Is electrical leak location helping us getting better with geomembranes?

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ABSTRACT

Electrical Leak Location (ELL) began being utilized nearly 25 years ago on geomembrane projects and has since grown in popularity and efficiency. Going forward, goals of ELL should be to identify failures in design, choice of materials, liner installation, and site construction. Previously, academic papers gave little information on the nature of holes detected or their cause. Based on, 'Lessons learned from 10yrs of leak detection surveys on geomembranes' (Forget et al.), written by two of the three authors of this paper, it will be determined if statistics collected over the past 3 years vary from those concluded by the previous paper published 12 years prior.

We will also compare those statistics to other companies that publish ELL information in the past in other areas of the world, to verify if numbers are similar. In addition, this paper will explain the main causes of leaks within geomembranes, based on the statistics observed by the author's company, and suggestions for prevention, in an attempt to help other professionals reduce their defect risks using geosynthetics.

1. INTRODUCTION

Increasingly, electrical leak location (ELL) is being performed on geosynthetic works to validate the quality of the work and the integrity of the system – so much so that synthetics are being constructed with the intent to facilitate leak validation, and in 2014, 22% of the liner installed in Quebec was validated using ELL (Charpentier et al.). In addition to confirming a leak-free works, it performs the secondary functions of added assurances and making various stakeholders accountable: The type, number, and size of leaks are recorded, and can then be attributed to various project shortcomings. Were most during the installation itself, or during the placement of the cover materials? Were they typically found around protrusions that could have been avoided or placed in less critical places? Should a more robust membrane have been used? By reviewing and sharing these ELL results the hope is that these questions can stop being asked.

Various papers have been published detailing what is considered to be "typical defect rates" depending on various variables such as thickness of membrane, presence of CQA, and type of ELL used. Abigail Beck stated in one of her numerous papers on the leak location topic that "(…) a landfill expansion where a leak location survey is not performed has a 22.2 percent chance of requiring corrective action (Beck, "A STATISTICAL APPROACH TO MINIMIZING LANDFILL LEAKAGE ", 2012). This paper will compare the defect rates of ELL projects performed from 2012-2016 to previous defect rates found. The data will also be reviewed in greater detail (type of leaks found, and leaks per sector) to determine where the industry has improved, and where improvements can be made. Not only must the amount of liquid leaving the systems (number and size of leaks) improve overall, but also it must improve in environmentally sensitive sectors.

2. DESCRIPTION OF THE ELL METHODS STUDIED

This paper evaluated the data available for two main types of ELL surveys: water puddle (on exposed) and dipole (soil covered).

2.1 Water Puddle Method

The water puddle method (ASTM D7002) was the electrical leak location method used to survey the exposed geomembrane. It relies on the intrinsic insulation properties of geomembranes for the detection of small perforations (<1 mm2) in the geomembrane generally produced at the time of installation. A continuous DC voltage is applied into the metallic water puddle structure, and a grounding electrode is placed outside of the limits of the geomembrane. In the presence of a leak, the current will pass from the metallic structure, through the defect, into the subgrade and to the grounding electrode. A visual and auditory signal will be produced, indicating the presence of a leak to the technician. This technique requires only a thin film of water on the surface of the geomembrane, and provides a validation of the entire exposed surface surveyed.

The efficacy of the water puddle method is influenced greatly by the presence of wrinkles, which do not allow for direct and immediate contact between the water leaving the lance, the subgrade and the lance. However ensuring contact between the water puddle lance, the geomembrane and the subgrade can counteract this negative effect.

2.2 Dipole Method

To detect perforations in the geomembrane after the placement of the cover material, the dipole method (ASTM D7007) was used. It relies on the intrinsic insulation properties of geomembranes for the detection of perforations that were created during the installation of the cover material. It is used after the placement of the cover material.

