

# Alphard

January 13, 2025

Mr. Patrick Dumont  
Project Manager  
Galaxy Lithium (Canada) Inc.  
800-2000, Mansfield Street  
Montréal, Québec H3A 2Z5

Subject: Geomembrane waterproofing monitoring and quality assurance program  
Haulage road with geomembrane – James Bay Lithium Mine - Galaxy Lithium (Canada)  
N/Dossier Alphard : GAL-002-4C-RAP-002-R03\_ENG

---

Dear Sir,

Groupe Alphard Inc (“Groupe Alphard”) is pleased to submit its detailed report on the monitoring and quality assurance program for the waterproofing of the LLDPE, 1.5 mm textured geomembrane included in the proposed design for the construction of the haulage road at the Galaxy Lithium Mine in James Bay. The monitoring and quality assurance program detailed in the following sections is a response to COMEX (Environmental and Social Impact Review Committee) condition 8, which reads as follows:

*“In order to reduce or eliminate risks that could compromise the integrity of the watertightness of the structure during its construction and operation, the proponent has undertaken to implement a leak detection campaign on the geomembrane covered with leachable waste tailings, using a standardized geoelectric method. Such monitoring must be carried out for as long as the leachable materials remain on the said membrane. **The proponent must submit its membrane leakage monitoring program to the Provincial Administrator for authorization prior to the start of haulage road construction.** The results of this monitoring must be presented as part of the annual environmental monitoring report.”*

This detailed report includes four (4) separate sections addressing the following topics:

1. Background;
2. Monitoring and quality assurance program for geomembrane waterproofing during haulage road construction:
  - 1) Implementation of the haulage road waterproofing system;
  - 2) Quality assurance - Geomembrane installation;
  - 3) Verification of geomembrane integrity - Geoelectric leak detection method.
3. Monitoring and quality assurance program for geomembrane watertightness during haulage road operation;
4. Quality assurance and control program during restoration work.

## 1. BACKGROUND

---

On May 11, 2022, Groupe Alphard submitted a Technical memorandum<sup>1</sup> on the proposed design for the haulage road, concluding that the use of a 1.5 mm thick LLDPE geomembrane textured on both (2) faces is adequate to ensure the waterproofing function of the structure in question, and will effectively prevent groundwater contamination. This report details the geomembrane monitoring and quality assurance program to be applied during the construction and operation phases in order to reduce or eliminate the various risks that could compromise the integrity of the waterproofing system, thus guaranteeing that the anticipated performance and durability of the structure are achieved, as well as protecting the environment.

## 2. MONITORING AND QUALITY ASSURANCE PROGRAM FOR GEOMEMBRANE WATERPROOFING DURING HAULAGE ROAD PATH CONSTRUCTION

---

### 1. Implementation of the haulage road waterproofing system

The performance expectations for any geomembrane waterproofing system are generally set at the design stage (choice of waterproofing systems, geometry, natural and geosynthetic materials, etc.). However, the construction stage remains the most critical phase, which will have the effect of controlling the actual performance of the structure.

In order to ensure the integrity of the LLDPE (Linear low-density polyethylene) geomembrane designed to guarantee the watertightness of the haulage road, including the side ditches, the following provisions must be respected and rigorously followed during the following construction stages:

#### Preparation of geomembrane subgrade

The subgrade for the geomembrane consists of a 300 mm layer of fine sand. When installing the geomembrane, the Contractor must remove any objects (such as stones, debris, blunt objects, etc.) from the subgrade that could damage the geomembrane. The exposed surfaces to be covered by the geomembrane must be perfectly levelled, with no depressions, ruts or bulges greater than 50 mm. Any ruts left by the machinery used to deploy the geomembrane must be removed.

Once the subgrade has been accepted by the quality assurance manager, the geomembrane installer is responsible for ensuring its integrity. The installer must take every precaution to avoid damaging synthetic or natural surfaces during geosynthetic installation.

#### Geomembrane installation

Geomembrane installation is subject to rigorous, ongoing on-site monitoring by a quality assurance specialist. A quality assurance and control program for the geosynthetics used in the project will be implemented by an independent expert with recognized expertise in the field of geosynthetics. For your information, a typical quality assurance and control program for geosynthetics is attached in Appendix I of this report. This program is provided for information only. It will be adjusted during detailed engineering and included in the plans and specifications “for construction” of the haulage road.

---

<sup>1</sup> Groupe Alphard. *Technical memorandum* (Avis technique), May 11, 2022, GAL-002-RAP-R00, 137 pages.

The geosynthetics installation mandate will be entrusted to an installer with the expertise and resources qualified for this type of work. Before recommending an installer, the third-party expert will carry out all the necessary checks, including the following:

- The installer's experience (projects completed, types of geomembrane and quantities installed);
- The installer's specialized resources and equipment;
- The experience and skills of the foreman who will be in charge of the installation work (projects completed, types of geomembrane and quantities installed);
- The experience and skills of the welders (projects completed, types of geomembrane and quantities installed). At least one welder must be IAGI (*International Association of Geosynthetics Installers*) certified;
- The experience of the installer's quality control manager (projects completed, types of geomembrane and quantities installed).

Prior to the start of field work, the installer awarded the geomembrane installation contract must provide at least the following documents to the third-party expert for approval:

- A work schedule;
- A geomembrane panel deployment plan;
- Geomembrane installation procedures;
- Quality control program;
- Occupational health and safety program;
- A list of proposed personnel and their qualifications;
- A list of equipment to be used with calibration certificates, if applicable;
- A plan signed by an engineer demonstrating the load-bearing capacity of the spreader bar to be used for geomembrane deployment of the geomembrane.

The geomembrane installation work will be coordinated by the various parties involved on site (contractor, installer and third-party expert) to ensure that the required level of quality is achieved. The following installation work:

- The contractor responsible for building the haulage road must prepare sufficient subgrade surface so as not to delay the installation of the geomembrane;
- The geomembrane will be deployed in such a way that all geomembrane panels are welded or assembled at the end of the working day.
- The deployment method must not damage the geomembrane subgrade, which consists of a layer of fine sand;
- The deployment method must minimize the formation of folds in the geomembrane;
- When the geomembrane panels are deployed, they must be sufficiently loaded with sandbags to enable them to be ballasted and thus protect them from wind uplift;
- The geomembrane installer must allow for expansion or contraction of the geomembrane in response to external temperatures that may occur during deployment, to avoid stresses, folds and uplift;

- The geomembrane must not be deployed in the presence of precipitation, water-saturated surfaces or excessive winds;
- Thermal equipment or generators must be switched off when not being supervised by the installer;
- Special care must be taken when using knives and tools to avoid puncturing or perforating the geomembrane. When cutting geomembrane parts for repair or other purposes, a protective piece of geomembrane must be placed under the work area to prevent damage to installed surfaces;
- All equipment used on the geomembrane (generator, tensiometer, etc.) must be installed at all times on a piece of geomembrane that protects against puncturing or hydrocarbon spills;
- Personnel working on the geomembrane must not smoke or take any harmful action that could affect the integrity of the geomembrane. Anyone not working on geomembrane installation is forbidden to drive on the geomembrane without authorization from the person in charge of quality assurance;
- No machinery is allowed to travel directly on the geomembrane, except light all-terrain vehicles authorized by the quality assurance manager for geomembrane deployment;
- Garbage collection must be carried out daily to keep work areas free of debris and prevent it from scattering during windy conditions.

#### Placement of covering material

The cover material to be laid over the geomembrane consists of a 300 mm thick layer of draining sand. Placing this cover layer is one of the most critical phases in the construction process.

The installation of the cover layer must be rigorously monitored on an ongoing basis to ensure proper placement and preserve the integrity of the geomembrane. Here are our recommendations and the best practices to follow during this stage of the work:

- Placement of the cover layer must be carried out using *low ground pressure* equipment (bulldozers, excavators, etc.);
- Equipment (bulldozers, excavators, etc.) used to place and level the cover layer must be operated on safe material thicknesses to avoid damaging the geomembrane (these thicknesses will be determined at the appropriate time, depending on the equipment to be used);
- Sharp turns by the equipment used for this work are strictly prohibited (to avoid stressing the geomembrane and causing tears);
- Trucks and other equipment used to transport drainage sand must travel on access ramps and temporary roads with a minimum thickness of 1 m above the geomembrane (this thickness will be validated later, depending on the trucks and equipment to be used). Ideally, the transported material should be dumped onto the roadway and then spread with a bulldozer. It should not be dumped directly from the truck bed onto the geomembrane. This best practice will minimize the impact on the geomembrane and preserve its integrity;

- Particular care must be taken when installing the cover layer using a bulldozer, as the latter tends to form folds in the geomembrane by pushing the materials. Therefore, field experience shows that the excavator-bulldozer combination is the most suitable method for minimizing fold formation and thus preserving the integrity of the geomembrane.
- When installing 100-200 mm riprap on the walls of the watertight side ditches along the haulage road, always proceed with the placement of materials from the bottom up to avoid creating stress on the geomembrane.

## 2. Quality Assurance – Geomembrane Installation

The durability and waterproofing of geomembranes can be significantly affected during on-site assembly procedures. It is therefore essential to ensure that the installed product is the same as the one produced in the factory, a condition that can be easily achieved with planned monitoring of calibrated equipment and installers with the required expertise and certifications.

The geosynthetics used in the construction of the haulage road, including the side ditches, will be subject to rigorous monitoring from the time they leave the factory until final acceptance, once installed on site. All inspections, testing, and testing methods must comply with recognized practices. In addition, they must comply with the standards, methods and procedures of the *American Society for Testing and Materials* (ASTM), the *Canadian General Standards Board* (CGSB), and the *Geosynthetic Research Institute* (GRI – specifically GRI GM17 in relation to the LLDPE geomembrane), which must be used according to the specific geosynthetic material.

The quality assurance program that will be implemented during geomembrane installation aims to validate the conformity of specifications and the quality of materials before and after installation. It includes, but is not limited to:

- Management and verification of documentation submitted by the geomembrane manufacturer and installer;
- Monitoring of geomembrane installation;
- Performing on-site and laboratory verification tests;
- Preparing required reports.

Throughout the entire scope of work, the quality assurance manager may conduct or commission tests on the work completed and all materials and equipment supplied or used by the installer. The conformity of the geomembrane will be verified at each stage of its installation, in accordance with the requirements of the project specifications.

The supply and installation of the geomembrane are subject to the following quality assurance procedures:

- Verification of quality control documents;
- Performance of material conformity tests in an external laboratory;
- Verification of welding equipment calibration tests;
- Joint inspection and acceptance of the subgrade with the installer;
- Verification of installation and welds;
- Verification of non-destructive testing;

- Verification of destructive tests;
- Final inspection.

### Geomembrane assembly

Since waterproofing is the primary function of any geomembrane, their assembly by welding is of major importance, and can significantly affect the achievement of anticipated performance.

The main characteristic of a weld is to ensure a seal between the geomembrane sheets to prevent any liquid (leachate or other) from flowing into the structure's subgrade. Therefore, it is essential to ensure that the weld is continuous and that the adhesion between the sheets can withstand the mechanical forces that will be transmitted and applied.

Assembly of the geomembrane panels will only be permitted once the following procedures have been completed:

- Proper alignment of the panels;
- Appropriate overlap of the panels;
- Cleanliness of the surfaces to be joined;
- Drying of the surfaces to be joined;
- Adequate identification of the panels;
- Calibration of the assembly equipment;
- Qualified assembly personnel.

Calibration tests consist of verifying the mechanical resistance of the welds to peel and shear on a geomembrane sample. No assembly equipment may be used on site without a prior calibration test that meets the specifications.

The assembly of the LLDPE geomembrane, which will be installed along the towpath and side ditches, must be carried out using double fusion welds, except in special situations (repairs, restricted space) in which case the weld may be performed by extrusion.

Here is an overview of the authorized techniques for geomembrane assembly:

#### a) Double fusion welding

This welding technique involves applying sufficient energy to partially fuse the two (2) geomembrane surfaces that will be in contact and applying pressure to obtain a uniform weld.

Where possible, automated double fusion welding with heating elements should be preferred. These devices are developed by incorporating electronic equipment to continuously measure and adjust the sheet temperature, the temperature of the heating elements, the applied pressure, and the welding speed. Double fusion welding allows for non-destructive continuity testing by pressurization.

Factors related to the double fusion welding process that can influence the level of sheet embrittlement include: a temperature gradient that is too great between the sheet and the heating medium, a melting temperature that is too high, a welding speed that is too slow (overheating), and a welding pressure that is too high.

An automated process (double fusion) allows for better weld uniformity and higher peel and shear strengths than the manual extrusion process.

#### b) Extrusion Welding

This welding technique is only used in hard-to-reach areas for double fusion welding and for repairs.

This is a manual process using an extrusion gun fed with a bead of polymer (the same resin as the geomembrane used). Under the action of heat and pressure, the polymer fuses and is conveyed to the gun nozzle. A bead of molten material flows from the nozzle. The operator must spread the bead over the previously prepared joint. Since this is a manual process, the operator controls the thickness of the bead spread over the joint to be welded, as well as the alignment of the weld. This is why experienced personnel are required.

#### Non-destructive Testing (Leaktightness)

Non-destructive testing is used to ensure the continuity and leaktightness of all welds constructed over 100% of their length.

#### a) Weld Pressurization Test

To perform this test, the ends of the double-fusion weld channel must be sealed. A hollow needle equipped with a pressure gauge is then inserted into the central channel at one end of the weld and connected to a hand pump to inject air.

The pressure test is performed by applying an air pressure of approximately 210 kPa (30 psi) to the weld channel for five (5) minutes. The allowable air pressure loss is 20 kPa (3 psi) or less according to ASTM D5820. After the observation period, the weld is opened at the opposite end of the needle to verify that the air escapes and the pressure drops to zero. All perforations created to perform the pressure test are repaired and then checked using the vacuum box test.

#### b) Vacuum Box Test

This test is used wherever the pressure test cannot be applied for practical reasons: very short welds, lack of a central channel between welds, extrusion welds, etc.

The vacuum box test is performed by maintaining a negative pressure of approximately 35 kPa (5 psi) across the weld overlap for a period of at least five (5) seconds according to ASTM D5641. If there is a puncture or discontinuity in the area under observation, bubbles will form at that location and can be visually detected by the observer.

### Destructive Testing (Mechanical Strength)

Destructive testing is used to measure the mechanical strength of constructed welds against peel and shear.

Welds must withstand shear forces and elongations transmitted to the geomembrane during the construction and commissioning phases. These forces result, among other things, from the weight of the covering materials and equipment, chemical contractions, hydrostatic pressure, and subgrade settlement.

- Peel test: measures the degree of adhesion of a weld;
- Shear test: measures the weld's resistance to elongation forces (simulation test of real-life stresses on structures).

Under the supervision of the quality assurance manager, the geomembrane installer verifies the mechanical peel and shear strength of the double fusion or extrusion welds made on site using a calibrated portable tensiometer. At the same time, the mechanical strength of these welds is verified in an external laboratory by the quality assurance manager to validate the results obtained on site.

The location of the destructive quality control tests is determined by the quality assurance manager.

### Geomembrane Repair

All punctures and tears must be repaired with a patch of the same type of geomembrane over the entire installed surface. The rounded patch must extend at least 150 mm beyond the defect in all directions. The installer must round off the ends of the defects to avoid creating weak points.

Benefits of the quality assurance program:

- Independent oversight and shared responsibility with the expert responsible for implementing the quality assurance program during construction work;
- Expertise on materials and their installation, enabling the resolution of problems that may arise during construction;
- High impact on the quality of work and the achievement of targeted performance of the completed structures;
- Assessment of the actual quality of the materials and equipment used;
- Validation of the work's compliance with specifications and regulatory requirements;
- High-level performance of the sealing system by applying leak detection techniques.

### **3. Geomembrane Integrity Verification – Geoelectrical Leak Detection Method**

To verify the integrity of the LLDPE geomembrane intended to ensure the waterproofing function of the towpath including the side ditches, we plan to apply the dipole geoelectrical leak detection method to the geomembrane covered with a 300 mm thick layer of draining sand and a 100-200 mm thick 300 mm layer of stone at the side ditches.

The application of the geoelectrical leak detection method will allow:

- To verify the integrity of installed geomembranes covered with soil cover on all their surfaces;
- To detect the presence of perforations as small as 6 mm in diameter;
- To ensure and achieve maximum hydraulic performance of waterproof geomembranes.

The risks of perforation of a geomembrane during the construction phase are numerous and can result from punctures and tears during installation and covering, poor welding, knife cuts, and the movement of trucks and machinery during covering work.

Factory defects during geomembrane manufacturing can be a source of leaks through the geomembrane, although this risk remains minimal compared to the risks of perforation that can occur during the construction phase.

