4218). When the resin is not preblended, carbon black is added during the production of the geomembrane roll.

PRODUCT QUALITY REPORT

Each lot of raw material and of carbon black material from a supplier is accompanied by an analysis certificate. A copy of this report is sent directly to the quality control department for approval before use.
RAW MATERIAL TESTING / ACCEPTANCE

The quality control and quality assurance for geomembrane manufacturing starts with the testing of raw materials.

1. Upon arrival at our facility, a resin sample is taken from one compartment of each railcar by a Quality Control Technician. The resin is to be placed in a plastic storage bag which is immediately identified with the railcar number and lot number.

2. The resin sample is to be taken to the Quality Control Laboratory and allowed to acclimatize to standard laboratory conditions.

3. The following tests are to be performed by the Quality Control Department on each shipment of resin received to ensure that it meets the specifications necessary to produce geomembrane: Density according to ASTM D-1505, Melt Flow according to ASTM D-1238 (condition E and F).

4. The Quality Control Department is to visually inspect incoming resin for: Package condition; Date of manufacture; Manufacturer or supplier; Batch number; Cleanliness.

5. The results are to be recorded and compared to the resin supplier certificates of analysis provided by the resin manufacturer. Anomalous differences are to be investigated and reconciled by both the resin manufacturer and Solmax.

- If the material does not comply with the specifications, it is to be immediately returned to the resin manufacturer.
- If the material complies with the specifications, it is to be released for manufacturing use by the Quality Control Department.

6. A sample (plastic bag) of resin is to be kept in the sample storage box and is archived in a building dedicated to Quality Control Sample Storage for a period of 10 years.

7. All resin shall remain in the railcar until the testing is completed and authorization is issued by the Quality Control Department.

8. Resin Certificates of Analysis are to be issued for each resin lot and submitted with the quality control documentation.

The resin is used only when all the laboratory tests are completed and the results are satisfying.
BATCH PREPARATION

At Solmax, all resin & carbon black are pumped by a vacuum system to avoid any contamination. In addition to the QA/QC standard procedure and as the specific request of the project, we at Solmax confirm that:

1. The virgin resin shall be mixed with approximately 2-3 percent of carbon black.

2. Carbon Black content is to be monitored during production.

3. Rolls which fail to meet the specification for carbon black are to be marked as “SCRAP” and discarded.

RESIN STORAGE

Upon approval of test results, the resin is stored in numerous storage silos. The resin is used on a “first-in, first-out” basis. Colorant and other additives delivered in a box are stored in previously identified zones.
ROLL GOODS QUALITY CONTROL
POLYETHYLENE GEOMEMBRANE MANUFACTURING
ROLL GOODS QUALITY CONTROL

MANUFACTURING PROCESSES

Solmax international has two manufacturing plants for polyethylene geomembranes. The first one is located in Varennes, Québec, Canada, on the south-shore of Montréal. The plant comprises two film production units: a three layer one and a single layer one. The plant has a standard geomembrane production capacity of around 60,000 kg per day, and approximately 20 million kg annually.

The second plant, Pelabuhan Klang, Malaysia, is equipped with a three layer production unit and has a production capacity of around 10 million kg annually.

This equipment can produce all the common types of polyethylene geomembrane ranging from 6.15 to 8 m in width, with a thickness between 0.5 and 2.50 mm. Solmax is able to transform several types of resins, including High Density Polyethylene (HDPE) and other polyethylene configuration, as well as low density polyethylene (LLDPE). All these resins can be used in the manufacturing of smooth or textured (on one or both sides, in order to improve the friction properties) geomembranes.

MANUFACTURING QUALITY ASSURANCE

Solmax’s manufacturing Quality Control policy is to adhere to the highest standards of quality. All employees are required to strictly adhere to all published Quality Control standards at all times. Quality Assurance is an attitude that must prevail among all employees and that attitude, coupled with a strong Quality Control program, will ensure the highest quality of product possible.

Solmax’s Quality Control and research laboratory will perform concurrent testing to assure control over all products. The laboratory will also be capable of supporting manufacturing, product development, and research needs. To this end, Solmax is sensitive to Quality Assurance suggestions from its personnel, and welcomes the suggestions of its customers.

Quality control is critical during manufacturing. The production of rolls is monitored and rolls are punctually inspected visually for identification of all repetitive defects by Solmax QC Inspectors as well as Operators. Any roll identified as nonconforming is set aside and stored separately.

The production lines are equipped with hole detectors (spark tester) into which all materials go before being wound into rolls. If there is a hole in the geomembrane sheet, an alarm advises the operators who can locate and cut off the defect or, according to the case, discard the roll.
...CONTINUED

TESTS FREQUENCY

1. Geomembrane tests are to be conducted in accordance with the technical data sheet. The information concerning the tests, test methods, specifications, quality control testing frequencies and minimum values are indicated on the work order.

