Proceedings of Tailings and Mine Waste 2019
November 17—20, 2019, Vancouver, Canada
Published by the University of British Columbia, 2019

Improved QA and QC of Double-Lined Ponds for Processed Water Containment

Heather D. McDaniel, Souder Miller & Associates, USA
Roman Belts, Groupe Alphard, CANADA
Pascal Saunier, AFITEX-Texel, CANADA

Abstract

Processed water storage is one of the main concerns for regulators and owners of operations in the shale gas and the oil sand industry, and for good cause: these extremely pollutant liquids concentrate all the toxic, organic, and chemical parts of the residues that are treated in the facilities. It is therefore necessary to be able to ensure storage under completely leakproof conditions – or at least, the most leakproof conditions we can achieve. Since assembled geomembranes are not 100% free of leaks, it is essential to consider the state of the art in quality assurance and quality control (QA/QC).

Experience all over the world shows that an average of 10 leaks per hectare can generally be found on a lined project where everyone is following the standard QA/QC guidelines (internal QC on site during installation, vacuum box, and basic visual inspection). However, several studies show that the application of additional control practices can lead to an almost zero-defect project to the level detectable. Among these practices is a strong third-party engineer dedicated to improving the quality on site during all stages of the project, from design to operation. The engineer's tasks will also include leak detection surveys during and after the installation of the geomembranes. These last methods, described by American Society for Testing and Materials (ASTM) standards, can be complicated – or even ineffective – depending on the materials used for the construction and the size of the defect.

Based on a recent case study that is currently occurring in a project related to the mining industry in the USA, this paper will present the importance of those complementary quality controls and the limits of traditional geosynthetic solutions, and will show how conductive multi-linear drainage geocomposites offer an effective solution to enhance the quality of storage ponds, reduce the construction time, and limit environmental risks.

Introduction

The project started in the southwestern United States in the oil and gas industry. The produced water pits are a direct result of the industry's usage of hydraulic fracturing since the 1940s, the by-products of these wells (produced water), and the long-standing drought that the southwest has been facing for nearly 15 years. When mass hydraulic fracturing started to become the norm in the southwest, with upwards of 6 to 10 horizontal wells per pad, the oil and gas industry started to acquire vast amounts of water rights to meet operational needs. With landowners, ranchers, and municipalities starting to struggle to maintain water usage demands, the public perception of oil and gas using upwards of 600 acre-feet of water per multi-well pad was not well received. The industry decided that instead of injecting the produced water into saltwater disposal wells, they could reduce trucking costs and improve neighbour relations by re-using a product that had been a nuisance of production.

Global quality

In this document, the global quality of a project is defined as the product of the quality levels of each of three principal components of a typical double lined pond project, which are:

- the design, or conception stage;
- the construction stage; and
- the operation stage.

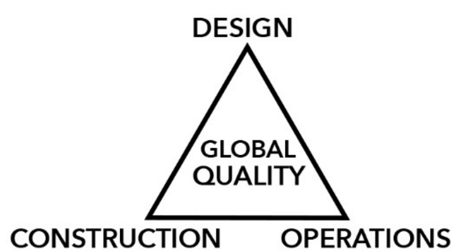

Figure 1: The three components of the global quality of a project

The global quality of the entire project can be calculated as follows:

$GQ = Q_{Design} \times Q_{Construction} \times Q_{Operations}$

Design

Two important design criteria when determining the liner materials are:

1. the long-term operational requirements of the system, i.e., fresh water versus produced water, circulation versus non-circulation, types of pumping and piping being used within the system; and

2. the client's operational knowledge of liners, i.e., does the operator understand the fragility of liners?

In this example, it was assumed that the client understood the liner fragility and their operational requirements during design. This assumption led to many of the lessons learned throughout the project. Ultimately, the process led us to a design that included a secondary and primary liner system comprised of 45 Mil LLDPE scrim-reinforced liners, as shown in Figure 2.

The Client's design guidelines were clear: fit an operational treatment area within a small rig anchor pattern, supply ample room for operational vehicles, meet state design regulations, maximize the amount of produced water storage within the permitted federal boundary, and deliver a full set of construction plans from start to finish within 30 days. The Client started earthwork on the project five days before the plans were complete.