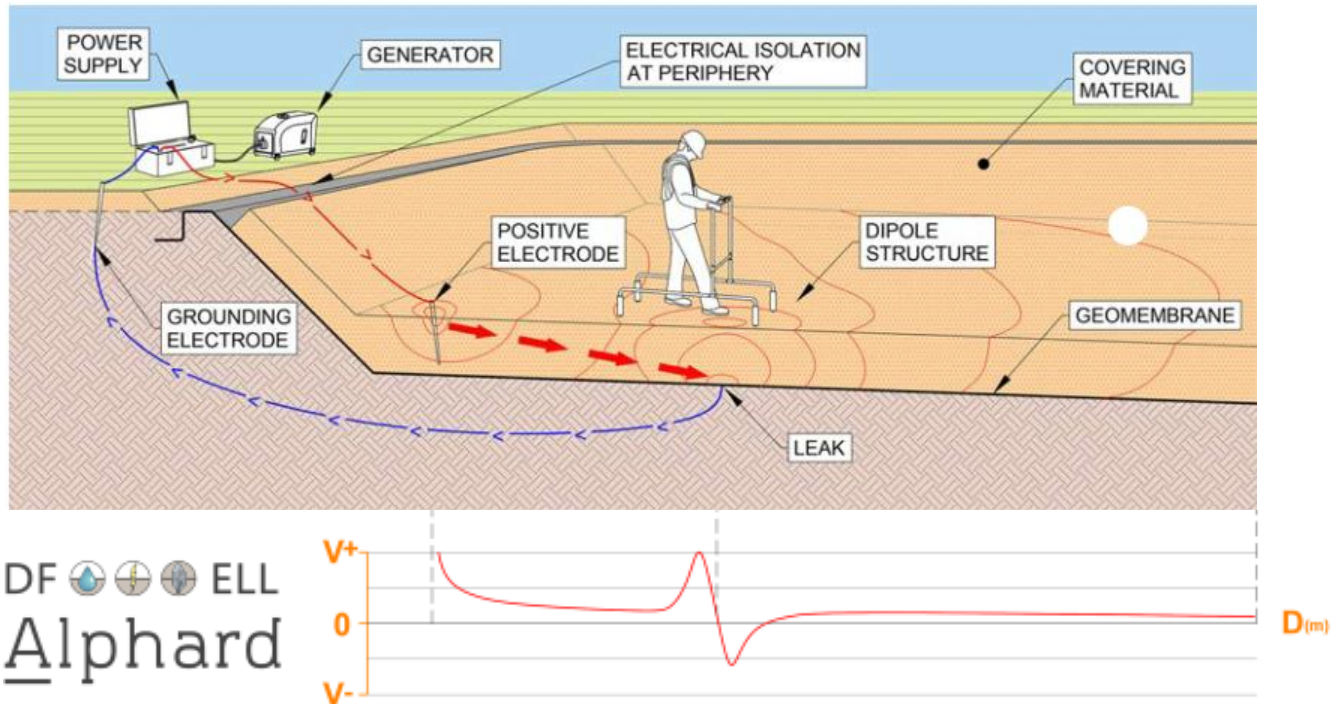
#### Dipole Method – Covered Geomembrane

Description:

The dipole leak detection campaign (according to ASTM D7007 – "*Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials*") detects potential perforations caused by the placement of cover materials over the geomembrane.

The geoelectric dipole method uses the geomembrane's electrical insulation property to locate perforations (see figure below). A voltage of approximately 550 V DC is directly injected into the drainage sand cover, then a ground is placed off-site to force the electrical current to pass through any potential leaks in the geomembrane, thus generating a typical electrical field that can be identified on the surface by a qualified technician. This technology can detect perforations as small as 6 mm in diameter, and even smaller in favorable ground conditions. The dipole method is applicable to a maximum granular cover of 1 m in thickness.

## ASTM-D7007 : DIPOLE



Limitations of the dipole method:

The dipole method requires surface moisture on the cover to ensure good contact between the reading device and the soil. If field calibration shows that the material is too dry, surface moistening is required. The dipole method is not applicable when the material above or below the geomembrane is frozen, or the cover material is thicker than 1 m. To ensure better quality of the work, geomembrane installation and application of the dipole method must be planned before the ground freezes.

To achieve optimal signal quality, the cover material placed over the geomembrane must be electrically isolated from the ground outside the site, using a trench excavated (~0.5 m) around the entire periphery, exposing the geomembrane and ensuring that there is no contact between the geomembrane cover material and the external material. If this is not the case or if it is not possible, the size of detectable leaks will be larger as they approach the peripheries of the geomembrane (small leaks will have a signal that is too weak compared to external losses).

The LLDPE geomembrane planned for the haulage road, including the side ditches, will be exposed over a minimum width of 0.5 m at the crest of the external berm along the side ditches to achieve optimal signal quality and thus enable the application of the dipole method once the 300 mm thick drainage layer is placed over the geomembrane.

An explanatory brochure detailing geoelectrical leak detection methods, including some statistics and completed projects, is attached as Appendix II to this report.

### 3. QUALITY MONITORING AND ASSURANCE PROGRAM FOR GEOMEMBRANE SEALING DURING OPERATION OF THE HAULAGE ROAD

---

During the haulage road operation phase, and as detailed in Groupe Alphard's Technical memorandum, a monitoring and maintenance program will be developed by the third-party expert and rigorously implemented by the site operator. The program will include, among other things, the following elements:

- Annual surveys of the wearing course along the haulage road to check for settlement that could occur during site operation and, if applicable, determine the impact of such settlement on the durability of the structure and its waterproofing system;
- Preventive maintenance, including any activity to be carried out aimed at preventing premature deterioration of the haulage road's wearing surface or delaying its deterioration (filling minor depressions and maintaining side slopes to prevent water accumulation on the wearing surface). It aims to increase the useful life of the haulage road;
- Corrective maintenance consists of localized interventions following the discovery of defects along the haulage road (presence of ruts in the wearing course) that require corrective work (addition of granular materials and recompaction of the affected areas). The surface of the wearing course must remain uniform throughout the structure's operational life to maintain a constant cover thickness over the waterproof geomembrane.
- Although unlikely, the observation of major differential settlements along the towpath could affect the integrity of the geomembrane. In this specific case, it is proposed to delineate the affected area and remove the wearing course and part of the subgrade to reduce the total thickness of the granular materials above the geomembrane by no more than 1,000 mm to allow for the use of the dipole leak detection method. The dipole method will verify the integrity of the geomembrane and repair it if a perforation is detected;
- Monitoring groundwater levels and chemical parameters in observation wells located near the towpath to detect any significant changes that could indicate a variation in water flow or alteration of the towpath's waterproofing system. Following the detection of groundwater contamination, the site operator (Galaxy) will install a pumping well at the appropriate location and redirect the contaminated water into the north basin for subsequent treatment at the water treatment plant.

The results and conclusions of the monitoring planned during the haulage road operation phase will be presented by the site operator in its annual environmental monitoring report.

### 4. QUALITY ASSURANCE AND CONTROL PROGRAM DURING RESTORATION WORK

---

The construction work planned for this stage will be carried out in accordance with the restoration plan submitted by the site operator. A quality assurance and control program will be rigorously implemented to identify any contamination of the granular materials used during the construction of the towpath and to ensure that all procedures and requirements related to the handling, transportation, and disposal of materials are complied with.

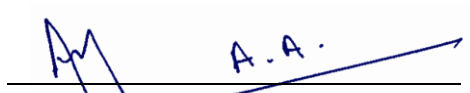
The contaminated granular materials, as well as the geomembranes and geotextiles recovered at the end of the towpath operation, will be transported to and disposed of in landfill sites authorized by the *Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs* (MELCCFP).

The uncontaminated granular materials will be disposed of in the waste rock piles located within the mine site.

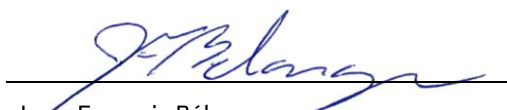
We hope that everything meets your expectations.

Thank you for the trust you have placed in us.

Sincerely yours,

Handwritten signature in blue ink, consisting of a stylized 'AM' followed by 'A.A.' and a long horizontal stroke.

Ahcene Ait Mekourta, Eng.  
Project Director, Construction

Handwritten signature in blue ink, appearing as 'JF Bélanger' with a long horizontal stroke.

Jean-François Bélanger  
Project Director, Environmental Engineering

---

Appendix I: Geosynthetic Quality Assurance and Quality Control  
Program (GQACP)



## Geosynthetic Quality Assurance and Quality Control Program (GQACP)

ALLKEM (Galaxy)

REF. NO.: GAL-002

MAY 2022

VERSION FOR TECHNICAL MEMORANDUM

# Alphard

# Alphard

ALKEM (Galaxy)

Haulage road with Geomembrane - James Bay Lithium Mine - Galaxy Lithium (Canada)

## APPENDIX II

Geosynthetic Quality Assurance and Quality Control Program (GQACP)

Original : Programme d'assurance et de contrôle qualité des géosynthétiques (PACQG)

REF. NO: GAL-002-RAP-R00

MAY 2022

Version for: Technical memorandum

Prepared by:

---

Ahcene Ait Mekourta, Eng.  
Project Director, Construction  
No OIQ : 140952

Approved by:

---

Jean-François Bélanger, Eng.  
Project Director, Environmental Engineering  
N° OIQ : 119098

## Table of Contents

1.	General Conditions.....	1
1.1	Definitions.....	1
1.1.1	Quality Assurance .....	1
1.1.2	Quality Control .....	1
1.2	Stakeholders.....	1
1.2.1	Owner.....	1
1.2.2	Owner’s Representative.....	1
1.2.3	Installer.....	1
1.2.4	General Contractor.....	1
1.2.5	Manufacturer .....	2
1.2.6	Designer/Engineer .....	2
1.2.7	Quality Assurance Consultant.....	2
1.2.8	Geosynthetics Testing Laboratory .....	2
1.3	Scope of Program.....	2
1.3.1	Quality Control .....	2
1.3.2	Quality Assurance .....	3
1.3.2.1	Geomembranes.....	3
1.3.2.2	Geotextiles, Geonets, Geocomposite Drainage Nets and Geosynthetic Clay Liners.....	3
1.4	Standards, Methods and Procedures.....	4
1.5	Meeting.....	4
1.5.1	Pre-construction Meeting .....	4
1.5.2	Kick-off Meeting .....	4
1.5.3	Weekly Meetings.....	4
2.	Geosynthetics Manufacturers’ and Installer’s Qualifications .....	6
2.1	Geosynthetics Manufacturer .....	6
2.2	Geosynthetics Installer .....	6
2.2.1	Foreman.....	6
2.2.2	Welders .....	6
2.2.3	Quality Control Technician .....	7
3.	Information to be Provided by the Installer .....	8
3.1	Schedule and Work Plan.....	9
3.2	Proposed Geomembrane Layout Plan.....	9
3.3	Shop Drawings .....	9
3.4	Quality Control Program.....	9
3.5	Occupation Health and Safety Plan .....	9
3.6	Organizational Chart and Competencies of the Proposed Workforce .....	9
3.7	Documentation of the Geosynthetics Manufacturers .....	10
3.7.1	Pre-approval Samples.....	10

- 3.7.2 Manufacturer's Warranty .....10
- 3.7.3 List of Geosynthetic Rolls and Certificates of Compliance .....10
- 3.7.4 Tensiometer Calibration Certificate.....10
- 3.7.5 Load Capacity of the Spreader Bar.....10
- 3.7.6 Subgrade Surface Acceptance .....11
- 3.7.7 Acceptance of the Installed Geosynthetics .....11
- 3.7.8 Final Quality Control Report.....11
- 4. Information Provided by the QA Specialist..... 12
- 5. Quality Assurance Documents ..... 13
  - 5.1 Site Reports.....13
  - 5.2 Final Report.....13
- 6. Conformance Testing (Quality Assurance)..... 15
  - 6.1 Geomembrane Testing.....15
  - 6.2 Geotextile Testing.....16
  - 6.3 Geonet and Drainage Geocomposite Testing.....17
  - 6.4 Geocomposite Clay Liner Testing .....17
  - 6.5 Verification of the Results.....18
  - 6.6 Non-Compliant Results and Additional Testing.....18
- 7. General Procedures..... 19
  - 7.1 Documentation .....19
  - 7.2 Plant Assembly.....19
  - 7.3 Transport and Handling.....19
  - 7.4 Delivery.....19
  - 7.5 Geosynthetics Lay Down Area .....20
  - 7.6 General Installation Procedures .....20
    - 7.6.1 Approved Techniques .....20
    - 7.6.2 Equipment Inspection.....21
    - 7.6.3 Installation on a Slope.....21
    - 7.6.4 Subgrade.....22
    - 7.6.5 Circulation on the Geosynthetics .....22
    - 7.6.6 Approval of the Geosynthetic Layers .....23
    - 7.6.7 Unfavourable Conditions.....23
    - 7.6.8 Wind Protection.....23
    - 7.6.9 Specific Work Methods .....23
  - 7.7 Visit by the Manufacturer.....24
- 8. Geomembranes – Installation and Control..... 25
  - 8.1 Geomembrane Installation .....25
    - 8.1.1 Acceptance of Work .....25
    - 8.1.2 Respect for the Proposed Geomembrane Layout Plan .....25
    - 8.1.3 Initial Welding Procedures .....25

- 8.1.4 Restrictions.....25
- 8.1.5 Weather Conditions (Standard) .....26
- 8.1.6 Special Considerations in Winter for Polyethylene Geomembranes (PE).....26
  - 8.1.6.1 Trial Test Welds .....27
  - 8.1.6.2 Destructive Tests.....27
- 8.1.7 Anchor .....27
- 8.1.8 Overlap.....28
  - 8.1.8.1 Overlap Direction.....28
  - 8.1.8.2 Overlap Width.....28
  - 8.1.8.3 Overlap Cleanliness .....28
- 8.1.9 Panel Identification.....28
- 8.1.10 Supervision of Geomembrane Welding .....29
- 8.1.11 Documentation .....29
- 8.2 Correction of Deficiencies .....29
  - 8.2.1 Repairs, Re-Touches and Replacements .....29
  - 8.2.2 Approval of the Repairs.....30
  - 8.2.3 Additional Repairs .....30
  - 8.2.4 Documentation .....30
- 8.3 Control and Verification Testing of the Geomembrane Installation.....31
  - 8.3.1 Trial test welds .....31
    - 8.3.1.1 Samples.....31
    - 8.3.1.2 Frequency .....32
    - 8.3.1.3 Conditions .....32
    - 8.3.1.4 Requirements .....32
  - 8.3.2 Non-Destructive Quality Control Tests.....35
    - 8.3.2.1 Approved Techniques .....35
    - 8.3.2.2 Documentation .....35
  - 8.3.3 Destructive Tests .....36
    - 8.3.3.1 Frequency .....36
    - 8.3.3.2 Sampling Location.....36
    - 8.3.3.3 Sampling.....36
    - 8.3.3.4 Compliant Results .....37
    - 8.3.3.5 Non-Compliant Results .....37
    - 8.3.3.6 Conflicting Results from Laboratory Testing .....38
    - 8.3.3.7 Documentation .....38
  - 8.3.4 Laboratory Destructive Tests (Quality Assurance) .....39
- 9. Geotextiles – Installation and Control..... 40
  - 9.1 Geotextile Installation .....40
    - 9.1.1 Monitoring by the QA Specialist .....40
    - 9.1.2 Deployment .....40
    - 9.1.3 Anchoring .....40
    - 9.1.4 Overlap.....40
      - 9.1.4.1 Direction of Overlap.....40
      - 9.1.4.2 Overlap Width.....41

9.1.5	Geotextile Panel Assembly .....	41
9.1.5.1	Sewing.....	41
9.1.5.2	Other Methods.....	41
9.1.6	Visual Inspection .....	41
9.1.7	Repairs .....	41
9.2	Destructive Verification Tests at the External Laboratory .....	42
10.	Geonet and Drainage Geocomposite – Installation and Control.....	43
10.1	Quality Assurance Supervision .....	43
10.2	Deployment .....	43
10.3	Clogging .....	43
10.4	Anchoring .....	43
10.5	Overlap .....	44
10.5.1	Overlap Direction .....	44
10.5.2	Overlap Width .....	44
10.6	Assembly .....	44
10.6.1	Geonet.....	44
10.6.2	Geotextile (for Geocomposite Drainage Net only) .....	44
10.7	Visual Inspection .....	44
10.8	Repairs .....	45
11.	Geocomposite Clay Liner – Installation and Control .....	46
11.1	QA Supervision.....	46
11.2	Deployment .....	46
11.3	Anchoring .....	46
11.4	Overlap .....	46
11.4.1	Overlap Direction .....	46
11.4.2	Overlap Width .....	47
11.5	Installation .....	47
11.5.1	Bentonite Powder.....	47
11.6	Visual Inspection .....	47
11.7	Repairs .....	47

## List of Figures

Figure 1:	Dimensions of HDPE or LDPE geomembrane samples for conformance testing .....	16
Figure 2:	Dimensions of geotextile samples for conformance testing.....	16
Figure 3:	Dimensions of geonet or drainage geocomposite samples for conformance testing. ....	17
Figure 4:	Dimensions of Geocomposite clay liner samples for conformance testing.....	18
Figure 5:	Acceptable deployment pattern of geosynthetics in slopes and at the toe of slopes .....	21
Figure 6:	Acceptable deployment pattern of geosynthetics in slopes and at the toe of slopes .....	22

Figure 7: Overlap direction of the geomembrane and geosynthetics – following the direction of water flow .....28

Figure 8: Geomembrane patch repairs .....30

Figure 9: Method for cutting coupons for trial weld testing.....32

Figure 10: Break types for double fusion welds .....33

Figure 11: Break types for extrusion welds .....34

Figure 12: Sampling method for weld specimens for destructive testing .....37

List of Tables

Table 1: Frequency of trial test welds based on geomembrane temperature .....27

## 1. General Conditions

### 1.1 Definitions

#### 1.1.1 Quality Assurance

All actions and means taken to ensure the compliance of the construction methods and materials. These services are usually provided by the Quality Assurance Consultant (QA Specialist).