A current of up to 550 V is injected into the cover material (through a plate of positive electrode), and a grounding electrode is placed outside the limits of the geomembrane. If a defect is present, the current will pass through the hole to reach the ground (negative electrode), which then generates a distinct electrical signature that can be identified and located by a specialized technician. The efficacy of the dipole method is heavily influenced by the isolation of the cover material from the exterior of the works, the thickness, humidity and homogeneity of the cover material. Additionally, the method does not work when the cover material or subgrade are below a certain temperature. Coordination is therefore necessary to ensure the proper survey is performed (time of year, isolation, project planning).

3. DATA STUDIED

The data was obtained from the various leak location projects which Alphard performed from 2012-2016 inclusively. A total of 41 water puddle (999,894 m^2) and 46 dipole (975,951 m^2) projects were performed, on HDPE, LLDPE, PVC, and bituminous geomembranes.

For this article, the information evaluated included the project size and sector, whether any third party supervision was performed, the leak location method used, and finally the number and types of leaks found.

This information was analyzed to determine the average number of leaks per hectare found using the dipole and water puddle methods, with various factors considered: presence of CQA, whether the water puddle survey was performed prior to the dipole survey, as well the sector. The types of leaks found were also evaluated, based on the type of ELL performed and the presence of CQA. The size of the leaks themselves were not studied, however, inferences were made regarding the relative size of the leaks based on leak types.

3.1 Limitations and Biases of Methodology

As with any study, a few factors may bias the results. Firstly, the timeframe of the data (and therefore surface area and number of leaks) is much smaller than that analyzed in the paper by Forget et al. Either one large project, or one highly defective project, can have a great influence on the data presented. These projects were not removed from the data set, as lessons can be learned from them, and are discussed later in this paper. Additionally, with a few exceptions, all projects were used in this study regardless of their size. These exceptions are noted in their respective sections, and account for the small variations in average defects rates.

Furthermore, over two-thirds of the leak location projects were performed on projects in Quebec – a relatively small market. In general, the design engineers, installers, ELL, and CQA personnel have worked on projects together. In many instances, the designs, and therefore installation work, are repeated, and the stakeholders have an understanding of the various project stages (design, earthworks, installation) and can therefore provide suggestions for improvement, if necessary.

Finally, several other projects included returning clients, who are aware of the requirements for performing ELL, and plan for electrical isolation early. This decreases the amount of handling of the cover material and therefore the risk of damaging the geosynthetics. Also, clients who engage leak location services (when not obligated by law) may also be doing so out of a desire to ensure the highest quality projects, and are therefore more likely to be engaged throughout, and be knowledgeable about the quality of the subcontractors, and of the works.

4 RESULTS

4.1 – Average leaks per hectare

The average leaks per hectare for the water puddle and dipole method were calculated, both with and without third party supervision, to determine if the quality of geomembrane installation projects had improved in the 12 years since Forget et al.'s paper. The leaks per hectare for the dipole method was subdivided into whether or not the water puddle survey had been first performed.

The extent of the third party supervision (continuous or spot-check only) could not be confirmed for all projects. Regardless, even projects which were known to have only "spot-check" CQA were included in this group, the impact of which is discussed in a later section. Two water puddle projects (6 leaks; 37,350 m^2) and one dipole project (1 leak; 2,297 m^2) were excluded from this analysis, as it could not be determined whether there was any third party supervision. All other projects were included.

4.1.1 Water puddle survey

As per Forget et al. the average leakage rate for water puddle projects with rigorous CQA is approximately four leaks per hectare, whereas for water puddle projects without rigorous CQA it is 22 leaks per hectare.

Table 1. Average defect rates found using water puddle survey, with and without CQA

	# of projects	# of leaks	area (m^2)	leaks per ha
CQA	23	241	638 891	3.77
NO CQA	16	105	323 653	3.24
TOTAL	39	346	962 544	3.59

An average of nearly four leaks per hectare were found using the water puddle method, for the projects from 2012-2016, regardless of CQA. This is fairly comparable to the values found by Forget et al. for projects with CQA, however for project without CQA it is vastly lower.