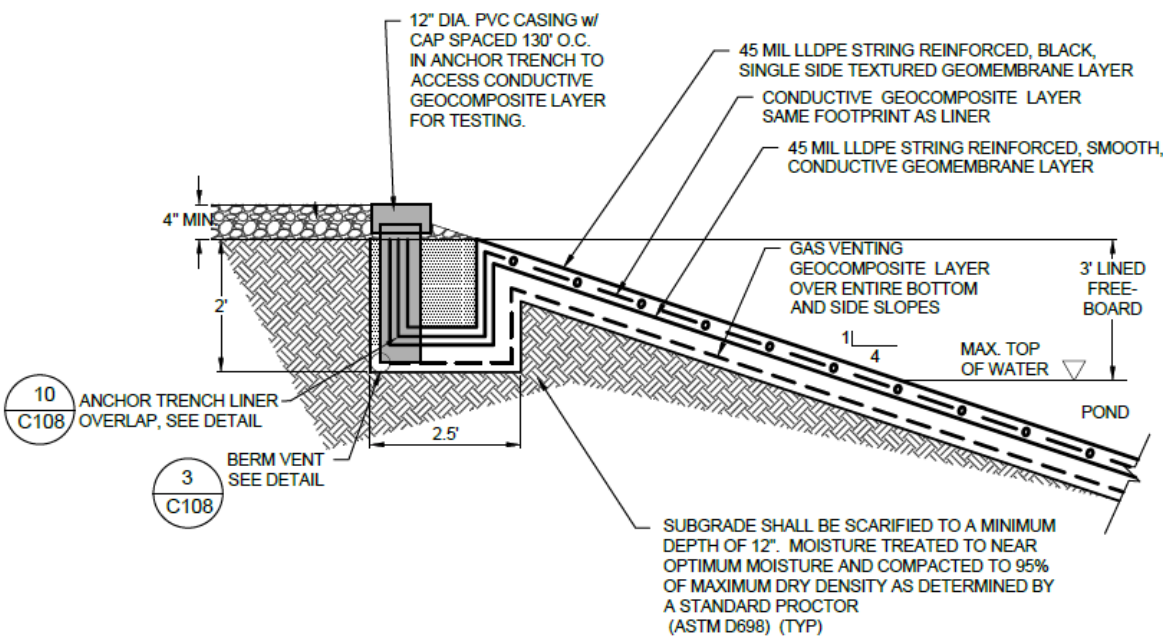

Figure 2: Typical cross-section on the slopes and anchor trench

Below the secondary liner, a multi-linear drainage geocomposite is used as a groundwater/gas venting system as well as a protection layer. Between the primary and the secondary liner, another multi-linear drainage geocomposite is installed for leak detection drainage. Both materials are comprised of 20 mm (¾ inch) corrugated polypropylene perforated pipes spaced on 1 m (40 inches) centres between two non-woven polypropylene geotextile layers (Figure 3). In addition to this, a conductive grid is inserted into the second product in order to make leak location surveys on the primary possible.

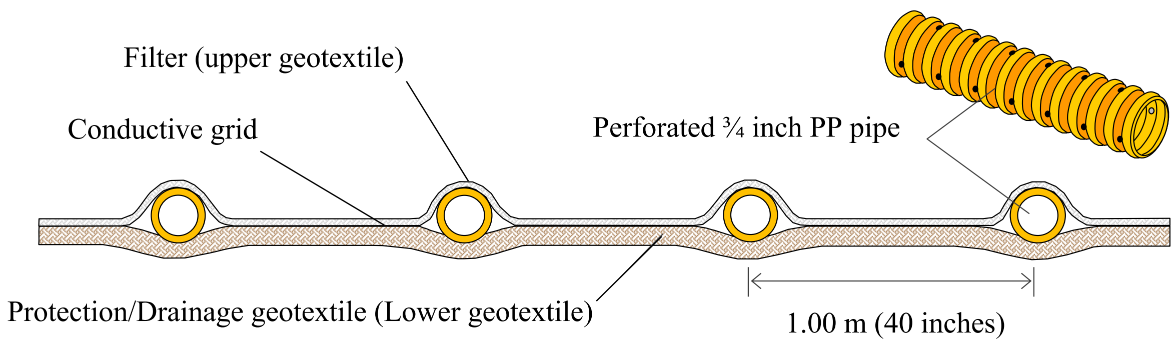

Figure 3: Conductive multi-linear drainage geocomposite description

Multi-linear drainage geocomposites have been used in landfill and mining (ponds) applications in Europe and Africa for 25 years. An important characteristic of those drainage geocomposites is that they maintain their transmissivity under significant normal stresses (Saunier et al., 2010) because they don't experience geotextile intrusion into the primary high-flow component (the primary flow being the drainage net in biaxial or triaxial geonet geocomposites type of products and the pipes in multi-linear drainage geocomposites). Therefore, for most of the applications, the applied combined reduction factors for multi-linear drainage geocomposite are almost half of those applied to standard biaxial/triaxial geonet geocomposites (Maier and Fourmont, 2013).