#### 1.1.2 Quality Control

All actions and means taken to measure the characteristics of an element to ensure it meets the requirements of the specifications. These services are usually provided by the Geosynthetics Installer.

### 1.2 Stakeholders

#### 1.2.1 Owner

The natural or legal person on whose behalf the works are executed.

#### 1.2.2 Owner's Representative

The natural or legal person who, for his technical competence, is charged by the Owner to control the execution of the works, to propose acceptance of the works, and to propose payment for the works.

#### 1.2.3 Installer

Company, or its representatives, contractually retained by the Owner or the General Contractor and who is responsible for the execution of the work related to the installation of geosynthetics.

#### 1.2.4 General Contractor

Company, or its representatives, retained as contracting party with the client, and who is responsible for the execution and safety of all the works. The General Contractor is usually responsible for the preparation of the surfaces on which the geosynthetics are laid as well as the placement of the granular materials constituting the drainage and protection layers of the waterproofing system.

### 1.2.5 Manufacturer

The Manufacturer is the stakeholder responsible for the factory production of the geosynthetics.

### 1.2.6 Designer/Engineer

The Designer is the person responsible for the design of the works relating to the geosynthetics as well as the preparation of the plans and specifications.

### 1.2.7 Quality Assurance Consultant

Company that is responsible for the application of the Geosynthetics Quality Assurance Program and the supervision of the installation work. The QA Specialist can be the Owner's Representative, the General Contractor or an external company. It must be independent of the Installer, its subcontractors and manufacturers.

### 1.2.8 Geosynthetics Testing Laboratory

The Geosynthetics Testing Laboratory is the stakeholder (independent of the Owner, Owner's Representative, Manufacturer and the Installer) responsible for the various laboratory conformance tests on the geosynthetic samples taken from site.

## 1.3 Scope of Program

### 1.3.1 Quality Control

The Installer's Geosynthetics Quality Control Program must comply with the requirements of this document.

Within the limits of this document and throughout construction, the Installer will be required to perform, or to have performed, certain tests on the works and on all materials and equipment supplied or used to complete the work, in accordance with specifications.

The Quality Control Program applies to the supply and installation of the geosynthetics. At a minimum, the following quality controls must be performed:

- Submittal of the Manufacturer's certificates of compliance for the geosynthetic materials to be installed (from the plant);
- Submittal of the tensiometer calibration certificate;
- Inspection and approval of the subgrade in conjunction with the QA Specialist;
- Performance of trial test welds for the welding equipment;

- Supervision of the deployment of the geosynthetics;
- Visual inspection of the geomembrane welds and other assemblies of geosynthetics (installation);
- Non-destructive testing of the welds;
- Destructive testing of the mechanical strength of the welds;
- Final inspection.

### 1.3.2 Quality Assurance

Quality Assurance includes, but is not limited to, the following elements:

- Managing and verifying the documentation submitted by the Manufacturer(s) and the Installer;
- Monitoring the geomembrane installation;
- Ensuring the field and laboratory verification tests are performed;
- Preparation and submittal of the required reports.

Throughout the works, the QA Specialist may perform, or have performed, tests on the works and on all materials and equipment provided or used by the Installer, in accordance with the requirements of this document or the specifications.

The supply and installation of the geosynthetics are subject to the following quality assurance procedures:

#### 1.3.2.1 Geomembranes

- Verification of the quality control documents;
- Realization of material conformance tests at an external laboratory;
- Verification of the trial test welds;
- Inspection and joint acceptance of the subgrade surface with the Installer;
- Verification of the installation and the welds;
- Verification of non-destructive tests;
- Verification of destructive tests;
- Final inspection.

#### 1.3.2.2 Geotextiles, Geonets, Geocomposite Drainage Nets and Geosynthetic Clay Liners

- Verification of quality control documents;
- Realization of material conformance tests at an external laboratory;
- Verification of the installation and the assembly of the panels (seaming);

- Final inspection.

## 1.4 Standards, Methods and Procedures

All inspections, control and test methods must be performed in accordance with the recognized practices and in consideration of the materials in question. Moreover, they must comply with the standards, methods and procedures of the American Society for Testing and Materials (ASTM), the Canadian General Standards Board (CGSB) and the Geosynthetic Research Institute (GRI).

## 1.5 Meeting

### 1.5.1 Pre-construction Meeting

A pre-construction meeting must be held before construction work begins. The Installer, QA Specialist, Designer and General Contractor must all be present at this meeting.

The purpose of this meeting is to plan the various steps, to review the construction and installation methods to be used, to validate the schedule, to review the responsibilities of each stakeholder, to present the Quality Assurance Program and to perform the site visit.

Minutes of this meeting shall be produced by the Owner's Representative and distributed to all participants.

### 1.5.2 Kick-off Meeting

The kick-off meeting must be held prior to the geosynthetics installation work and may be combined with the pre-construction meeting as needed. The Installer, QA Specialist, Designer and General Contractor must all be present at this meeting. The discussion points should include, but not be limited to, reviewing the responsibilities of each stakeholder, the lines of communication, and the various elements necessary for the proper execution of geosynthetic installation work.

Minutes of this meeting shall be produced by the Owner's Representative and distributed to all participants.

### 1.5.3 Weekly Meetings

A weekly meeting must be held with the Installer, the QA Specialist, the Designer, the Owner's Representative, the General Contractor and all other concerned parties.

During this meeting, problems encountered in the field or upon revision of working procedures or otherwise may be discussed.

Minutes of this meeting shall be produced by the Owner's Representative and distributed to all participants.

In addition, the QA Specialist may decide to hold additional meetings or discussions to which all other relevant persons must attend.

## 2. Geosynthetics Manufacturers' and Installer's Qualifications

### 2.1 Geosynthetics Manufacturer

The materials Manufacturer(s) must have manufactured a minimum of 500,000 m<sup>2</sup> of the geosynthetic product(s) they intend to supply unless otherwise authorized by the Designer. The plant must have sufficient production capacity to provide the necessary geosynthetic quantities for the project without causing delivery delays.

### 2.2 Geosynthetics Installer

The geosynthetics Installer must demonstrate that they have the necessary experience and resources to carry out the project by submitting a list of projects completed over the last three years. This list must include the project name and location, the dates of installation, client name, as well as the types of geosynthetics installed and their respective quantities.

#### 2.2.1 Foreman

The Installer must designate a Foreman who, notwithstanding other responsibilities, has the responsibility of ensuring that the requirements of the quality-control program are systematically implemented during installation and has the authority to do so.

The Foreman must have at least 500,000 m<sup>2</sup> of HDPE geomembrane installation experience, unless otherwise specified. The details of the projects (project name and location, the dates of installation, the name of the client, as well as the types of geosynthetics installed and their respective quantities) on which he worked must appear in the information to be provided by the Installer.

#### 2.2.2 Welders

Welders must demonstrate that they have the skills and experience necessary to operate the welding equipment. Each welder must have installed a minimum of 300,000 m<sup>2</sup> of HDPE geomembrane unless otherwise stated.

The details of the projects (project name and location, the dates of installation, the name of the client, as well as the types of geosynthetics installed and their respective quantities) on which the welders worked must appear in the information to be provided by the Installer.

At least one welder from the workforce onsite must be IAGI certified (International Association of Geosynthetics Installers).

If necessary, the Installer may propose additional staff. Their competencies must be proven to the satisfaction of QA Specialist before they can be authorized on site.

### 2.2.3 Quality Control Technician

The Quality Control (QC) Technician must have sufficient experience and be capable of keeping pace with the installation.

The details of the projects (project name and location, the dates of installation, the name of the client, as well as the types of geosynthetics installed and their respective quantities) on which he worked must appear in the information to be provided by the Installer.

The Installer must designate a QC Technician who will be on site at all times. This QC Technician shall conduct all trial weld tests as well as destructive and non-destructive weld tests under the supervision of the QA Specialist. He shall also perform an inspection of the installed materials and produce required quality control reports.

### 3. Information to be Provided by the Installer

The Installer must provide the QA Specialist with the documents and/or information described in this program.

Two (2) weeks prior to the start of the Installer's work:

1. Schedule and work plan	
2. Proposed geomembrane layout plan	
3. Shop drawings	
4. Quality control program	
5. Occupational health and safety plan	
6. Organizational chart and competencies of the proposed workforce	
7. Geosynthetics Manufacturers' documentation (warranties, bills of lading, and certificates of compliance)	
8. Calibration certificate for the tensiometer	
9. Plan signed by an engineer demonstrating the load capacity of the spreader bar	

During installation work:

1. Subgrade acceptance forms	
2. Installed geomembrane acceptance forms	

Two (2) weeks after the completion of the Installer's work:

1. Final quality control report	
---------------------------------	--

At all times, the results of the quality control tests must be available for inspection at the request of the QA Specialist.

### 3.1 Schedule and Work Plan

The Installer shall provide the QA Specialist with a detailed description of his work plan, including the equipment, methods and schedule proposed to complete the works in accordance with the requirements of this program and the specifications.

The Installer must make known in advance his proposed method for deploying the geosynthetics. The procedure may be discussed at the pre-construction meeting.

### 3.2 Proposed Geomembrane Layout Plan

The Installer shall submit to the QA Specialist a layout plan for each type and surface of geomembrane foreseen in the project. The plan(s) shall clearly indicate the chronological order and arrangement of the geomembranes.

The installation of the panels (widths) must, as closely as possible, respect the proposed layout plan. If not, the proposed changes must be submitted to the QA Specialist for acceptance prior to installation.

### 3.3 Shop Drawings

The Installer shall submit to the QA Specialist the shop drawings detailing at least the following: method for sealing around pipes and other singular points (settlement plates, vents), mechanical or chemical anchors, and any other elements where applicable.

### 3.4 Quality Control Program

The Installer shall provide the QA Specialist with a detailed description of the proposed procedures, tests and control measures that will be used to verify the quality of the work, in accordance with the requirements of this document and/or the specifications.

### 3.5 Occupation Health and Safety Plan

The Installer shall submit the QA Specialist an occupational health and safety program in accordance with Health and Safety Regulations.

### 3.6 Organizational Chart and Competencies of the Proposed Workforce

The Installer shall submit the QA Specialist for approval a list of the proposed workforce detailing their roles and competencies.

## 3.7 Documentation of the Geosynthetics Manufacturers

### 3.7.1 Pre-approval Samples

If necessary, prior to the start of the site work and in accordance with the specific requirements and quantities of the specifications, the Installer shall submit samples of each type of material to be installed onsite, for the purpose of analysis and evaluation.

### 3.7.2 Manufacturer's Warranty

Prior to the commencement of the work, the Manufacturer must provide the QA Specialist a written warranty against any manufacturing defect. At the end of the work, a guarantee covering the supply of geosynthetic rolls must be provided to the Client; it shall offer him full protection, without an exceptional clause. This guarantee must fully indemnify the Client for any direct or indirect costs incurred by the discovery or presumption of manufacturing defects.

### 3.7.3 List of Geosynthetic Rolls and Certificates of Compliance

The Installer must provide the QA Specialist with the list of the geosynthetic rolls to be delivered to site and their corresponding certificates of compliance before the start of the work.

### 3.7.4 Tensiometer Calibration Certificate

The Installer must master and maintain the welding machines and the control and measurement equipment (tensiometer). The tensiometer must pull at 50 mm/min for HDPE. The devices must be clearly labelled.

The Installer must provide the QA Specialist the calibration records for the tensiometer two weeks prior to the start of the work. The calibration certificate must be dated from the current year.

### 3.7.5 Load Capacity of the Spreader Bar

Before the start of the work, the Installer must ensure that the spreader bar intended to deploy the geosynthetics is safe to transport the rolls and support their load. The maximum lifting capacity (in kg or MT) must be indicated on the bar. The Installer must also provide the design plan for the spreader bar signed by an engineer.

### 3.7.6 Subgrade Surface Acceptance

The subgrade surface must be accepted by the Installer and the QA Specialist before geosynthetics may be installed. This acceptance may be subdivided to cover only a portion of the surface at a time. Once the surface is accepted, the Installer shall be responsible for ensuring its integrity and for preventing any damage to it before the deployment of geosynthetics.

### 3.7.7 Acceptance of the Installed Geosynthetics

The installed geomembrane surface must be approved by the QA Specialist and the Installer before any geosynthetic or natural material may be placed over top. This acceptance may be subdivided to cover only a portion of the surface at a time. After the surface has become accepted, the Installer shall be responsible for ensuring its integrity and for preventing any damage to it until it is covered.

### 3.7.8 Final Quality Control Report

Two weeks after completion of the installation work, the Installer shall submit a final report to the QA Specialist, which shall include at least the following elements:

- Description of all geosynthetic installation activities;
- Description of all quality control activities;
- Data sheets and certificates of compliance for the geosynthetics;
- List of the geosynthetic rolls delivered to site
- Quality control activities related to the panel pre-assembly (if applicable);
- Quantity of geosynthetics installed;
- Results of the onsite quality control tests;
- The certificate of compliance for the work;
- The Installer's representative's signature;
- The geomembrane as-built plans, to scale;
- The as-built plan must show, locate and identify the following information:
  - Geomembrane panels;
  - Geomembrane welds;
  - Destructive test samples;
  - Geomembrane repairs;
  - Reconstructed geomembrane welds;
  - Boots for pipes and other elements;
  - Mechanical anchors.

#### 4. Information Provided by the QA Specialist

The QA Specialist shall provide the Installer with the following documents and information:

Prior to the start of the installation work:

1. Acceptance of the Installer's skills	
2. Acceptance of the workforce proposed by the Installer	
3. Copies of the plans and documents to perform the work	
4. Acceptance of the proposed materials	
5. Acceptance of the schedule and work plan	
6. Acceptance of the shop drawings	
7. Acceptance of the proposed geomembrane layout plan	
8. Acceptance of the quality-control program	
9. Acknowledgment that the occupational health and safety program was received	
10. Acceptance of the measuring device (tensiometer)	

During the installation work:

1. Joint acceptance of the subgrade surface	
2. Joint acceptance of the installed geosynthetics prior to backfilling	

Upon completion of the installation work:

1. Final acceptance of work	
-----------------------------	--

## 5. Quality Assurance Documents

The QA Specialist is the person designated to administer the quality assurance program required by this document.

### 5.1 Site Reports

On a daily basis, the QA Specialist must document the following:

- Project and date;
- Weather conditions;
- Scope of work performed during the day;
- Type and quantity of materials installed during the day;
- Plans showing the geomembrane installed during the day;
- Installer workforce;
- Field trial test welds performed during the day;
- Panels deployed, and welds performed during the day;
- Any other tests performed during the day;
- Repairs.

### 5.2 Final Report

Upon completion of the installation work, the QA Specialist shall present a final report including at least the following:

- A description of the construction activities;
- A description of the quality assurance activities;
- Certificate of compliance of the works;
- The results of field tests and observations;
- Any photographs taken during the works;
- List of amendments to the original plan;
- List of amendments to the specifications;
- Certificates of conformance for the various materials;
- Results of the compliance tests performed on materials upon delivery;
- Signature of the QA Specialist;
- Installer quality control report;

- Final plan for the geomembrane installation, including:
  - Panels (widths);
  - Welds;
  - Reconstructed welds;
  - Destructive tests;
  - Repairs (piece, extrusion bead);
  - Boots for pipes and other elements;
  - Mechanical anchors.

## 6. Conformance Testing (Quality Assurance)

The geosynthetic materials must comply with the minimum requirements of the technical specifications.

Samples of the geosynthetics shall be taken by the QA Specialist for conformance testing upon their delivery to site. The Contractor or Installer must provide the necessary equipment and means for handling the geosynthetics so that the onsite sampling may be performed. Conformance testing shall be performed at the Owner's Representative's expense.

The geosynthetic sampling frequency is detailed in the specifications. If too many batches are submitted, then additional samples and tests may be required; these will be at the Installer's expense.

A batch consists of a group of rolls sequentially numbered and from the same manufacturing formulation. The QA Specialist shall designate the geosynthetics testing and analysis laboratory prior to the commencement of the work. The laboratory must be independent of the Installer, its subcontractors and manufacturers. No material may be deployed until the QA Specialist has verified the results of the conformance tests.

At the end of the work, the laboratory shall present a report including the following elements:

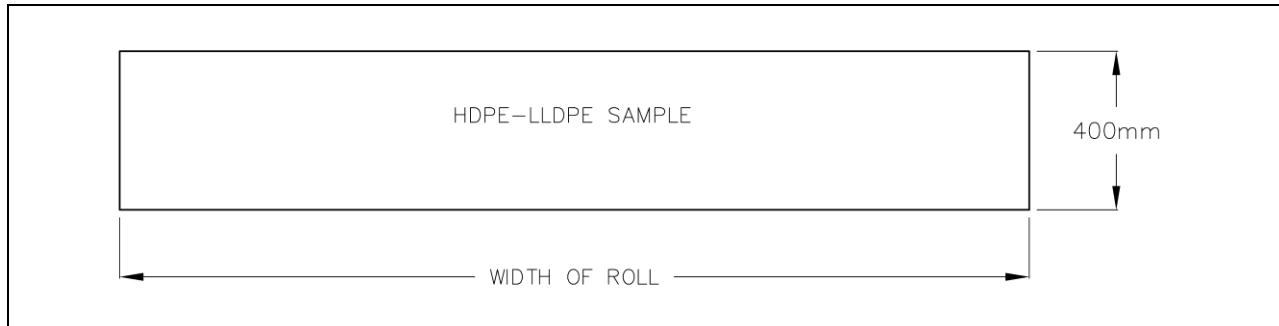
- Description of the materials tested;
- Properties evaluated;
- Test methods used;
- Results obtained;
- Relevant comments;
- Graphical results of the tests;
- Signature of the laboratory manager.

