

ELECTRICAL LEAK LOCATION SURVEY GENERAL GUIDE



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1.0 HANDBOOK INSTRUCTIONS

This handbook is intended for use by design engineers, regulatory agencies, construction quality assurance agencies, earthworks and liner installer contractors, and any individuals seeking a basic knowledge of electrical leak location (ELL) surveys. It is not a comprehensive guide for the performance of ELL surveys. It describes the most commonly used ELL methods. An experienced leak location practitioner should review project specific construction plans and specifications for the applicability of ELL methods. ASTM D6747 may also be used as a reference for method selection.

For more specific information related to your project, contact Abigail Gilson, TRI Environmental Director of Liner Integrity Services, at abeck@tri-env.com, 512-623-0511.

2.0 STANDARDIZED ELECTRICAL LEAK LOCATION METHODS

2.1 Exposed Geomembrane Methods

- References:**
- ASTM D6747: Standard Guide for Selection of Techniques for Electrical Detection of Leaks in Geomembranes
 - ASTM D7002: Standard Practice for Leak Location on Exposed Geomembranes Using the Water Puddle System
 - ASTM D7703: Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Lance System
 - ASTM D7240: Leak Location using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive Geomembrane Spark Test)
 - ASTM D7953: Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Arc Testing Method

2.1.1 Method Comparison

All of the bare geomembrane ELL methods must demonstrate the ability to detect a pinhole. What informs the application of one method over another is site configuration and conditions. Alternative methods are allowed by each ASTM standard based on particular project requirements and site conditions, which can change quickly.

2.1.2 Water Puddle Method (ASTM D7002)

The water puddle method is generally the preferred method for bare geomembrane due to its survey speed, but it requires a water source and becomes less sensitive on extreme side slopes and on sites with poor boundary conditions. When slopes are steeper than 3H:1V, and/or feature smooth geomembrane, the water lance or arc testing method should be used. This method is extremely tolerant of wet and/or dirty site conditions.

A low voltage direct current source is introduced to the water sprayed above the geomembrane and grounded to the underlying semi conductive layer. An ammeter in series with the circuit converts the increase in current flow to an audible signal when the equipment passes over a leak.

The water sprayed onto the survey area to perform the test must be contained in the survey area (above the geomembrane to be tested). Conductive features such as concrete sumps and batten strips must be isolated and cannot be tested, since they will ground out the survey (give a false positive signal). Holes will not likely be detected on wrinkles unless conductive-backed geomembrane is used, or if the operator makes a successful attempt to push down the wrinkles and create intimate contact between the geomembrane and the underlying layer.

2.1.3 Water Lance Method (ASTM D7703)

The water lance method is generally used when slopes are steeper than 2H:1V, but it can also be used on flat areas. It requires a water source and becomes less sensitive on sites with poor boundary conditions. This method is extremely tolerant of wet and/or dirty site conditions.

A low voltage direct current source is introduced to the water sprayed above the geomembrane and grounded to the underlying semi conductive layer. An ammeter in series with the circuit converts the increase in current flow to an audible signal when the equipment passes over a leak.

The water sprayed onto the survey area to perform the test must be contained in the survey area (above the geomembrane to be tested). Conductive features such as concrete sumps and batten strips must be isolated and cannot be tested, since they will ground out the survey (give a false positive signal). Holes will not likely be detected on wrinkles unless conductive-backed geomembrane is used, or if the operator makes a successful attempt to push down the wrinkles and create intimate contact with the subgrade.

2.1.4 Conductive-Backed Geomembrane Spark Testing Method (ASTM D7240)

The conductive-backed geomembrane spark testing method is used only for bare conductive-backed geomembranes and cannot be used on other types of geomembranes. Only this method can be used to test conductive-backed geomembrane unless the geomembrane is installed as an electrically isolative conductive-backed installation (See Section 3.2.1). The surface of the geomembrane must also be clean and dry.

A high voltage pulsed power supply charges a capacitor formed by the underlying conductive layer, the non-conductive layer of the geomembrane and a coupling pad. The area is swept with a brush-like test wand to locate points where the capacitor discharges through a leak. When the system senses the discharge current, it is converted into a visible spark and an audible alarm.