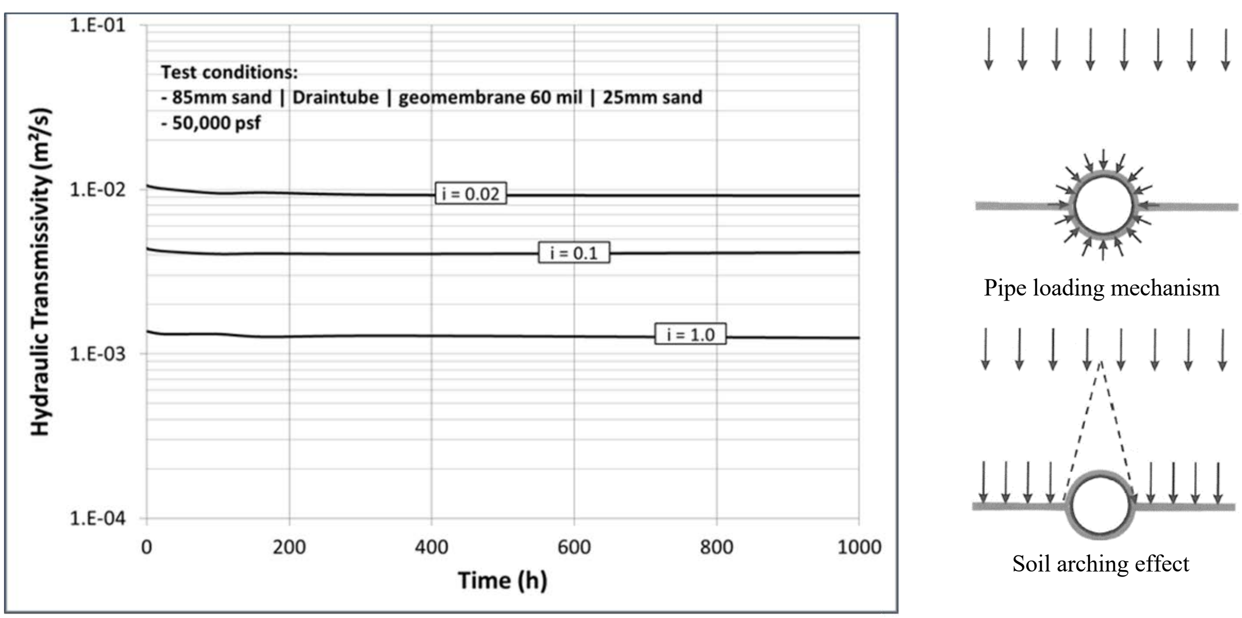

Figure 4: Measurement of transmissivity over time under high load

Construction

One of the major selling points of the design was using reinforced polyethylene (RPE) preassembled panels and multi-linear drainage geocomposite for extremely high installation speed. The four-panel geosynthetics layers design allowed the owner to line their 6-acre pond within a week.