### 6.1 Geomembrane Testing

Laboratory conformance testing of the geomembrane (smooth and/or textured) must include the types of tests detailed in the specification and respect the sampling frequencies found therein. For informational purposes, the following tests are usually requested:

- Thickness;
- Relative density;
- Carbon Black Content;
- Carbon Black Dispersion;
- Tensile Strength;
- Oxidative Induction Time (OIT);
- Resistance to stress cracking.

Figure 1: Dimensions of HDPE or LDPE geomembrane samples for conformance testing

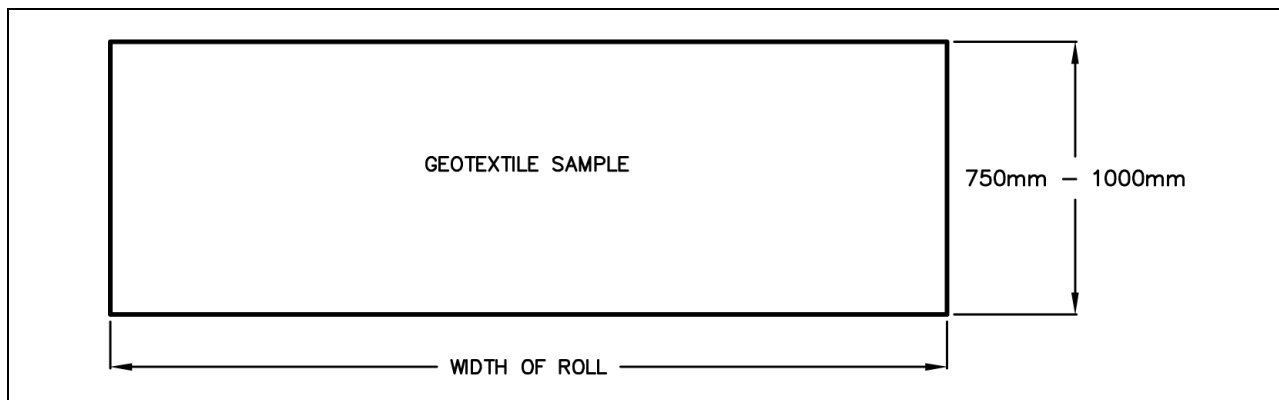


## 6.2 Geotextile Testing

Laboratory conformance testing of the geotextiles must include the types of tests detailed in the specification and respect the sampling frequencies found therein. For informational purposes, the following tests are usually requested:

- Thickness;
- Mass per unit area;
- Tensile strength;
- Puncture strength;
- Tear strength;
- Filtration opening size.

Figure 2: Dimensions of geotextile samples for conformance testing

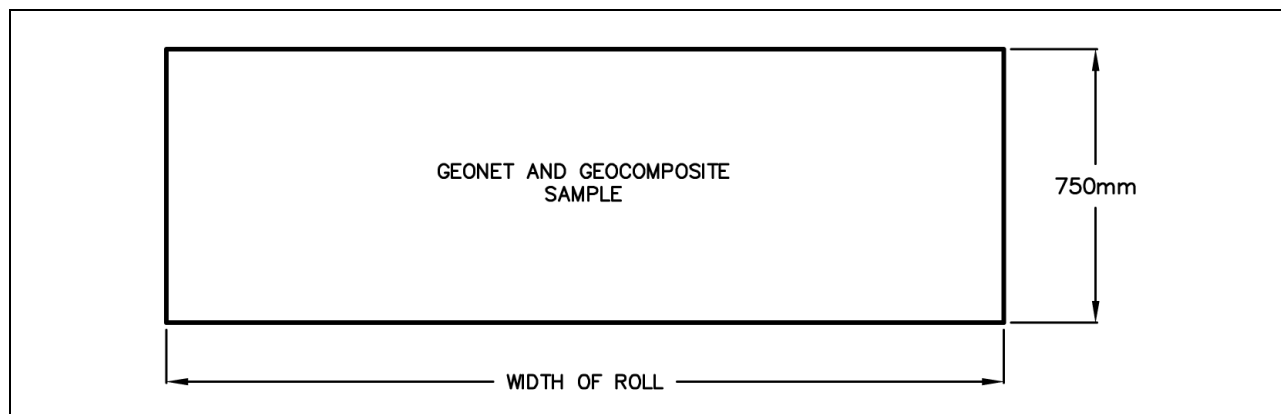


### 6.3 Geonet and Drainage Geocomposite Testing

Laboratory conformance testing of the geonet and drainage geocomposite must include the types of tests detailed in the specification and respect the sampling frequencies found therein. For informational purposes, the following tests are usually requested:

- Thickness;
- Mass per unit area;
- Density;
- Carbon Black Content;
- Compression Resistance;
- Tensile strength;
- Puncture resistance;
- Filtration opening size;
- Transmissivity (permittivity).

*Figure 3: Dimensions of geonet or drainage geocomposite samples for conformance testing.*

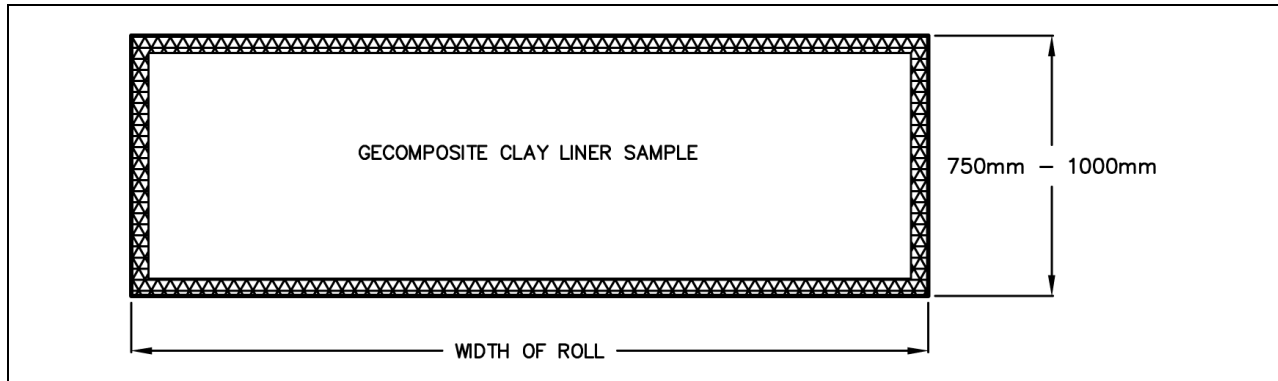


### 6.4 Geocomposite Clay Liner Testing

Laboratory conformance testing of the geocomposite clay liner (GCL) must include the types of tests detailed in the specification and respect the sampling frequencies found therein. For informational purposes, the following tests are usually requested:

- Thickness;
- Mass per unit area;
- Tensile strength;
- Peel strength;
- Hydraulic permeability;
- Bentonite content.

Figure 4: Dimensions of Geocomposite clay liner samples for conformance testing



## 6.5 Verification of the Results

The QA Specialist shall compare the results of conformance tests with the control tests provided by the Geosynthetics Manufacturer and the requirements of the specifications.

The QA Specialist shall confirm the compliance or non-compliance of the materials.

## 6.6 Non-Compliant Results and Additional Testing

If the results of the laboratory tests prove to be non-compliant with the specifications, all rolls associated with the non-compliant sample lot, with production numbers between two compliant results, shall be rejected.

However, the Installer may request that the QA Specialist take samples from the rolls that are numerically before and after the non-compliant roll in order to have them conformance tested. Should the results from both rolls be compliant with the specifications then they shall be accepted, and the rolls associated with the non-compliant results rejected.

If one of the results is compliant and the other is not, then the rolls whose production numbers follow or precede the non-compliant result shall be rejected until the last roll with a compliant result. Rolls with production numbers that follow or precede the compliant result shall be accepted and may be installed.

All additional tests requested of the QA Specialist and carried out by the Laboratory are at the Installer's expense.

## 7. General Procedures

### 7.1 Documentation

The documentation submitted by each Manufacturer must provide traceability for each material delivered to site and identify the resins used during the roll manufacturing process. This documentation must include at least the following items:

- Identification of the resin;
- Identification of the resin manufacturer;
- Identification of the rolls;
- Copies of the Manufacturer's quality control results.

### 7.2 Plant Assembly

Pre-assembly of geosynthetic rolls is defined as any assembly performed outside of the construction site either at the plant or elsewhere. Pre-assembly may be necessary if a particular shape is necessary or to produce oversized panels. Only pre-assembly techniques previously approved by the QA Specialist at the proposal stage shall be accepted.

### 7.3 Transport and Handling

The Installer is responsible for the transportation, reception, unloading and on-site storage of geosynthetics. In the event that geosynthetics are delivered prior to the arrival of the Installer, the General Contractor must have obtained the Installer's approval prior to unloading. The General Contractor shall then become responsible for any damage to the geosynthetics due to handling.

Offloading and handling techniques used must ensure material integrity at all times.

Any section of geosynthetic damaged during transport or storage must be repaired or replaced by the Installer at his expense and to the satisfaction of the Quality Assurance Specialist.

### 7.4 Delivery

The Installer shall visually inspect the offloading of the rolls or panels and shall ensure that all items are intact and correctly identified with the following information:

- Project name or number;
- Manufacturer;
- Product type and thickness;
- Roll dimensions and weight;

- Lot number;
- Roll or panel number;
- Copies of the Manufacturer's quality control results.

## 7.5 Geosynthetics Lay Down Area

Temporary geosynthetics lay down areas must have a slight slope to promote the flow of water and be covered with a layer of sand free of rocks and/or debris. The lay down area must be approved by the QA Specialist and be made available to the Installer before any materials are delivered to site. Lay down areas should be chosen to minimize the transport and handling of geosynthetics on site.

The Installer shall be responsible for organizing, managing and maintaining the lay down areas and shall protect the materials against physical damage, prolonged exposure to ultraviolet rays, precipitation or flooding, mud, dust, punching, tears, vandalism or any other agent that may affect their behaviour.

Unless there are more stringent recommendations from the Manufacturers, the geosynthetics may not be stacked more than three (3) rolls high.

Geocomposite clay liners must be covered with a plastic tarp at all times to protect them from the weather.

## 7.6 General Installation Procedures

### 7.6.1 Approved Techniques

The installation techniques used by the Installer must ensure that there is continuous, intimate contact between the geosynthetics and the surface to be covered. The geomembrane shall be installed without tension or creases in order to avoid any damage or residual tension. During installation, the Installer must consider the different temperatures during the day that will cause expansion and/or contraction of the geomembrane.

No other material shall be left in contact with the surface to be covered, including, but not limited to, non-welded sacrificial geosynthetic strips. These materials must be removed before installing any overlying layer. However, subject to approval from the QA Specialist, strips of biodegradable material may be left in place.

### 7.6.2 Equipment Inspection

The QA Specialist reserves the right to inspect or to have inspected the equipment used to weld the geosynthetics, at any time. The QA Specialist likewise reserves the right to refuse, where appropriate, the use of a part or equipment that is inadequate or not in compliance with the requirements of this document.

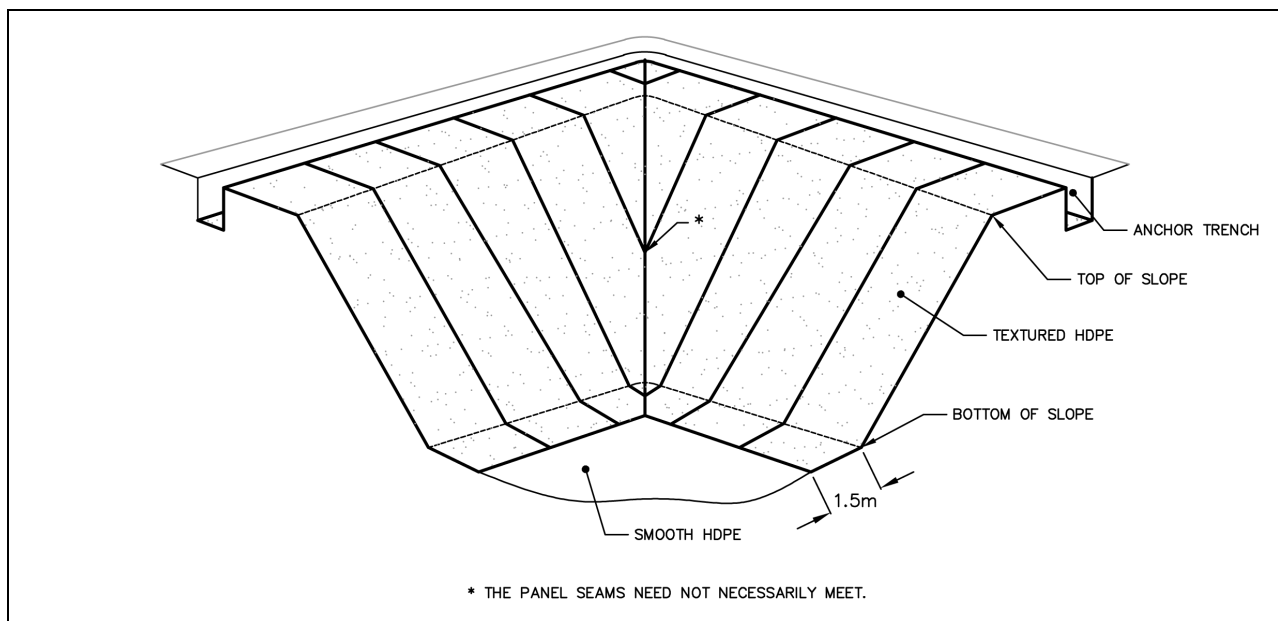
The spreader bar, or any other lifting equipment, must be inspected by the Installer before the installation work commences and daily thereafter to ensure that it is safe to transport and support the roll load. It must be marked with a stamp specifying its maximum lifting capacity and the Installer must provide a plan signed by an engineer during the design.

### 7.6.3 Installation on a Slope

No geosynthetic roll may be deployed perpendicular to the direction of a slope. No welding, seaming or longitudinal overlap oriented perpendicular to the direction of a slope is permitted unless specific approval is received from the Designer and the QA Specialist. Slopes with less than 10% inclination are considered a flat surface.

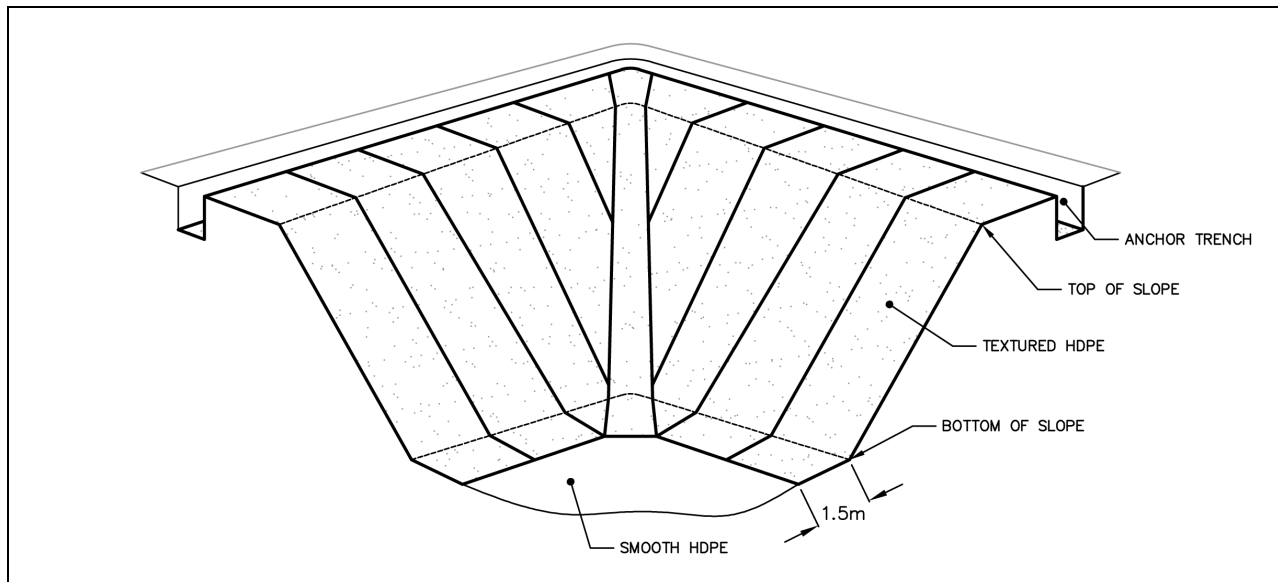
All geosynthetics placed on a slope (including the weld or seam) must extend at least 1.5 m beyond the toe of the slope (see Figures 5 and 6).

*Figure 5: Acceptable deployment pattern of geosynthetics in slopes and at the toe of slopes*



The mention of “smooth HDPE” in the previous figure is for illustration purposes only and does not in any way exclude the installation of another type of geomembrane at the toe of the slope. In all cases, the weld should be at least 1.5 m past the toe of the slope.