Unless the conductive geomembrane has been installed as an electrically isolated conductive-backed installation, this method cannot be used to test fusion-welded seams. Holes can be detected on wrinkles and other “poor contact” conditions due to the conductive backing of the geomembrane.

2.1.5 Arc Testing Method (ASTM D7953)

The arc testing method is the preferred method for bare geomembranes on extremely sloped and especially vertical surfaces, since the leak detection does not depend on water getting through the leak. It is also preferred by installers since it does not require the application of water or isolation of said water, so it can be performed immediately behind liner installation of any configuration. The drawback to this method is that it is the slowest method to perform. The surface of the geomembrane must also be clean and dry.

A high voltage power supply is applied to a test wand above the geomembrane and is grounded to the underlying semi conductive layer. The area is swept with a test wand and an electrical arc is formed in the presence of a leak. When the system senses the discharge current arc, it is converted into visual and audio alarms. The test wand can be custom sizes and shapes for specific applications.

This type of test requires that the geomembrane is in contact with the subgrade. If the separation distance is greater than 3 cm, such as on a wrinkle or other “poor contact” conditions, the instrument is not likely to arc. Therefore, in the presence of wrinkles, it may not be the preferred method unless the survey is being performed on conductive-backed geomembrane.

2.2 Covered Geomembrane Methods

References: ASTM D6747: Standard Guide for Selection of Techniques for Electrical Detection of Leaks in Geomembranes

ASTM D7007: Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials

ASTM D8265: Standard Practices for Electrical Methods for Mapping Leaks in Installed Geomembranes

2.2.1 General Requirements for ELL on Covered Geomembranes

The boundary conditions of the site will determine the effectiveness of any electrical leak location method applied to covered geomembranes (See Section 3.1). The material covering the geomembrane must be electrically isolated from the surrounding ground. This typically entails leaving a strip of geosynthetics (geomembrane or geomembrane covered by geotextile or geocomposite) uncovered all along the perimeter of the survey area(s). The geosynthetics should be as dry as possible. Any feature(s) that can carry current from the survey area to the surrounding ground should not be in place during the ELL survey.