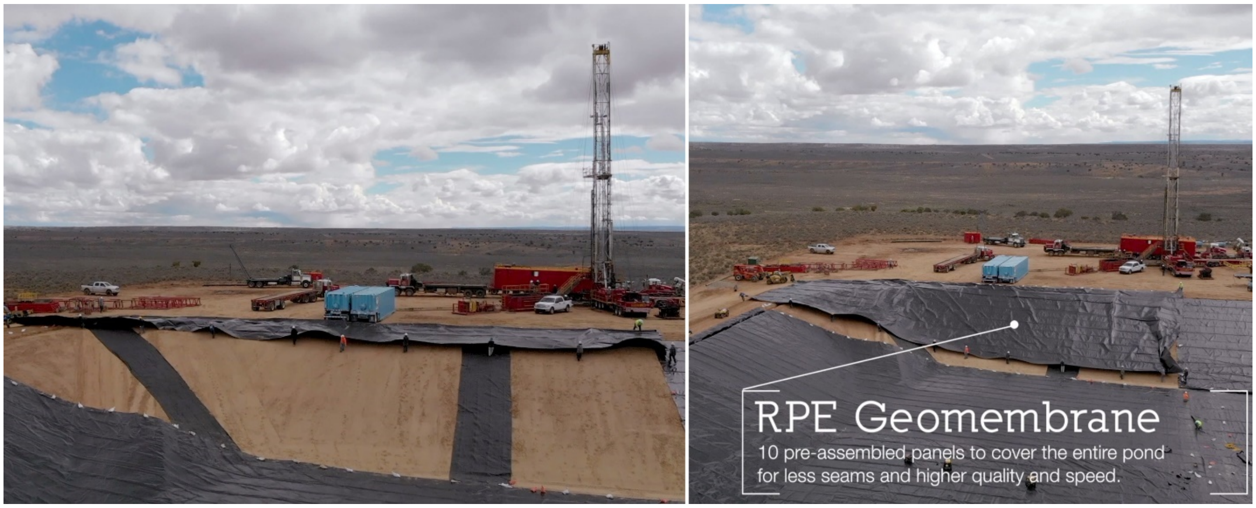

Figure 5: Deployment of a RPE panel in the slope

Figure 6: Deployment of the conductive multi-linear DRAINTUBE from the top of the slope

Figure 5 shows how to deploy each panel of RPE. Because larger panels can be pre-assembled at the factory, the installation allows for fewer seams in the field, reducing the risk of leaks at the joints compared to a traditional installation with narrow rolls. For this reason, the installation of the liner is faster and safer.

Figure 6 shows the lightness of the multi-linear drainage geocomposite. The rolls can be handled like geotextiles, unrolled from the top of the slope. Also, their structure is soft enough against the liner to avoid any risk of perforation due to heavy loads or harsh angles of plastic. Also, the installation is accelerated (in the order of 20 to 30% more productivity) and a lot safer for the crew than the installation of a geonet-type drainage geocomposite. Indeed, as most multi-linear drainage geocomposites products are made of geotextiles and plastic pipes, they can be easily cut with traditional tools, whereas cutting a rigid heavy geonet might take longer and have increased risks of cuts to workers' hands.

Operations

As soon as the ponds are constructed, it is mandatory to control the access by external workers before filling with processed water. The operations are variable from site to site. In most cases, when the ponds are fully constructed they are immediately filled, without other human intervention. In this particular case, a lot of work was required after the primary layer was completed, i.e., equipment, pipes, pumps needed to be installed, and sometimes external works from sub-contracting companies.

Liners do leak

The simple act of using geosynthetics on a project does not guarantee imperviousness of the barrier layer. If fabrication practices are done properly, a geomembrane by itself is a fully impermeable material. However, every operation required to transform a manufactured geomembrane roll into an installed liner exposes the geomembrane to potential damage (mostly mechanical damage from impacts, but can also take the form of chemical degradation, resulting from improper storage, for instance).

Therefore, wherever a high level of uncompromised impermeability is demanded from the barrier layer, the use of third-party quality assurance and leak location services is imperative. We understand by third-party quality assurance an independent engineer hired by the owner to act as a global reviewer of the project including design, construction, and controls.

The relationship between third-party quality assurance (QA) and electrical leak location (ELL) is that of mutual dependency. The QA party is dependent on the ELL party for spotting breaches in geomembrane that have been overlooked, are invisible to the naked eye, or have occurred following the installation of subsequent system layers. Whereas the ELL party relies on the QA party for ensuring the adequacy and traceability of all installed materials, in addition to minimizing the number of geomembrane defects through oversight of the storage, handling, and installation phases of the work. Thus, ELL ensures that the geomembrane is uncompromised at the time of the inspection, while QA ensures that the geomembrane will continue to fulfil its function for the entire life expectancy of the project.

CQA third-party control

Internal quality control, which is conducted by the installer and controlled by the engineer representative, is typically a flawed process due to the inherent conflict of interest existing between the installation team and the quality team: both parties operate under an authority whose underlying interest is generally the fastest possible installation of geosynthetics on a given project. Thus, the employment of an independent quality assurance party introduces an unbiased stakeholder whose underlying interest is the best possible installation of geosynthetics. More specifically: the mandate of a third-party QA inspector is to ensure the work is carried out as per project plans and specifications.