One factor influencing the low defect rate for the non-CQA projects is that one project accounted for 250 000 m^2 (77% of total non-CQA area) and had a very low defect rate: less than 1%. The project in question had a very simplistic design, with few penetrations and joints (many long side-to-side seams), and an experienced installation team. Also, despite there being no formal CQA supervision, the ELL team was present onsite during most of the installation work, and surveyed just after membrane installation. Installers tend to be more careful knowing their work will be validated immediately.

When looking at the projects with and without CQA in terms of ranges of defect, the difference between CQA and non-CQA projects can be seen. Only 30% of water puddle projects with CQA have more than five leaks per hectare, compared to 50% for non-CQA projects. Similarly, a greater percentage of projects without CQA have more than 10 leaks per hectare (38% vs 22%). This would suggest that with a well-applied CQA program, there is a greater chance that the quality of the work will be consistent – without it, there risks having “outlier” projects with a much greater than average defect rates.

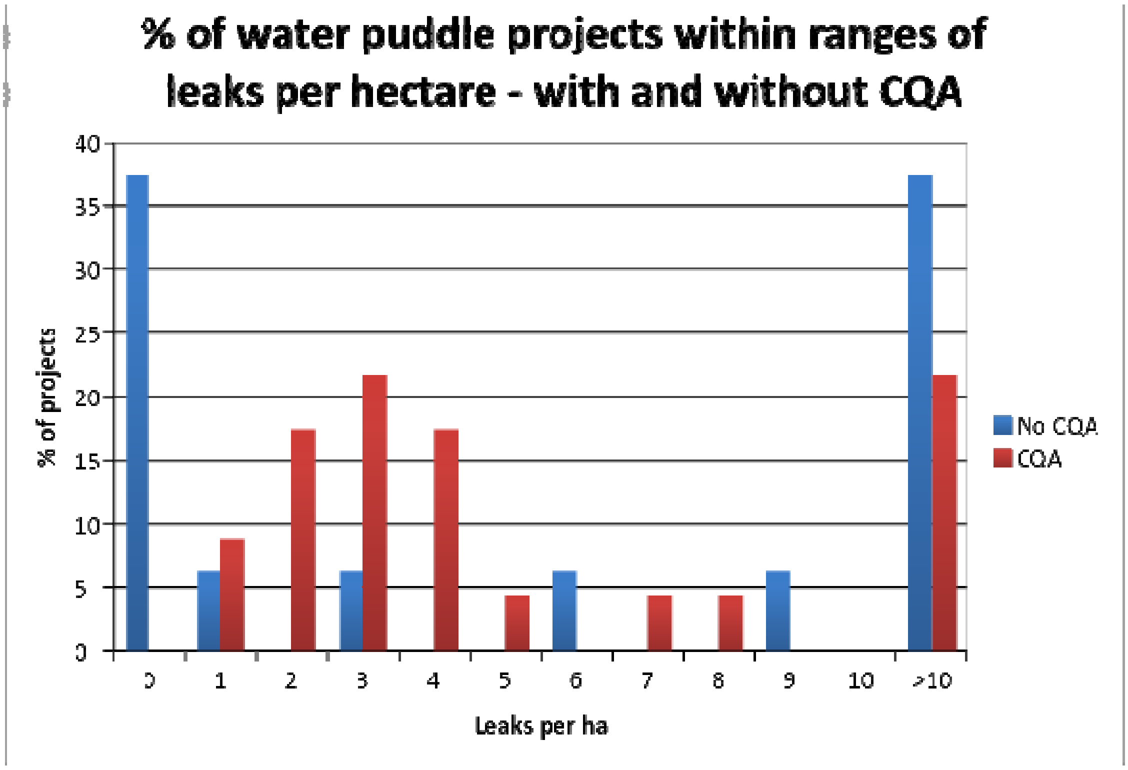

Figure 1. Graph showing percentage of water puddle projects within given defect rate ranges

4.1.2 Dipole survey

For projects validated using the dipole survey, the average defect rate from 2012-2016 for CQA projects was again comparable to the rate found by Forget et al. (0.29 vs. 0.5 leaks/ha). However, for non-CQA projects the defect rate was much lower from 2012-2016 (0.18 vs. 22 leaks/ha).