2.2.2 The Dipole Method

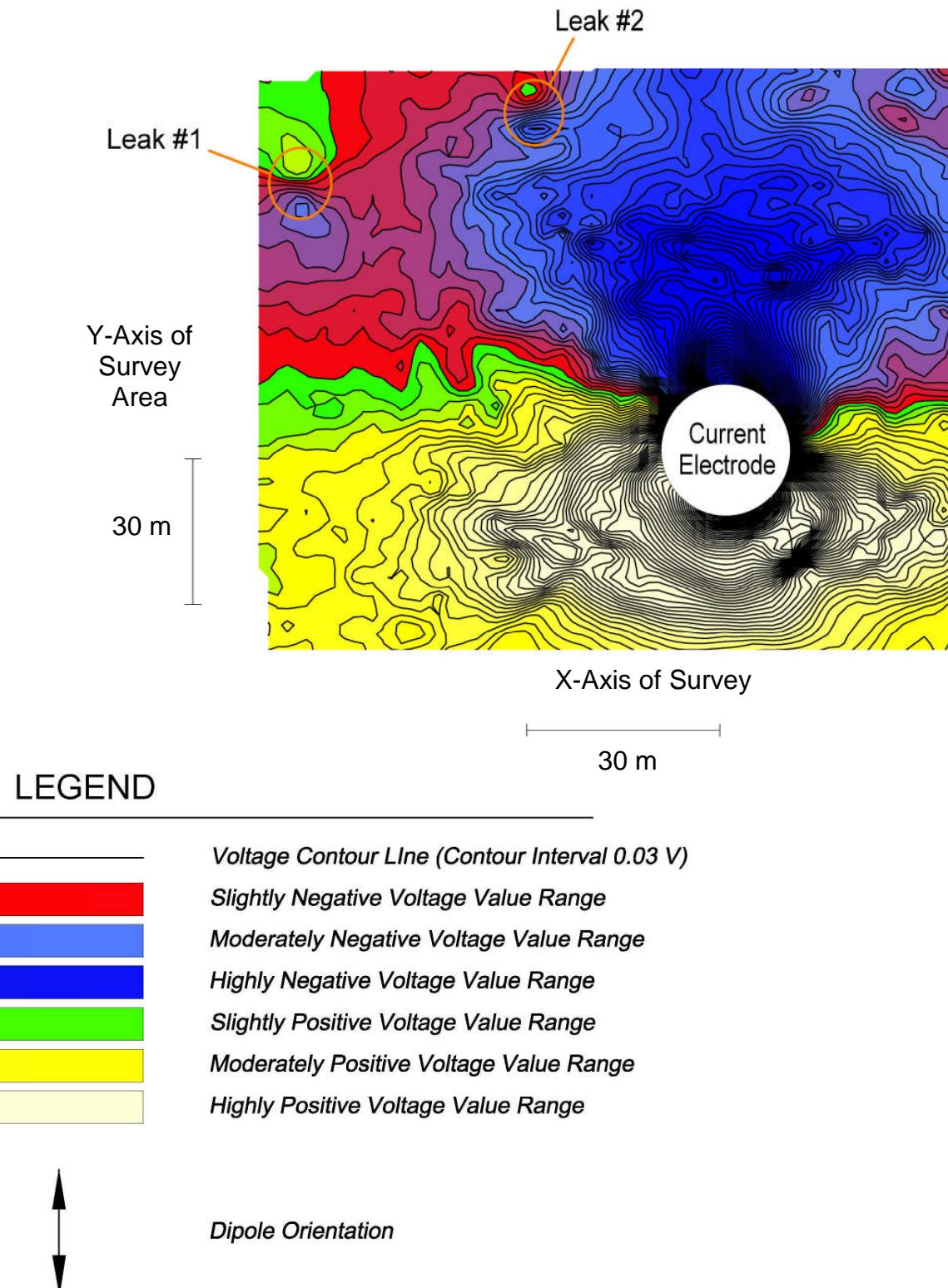
Several electrical methods exist for detecting leaks in installed geomembranes. However, significant research conducted in multiple locations around the world resulted in the choice of the dipole method as the most effective and practical method for geomembranes covered with a relatively thin layer of earthen material (up to approximately 3 meters) and/or water. The first ASTM Standard Practice developed for the dipole method was ASTM D7007. This standard has since been eclipsed by the more recently published ASTM D8265. ASTM D8265 addresses the shortcomings of ASTM D7007 and is the only method that can provide clear and transparent results of the ELL testing, so it should always be specified for covered geomembranes. For this reason, only ASTM D8265 is discussed here.

To apply the Dipole Method, a DC voltage is applied to the cover material with a current injector electrode. The power source is grounded to the semi conductive layer underneath the geomembrane being tested. Voltage measurements are taken in a grid pattern throughout the survey area using a dipole instrument. Leak locations cause a sine wave pattern in the voltage measurements as the dipole instrument travels across a hole location.

The data collected by the roving dipole instrument is recorded and downloaded into computer software for analysis. Voltage contour mapping data analysis shows the voltage measurements in plan view of the survey area, but the dipole must be pointed the same direction throughout the survey area in order for the measurements to make sense from a mapping perspective. An example of voltage contour mapping data analysis is shown in Figure 1.

The negative/positive polarity of the entire survey area is created by the current injector electrode. The characteristic leak signal voltage pattern is opposite that of the current injector electrode, since current is exiting the survey area at current leakage locations and entering the survey area at the current injector location. Anomalies indicative of leak locations on these maps feature a positive circular peak on top of a negative circular peak, separated by closely spaced contour lines. The shape of a leak signature is similar to that of a butterfly on its side.

Figure 1: Voltage Contour Mapping Data Analysis.