Figure 6: Acceptable deployment pattern of geosynthetics in slopes and at the toe of slopes



The mention of “smooth HDPE” in the previous figure is for illustration purposes only and does not in any way exclude the installation of another type of geomembrane at the toe of the slope. In all cases, the weld should be at least 1.5 m past the toe of the slope.

#### 7.6.4 Subgrade

The Installer shall remove any object from the subgrade, such as stones, debris, blunt objects, etc., that may damage the geosynthetic. The subgrade surface must not have depressions, ruts or bumps greater than 50 mm. Any ruts left by machinery during the deployment of the geosynthetics must be corrected.

The Installer must comply with all of the requirements of this document, especially those concerning ground pressure under equipment used near the geosynthetics in order to avoid any perforation or punching.

The Installer is responsible for ensuring the integrity of the subgrade once it has been accepted. The Installer shall take all the necessary precautions to avoid damaging the geosynthetics or natural surface while placing the geosynthetics.

#### 7.6.5 Circulation on the Geosynthetics

No vehicular traffic is allowed directly on the geosynthetics except light off-road vehicles authorized by the QA Specialist. A minimum of 1 m (or as specified in the specifications) of natural materials is required above the geosynthetics for transport vehicles to circulate overtop.

### 7.6.6 Approval of the Geosynthetic Layers

Each geosynthetic layer must be assembled, verified and recorded as completed prior to the placement of another geosynthetic layer or cover material overtop. The Installer must inspect the cover material and remove any sharp or perforating element that may damage the geosynthetics.

Written acceptance, to be approved by the QA Specialist, is required for each geosynthetics layer to certify that it is approved to be covered. This acceptance can be fragmented to include only one section at a time.

### 7.6.7 Unfavourable Conditions

No material shall be installed under improper work conditions in accordance with the requirements of this program or the specifications. This includes rain, snow, cold weather, wind, poor condition of materials or any other adverse condition.

### 7.6.8 Wind Protection

Geosynthetic panels (widths) must be kept in place (ballasted) with sandbags or any other authorized loads pending assembly and cover.

It is the responsibility of the Installer to protect the exposed surfaces at all times during the entire installation process.

The weights used (sandbags or otherwise) to ballast the geosynthetics must not damage or negatively affect the geosynthetic materials. The sandbags must not contain rocks and must be hermetically closed so as not to contaminate the geosynthetic surfaces. At temperatures below 0 °C, special care should be given if bags containing frozen materials are used.

### 7.6.9 Specific Work Methods

The work methods used must ensure that the required quality of work can be achieved. The following specific practices must be observed:

- Any geosynthetics deployed during the day must be welded or seamed by the end of the work day;
- Any heating equipment or power generators must be turned off when not under the Installer's supervision;
- Particular care must be given to knives and other sharp tools in order to prevent the geosynthetics from being punctured or permanently deformed. When cutting geosynthetic pieces to perform repairs, or for other purposes, a geomembrane protector should be placed under the work area to prevent damage to the installed surfaces;
- At all times, all equipment used on top of the geosynthetics (generators, tensiometers, etc.) must be placed on a piece of geomembrane that protects against punctures or oil spills;
- It is forbidden to smoke near or over the geosynthetics;

- It is forbidden for anyone not involved in the installation process to walk or circulate over the geosynthetics unless authorized by the QA Specialist;
- Waste materials, including scrap geosynthetic pieces, must be cleaned up a daily basis to avoid dispersion caused by weather or other conditions.

## 7.7 Visit by the Manufacturer

If the QA Specialist deems it necessary, he may require the geosynthetics Manufacturer or the fabricator of the welding equipment to be present onsite to observe the methods and conditions for installing the geosynthetics or the methods for manipulating the materials or equipment onsite. If the Manufacturer considers the Installer's methods and conditions for installing the geosynthetics or the methods for manipulating the materials or equipment to be satisfactory, the travel expenses shall be borne by the Client. If the Manufacturer deems any of them to be inadequate, the Installer shall bear the costs of the visit and must immediately correct his methods accordingly.

## 8. Geomembranes – Installation and Control

### 8.1 Geomembrane Installation

#### 8.1.1 Acceptance of Work

The geomembrane may not be covered nor backfilled by natural or geosynthetic material until the QA Specialist has provided written acceptance of the installed materials.

Acceptance of work may be segmented to cover only a portion of the completed work area.

The QA Specialist shall inspect the work and draw up a list of additions, corrections or repairs to be made. The Installer shall perform these corrections or repairs to the satisfaction of the QA Specialist, after which final acceptance may be granted.

#### 8.1.2 Respect for the Proposed Geomembrane Layout Plan

The installation of the geomembrane must, as much as possible, respect the proposed geomembrane layout plan submitted by the Installer and approved by the QA Specialist.

Any changes to the layout plan must be approved in advance by the QA Specialist.

#### 8.1.3 Initial Welding Procedures

Panels (widths) may only be welded once the following have been ensured:

- Proper alignment of the panels;
- Proper overlapping of the panels;
- Sufficient cleaning of the surfaces to be welded;
- Sufficient drying of the surfaces to be welded, as necessary;
- Proper identification of the panels;
- Calibration of the welding equipment (trial test welds);
- Qualification of the welding personnel (trial test welds).

#### 8.1.4 Restrictions

The installation techniques used by the Installer must ensure that the panel does not become damaged and/or stressed. Any technique deemed unacceptable by the QA Specialist must be corrected immediately by the Installer.

### 8.1.5 Weather Conditions (Standard)

Unless otherwise specified, geomembrane welds are prohibited when the geomembrane temperature is below 0 °C or above 50 °C. The temperature of the geomembrane should be measured using a portable infrared thermometer.

No geomembrane may be deployed when there is precipitation, excessive moisture, excessive saturated water, or excessive wind that can affect the safety of the workforce and/or the integrity of the structure.

### 8.1.6 Special Considerations in Winter for Polyethylene Geomembranes (PE)

According to GRI GM9<sup>1</sup>, polyethylene geomembrane can be welded in winter if the temperature of the geomembrane is between 0 °C and -15 °C. For geomembrane temperatures below -15 °C, welding is not recommended. The temperature of the geomembrane should be measured using a portable infrared thermometer.

No geomembrane may be deployed when there is precipitation, excessive moisture, excessive saturated water, or excessive wind that can affect the safety of the workforce and/or the integrity of the structure.

The Installer must demonstrate that he is able to defrost the two internal walls of the weld and eliminate the presence of any moisture. Special attention must be given to the textured geomembrane as frost and moisture are more difficult to remove. A strip of geomembrane under the weld is recommended to keep the welding equipment clean and free from ice or frost.

Under these special conditions, the frequency for trial test welds and the destructive tests shall be increased.

---

<sup>1</sup> GRI Practices ([www.geosynthetic-institute.org](http://www.geosynthetic-institute.org))

Table 1: Frequency of trial test welds based on geomembrane temperature

Geomembrane temperature	Minimum frequency for trial test welds	Special conditions
> 50 °C	Welding not recommended	
0 °C to 50 °C	1 test per shift (max. 5 hours)	Minimum of one trial test weld per shift for a maximum of five (5) hours.
0 °C to -7.5 °C	1 test every 3 hours	Minimum of one test every three (3) hours.
-7.5 °C to -15 °C	1 test every 2 hours	Minimum of one test every two (2) hours.
< -15 °C	Welding not recommended	

#### 8.1.6.1 Trial Test Welds

Under standard conditions, trial test welds shall be performed at the beginning of each shift and are valid for a maximum of five (5) hours.

In winter conditions, the frequency of the trial test welds is modified according to the temperature of the geomembrane (see Table 1). This frequency may be increased at the discretion of the QA Specialist should the trial test welds be non-compliant.

#### 8.1.6.2 Destructive Tests

Under standard conditions, the frequency of destructive testing is one (1) test every 150 linear meters of weld. In winter conditions (geomembrane temperature between 0 °C and -15 °C), the frequency will increase to one (1) test every 100 linear meters of weld. This frequency may be increased at the discretion of the QA Specialist if the destructive tests are non-compliant.

#### 8.1.7 Anchor

The geomembrane anchor trenches must respect the dimensions shown on the plans. The geomembrane welds must extend fully to the end of the anchor trench. No stake may be used to fix the geomembrane to anchor trench. It is the responsibility of the Installer to ensure the stability of the geosynthetics before the anchor trench is backfilled.

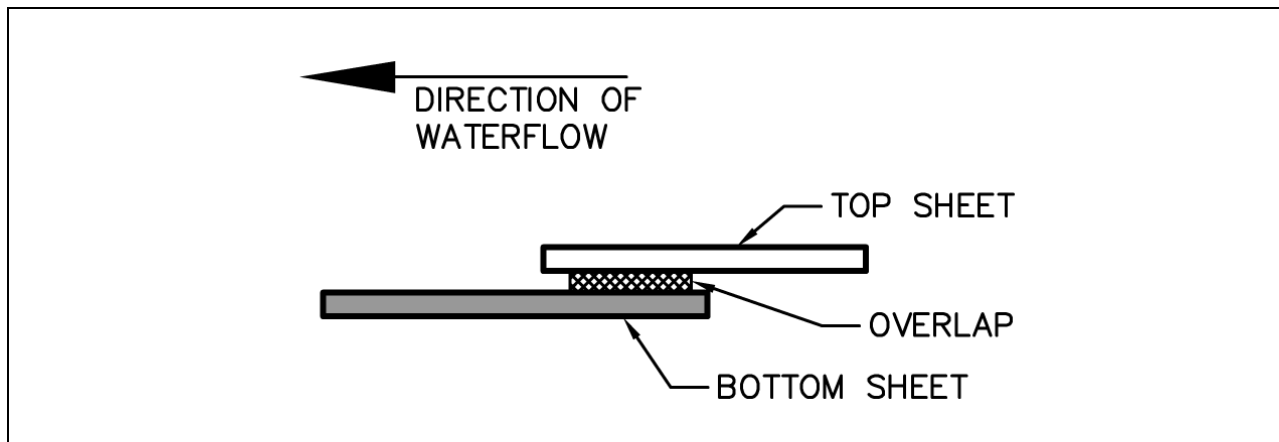
The QA Specialist and the Installer must both give their approval before any backfilling of the anchor trench may be performed.

### 8.1.8 Overlap

#### 8.1.8.1 Overlap Direction

Unless otherwise indicated, all overlaps must respect the direction of water flow from upstream to downstream (see Figure 7).

Figure 7: Overlap direction of the geomembrane and geosynthetics – following the direction of water flow.



#### 8.1.8.2 Overlap Width

The overlap flap must be large enough after welding to allow for destructive testing on both sides of the weld (peel and shear). Should this not be the case, the weld may be refused and may need to be redone at the Installer's expense.

#### 8.1.8.3 Overlap Cleanliness

The cleanliness of the overlaps must be irreproachable; no substance, foreign body, dust, filmy liquid or dirt may soil the surface.

### 8.1.9 Panel Identification

Following installation, each panel number and associated roll number must be clearly marked on the geomembrane by the Installer. The numbering system used by the Installer ensure that the information for each panel can be easily retraced.

To avoid confusion, the Installer and the QA Specialist must use different colours when marking the geomembrane.

### 8.1.10 Supervision of Geomembrane Welding

Supervision of the geomembrane welding includes the following tasks:

- Non-destructive testing (quality control);
- Destructive testing (quality control)
- Verification of non-destructive testing (quality assurance);
- Verification of destructive testing (quality assurance).

### 8.1.11 Documentation

The Installer must document the following information for each weld:

- Date and time of weld;
- Equipment used;
- Related trial test weld;
- Identification of weld;
- Identification of panels welded (panel and roll numbers);
- Type of material;
- Weld length and panel dimensions;
- Equipment operator;
- QC technician's name.

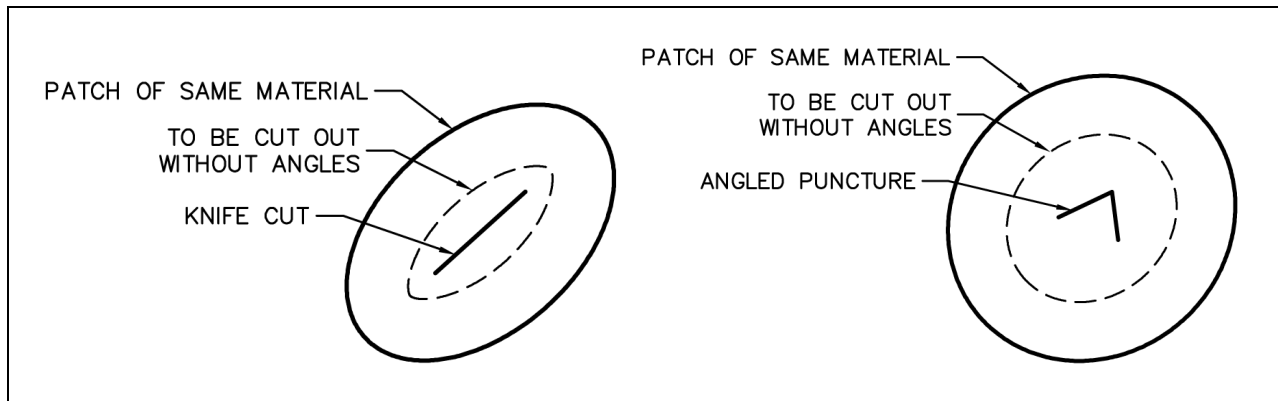
## 8.2 Correction of Deficiencies

Following the discovery of a defect, or of faulty work, the Installer must assess the extent of the affected area. If the defect is the result of unacceptable test results, the area concerned shall be delimited by additional tests as described in section 8.3.3. If the defect is related to adverse weather conditions, the work must be interrupted, and the affected area shall be marked off and subsequently repaired.

### 8.2.1 Repairs, Re-Touches and Replacements

Any perforation and tear on the installed geomembrane (including in the anchor trench) must be repaired using a piece of the same type of material. The rounded part must exceed the defect by at least 150 mm in all directions. The Installer must round off the ends of the defects in order to avoid creating weak points (see Figure 8).

Figure 8: Geomembrane patch repairs



The QA Specialist shall determine the method to be used.

The geomembrane must be grinded before any extrusion can be performed. The grinded area must not surpass the final weld by more than 5 mm and must not reduce the thickness of the geomembrane sheet by more than 10%.

All scratches and superficial punctures shall be repaired with an extrusion bead.

A fully reconstructed weld that meets the quality control and quality assurance requirements is considered a weld without deficiency.

The Installer must annotate the final plan to reflect any repairs, re-touches or replacements.

### 8.2.2 Approval of the Repairs

Repairs must meet the requirements of the specifications and be performed to the satisfaction of the QA Specialist. They must be verified by a non-destructive test and are subject to approval by the QA Specialist.

### 8.2.3 Additional Repairs

The QA Specialist reserves the right to require the Installer to perform additional repairs if he deems it necessary.

### 8.2.4 Documentation

The Installer shall identify each repair with the following information:

- Date and time of the repair;
- Identification of the repair;

- Identification of the corresponding trial test weld;
- Type of repair (patch or extrusion bead);
- Type of material;
- Dimensions of the repair;
- Location (corresponding panels);
- Corresponding seams (if applicable);
- Pipeboot dimensions (if applicable);
- Location of the repair on the final plan;
- Date and time of quality control tests;
- Corrective measures and date performed (if applicable);
- Results and date of new quality control tests (if applicable);
- QC technician's name.

## 8.3 Control and Verification Testing of the Geomembrane Installation

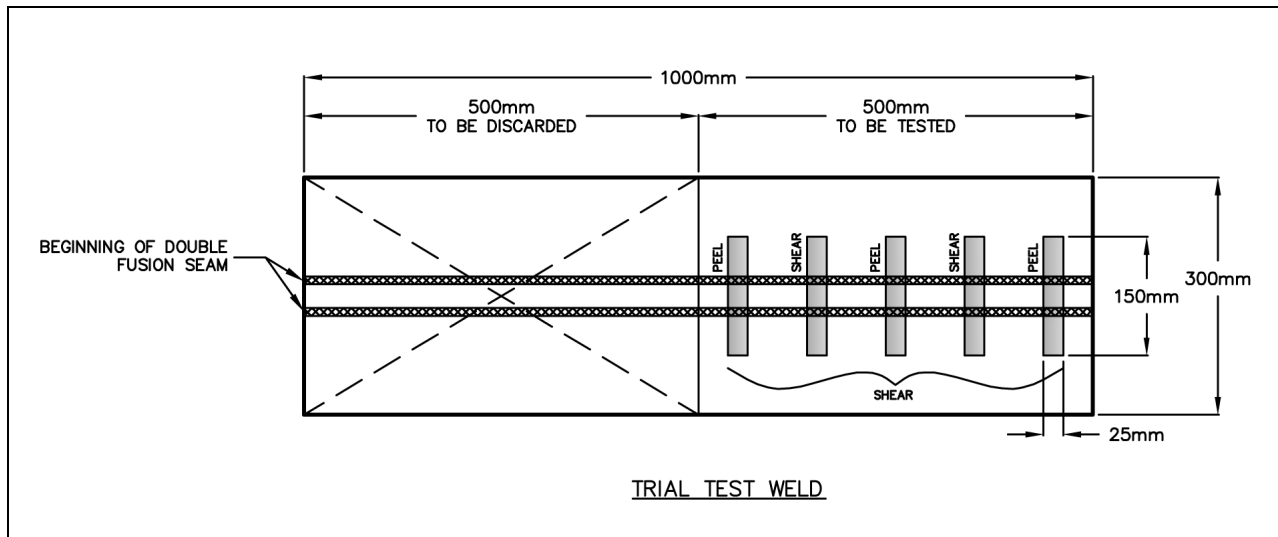
### 8.3.1 Trial test welds

Trial test welds are performed to verify the peel and shear strengths of a geomembrane weld sample. No welding equipment may be used onsite without a prior trial test that meets the requirements of the specifications.