2. For each roll produced, a sample measuring 30 cm x roll width is to be removed and allowed to acclimatize to standard laboratory testing conditions.

3. Dies and Hydraulic press are used to prepare the testing specimens. Dies are to be inspected for imperfections on a punctual basis. Dies not meeting ASTM Standards are rejected.

4. The testing is to be performed by the technician to ensure that it meets the specifications on the production work order. In addition, every roll is tested according to the specified test frequency, as well as the first roll after any product change. Solmax uses the same test frequency for all its materials. The thickness (MI-LAB-10), the dimension of the rolls and the weight are measured for each roll produced. As for the tensile resistance test (MI-LAB-09), the liner density (MI-LAB-06) and the carbon black content (MI-LAB-14), they are tested at a frequency of one every two rolls (at around every 3,400 kg). The carbon black dispersion (MI-LAB-07), the tear resistance (MI-LAB-08), the puncturing resistance (MI-LAB-12) and the dimensional stability (MI-LAB-04) are tested every 6 rolls (at around every 10,200 kg). For each textured geomembrane produced, the asperity height is measured according to the standards GRI-GM12 (MI-LAB-01). In addition, each roll coming from a new resin batch is completely tested, just as a first roll after a production change (i.e. thickness or surface texture). For properties where the tests are not conducted on every roll, the non tested properties for this roll are certified according to the results obtained for the tested rolls before and after.

5. After the testing has been conducted, the results are to be recorded into a database and compared to the specifications of the product.

TEST DATA AND ARCHIVES

For each roll produced, a piece of 22.8 cm x 30.5 cm (9” x 12”) is to be removed and identified (with the roll number) from the test sample for archive. The roll number is marked with a permanent white marker on the piece and archived in a building dedicated to Quality Control Sample Storage for a period of at least ten (10) years. The Quality Control Sample Storage is not to be exposed to UV radiation and extreme temperature, or any other environmental conditions which might lead to question the validity of the test results.
The test results incorporated in the database allow the issuance of the conformity certificates. The database also allows the generation of specific reports for projects, type of material, manufacturing dates, thickness, resin batch, etc. All these data allow the traceability of the raw material versus their use (MP-CQ-08). Reports of test data are also available on customers’ demand.

### TEST METHODS

All test methods used by Solmax are approved under either ASTM (GAI-LAP) or GRI (Geosynthetics Research Institute, Drexel University). The test methods under which the properties are tested are listed on the Solmax geomembrane technical data sheets, showing all routine testing, frequencies and internal specifications (see annex A for a list of all conducted tests). The specifications listed are minimum roll values.

When technical data sheets include non-standard testing, a comparison table is created and provided to the customer upon request. Any property not included in the Standard Manufacturing Quality Control Program is certified by Solmax according to independent laboratory test results.

### TEST EQUIPMENT CALIBRATION

In accordance with the industry’s best practices, Solmax International is also responsible for ensuring that:

- Appropriate test equipment of required accuracy and precision is used to ensure that accurate tests and measurements are conducted in accordance with the properties of the materials specified;
- All laboratory equipment is periodically checked for proper calibration;
- All laboratory testing machines are calibrated annually by an independent expert;
- Calibration procedures and records calibration are established, documented and filed;
- The equipment is routinely checked to ensure proper operating conditions;
- A system is documented and maintained to evaluate the validity of previous records in instances where measuring and test equipment is found to be out of calibration;
- Equipment is uniquely identified, kept and used in the correct manner/environment and that it is secure.
EQUIPMENT PRE-START CHECKS

Before a start-up or a change of the material production, the following have to be controlled and verified to assure the quality of the desired final product:

- Speed of production
- Extruders’ temperature
- Die temperature
- Pressure
- Velocity

CONFORMANCE TESTING

The QAC will review the test data results from Solmax. If necessary, they can select random samples for conformance testing.
IDENTIFICATION, HANDLING & STORAGE
POLYETHYLENE GEOMEMBRANE MANUFACTURING
IDENTIFICATION, HANDLING & STORAGE

ROLL IDENTIFICATION

Each manufactured roll is given a unique roll number, regardless of the type of material. The roll number is attributed chronologically to each roll manufactured. All manufacturing and quality control data relative to each roll is stored in the same database, under the roll number. This information allows Solmax to keep track of all the rolls produced, quality control results, roll dimensions and weight, date shipped, client, etc. (MP-CQ-08).

Each roll is identified immediately with at least three labels: one inside the core and two others under the first wrap of material, directly on the geomembrane sheet, at each end of roll. These labels show the roll number, resin blend, product code, dimensions, weight and date of manufacture. These roll tags must be legible, waterproof and printed with non-fade ink.