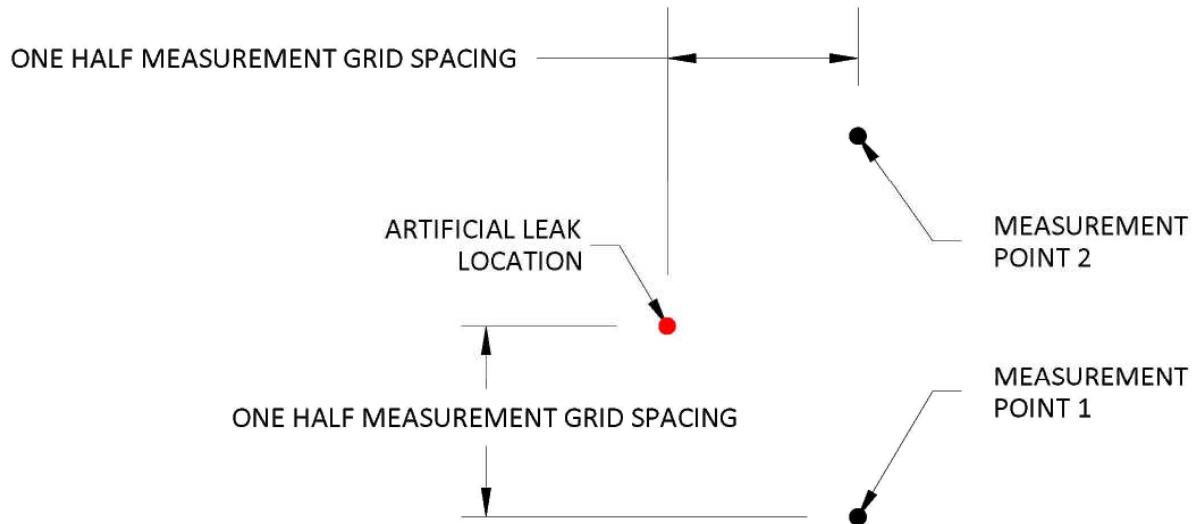


2.2.3 Functionality Testing

Method functionality testing is performed with an “artificial leak”. An artificial leak is a conductive object, usually a stainless steel disk, which is connected by an insulated wire to the same semi conductive layer underlying the geomembrane as the return electrode of the power supply. This simulates a leak in the lining system electrically but is not an actual hole.

This functionality test shows that the survey circuit is properly set up, a proper voltage is being applied, and it documents the detectability of a leak with good electrical contact. Dipole measurements are taken in four positions; the front foot of the dipole directly over the artificial leak, the back foot of the dipole directly over the artificial leak, the front foot of the dipole directly over measurement point 1, and the back foot of the dipole directly over measurement point 2. These voltage values represent the “best case” and “worst case” signal strengths of the artificial leak.

Figure 2: Artificial Leak Functionality Test



3.0 DESIGNING FOR ELL

Not all site configurations are amenable to ELL methods. Some facilities may only be tested at certain stages throughout the construction process. Special provisions must be made to test a site throughout its service life. It is important that anyone specifying ELL is knowledgeable about the requirements and limitations of the specified methods.

3.1 Boundary Conditions

The four critical boundary conditions in order to conduct an electrical leak location survey are:

1. Conductive material over geomembrane (unless the geomembrane is bare)
2. Conductive material below geomembrane
3. Good contact of material above and below geomembrane through leak
4. Material above and below geomembrane are only in contact through leak locations

The following sections describe how these four conditions must be addressed during the design and construction of a facility where a leak location survey is specified.

3.2 Material Specifications

3.2.1 Geomembranes

Geomembranes must be electrically insulative. Polyethylene, polyvinyl chloride, polypropylene, chlorosulfonated polyethylene and bituminous geomembranes are sufficiently electrically insulative. EPDM is not sufficiently insulative at the voltages required for testing covered geomembranes, but can be tested while bare with the low voltage water-based methods. Excessive leakage in terms of number or size of holes in the geomembrane will compromise the sensitivity of a leak location survey. Any locations of poor hole contact (wrinkles, subgrade depressions) will decrease the sensitivity of a survey and possibly result in undetected leaks. Material and placement methods should minimize the production of wrinkles and areas of trampolining.