#### 8.3.1.1 Samples

The Installer shall prepare a sample at least 1000 mm long and 300 mm wide with the weld centred along the width. Five (5) coupons shall be cut using a punch. The samples must be cut evenly spaced along the length, and the cut coupons shall alternatively be tested in peel and shear. Three (3) coupons shall be tested in peel and the other two (2) in shear. For each coupon tested in peel, two (2) results shall be obtained for a double-fusion weld and one (1) result for an extrusion weld. For each coupon tested in shear, one (1) result shall be obtained for both types of welds. Coupons shall measure 25 mm wide and 150 mm long and be cut evenly using a punch (see Figure 9).

Figure 9: Method for cutting coupons for trial weld testing



### 8.3.1.2 Frequency

At the beginning of each shift, trial test welds must be performed and documented by the Installer for all welding equipment to be used. Under standard conditions the trial test weld results are valid for five (5) hours. For special conditions in winter, refer to section 8.1.6.

The QA Specialist reserves the right to require additional trial weld testing due to changing climatic conditions or in the event of equipment failure or malfunction.

### 8.3.1.3 Conditions

The seaming equipment must be calibrated by testing samples of geomembranes seamed using the same types of materials and under the same atmospheric conditions as those anticipated during the assembly of the panels (widths).

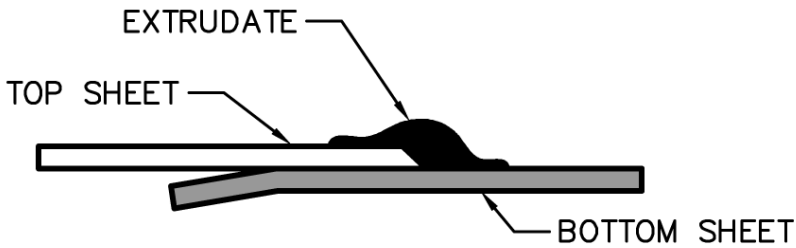
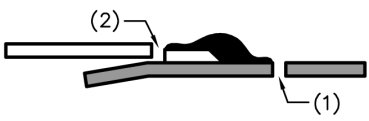


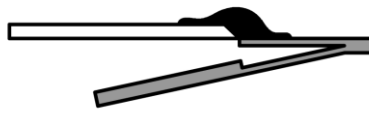


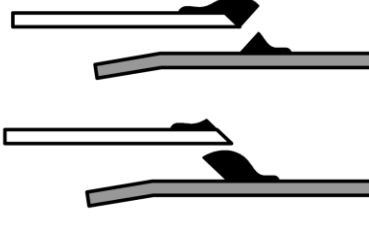

### 8.3.1.4 Requirements

Once cut, the samples must be field tested using a calibrated portable tensiometer and each coupon must meet the strength and break type requirements for peel and shear as indicated in the specifications and in Figures 10 and 11 presented below. Should one result be non-compliant, then the calibration test must be resumed with a new sample.

Figure 10: Break types for double fusion welds

	BRK	Break in sheeting. (Break can be in either top or bottom sheet)	Approved
	SE1	Break in outer edge of seam. (Break can be in either top or bottom sheet)	Approved
	SE2	Break at inner edge of seam through both sheets.	Approved
	SIP	Separation in the plane of the sheet. (Break can be in either top or bottom sheet)	Approved
	AD	Adhesion failure	Refused
	AD-BRK	Break in first seam after some adhesion failure. (Break can be in either top or bottom sheet)	Refused

Figure 11: Break types for extrusion welds

			
	SE1 SE2	Break at seam edge, in bottom sheet (1) or top sheet (2). (applicable to shear only)	Approved
	SE3	Break at seam edge in the bottom sheet. (applicable top peel only)	Approved
	BRK1 BRK2	Break in the bottom sheeting (1) or the top sheeting (2). A "B" in parentheses following the code means the specimen broke in the buffed area.	Approved
	SIP	Separation in the plane of the sheet	Approved
	AD1	Failure in adhesion. Specimens may also delaminate under the bead and break through the thin extruded material in the outer area.	Refused
	AD2	Failure in adhesion.	Refused
	AD-WLD <sup>(1)</sup>	Break through the fillet. Off-centred bead. (1) Acceptance of AD-WLD breaks may depend on whether test values meet a minimum specification value.	Refused
	AD-BRK	Break in bottom sheeting after some adhesion failure.	Refused

The Installer shall identify each trial test weld with the following information:

- Date and time of test;
- Identification of test;
- Ambient temperature;
- Operator name;
- Identification of equipment;
- Equipment temperature;
- Preheat temperature (if applicable);
- Equipment speed (if applicable);
- Type of material;
- Peel and shear strengths;
- Break types (see Figures 10 and 11);
- Quality Control technician's name.

### 8.3.2 Non-Destructive Quality Control Tests

Each weld or repair shall be subject to non-destructive testing on 100% of its length to ensure continuity.

#### 8.3.2.1 Approved Techniques

Only the following techniques are approved for non-destructive testing of the seams:

- Air channel tests: the test is performed by pressurizing the weld channel to 210 kPa (30 psi) for five (5) minutes. The allowable air pressure loss is 20 kPa (3 psi) or less according to ASTM D5820. All perforations created to perform the pressurization test must be repaired and then checked using the vacuum box test.
- Vacuum box test: the vacuum box test is performed by maintaining a negative pressure of 35 kPa (5 psi) on the overlap of the weld for a period of at least five (5) seconds in accordance with ASTM D5641.

#### 8.3.2.2 Documentation

The Installer shall document non-destructive testing by noting the following information for each weld verified:

- Date and time of the test;
- Identification of the non-destructive test;
- Identification of the weld (if applicable);
- Identification of the repair (if applicable);

- Identification of the panel(s)
- Identification of the equipment used;
- Results of the test;
- Identification of any non-compliance;
- Corrective measures and date taken (if applicable);
- Results of the new tests and date performed (if applicable);
- Quality Control technician's name.

### 8.3.3 Destructive Tests

The Installer shall verify the peel and shear strength of the double-fusion or extrusion welds using a calibrated tensiometer. The strength of these welds shall likewise be verified at the external laboratory QA Specialist.

#### 8.3.3.1 Frequency

At the beginning of the project, the destructive tests shall be taken at a frequency of one test for every 150 m of weld. This frequency can subsequently be modified according to the performance of the installation team in terms of the results of the destructive tests.

When conditions warrant ten (10) consecutive compliant destructive tests – the distance between the destructive tests may be increased by 50 m, up to a maximum frequency of one test per 300 m of weld. However, should one destructive test fail, the distance between the tests will return to a frequency of one test per 150 m of weld.

For destructive testing on extrusion welds, the frequency is one (1) destructive test per layer (primary or secondary or as requested by the QA Specialist).

#### 8.3.3.2 Sampling Location

The location of the destructive quality control tests shall be determined by the QA Specialist.

#### 8.3.3.3 Sampling

For each destructive test marked, the Installer must cut a sample that is at least 1,050 mm long and 300 mm wide, with the weld centred in the middle. The sample shall be cut into three sections: 300 mm for field testing, 450 mm for laboratory testing (quality assurance) and 300 mm to be retained by the QA Specialist.

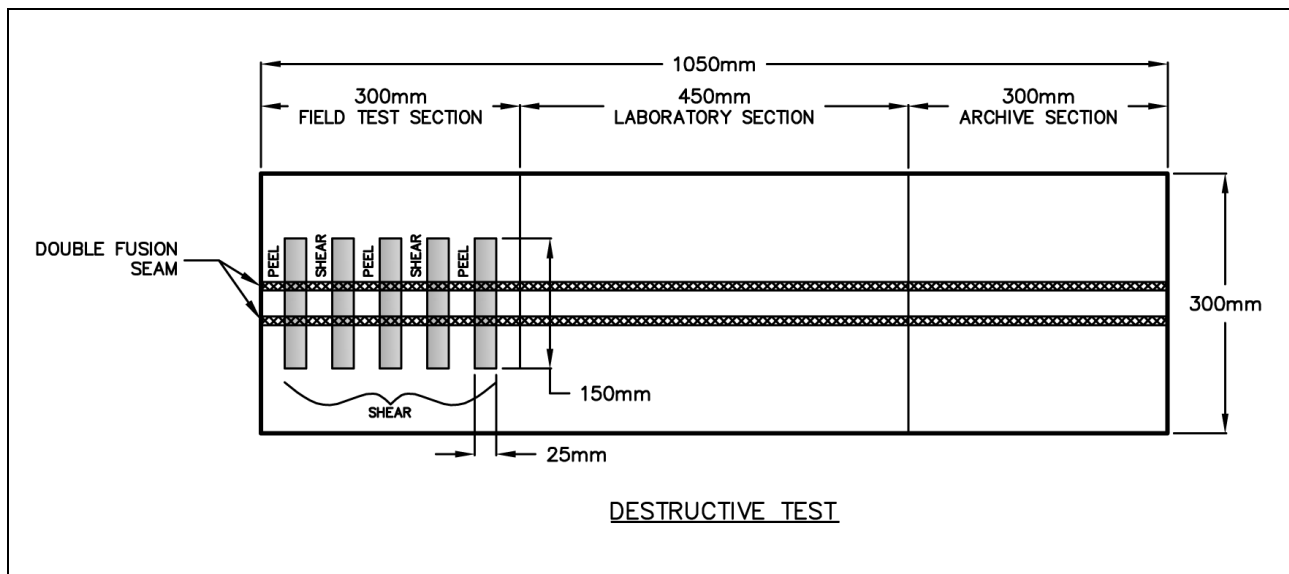
Five (5) coupons shall be cut from the portion for field testing. The cut coupons shall be alternatively tested in peel and in shear. Three (3) coupons shall be tested in peel and the other two (2) in shear. Coupons shall measure 25 mm wide and 150 mm long and be cut evenly using a punch.

Ten (10) coupons shall be cut from the section intended for laboratory testing. The cut coupons shall be alternatively tested in peel and in shear. Five (5) coupons shall be tested in peel, and the other five in shear.

For each coupon that is peel tested, two (2) results shall be obtained for a double-fusion weld and one (1) result for an extrusion weld.

For each coupon tested in shear, one (1) result for both types of welds shall be obtained.

Figure 12: Sampling method for weld specimens for destructive testing



#### 8.3.3.4 Compliant Results

Should the destructive test results comply with the strengths and break types prescribed in the specifications and in this document for all coupons, the Installer shall return the two remaining weld sections to the QA Specialist. The latter shall send the 450 mm section to the external laboratory for destructive testing at the frequency required by the specifications and shall retain the 300 mm section.

#### 8.3.3.5 Non-Compliant Results

In the event of a non-compliant result, the Installer, with the agreement of the QA Specialist, shall identify the extent of the defective weld by taking two additional samples. One sample shall be located at least 3 m before the defective test and the other at least 3 m after. Both new samples shall be destructively tested as described previously.

If one and/or the other new destructive test is (are) also non-compliant, one (two) other sample(s) shall be taken at a minimum distance of an additional 3 m in order to perform new destructive test(s). This procedure shall be repeated until the non-compliant test is bound on both sides by a compliant destructive test.

The non-compliant weld(s) must be redone integrally by double fusion; the non-compliant weld shall be cut out, and a new length of geomembrane large enough to allow a double fusion weld on both sides shall be installed. No other method of repair shall be accepted.

The weld is considered compliant when it is bound on either end by a compliant field and laboratory destructive test (quality assurance).

Additional field and laboratory tests to be performed as a result of non-compliant welds shall be performed at the Installer's expense.

#### 8.3.3.6 Conflicting Results from Laboratory Testing

If the results of the laboratory tests prove to be non-compliant, in contradiction with the results obtained onsite, the related welds shall be considered non-compliant until proven otherwise.

#### 8.3.3.7 Documentation

The Installer shall document all destructive tests using the following information:

- Date and time samples were cut;
- Date and time test was performed;
- Ambient temperature
- Identification of the destructive test;
- Identification of the seam and corresponding trial test weld;
- Identification of the corresponding panels;
- Type of material;
- Peel and shear strength test results;
- Break types (see Figures 10 and 11);
- Corrective measures and dates taken (if applicable);
- Date and results of the new destructive tests (if applicable);
- QC technician's name;
- Location on the final plan.

#### 8.3.4 Laboratory Destructive Tests (Quality Assurance)

All field samples shall be sent to the laboratory for destructive testing. As indicated above, the samples sent to the laboratory shall be used to verify the results obtained onsite and shall be subject to the same tests and the same criteria of acceptance or rejection.

Ten (10) coupons shall be cut from the section intended for laboratory testing. The cut coupons shall be alternatively tested in peel and in shear. Five (5) coupons shall be tested in peel, and the other five in shear.

For each coupon to be tested in peel, two (2) results shall be obtained for a double fusion weld and one (1) result for an extrusion weld.

For each coupon to be tested in shear, one result shall be obtained for each type of weld.

For the destructive test to be considered compliant, the results from all of the coupons must meet the requirements set out in this document and in the technical specifications for strength and break type.

The destructive test is considered non-compliant and the procedure for unacceptable results shall apply should any of the coupons have results not in accordance with the values and/or the types of breaks prescribed in this document or in the specifications.

## 9. Geotextiles – Installation and Control

### 9.1 Geotextile Installation

#### 9.1.1 Monitoring by the QA Specialist

The QA specialist shall supervise the installation of the geotextile, which includes the following tasks:

- Verification of the deployment of the geotextile rolls;
- Verification of the installation (assembly) of each panel;
- Visual inspection of the installed product.

#### 9.1.2 Deployment

No geotextile roll may be deployed without prior approval from the QA Specialist. This approval can only be obtained after the underlying materials, foundation or installed materials have been verified and accepted.

The installation techniques must ensure that no damage comes to the geotextiles. The Installer must assemble (seam) the panels as the rolls are deployed.

#### 9.1.3 Anchoring

The Installer must ensure that the panels are assembled along the full extent of the anchor trench. No stake may be used to fix the geotextile to anchor trench. It is the responsibility of the Installer to ensure the stability of the geotextiles until the anchor trench is backfilled.

The QA Specialist and the Installer must both give their approval before any backfilling of the anchor trench may be performed.

#### 9.1.4 Overlap

##### 9.1.4.1 Direction of Overlap

Rolls of geotextiles installed side-by-side must be overlapped in the direction of water flow (from the high point to the low point). See Figure 7.

#### 9.1.4.2 Overlap Width

The width of the overlap must adhere to the Manufacturer's recommendations.

Thermo-fused geotextiles must be overlapped by at least 300 mm when joined side-by-side and 600 mm when joined end-to-end.

The overlap width of the welded or sewn geotextiles must adhere to specifications of the machine used.

Before the work begins, the Installer must have his work methods approved by the QA Specialist.

#### 9.1.5 Geotextile Panel Assembly

##### 9.1.5.1 Sewing

The thread used to seam the geotextile (both at the factory and onsite) must have chemical and mechanical properties equal to or greater than those of the geotextile. Stitches must not be spaced more than 5 mm apart. Self-locking stitches are recommended. Different types of stitches may be used but must be doubled and meet the required spacing.

##### 9.1.5.2 Other Methods

The Installer may propose other assembly methods to the QA Specialist prior to the start of installation work. The QA Specialist reserves the right to refuse or accept the proposed method.

#### 9.1.6 Visual Inspection

Following installation, each geotextile panel shall be visually inspected by the QA Specialist to identify any areas that are damaged, likely to be damaged, or that appear abnormal. The Installer shall repair any damage at his own expense, to the satisfaction of the QA Specialist.

#### 9.1.7 Repairs

Any perforation or tear must be repaired with a piece of the same type of material as that installed. The piece must exceed the defect by at least 300 mm in all directions.

Repairs shall be subject to approval by the QA Specialist in accordance with the requirements of this document and/or the specifications. The QA Specialist reserves the right to require additional repairs from the Installer.

## 9.2 Destructive Verification Tests at the External Laboratory

If required by the specifications, the QA Specialist may request that destructive verification tests be performed on the seams.

Notwithstanding the test frequency detailed in the specifications, a special test frequency may be used at the discretion of the QA Specialist where visual observations indicate the presence of potential non-compliance such as:

- Variations in the seam;
- Visible variations in the quality of the materials;
- Incorrect adjustments to the equipment;
- Dirty or defective equipment;
- Faulty or malfunctioning equipment;
- Different personnel operating the equipment than authorized;
- Adverse weather conditions;
- At the QA Specialist's request.

## 10. Geonet and Drainage Geocomposite – Installation and Control

### 10.1 Quality Assurance Supervision

The QA specialist shall supervise the installation of the geonet or drainage geocomposite, which includes the following tasks:

- Verification of the deployment of the rolls;
- Verification of the installation (seaming) of each panel;
- Visual inspection of the installed product.

### 10.2 Deployment

No geonet or drainage geocomposite roll may be installed without prior approval from the QA Specialist. This can only be given once the QA Specialist has verified and accepted the required elements and work of the underlying elements.

The installation techniques must ensure that no damage comes to the geonet or drainage geocomposite.