An expert third-party quality assurance inspector will oversee all aspects related to geocomposite materials on site: transport, handling and storage of geocomposite rolls; ensuring all material has undergone appropriate factory QC testing and is compliant with project specifications; subgrade approval, visual inspection of installed panels and seams; validation of welding machine calibration; non-destructive testing and intermittent destructive testing, including coordination with a testing laboratory.

In addition to collection and verification of all factory-issued documentation (factory QC testing, mill test certificates, datasheet, etc.), QA personnel also keep daily logs of panel installation sequence and the respective in-situ testing results, thus ensuring full traceability of geosynthetic material from the factory floor to their final resting place on the project site.

Additionally, much like the influence of a leak location operation, the very existence and on-site presence of an independent QA party has the effect of raising diligence and operational level of the internal QC personnel and the installation team.

Leak location survey

Most commonly, electrical leak location is carried out with two standardized methods: the water-puddle method and the dipole method.

Water-puddle is the more direct, more effective method of testing for breaches in the barrier layer, as it is carried out directly on top of the exposed geomembrane. The concept behind such methodology is that a continuous, fully impermeable assembly of geomembrane panels will not allow surface water to come into contact with the underlying substrate layer. When such contact is made (denoted by a signal from an electrical setup involving one electrode above the geomembrane and the other electrode in contact with the underlying layer), a breach in the geomembrane – either a hole or a tear – is thus located.

In order to successfully carry out the dipole leak location operation, the geomembrane must be covered by a single layer of homogenous, electrically-conducting material (e.g., wet granular material). The concept is identical to that of the water-puddle method: a continuous, impermeable assembly of geomembrane panels will not allow current propagation from above the geomembrane to the underlying substrate. The presence of a breach in the barrier layer is indicated by a typical leak signal in electrical current detected by the dipole apparatus.

When required, and when possible, both leak location methods are used on the same barrier layer. In addition to a redundancy check, this allows for separation of liability: holes detected via the water-puddle methods are necessarily the responsibility of the geomembrane installer, whereas holes detected via the electrical dipole method are the responsibility of the civil-works contractor.

Average leakage per hectare

Typically, on a project in North America involving third-party QA oversight of geomembrane installation, a leak location operation will locate an average of 7 leaks/ha via the water-puddle method, and 1 to 4 leaks/ha via the dipole method (contingent upon whether a water-puddle survey had been first conducted). Unsupervised projects typically exhibit a much larger presence and range of breaches in the barrier layer. In some scenarios, the presence of breaches is so prevalent that it effectively nullifies the purpose of employing geomembrane panels in the first place (Forget et al., 2005).

Under favorable conditions, a thorough leak location survey will reduce the average presence of leaks down to 0 to 2 holes per hectare (it is important to keep in mind that the relationship between a hole and a leakage rate is dependent upon the size and the location of the hole within the containment basin).

In addition, in its history, the geomembrane system transformed from single- to double-lined (Peggs, 2009) because damage is unavoidable for a geomembrane during construction. The purpose of a double-lined system is that leakage through the primary geomembrane (with a constant hydraulic head on it) is collected by the secondary geomembrane and removed, so there is no head on the secondary. Therefore, the double-lining system doesn't leak – just as double-hulled ships do not sink.

Today, the most often applied primary Action Leak Rate (ALR) for water impoundments is 500 gallons per acre per day (gpad) as specified in *Recommended Standards for Wastewater Facilities* (Health Research Inc., 2004) by 10 northern states and in Canadian provinces for liners under 6 foot of water in waste water treatment plants. "Right sizing" the ALR to match the technical capabilities of the current leak-location methods is necessary (Darilek and Laine, 2011). Specifying a leakage rate that is too low can be a disaster if the source of the leakage cannot be located by current technology. If the source of the leakage cannot be located, then the only alternative is to reline the facility and hope that the new geomembrane does not also exceed the specified ALR.

According to the quality based action leakage (QBAL) method based on Giroud's equation for calculating flow through defects, with a good quality installation, a geomembrane could be expected to have 1 to 4 defects per acre and a poor-quality installation could have 10 to 20 defects per acre. This could equate to an ALR of 720 gpad to 3,600 gpad. Furthermore, according to Peggs (2009), a regulatory agency that holds to a zero-leakage policy is not being practical, which can lead to arguments, wasted time and efforts, and unnecessary expenses that benefit no one.