ROLL HANDLING AND STORAGE

The equipment used to handle the rolls must allow the handling, with ease, of a 2,270 kg (5000 lb) roll, without damaging it. Each roll is equipped with two polyester or nylon slings to allow the forklift to handle it properly. It is also possible to introduce a lift truck’s metal axis in the roll core to move it.

The polyethylene geomembrane rolls do not need a protective wrapping for outside storage. The geomembrane rolls can be stacked up to 4 rolls high for smooth geomembrane and up to 3 rolls high for textured geomembrane, without crushing the core (MI-LOG-04). They should not be placed in mud or in any places where there is an excess of water, or other kind of materials that could damage the geomembrane.

ROLL ALLOCATION

Each time a roll is ready to be shipped, it must be visually inspected before it is allocated for transportation.
CONTROL OF NON-CONFORMING PRODUCT
POLYETHYLENE GEOMEMBRANE MANUFACTURING
CONTROL OF NON-CONFORMING PRODUCT

Any material showing damage, such as holes, undispersed raw materials, telescoping or other defects, shall be identified as non-conforming and stored apart from other rolls (MP-CQ-03). All material identified as defective must be evaluated in order to determine the extent of the damaged area. Following the evaluation of each roll by Technical Services, they are classified as:

• Rejected: The roll is then ground into chips and incorporated into the production line at a maximum rate allowed by the production work order;

• Localized damage: The damaged area is cut out and the roll can be used like all others;

• Downgraded: There is no apparent damage to the roll except that it does not meet the specifications for the corresponding thickness. It is therefore used at a lower grade than it was originally produced for; Used by derogation: The roll could be used on a non-environmental project if approved by the client (Example: golf pond, fire pond, etc.).
ADDITIONAL INFORMATION
POLYETHYLENE GEOMEMBRANE MANUFACTURING
ADDITIONAL INFORMATION

ADDITIONAL INFORMATION, TO THE ATTENTION OF THE CUSTOMER

TRANSPORTATION DOCUMENTS

• ROLL TAGGING:
  Only rolls which are approved by the Quality Control Department shall be loaded.

• PACKING LIST PREPARATION
  The packing list for each container shall be prepared separately and shall contain roll numbers according to tags.

• FREIGHT DOCUMENTS
  - Bill of Lading
  - Commercial Invoice
  - Packing List
  - Customs Declaration Forms

  *Documents shall be prepared according to shipping company requirements.*

ROLL HANDLING

The equipment used should be able to handle a 5000 lb (2,270 kilo) roll with ease without damaging it. Each roll has two nylon slings for proper handling using a forklift. Rolls can also be handled by inserting a “metal carpet pin” into the cardboard core of the roll.
TRANSPORTATION & SITE DELIVERY

- All containers and/or trucks will be transported and unloaded on the project’s site.
- The rolls will be stored on three timber bearers (100mm x 100mm) evenly spaced and located on levelled and stable ground.
- Geomembrane rolls can be stacked up to four rolls high for smooth products and three rolls high for textured products, without any crushing of the core.

CERTIFICATION OF ACCEPTANCE

On those occasions whereby the owner, the general contractor or the owner’s representative receives, unloads or handles the materials, the following precautions must be taken:

- Upon delivery of the materials to the project site, the owner, the general contractor or the owner’s representative must conduct a visual inspection of the surface of all rolls to detect any defects and damage. This inspection shall be conducted without unrolling the geomembrane unless defects or damage are found or suspected.
- The QAC will record all roll numbers and will check every roll against the list of conformance tested rolls.
- Any flaws, defects or damage must be immediately reported to Solmax International and, if the damage is believed to have occurred during transit, to the carrier who transported the material as well.
- Prior to unloading, the owner, the general contractor or the owner’s representative must be certain that the equipment used to unload or handle the material on site is adequate and poses no undue risk of injury or damage to person or property.
- The unloading or other handling of the material must be carefully supervised to ensure that the material is handled with care and not damaged.
FINISHED PRODUCT STORAGE ON SITE

The owner, the general contractor or the owner’s representative shall provide storage area in a location sufficiently near the subgrade to be lined, to minimize additional handling. The storage area shall be protected from theft, vandalism, passing vehicles and other hazards which create a source of potential damage to the liner. The storage area shall be free of ponding, water, excessive dirt, rocks or debris which could potentially damage the geomembrane. The storage area shall be relatively flat as to prevent movement of the rolls thereafter. The geomembrane rolls can be stacked up to 4 rolls high for smooth geomembrane and up to 3 rolls high for textured geomembrane, without crushing the core (MI-LOG-04) and shall be securely wedged in order to prevent motion.