Table 2. Average defect rates found using dipole survey, with and without CQA

	# of projects	# of leaks	area (m^2)	leaks per ha
CQA (W/ WP)	18	12	407 063	0.29
NO CQA (W/ WP)	6	28	270 600	1.03
CQA (NO WP)	11	52	186 386	2.79
NO CQA (NO WP)	10	2	109 605	0.18
TOTAL	45	94	973 654	0.97

The “CQA, no WP” category has an impressive defect rate (2.79 leaks/ha), however this is mainly due to one particular project, where 27 leaks were found with dipole on only 10,000 m². This project was anomalous; the average leaks/ha would be significally lower without it. A full paper has also been written on that project, entitled "Dipole Leak Location Survey on woodchip: unusual but possible", for those who are curious to know more about it.

The "No CQA, w/ WP" category was also heavily influenced by one project: the large, low defect "No CQA" project discussed in the water puddle section. It accounted for approximately 93% of both the defects and the surface area. In contrast, the "No CQA, No WP" category, which had the lowest defect rate, consisted of many small to medium sized projects (all below 25,000 m^2).

4.2 – Types of Leaks Located

4.2.1 Types of leaks found per ELL method

When discussing the impermeability of a works, the types of leaks found can be equally as important as the number of leaks. Certain leak types are often larger than others, and, all other things being equal (soil permeability, pressure head, etc.) are likely to produce a greater flow rate; even one large leak can allow more liquid to escape than multiple small ones. Additionally, if a certain type of leak occurs frequently in a project, it can indicate an issue with a certain project stage: many fusion, extrusion or burn-through defects can indicate installation issues, or a poorly designed site or layout plan (many connections and/or penetrations). Likewise, an inordinate amount of punctures or tears after cover material placement is likely an earthworks problem, and the methods may need adjusted.

In this section, seven leak-type categories were used to classify the leaks found. The leaks were further divided into the three ELL categories: dipole without water puddle, and dipole with water puddle, water puddle, to better determine the stage at which the defects were created.

Table 3. Leak types found using water puddle and dipole

	Fusion Seam	Extrusion Seam	Puncture	Tear	Burn through	Cut	Superficial Damage	Other	Total Leaks	Total surface area	Leaks per ha
Dipole w/o WP	2	2	47	4	0	0	0	0	55	518 965	1.1
Dipole w/ WP	0	0	10	26	0	0	1	3	40	456 986	0.9
WP	28	95	107	46	6	44	7	19	352	999 894	3.5
Total	30	97	164	76	6	44	8	22	447	1 975 845	2.3

Overall, 79% of leaks were found using the water puddle method, 12% with the dipole method alone, and 9% with the dipole method after water puddle validation. This stands to reason as the water puddle method can find smaller leaks, and does not lose precision with bad site conditions, like the dipole would with bad electrical isolation or heterogenous cover material. Additionally, defects would be found with the water puddle first, and most geomembrane manipulation (a cause of damage) occurs during the installation stage.

In line with the results by Forget et al., approximately 31% of the leaks were located on seams and 69% on the panels. The "Other" category was excluded from this calculation.

More than 85% of fusion, extrusion, burn-through, cuts, superficial damage, and other types of leaks were found using the water puddle method. This is consistent with them being mostly installation defects, and some being generally too small to detect with dipole. In cases where isolation is ideal, however, it is possible to detect extrusion and fusion defects with the dipole.

Punctures account for the greatest percentage of leaks (37%), of which most (65%) were found using the water puddle method and 29% with the dipole method alone. This is consistent with the fact that puncture can produced during installation or cover material placement (poor subgrade and/or cover material placement) and are also large enough to be detected using dipole method alone.