From theory to reality

Due to the limited understanding of lined pits, the state agency was expecting absolutely no leakage. The Required Global Quality was maximum.

The pit and liner stability started to be challenged directly at liner installation. Due to operational pressures, drill rig schedules, and lack of understanding of the fragility of the liner system, the Client decided to forgo electronic leak location surveys on the secondary and primary liner systems. To compound the situation, the drill rig crews utilized the completed pit as a drill cuttings pit that they later shovelled, then pressure washed at extreme pressures.

Shortly after the pit was put into its intended use, the Client started to report leakage through the primary liner. In January and February leakage pumping data resulted in 2,023 gallons per month and 1,685 gallons per month, respectively, for a 2.3 acre pit.

Following regulatory pressures, the Client shut down the operations of the pit, cleaned out the system, and brought in an electronic leak location survey specialist.

Leak location surveys

Leak location surveys have been conducted on each of the subsequent ponds based on lessons learned from the initial installation. Due to the liner surface type and slope the leak location surveys have been conducted depending on whether the survey was targeting the slopes or the bottom. The water puddle method (see Figure 7a) was selected by the client to control the integrity of the ponds in the bottom. The arc test method (see Figure 7b) was used in the slopes of each pond.

The results of the primary liner electronic leak location survey yielded 70 holes in the bottom of one of the pits and 8 in the second one. Additional issues were identified that were contributing to the leakage rate, such as the LLDPE material being damaged by the high-pressure cleaning, seams had been impacted during removal of drill cutting removal, and holes had been generated by inappropriate access to the liner (see Figure 8).

For each test, the conductive multi-linear drainage geocomposite offered an adequate sensitivity (arc test and water puddle) and permitted the detection of holes ranging in size from large (Figure 8) to very small holes (1 mm in diameter which was the size of the calibration hole; see Figure 7b).