Polyethylene geomembrane rolls do not require a protective wrapping for outside storage. They only need to be covered by a tarp or other protective cover if stored outside for a period exceeding six months, in order to shield the materials from sunlight and excessive moisture and dirt.
## TECHNICAL DATA SHEET

**Geomembrane HDPE Smooth**

Solmax International Inc., 2801 Boul. Marie-Victorin, Varennes, Qc, Canada, J3X 1P7
Tel.: (450) 929-1234  Fax: (450) 929-2550      www.solmax.com

### SPECIFICATIONS

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST METHOD</th>
<th>FREQUENCY</th>
<th>UNIT</th>
<th>Solmax 460-9000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (min. avg.)</td>
<td>ASTM D-5199</td>
<td>Every roll</td>
<td>mm</td>
<td>1.50</td>
</tr>
<tr>
<td>Thickness (min.)</td>
<td>ASTM D-5199</td>
<td>Every roll</td>
<td>mm</td>
<td>1.35</td>
</tr>
<tr>
<td>Resin Density</td>
<td>ASTM D-1505</td>
<td>1/Batch</td>
<td>g/cc</td>
<td>&lt; 0.940</td>
</tr>
<tr>
<td>Melt Index - 190/2.16 (max.)</td>
<td>ASTM D-1238</td>
<td>1/Batch</td>
<td>g/10 min</td>
<td>1.0</td>
</tr>
<tr>
<td>Sheet Density</td>
<td>ASTM D-792</td>
<td>Every 10 rolls</td>
<td>g/cc</td>
<td>&gt; 0.94</td>
</tr>
<tr>
<td>Carbon Black Content</td>
<td>ASTM D-4218</td>
<td>Every 2 rolls</td>
<td>%</td>
<td>&gt; 2.0 / &lt; 3.0</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>ASTM D-5596</td>
<td>Every 10 rolls</td>
<td>Category</td>
<td></td>
</tr>
<tr>
<td>Oxidative Induction Time (min. ave)</td>
<td>ASTM D-3895</td>
<td>1/Batch</td>
<td>min</td>
<td>100</td>
</tr>
<tr>
<td>Tensile Properties (min. avg) (2)</td>
<td>ASTM D-6693</td>
<td>Every 2 rolls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength at Yield</td>
<td></td>
<td></td>
<td>kN/m</td>
<td>23</td>
</tr>
<tr>
<td>Elongation at Yield</td>
<td></td>
<td></td>
<td>%</td>
<td>13</td>
</tr>
<tr>
<td>Strength at Break</td>
<td></td>
<td></td>
<td>kN/m</td>
<td>43</td>
</tr>
<tr>
<td>Elongation at Break</td>
<td></td>
<td></td>
<td>%</td>
<td>700</td>
</tr>
<tr>
<td>Tear Resistance (min. avg.)</td>
<td>ASTM D-1004</td>
<td>Every 5 rolls</td>
<td>N</td>
<td>187</td>
</tr>
<tr>
<td>Puncture Resistance (min. avg.)</td>
<td>ASTM D-4833</td>
<td>Every 5 rolls</td>
<td>N</td>
<td>540</td>
</tr>
<tr>
<td>Dimensional Stability</td>
<td>ASTM D-1204</td>
<td>Per formulation</td>
<td>%</td>
<td>± 2</td>
</tr>
<tr>
<td>Stress Crack Resistance (SP-NCTL)</td>
<td>ASTM D-5397</td>
<td>1/Batch</td>
<td>hr</td>
<td>400</td>
</tr>
<tr>
<td>Oven Aging - % retained after 90 days</td>
<td>ASTM D-5721</td>
<td>Per formulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP OIT (min. avg.)</td>
<td>ASTM D-5885</td>
<td>%</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>UV Resistance - % retained after 1600 hr</td>
<td>GRI-GM-11</td>
<td>Per formulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP-OIT (min. avg.)</td>
<td>ASTM D-5885</td>
<td>%</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

### SUPPLY SPECIFICATIONS

(Roll dimensions may vary ±1%)

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th></th>
<th></th>
<th>m</th>
<th>8.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll Dimension - Width</td>
<td>-</td>
<td></td>
<td>m</td>
<td>140.0</td>
</tr>
<tr>
<td>Roll Dimension - Length</td>
<td>-</td>
<td></td>
<td>m</td>
<td>1120</td>
</tr>
<tr>
<td>Area (Surface/Roll)</td>
<td>-</td>
<td></td>
<td>m²</td>
<td></td>
</tr>
</tbody>
</table>

### NOTES

1. Testing frequency based on standard roll dimensions and one batch is approximately 180,000 lbs (or one railcar).
2. Machine Direction (MD) and Cross Machine Direction (XMD or TD) average values should be on the basis of 5 specimens each direction.

* All values are nominal test results, except when specified as minimum or maximum.
* The information contained herein is provided for reference purposes only and is not intended as a warranty of guarantee. Final determination of suitability for use contemplated is the sole responsibility of the user. SOLMAX assumes no liability in connection with the use of this information.