Interestingly, extrusion defects are the second most common defect (22%). During CQA, greater emphasis should be placed on supervising the extrusion seaming, as well as the vacuum box testing; extrusion seaming is not always performed as well on the field as it is during the trial testing, and often an inexperience QC technician performs the vacuum box testing.

Tears are the third most common defect. Surprisingly, roughly one-third of the defects are found using the dipole method after a water puddle survey has been performed. Therefore the placement of the cover material is a huge factor in the creation of tears, which can be substantially larger when caused by heavy machinery. CQA should place a greater importance on the supervision of the cover material placement, as this is an area to be improved upon, and, unlike geomembrane installers, earthworks crews may not necessarily have experience with geosynthetics, and may need to be familiarized with the best practices.

4.2.2. Types of leaks found with and without CQA
Although the number of leaks found with the dipole and water puddle surveys was roughly the same regardless of whether or not there was CQA, those numbers did not account for the types of leaks found.

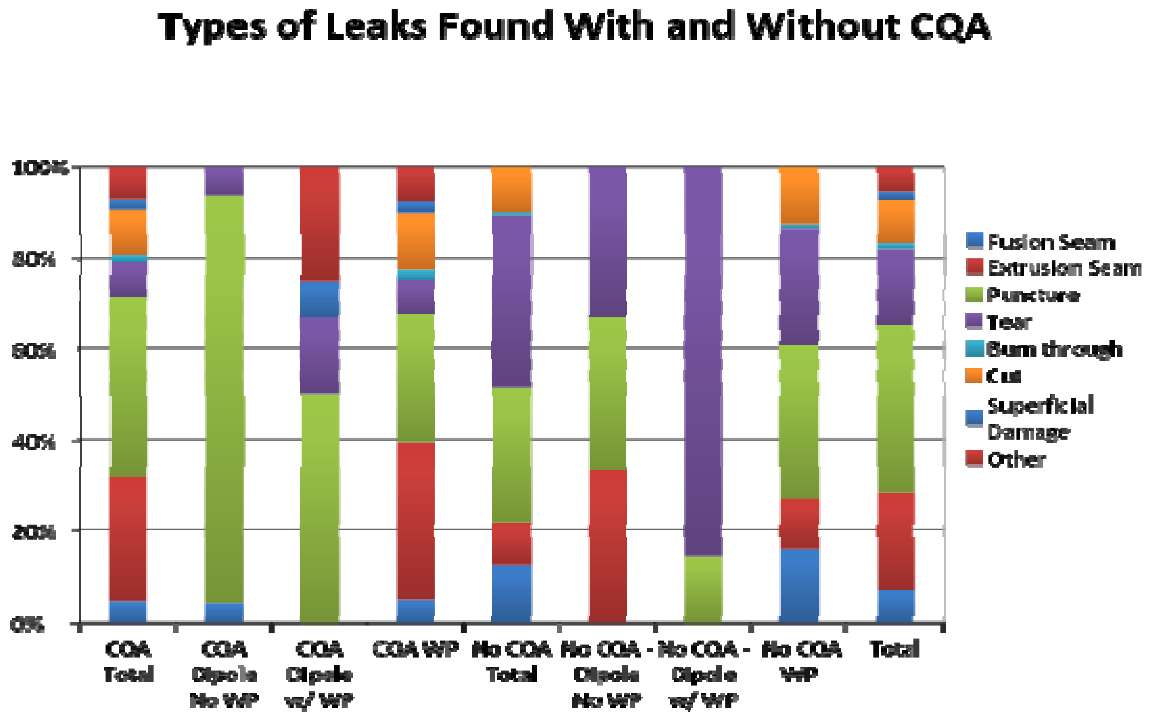

Figure 2. Types of leaks found with and without CQA

In general, tears and punctures are the dominant type of defect found in projects without CQA (68%), whereas for projects with CQA, it is punctures and extrusion defects (63%), with a greater diversity in other types of defects found.