Figure 7a: Water puddle method; Figure 7b: Arc test method

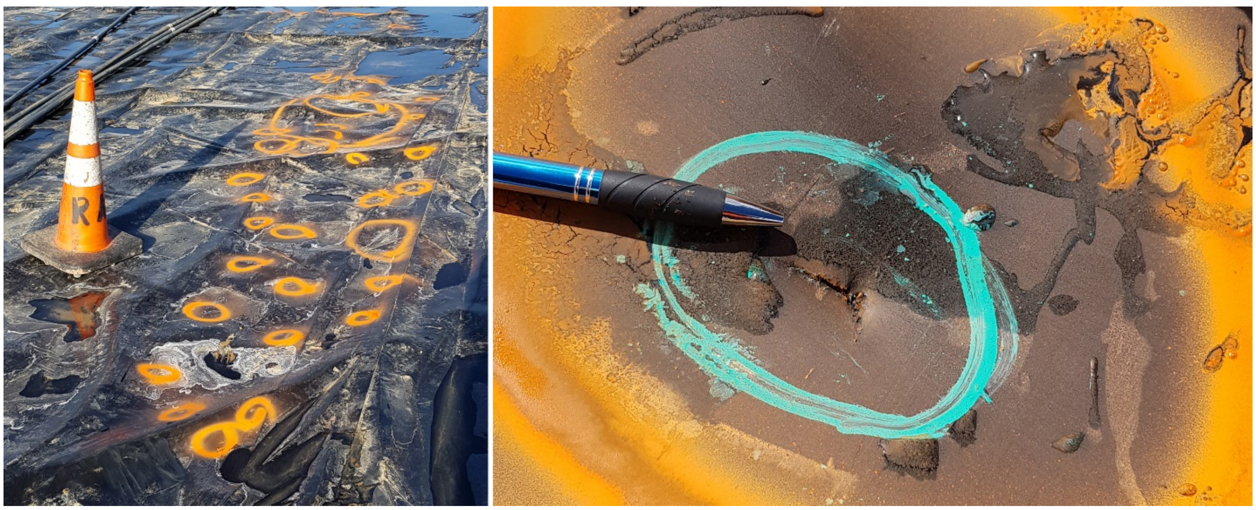

Figure 8: Example of leaks found on the primary liner at the bottom

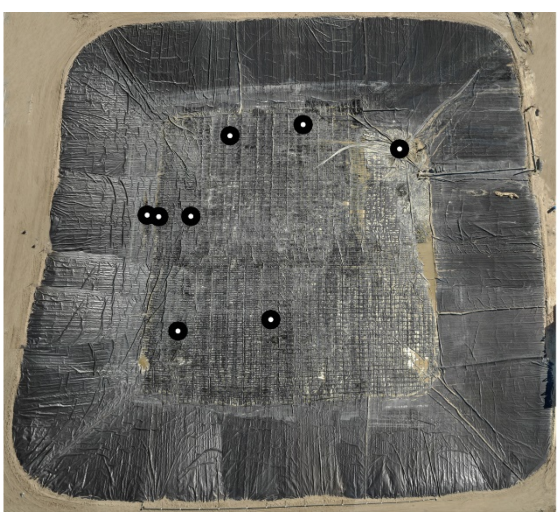


Figure 9a: Pond A (8 leaks); Figure 9b: Pond B (70 leaks)

Cost comparison

The costs have been compared, as is presented in Table 1. The scenario was as follows :

- Day 1: Pond filled up
- Day 1 + 1 month: Shut down the pond
- Day 1 + 2 months: Investigation, complete discharge of the pond, clean the bottom and run an ELL program
- Day 1 + 3 months: Relining of the primary liner, line a third layer and restart an ELL program
- Day 1 + 4 months: Pond filled up again and operated.

In this cost comparison, it is necessary to mention that every day of an active pond generating US$80,000 in revenue.

Good practices (ELL + 3rd Party QA/QC)		Bad Practices (no external QA/QC nor ELL)	
Leak location survey program	25 K$	720 k$	Pond shut down for 3 months
3rd Party QA/QC	25 k$	50 k$	Leak location survey program x 2
		50 k$	3rd Party QA/QC x 2
		250 k$	Relining the primary
Total Expected Costs	**50 K$**	**1,07 M$**	**Total Estimated Costs**

Table 1: Comparison of costs between having a ELL campaign + 3rd party QA/QC or not

Table 1 shows that a non-quality approach can cost over 20 times what it would have cost to have a proper quality program, including ELL and third-party QA from the beginning of the project.

Lessons learned

Ultimately, the lessons learned from this costly exercise resulted in new operation and maintenance expectations within the company for lined pits. This includes:

- Slopes of 4:1 on smooth textured liners.
- Slopes of 3:1 on textured liners.
- Improved leak detection systems and grading methods.
- Suspension of LLDPE scrim reinforced liner as the primary liner.
- All approved access points are a differentiating colour of liner and have a minimum of two sacrificial layers to protect the primary liner.

- All entry into the pit is treated as a permitted entry through the company and is restricted to trained personnel only.
- All secondary and primary liners are electronically tested for leaks during construction to establish a base line.
- Leakage is monitored on a weekly basis and Action Leak Rates are calculated for every pit to establish operating parameters.

Conclusion

This case study shows that despite a good design and a normal construction, the Global Quality level of a project can be far away from the regulation expectations. Indeed, even with a 1.0 for the design and a not too bad 0.9 for construction, a poor of Operation 0.7 due to a high presence of uncontrolled workers on-site caused the GQL to rank as $1.0 \times 0.9 \times 0.7 = 0.63$. This is a little over half of the value targeted by the regulatory authority with a 1.0 condition in the operation permit. There is absolutely no way to meet that constraint in a geosynthetic work without having a strong QA program that includes a third-party QA and a complete electrical leak location survey campaign. Conductive multilinear drainage geocomposites have demonstrated their efficiency in this project by helping the operators to find an important amount of leaks of different sizes.

References

Darilek, G.T. and D.L. Laine. 2011. Specifying allowable leakage rates. *The Geosynthetics Magazine,* August 2011.

Forget, B., A.L. Rollin and T. Jacquelin. 2005. *Lessons Learned from 10 Years of Leak Detection Surveys on Geomembranes.*

Health Research Inc. 2004. Recommended standards for wastewater facilities. Accessed from https://www.broward.org/WaterServices/Documents/states_standards_wastewater.pdf

Maier, T.B. and S. Fourmont. 2013. How tubular drainage geocomposite was used in landfill final cover. *Geosynthetics* 31(3): 48–51.

Peggs, I.D. 2009. Geomembrane liner action leakage rates: What is practical and what is not? Retrieved from Geosynthetica.com.

Saunier, P., W. Ragen and E. Blond. 2010. Assessment of the resistance of drain tube planar drainage geocomposites to high compressive loads. 9th International Conference on Geosynthetics. Guarujá, Brazil. Vol. 3.