The Installer must ensure that no rock, mud or other debris is present between the geosynthetic layer (geomembrane, geotextile or other) and the geonet or drainage geocomposite layer. The geonet or drainage geocomposite must be kept as clean as possible until it is covered.

### 10.3 Clogging

The Installer must pay special attention to remove any object or material (natural materials, clods of clay, etc.) likely to damage the geosynthetics or plug the geonet.

### 10.4 Anchoring

The Installer must ensure that the geonet and/or drainage geocomposite panels are assembled along the full extent of the anchor trench. No stake may be used to fix the geosynthetics to anchor trench. It is the responsibility of the Installer to ensure the stability of the geonet and/or drainage geocomposite until the anchor trench is backfilled.

The QA Specialist and the Installer must both give their approval before any backfilling of the anchor trench may be performed.

## 10.5 Overlap

### 10.5.1 Overlap Direction

Rolls geonet and/or the drainage geocomposite installed side-by-side, all components must be overlapped in the direction of water flow (from the high point to the low point). See Figure 7.

### 10.5.2 Overlap Width

Panels installed side-by-side must have a minimum overlap of 150 mm.

Panels installed end-to-end must have a minimum overlap of 600 mm.

## 10.6 Assembly

### 10.6.1 Geonet

In order to prevent the overlaps of adjacent rolls from separating, cable ties (Ty-Raps) shall secure the nets (geonet alone or drainage geocomposite) and shall be placed at a minimum spacing 600 mm in the slopes and every 1.5 m on the flat (slopes less than 10%). Geonets should be superimposed so that the grooves do not interfere with one another or reduce the drainage capacity of the product.

A minimum of three (3) cable ties, not exceeding a spacing of more than 600 mm between them, shall be used to secure end-to-end joints.

### 10.6.2 Geotextile (for Geocomposite Drainage Net only)

Once the geonet has been secured, the top geotextile of the drainage geocomposite must be thermo-fused (Leister fixture) or sewn to ensure no particles can penetrate between the layers. The lower geotextile need only be overlapped by 150 mm.

## 10.7 Visual Inspection

Following installation, each panel of geonet and/or drainage geocomposite shall be visually inspected by the QA Specialist to identify any areas that are damaged, likely to be damaged or that appear abnormal. The Installer shall repair any damage at his own expense, to the satisfaction of the QA Specialist.

## 10.8 Repairs

Any perforation or tear must be repaired with a piece of the same type of material as that installed. The repair piece must exceed the defect by at least 300 mm in all directions.

Geonet pieces must be secured with a minimum of four (4) cable-ties spaced no more than 600 mm apart. Geotextiles pieces must be completely sealed by thermo-fusion (Leister device). No opening in the geotextile should be visible.

All repairs are subject to approval by the QA Specialist in accordance with the requirements of this document and/or the specifications. The QA Specialist reserves the right to require the Installer to perform additional repairs.

## 11. Geocomposite Clay Liner – Installation and Control

### 11.1 QA Supervision

The QA specialist shall supervise the installation of the GCL, which includes the following tasks:

- Verification of the deployment of the rolls;
- Verification of the installation (assembly) of each panel;
- Visual inspection of the installed product.

### 11.2 Deployment

No GCL roll can be deployed without prior approval from the QA Specialist. This can only be given once the QA Specialist has verified and accepted the required elements and work of the underlying elements.

The installation techniques must ensure that no damage comes to the GCL rolls. The GCL must be cut with appropriate instruments (such as carpet knives) and must be kept as clean as possible and protected from exposure to water until it is completely covered by a geomembrane.

### 11.3 Anchoring

The Installer must ensure that the GCL panels are assembled along the full extent of the anchor trench. No stake may be used to fix the geosynthetics to anchor trench. It is the responsibility of the Installer to ensure the stability of the GCL until the anchor trench is backfilled.

The QA Specialist and the Installer must both give their approval before any backfilling of the anchor trench may be performed.

### 11.4 Overlap

#### 11.4.1 Overlap Direction

All overlaps must follow the direction of water flow (from the high point to the low point). See Figure 7.

## 11.4.2 Overlap Width

Panels installed side-by-side must be overlapped by at least 300 mm, or as recommended by the Manufacturer.

Panels installed end-to-end must be overlapped by at least 600 mm, or as recommended by the Manufacturer.

## 11.5 Installation

### 11.5.1 Bentonite Powder

Following the Manufacturer's specifications for the selected product, powdered bentonite must be used between all joints. The Installer must take the necessary precautions to ensure the powdered bentonite does not become dispersed into the air, onto the subgrade, or in the collection systems.

## 11.6 Visual Inspection

Following installation, each GCL panel shall be visually inspected by the QA Specialist to identify any areas that are damaged, likely to be damaged or that appear abnormal. The Installer shall repair any damage at his own expense, to the satisfaction of the QA Specialist.

## 11.7 Repairs

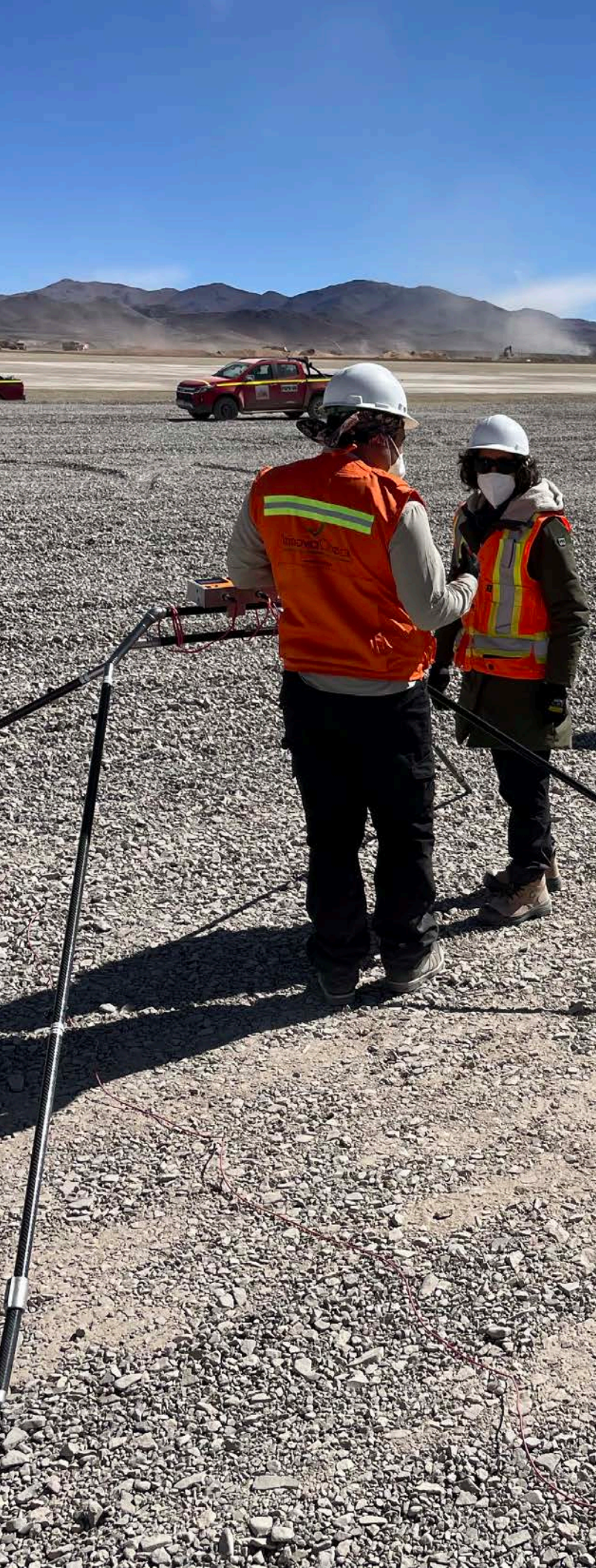
Any perforation or tear must be repaired with a piece of the same type of material as that installed. The piece must exceed the defect by at least 300 mm in all directions. In addition, powdered bentonite must be used between all joints.

If any area is hydrated or altered by water before being covered, it must be doubled.

All repairs are subject to approval by the QA Specialist in accordance with the requirements of this document and/or the specifications. The QA Specialist reserves the right to require additional repairs from the Installer.

---

## Appendix II: Electrical Leak Location



**ELECTRICAL  
LEAK LOCATION**

**Alphard**

rethinking engineering

We take that extra step for our clients

We are a people-centered engineering and professional services firm. Our multidisciplinary team of high expertise offers innovative and reliable solutions that meet the specific needs of each project.

Pragmatic, agile and highly committed, we take pride in the performance and success of our clients.

# TABLE OF CONTENTS

- 1 ..... ELECTRICAL LEAK LOCATION
- 3 ..... THE SPARK TEST METHOD
- 4 ..... THE WATER PUDDLE METHOD
- 5 ..... THE DIPOLE METHOD
- 6 ..... OUR SCHEMATICS
- 7 ..... OUR PROJECTS





# ELECTRICAL LEAK LOCATION

GROUPE ALPHARD

GEOSYNTHETIC MATERIALS PLAY A KEY ROLE IN THE MAJORITY OF CONTAINMENT WORKS.

The use of geosynthetic materials continues to grow in a variety of sectors including waste management, industrial and mining applications and contaminated soils management.

The performance of a containment site is directly affected by the presence of faults in its geomembrane layer. Potential risk factors for faults during the construction of containment works are varied, including perforation, welding errors (fusion, extrusion), tearing, cutting, vehicle damage and manufacturing faults. Groupe Alphard's range of leak location techniques ensures the integrity of containment works before they are put into operation, as well as providing effective diagnostic tools for existing containment sites.

Groupe Alphard's professionals have over 15 years experience in the field of electrical leak location. Their expertise includes performing leak location surveys on a variety of covered and exposed geomembranes, as well as developing new leak location technologies and assisting in the standardization of existing leak location techniques.

This document provides an outline of the electrical leak location methods currently offered by Groupe Alphard.

## SITES AND APPLICATIONS

- ✓ Technical landfill sites
- ✓ Industrial containment works
- ✓ Mine tailings parks
- ✓ Leachate ponds
- ✓ Site closures
- ✓ Water treatment reservoirs
- ✓ Dams and dikes
- ✓ Biogas barriers
- ✓ Contaminated soils treatment platforms
- ✓ Check dams



## A Few Statistics

4.6M

Groupe Alphard has performed electrical leak location surveys on over 4.6 million square metres of geomembrane material, covering 129 distinct projects.

396

The most leaks found on a single project was 203 leaks with the water puddle method, and 396 leaks with the dipole method.

12 m

The largest leak found to date was more than 12 m long. It was found by applying the dipole method through a natural covering layer.

21%

In 2014, less than 22% of all geomembrane installed in the province of Quebec was tested using ELL methods.

-13°C

The dipole method was successfully applied at -13 °C, the coldest leak location conditions experienced to date, requiring significant effort to heat the surrounding ground.

1.1 m

The thickest covering tested was a 1.1 m thick layer of fill dirt, stones and boulders (up to 40 cm wide). Several leaks were found in the underlying geomembrane material.

6 mm<sup>2</sup>

Leaks as small as 6 mm<sup>2</sup> were located and excavated in an evaporation pond in Chile.

---

# THE SPARK TEST METHOD

---

## ASTM D7240 STANDARD



The spark test method (standardized under ASTM D7240 – “Standard Practice for Leak Location Using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique [Conductive Geomembrane Spark Test]”) allows for the detection and localization of faults sustained during the installation of conductive geomembranes.

Recent developments in the manufacturing of coextruded geomembranes have made it possible to produce geomembranes with a conductive layer alongside the traditional isolating layer. It is this conductive layer that allows the geomembrane to be surveyed using the spark test method.

To perform the survey, the geomembrane must be installed with the conductive layer face down. A portable power source is then used to charge a conductive element (such as a neoprene pad), and this charge is transferred to the conductive layer through the capacitance effect. A leak location probe is then swept over the surface of the geomembrane. When the probe passes over a leak or fault, the conductive geomembrane layer is discharged, creating a spark that allows the fault to be identified and localized.

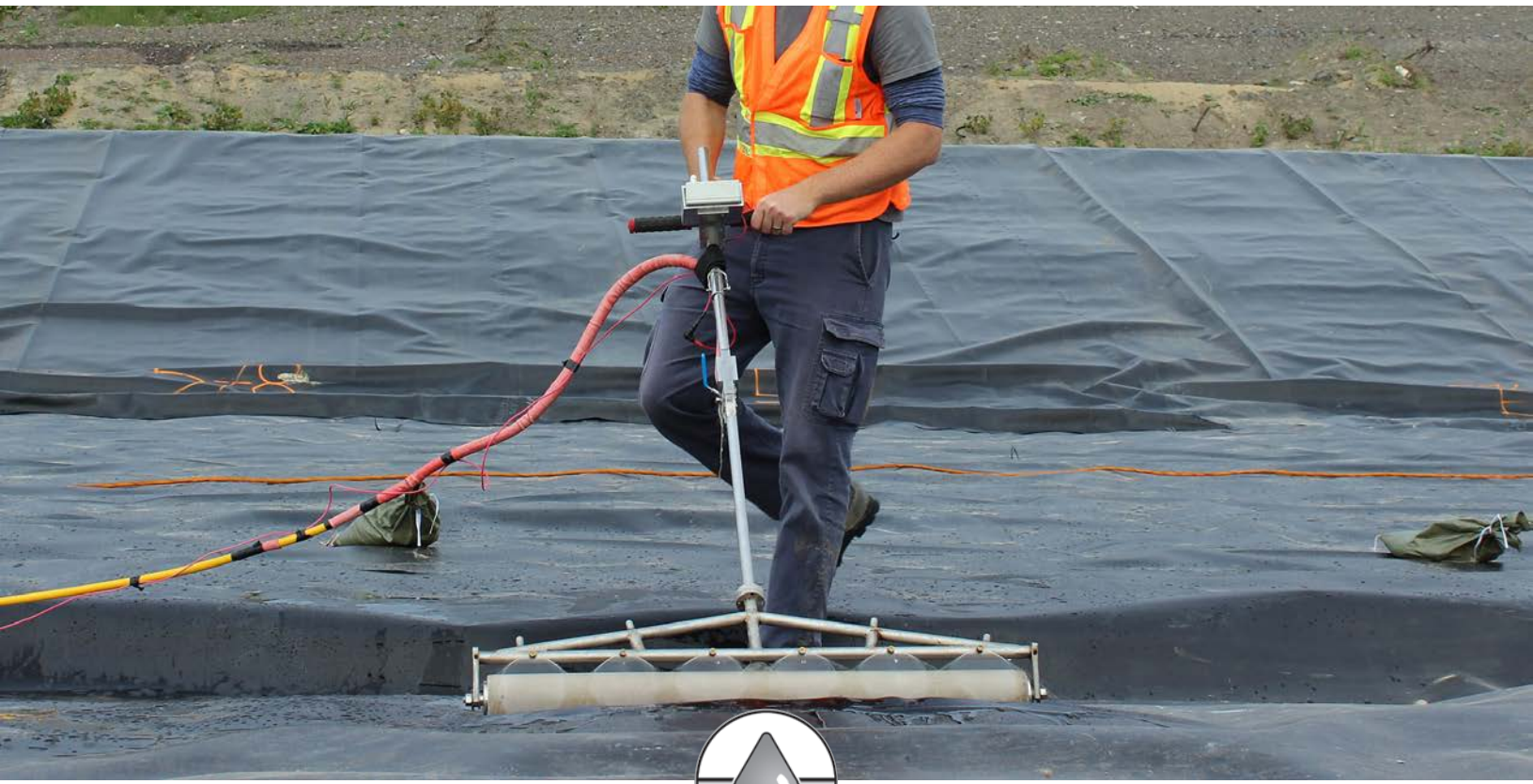
Different equipment can be used depending on the area to be surveyed. Small hand-held detectors are used in confined areas, whilst large detectors are generally used on expansive open areas. Leaks of less than 1 mm<sup>2</sup> can be localized using the spark test method.

---

# THE WATER PUDDLE METHOD

---

ASTM D7002 STANDARD



The water puddle method (standardized under ASTM D7002 – “Standard Practice for Leak Location on Exposed Geomembranes Using Water Puddle Method”) allows for the detection of faults sustained during the installation of geomembrane materials.

The water puddle method applies geoelectrical techniques which harness the insulating properties of geomembrane materials to detect leaks and faults (see figure below).

To perform the survey, a DC voltage is applied to a metal sprinkler carried by the technician. A grounding electrode is then placed outside of the

test site, creating a difference in electrical potential between the water distributed by the sprinkler and the underside of the geomembrane.

Once the technician reaches a fault sufficiently large to flow through, the water creates an electrical bridge between the positive voltage and the grounding electrode. An audible signal is then produced to inform the technician that a leak has been found. The water puddle method detects leaks smaller than 1 mm<sup>2</sup> whilst allowing for 100% of the test surface to surveyed, providing a leakproof guarantee across the entire geomembrane surface..

---

# THE DIPOLE METHOD

---

ASTM D7007 STANDARD



The dipole method of leak localization (standardized under ASTM D7007 – “Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials”) allows for the detection of leaks and faults sustained during the installation of covering materials.

The dipole method applies geoelectrical techniques which harness the insulating properties of geomembrane materials to detect leaks and faults (see figure below).