If survey sensitivity is a high concern, conductive-backed geomembrane should be specified. When a material is referred to as "conductive-backed geomembrane", it refers to an insulative geomembrane, with a conductive layer beneath the insulative layer, manufactured specifically to assist leak location surveys. The conductive backing allows leak detection on poor hole contact scenarios. If a dipole method survey is to be performed, the conductive-backed geomembrane installation requires a specialty welder and special installation protocols, resulting in an installation of conductive-backed geomembrane that features a continuously conductive surface on the bottom layer while electrically isolating the bottom conductive layer from the top insulating layer of the entire geomembrane installation. GSE's Leak Location Liner installation guidelines fulfill these requirements.

In a double-lined impoundment, a conductive layer must be present under the primary geomembrane. In the absence of a conductive layer (i.e. geocomposite only), conductive-backed geomembrane or other sufficiently conductive products such as conductive geotextile should be specified. Alternatively, the leak detection layer can be filled with water.

3.2.2 Geocomposites

Geocomposites alone are not conductive, but the application of water to the geocomposite can enable a leak location survey. Water can be added to the geocomposite during construction, or after construction via rainfall or surface watering, as long as enough water is added to travel down to the geocomposite. With hole contact being an important parameter in survey sensitivity, a geocomposite is likely to decrease method sensitivity unless it is saturated.

A conductive geotextile can be specified as the geotextile portion of the geocomposite directly in contact with the geomembrane to be tested in order to enable leak detection.

If a non-conductive geomembrane is used as the primary geomembrane in a double-lined impoundment and a geocomposite is present in the leak detection layer, the leak detection layer must be flooded with water to perform the survey. The primary geomembrane must also be flooded and the water-covered dipole method should be used.

3.2.3 Geotextiles

Geotextiles alone are not conductive, but the application of water to the geotextile will enable a leak location survey. Water can be added to the geotextile during construction, or after construction via rainfall or surface watering, as long as enough water is added to travel down to the geotextile. If a geotextile is adjacent to moist soil material and covered, the moisture tends to wick through the geotextile, thus enabling a survey. Geotextiles can be left intact in perimeter isolation trenches as long as they are dry. In the case of rainfall, it is typically necessary to wait for dry weather for the geotextile to dry out before performing a survey.

A conductive geotextile can be specified to be placed underneath the primary geomembrane in a double-lined impoundment in order to enable leak detection of the primary geomembrane. The conductive geotextile/geomembrane interface may still have contact problems unless the leak location is wet or dirty.

3.2.4 Geosynthetic Clay Liners (GCL)

The high quality clay component of a GCL is highly conductive, however due to the discrete clay granules surrounded by geotextiles, the moisture content of a GCL must be fairly high in order to perform a leak location survey. The minimum moisture content of a GCL required to perform a leak location survey can be estimated at 8%, though this value will vary for different GCL products. A single composite liner with GCL does not require any special preparation; moisture will easily wick into the GCL from the subgrade, since the GCL is extremely hydrophilic. Encapsulated GCL, however, will tend to stay at the moisture content that it was placed at. In arid climates where GCL panels are left uncovered for some time before being covered with the primary liner, the product can desiccate within one working shift. In arid climates, it is advisable to either rehydrate the GCL before covering with the primary liner, or specify a conductive geomembrane as the primary geomembrane. Encapsulated GCLs can also have problems with electrical conductivity over the panel overlaps, especially in arid climates. If the overlaps are not conductive, it is advisable to place a bare copper wire in a network under the GCL. The concept of the layout is to run the network of wires so that each and every panel is connected to at least one wire. The wire is then made accessible to the leak location surveyor by running it out through the anchor trench. At least two discrete wires should be placed, in order for the leak location surveyor to check the conductivity through the bulk of at least one GCL panel. If the overlaps are conductive, then two separate wires should be placed under the GCL; they do not need to touch every panel.