With no CQA (total), the percentage of tears is greater than average. Of the 76 total tears, 53 were found in projects without CQA. The high percentage of tears found in the “No CQA, Dipole, w/ WP” category (24 tears) would suggest that it could be due to lack of supervision during placement of the cover material, or that the specifications did not detail thick enough access or circulations routes for the type of machinery, or that the machinery operators not paying enough attention when working.

Of the 164 puncture defects, 120 were found on projects with CQA. Of that, 27 were found in the "CQA, No WP" project previously discussed. In CQA, emphasis is sometimes placed too highly on seam verification alone, however a greater importance should be placed on "walking the panels".

4.3 – Defect Rate Per Sector

As discussed in the paper by Giroud, when discussing leaks "the detrimental consequences of the leakage" itself must also be considered – not just the number of leaks found. In other words, a leak in a surface water retention basin likely will not have the same environmental impact as a leak from leachate basin. The average defect rates (water puddle and dipole) were calculated for the 6 different sectors.

Table 4. Defect rate per sector.

	Water Puddle			Dipole		
Sector	Area Surveyed (m^2)	Leaks	leaks/ha	Area Surveyed (m^2)	Leaks	leaks/ha
Alternative Energy	40	9	2 250	-	-	-
Water Management	97 903	82	8.4	52 497	4	0.76
Oil and gas	59 739	24	4.0	61 906	0	0.00
Residual materials	65 941	47	7.1	100 065	42	4.20
Mining	412 642	88	2.1	350 828	40	1.14
Contaminated soils & toxic residues	363 629	102	2.8	410 655	9	0.22
Total	999 894	352	3.52	975 951	95	0.97

Although obviously not representative of its sector, the one alternative energy (bio-tank) project was included in this list to highlight the importance of proper design. In a 40 m2 area, nine extrusion leaks were found. In this case, the choice of material and design were poor. There were far too many protrusions – pipes crossing the tank and internal membrane - with awkward angles that could not be properly reached.

The residual materials sector also has a higher than average defect rate, for both the water puddle and the dipole categories: overall it accounts for nearly 20% of all leaks, but only 8.4% of the surface area, with a relatively similar defect rate found using the dipole method and the water puddle method.

Similarly, water management sector accounts for 19% of leaks, but only 7.6% of area surveyed. In this case, however, the defects were mainly found using the water puddle method, which may be due to water management basins not always being covered. Additionally, none of the water management projects were subject to CQA.

5. CONCLUSION

The average defect rates for the ELL projects surveyed from 2012-2016 would suggest that great improvements have been made in terms of quality of geosynthetics projects. Indeed, when averaged out, in projects without a CQA there can be little difference in terms of the average number of leaks found. However, without CQA there is a greater likelihood of having an aberrant project with very large number of leaks. CQA is therefore still important to provide oversight in the event that something does go wrong, particularly in uncommon type projects.

Additionally, a consistent and continuous CQA program should always be applied—by a knowledgeable CQA specialist—simply having someone perform spot-checks and/or verify testing results does not guarantee against having one of the “aberrant” high defect rate projects.

CQA had biggest influence on tears, particularly with relation to cover material placement, likely due to earthworks teams not always having experience with geosynthetics works. Water puddle was particularly important for finding leaks not visible to naked eye, such as extrusion defects, where even a CQA specialist would not necessarily have been able to spot them.

On average, everything is improving, but it is the outliers that are telling an interesting story in terms of how a project can go poorly. Areas that can be improved upon include the design of systems that are not standard (designing so as to reduce number of joints and appurtenances), the placement of cover materials, and the level of tolerance for unsorted materials based on the geosynthetic materials selected. Also, it is our opinion that the designer should always plan ahead to facilitate every single step of the construction.

Improvements appear to be in areas where people are becoming more familiar—therefore the more knowledgeable everyone is in the industry, in all stages of the job, the better the overall quality. Hopefully, both CQA and ELL will no longer be services that are reactive.

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