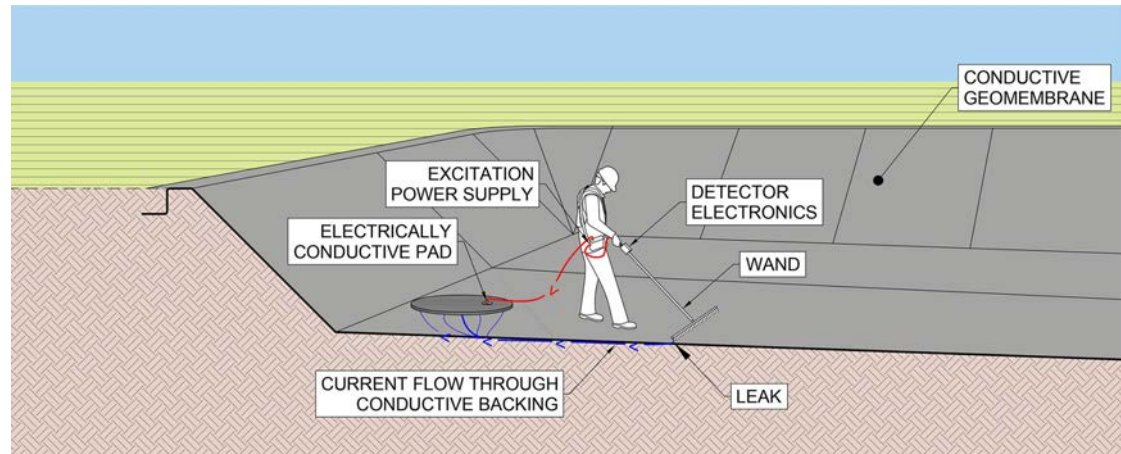
A voltage of around 550 V (DC) is passed directly into the covering materials whilst a grounding electrode is placed outside the limits of the geomembrane. If a fault or leak is present, the electrical charge will pass through the defect to reach the grounding electrode, generating a distinct electrical signature that can be identified and localized by a qualified technician.

The dipole method allows for the detection of faults around 6 mm in diameter through covering materials up to 1 m thick.

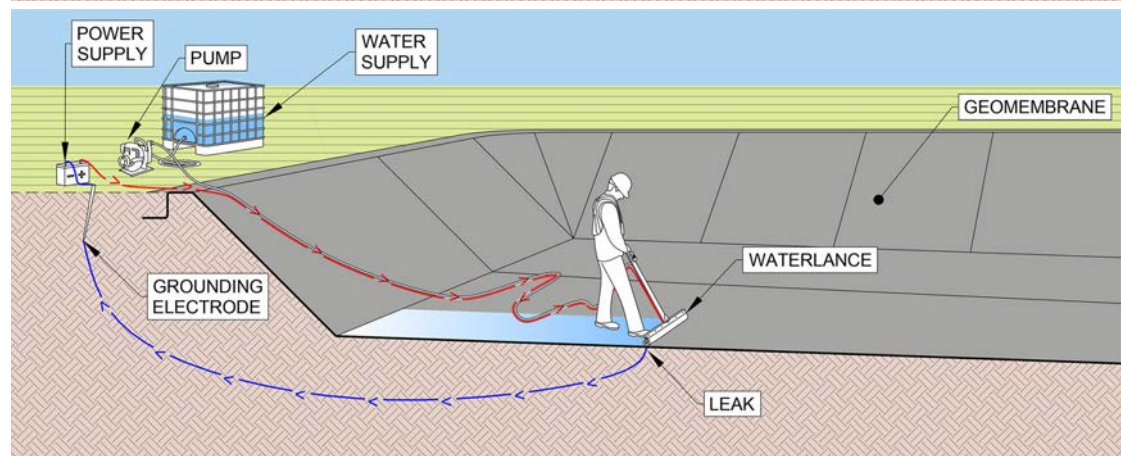
# OUR SCHEMATICS



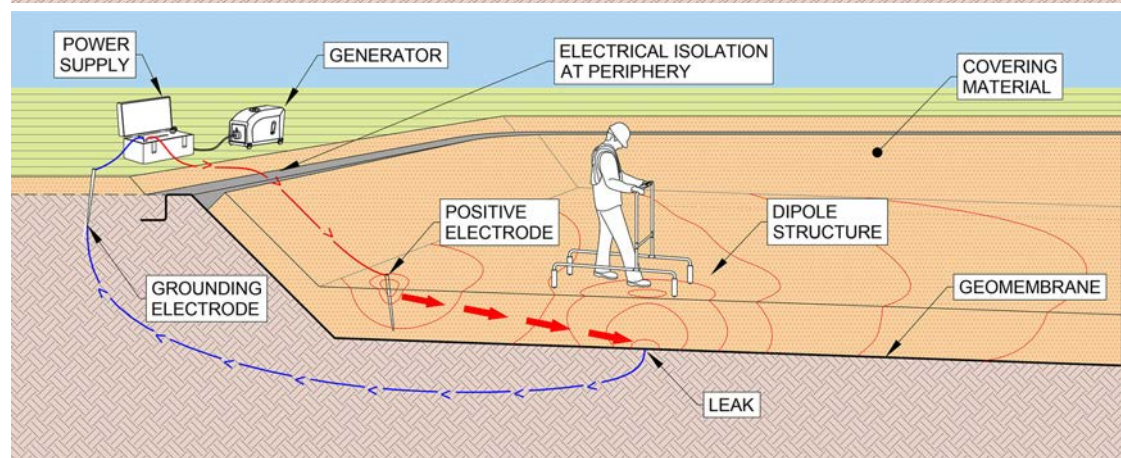
**SPARK TEST**  
ASTM D7240



**WATER PUDDLE**  
ASTM D7002



**DIPOLE**  
ASTM D7007





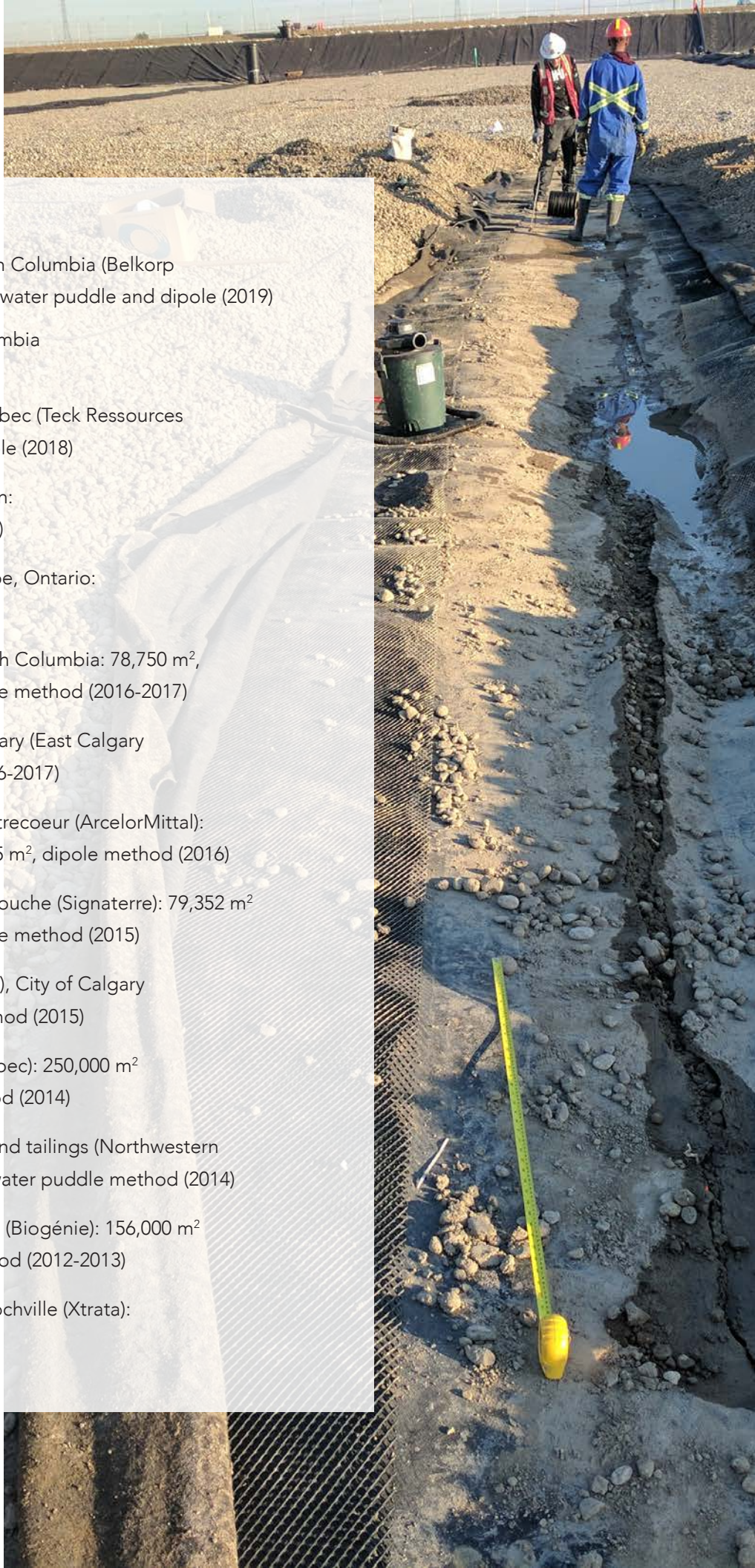
# OUR PROJECTS

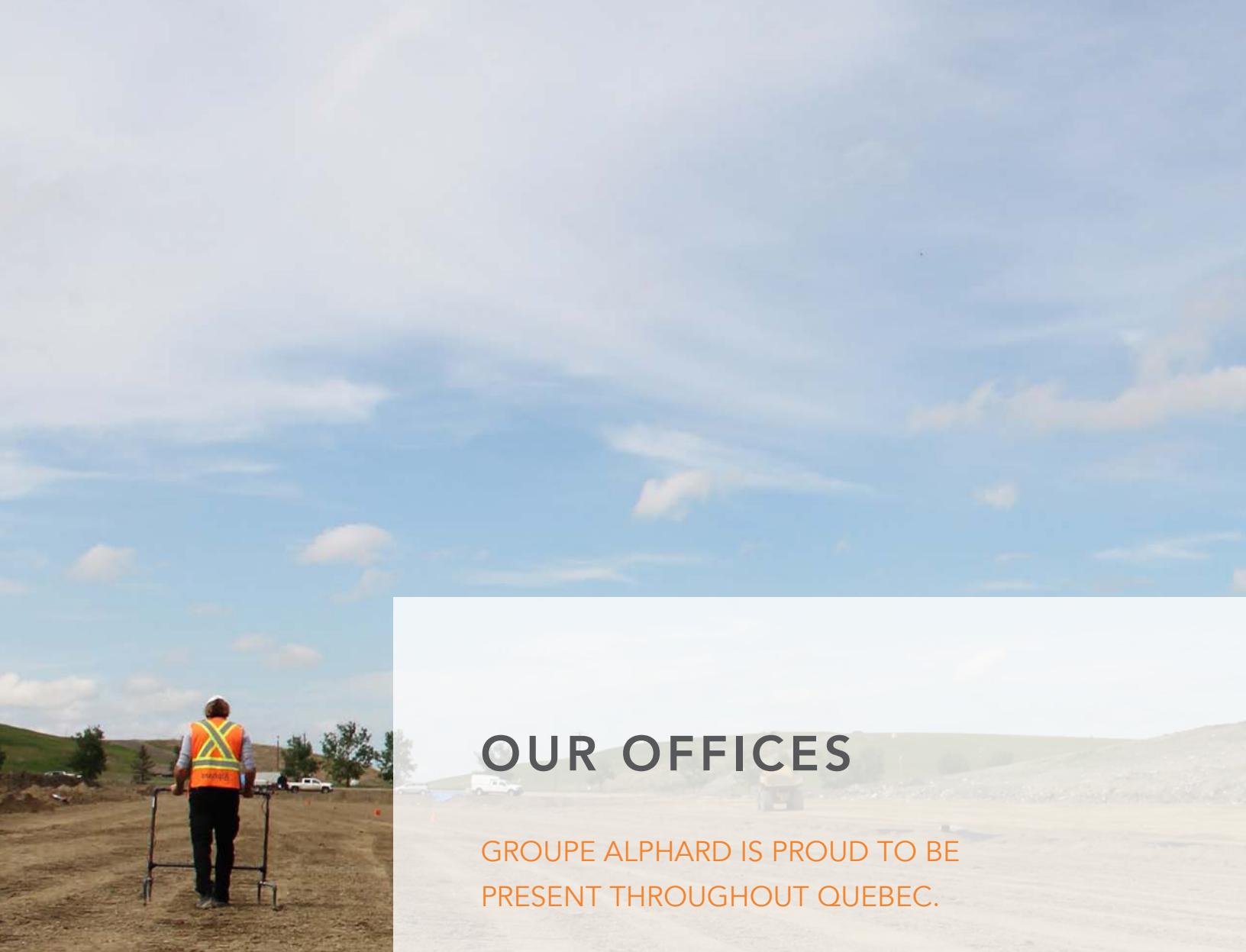
Groupe Alphard's leak location professionals have over 15 years of experience in the domain, during which they have developed a diverse portfolio of public and private clients. The following list provides an overview of our major leak location projects.

## A FEW OF OUR PROJECTS:

- Two permanent covering of mine residues and tailings in France, Rio Tinto : 193,000 m<sup>2</sup> dipole method (2022)
- New tailings pond, Agnico Eagle, Rouyn-Noranda: 507,000 m<sup>2</sup> water puddle method (2020-2021-2022)
- Paper mill waste Phase 2 for Cariboo Pulp and Mill, British Columbia: 25,000 m<sup>2</sup> water puddle method and 7,500 m<sup>2</sup> dipole method (2022)
- Borden Military Base (Ontario), Sanexen Environmental Services Inc.: 47,000 m<sup>2</sup> water puddle method (2021)
- Validation of partial pond for ArcelorMittal, Fournier & Fils (contractor) requested by BBA (engineer), Fermont (2021)
- New contaminated soil cell at Signaterre, CAP Excavation (contractor) for AECOM (engineer) (2021)
- SQM Salar, Chili: 230,000 m<sup>2</sup> dipole method (2020)
- New Waste Cell, Big Time Operation, Alberta: 44,000 m<sup>2</sup> dipole method (2020)
- Pond verification, Portugal (Lundin Mining): 12,000 m<sup>2</sup> water puddle method (2020)
- New tailings pond, Agnico Eagle, Rouyn-Noranda : approximately 600,000 m<sup>2</sup> water puddle over 3 years (2020)
- Zink mine water storage pond, Portugal (Lundin Mining): 12,900 m<sup>2</sup> water puddle method (2019)

- Domestic waste landfill stage 1A, British Columbia (Belcorp Environmental Services Inc.): 63,900 m<sup>2</sup> water puddle and dipole (2019)
- Pulp mill landfill extension, British Columbia (Harmac): 32,000 m<sup>2</sup> dipole (2018)
- Permanent mining cap in Val d'Or, Quebec (Teck Resources Ltd): 122,800 m<sup>2</sup> water puddle and dipole (2018)
- Rainwater storage reservoir, Washington: 171,000 m<sup>2</sup> water puddle method (2017)
- Radioactive waste landfill site, Port Hope, Ontario: 92,000 m<sup>2</sup> dipole method (2017)
- Comox Valley landfill site – Cell 1, British Columbia: 78,750 m<sup>2</sup>, water puddle method; 46,700 m<sup>2</sup>, dipole method (2016-2017)
- Extension of technical landfill site, Calgary (East Calgary Landfill): 64,940 m<sup>2</sup> dipole method (2016-2017)
- Industrial landfill capping – Cell B, Contrecoeur (ArcelorMittal): 29,545 m<sup>2</sup> water puddle method; 28,675 m<sup>2</sup>, dipole method (2016)
- Decontamination of soil cells 1-4, Mascouche (Signaterre): 79,352 m<sup>2</sup> water puddle method; 60,523 m<sup>2</sup>, dipole method (2015)
- Spyhill dump, Stage 3 (municipal dump), City of Calgary dump (AECOM): 55,625 m<sup>2</sup> dipole method (2015)
- Closure of Barvue Mine, Barraute (Quebec): 250,000 m<sup>2</sup> water puddle, 253,000 m<sup>2</sup> dipole method (2014)
- Permanent covering of mine residues and tailings (Northwestern Territories): Tundra Mines, 132,500 m<sup>2</sup> water puddle method (2014)
- Contaminated soils landfill, L'Épiphanie (Biogénie): 156,000 m<sup>2</sup> water puddle method and dipole method (2012-2013)
- Waste water treatment reservoir, Murdochville (Xtrata): 17,000 m<sup>2</sup> water puddle method (2012)





## OUR OFFICES

GROUPE ALPHARD IS PROUD TO BE  
PRESENT THROUGHOUT QUEBEC.

### **Head Office**

5570 Casgrain Avenue,  
Suite 101  
Montréal (QC) H2T 1X9

### **Québec**

1255 Lebourgneuf Blvd,  
Suite 480  
Québec (QC) G2K 0M6

### **South shore of Montréal**

5005 Lapinière Blvd,  
Suite 3070  
Brossard (QC) J4Z 3H8

### **Saguenay**

260 Racine Street,  
Suite 101  
Saguenay (QC) G7H 1R9



[www.alphard.com](http://www.alphard.com)



[www.linkedin.com/company/groupe-alphard](http://www.linkedin.com/company/groupe-alphard)