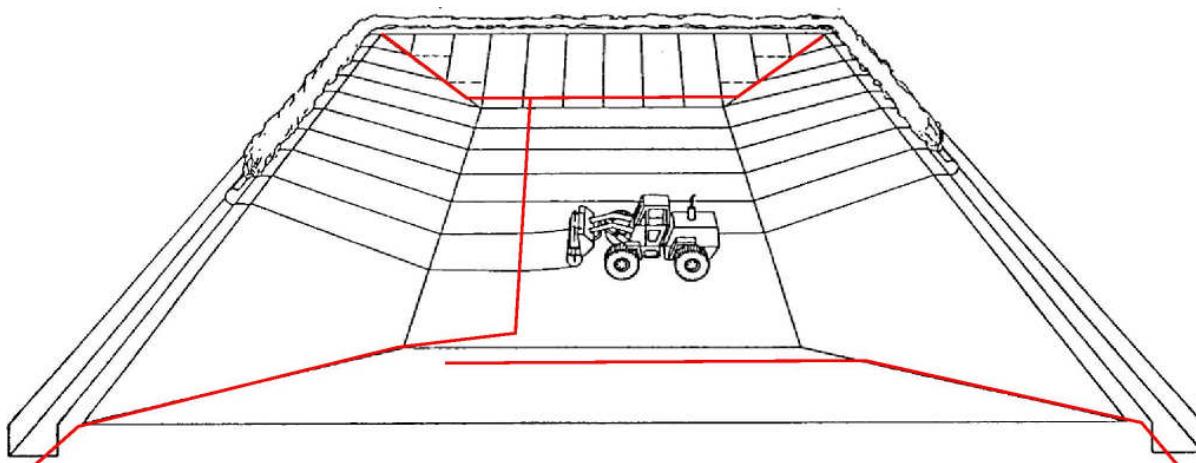


Figure 3: Hypothetical copper wire layout for encapsulated GCL. Copper wire is shown as a red line.

3.2.5 Cover Material

The material covering the geomembrane should always be moisture conditioned, unless the project is located in a wet climate and the material is already sufficiently moist. Highly porous material such as gravel does not require moisture conditioning, since the material will require watering during the leak survey regardless. This is only true for large gravel particles (greater than approximately 5 cm). All other materials should have moisture within the mass of the cover layer. Surficial watering directly in front of the leak location survey may be required regardless, depending on local climate.

3.2.6 Subgrade Material

Subgrade conductivity will not be a problem with a compacted clay liner. However, if there is no design requirement for a compacted clay liner and onsite soils are used, there is a small chance that the material will be either too dry or contain a mineral content that is not sufficiently conductive. In that case, the subgrade material must be watered before placement of the geomembrane. Subgrade conductivity testing should be performed in the case of questionable site soils, or a conductive-backed geomembrane should be specified as the geomembrane type.

Geomembrane rub sheets should not be allowed to remain under the geomembrane to be tested.

3.3 Construction Sequencing

3.3.1 Dipole Method – Soil Covered Geomembrane (ASTM D8265)

An isolation trench must be specified as part of construction sequencing around the perimeter of the survey area. In climates with spells of extreme rain events, a rain flap should also be considered. Rain flaps are welded in the isolation trenches and propped up by soil so that in the case of extreme rain where the trench will fill up with water, electrical isolation will still be provided by the rain flap. The rain flap must be welded to the base geomembrane.

Access roads can typically remain in place, as long as there is a strip of geomembrane or rain flap bisecting the access road, creating electrical isolation.

3.3.2 Dipole Method – Water Covered Geomembrane (ASTM D8265)

Consideration for the installation of any grounded objects should be given with respect to the construction sequencing. The survey should be performed before any necessary grounded objects are installed.

If a double-lined impoundment lacks a conductive-backed geomembrane for the primary geomembrane or lacks a conductive geotextile underneath the primary geomembrane, the leak detection layer must be flooded in order to survey the primary geomembrane. There should be ballast over the primary geomembrane to avoid damage, or the impoundment should be filled with water at the same rate that the leak detection layer is filled (or before).

3.3.3 Water Puddle and Water Lance Methods (ASTMs D7002 and D7703)

The geomembrane must be completely installed in the area to be tested. Consideration for the direction of run-off flow should be given for bare geomembrane survey methods using water as a conductive medium. If water is allowed to flow freely out of the survey area to touch ground, an electrical short will be created. Interim rain flaps can be used where necessary to contain the water within the survey area.

3.3.4 Arc Testing and Spark Testing Methods (ASTM D7953 and D7240)

The geomembrane must be clean and dry. Testing can be performed directly up to but not including any grounded features.

3.4 Grounded Objects

Objects that will provide a source of electrical grounding should be carefully designed, or the construction sequence modified to enable a leak location survey. For example, a metal pipe penetrating the liner system should have a plastic boot so that water sprayed on the geomembrane or soil covering it will not touch the metal pipe. For pond applications, concrete inlet or outlet structures, including metal batten strips, will ground out the survey. In some cases the design cannot be modified, but a rain flap can be welded as an interim measure to intercept water flowing to a grounded object.

3.5 Specifying Methods

The appropriate survey method will depend on the site configuration, the condition of the geomembrane during the survey; whether the geomembrane is bare or covered, whether it is the primary geomembrane or the secondary geomembrane, whether the geomembrane has a conductive backing or not, and how the conductive-backed product is installed. Simply specifying ASTM D8265 is sufficient for geomembranes to be covered with earthen material and/or water. For bare geomembranes, it is best for a Leak Location Contractor to advise which method should be used.

A survey can be conducted either before or after cover material placement, or both. For geomembranes that are to be covered by earthen materials, a survey should be performed both directly after liner installation and after cover material placement. This will result in the maximum leak detection sensitivity. If small holes are not a concern and only one method can be specified due to cost constraints, then a dipole survey should be performed after placement of the cover materials, since this method will locate the major leaks caused by placement of the cover material.

3.5.1 Specifying Leakage Rates

It is impossible to construct a “leak free” lining system, since even in the absence of breaches through the geomembrane, vapor diffusion occurs through a geomembrane and condensation also occurs between geomembranes. Setting an allowable leakage rate should be informed by the existing available technologies and the maximum leakage that would cause impairment to groundwater. Setting an allowable leakage rate too low to achieve with existing technologies is simply a recipe for failure.

Several studies have shown that the Giroud equation is probably not applicable to typical geomembrane construction (Beck, 2014, Gilson-Beck 2019). Rather, the Rowe equation should be used, assuming that the contact between the geomembrane and the underlying subgrade will likely contain wrinkling. The assumed undetected leak frequency can be used to inform the number of leaks contributing to leakage.

For a landfill designed to maintain less than one foot of head over the liner, in order to stay under a leakage rate of 20 gallons per acre per day, it is recommended to perform both a bare geomembrane survey method and the dipole method after placement of any cover material. In order to stay under a leakage rate of 5 gallons per acre per day, it is recommended to specify either white or conductive-backed geomembrane and perform both a bare geomembrane survey method and the dipole method after placement of any cover material (Beck, 2015).

With currently available technologies, the lowest level of potential leakage can be achieved by specifying specialty conductive-backed geomembrane installed as an electrically isolated conductive-backed geomembrane installation, performing a bare geomembrane survey directly after geomembrane installation, and then performing the dipole method after the installation of cover material, if applicable. It is technically possible to install a geomembrane without breaches with this prescription since, if installed and surveyed correctly, it eliminates the known sources of limitations in the leak location survey technologies. However, room should always be granted for human error to avoid a specification that cannot be met.

3.5.2 Quality Control of Surveys

Survey quality control starts by the selection of a reputable and qualified Leak Location Contractor. A reasonable minimum qualification is that the company has been performing ELL surveys for at least three years and has tested projects similar to the proposed project.

Effective oversight of electrical leak location surveys is probably more effective than prescribing minimum experience qualifications. The main intent of the survey oversight should be the conformance to the applicable ASTM Standard Practice. The functionality testing procedures of the applicable Standard Practice should be reviewed and understood by the entity providing oversight. The survey should be performed with the same parameters as were employed during the functionality and/or sensitivity test. In addition, the oversight entity should verify that the method was comprehensively applied to the entire survey area. Special attention should be paid to fatigued operators, especially with bare geomembrane surveys where a digital record of the survey does not exist.

4.0 REFERENCES

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