Geomembrane Liner Action Leakage Rates:
What is Practical and What is Not?

by Ian D. Peggs

THE objective of using a geomembrane liner in a potable water reservoir, a waste water treatment plant lagoon, a CAFO pond, or any other kind of liquid containment facility is, of course, to prevent loss of liquids which are obnoxious or valuable. Leaks are most undesirable, to say the least. But we have learned over the years that while non-leaking facilities can apparently be built, we should not rely on single liners to be totally impermeable, for nothing is; least of all a large area of thin plastic that is placed on the ground and then covered by several feet of water or soil. Damage happens and should be considered unavoidable. Hence the development of double lining systems in which 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 does not leak – just as double-hulled ships do not sink. Thus, the leakage rate we discuss here is the leak flow rate through the primary liner of a double lining system.

Sensible designers, regulators, and facility owners, have learned to accept some leakage and to incorporate an under-drain or leakage detection system (LDS) that will safely remove that leakage without further damage to the subgrade or the lining system. But what should that maximum allowable, or Action Leak Rate (ALR) be, above which the leak must be found and repaired? Zero is not, as they say, an option if for no other reason than water in a deep pond will diffuse through a geomembrane at a significant rate. USEPA terms this the "de minimis" leak flow rate which for a reference evaporation pond 70 acres in area and with an average depth of 30 ft is 28 gallons per acre per day (gpad), or a total of 840 gallons per day (gpd) for a 0.040 in. thick HDPE geomembrane. This is not insignificant! In facilities where owners/regulators/designers have expected absolutely zero leakage and required that repairs be made because "leak" water is dripping out of the LDS system, the rate is invariably increased due to collateral damage from the added traffic and equipment on the liner required to make the repair. So what is an adequate ALR?

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The ALR is a parameter that essentially evaluates the quality of the installed liner. It should not be too high that low quality liners can meet it. Nor should it be too low that good liner installers cannot meet it. An unachievable target serves no purpose. It should be at a level that can be met by installers working at the state-of-practice of installation, welding, and CQA/CQC testing technologies. These days this should include a geoelectric liner integrity survey at the completion of construction of the lining system whether it be for an exposed liner or a covered liner. Such surveys show that ~24% of liner damage is done during liner installation, but that ~74% is done when the liner is covered by drainage or protective soil (Nosko et al. 1996). Most damage occurs on the floor liner. Rollin (1999) shows that surveys find a decreasing number of holes as pond area increases, from ~5/acre in small detailed facilities to ~1/acre over ~2.5 acre. Such holes may be minute leaks in welds (Figure 1) to excavator bucket holes (Figure 2).

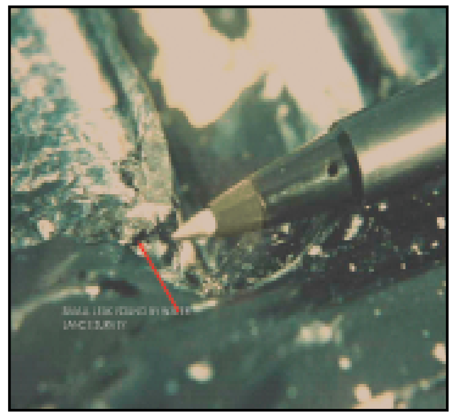
Figure 1.


Figure 2.

In 1992 after much research the USEPA promulgated a Final Rule for the ALRs through the primary liners of double lining systems in solid and liquid hazardous waste surface impoundments. They arrived at 100 gpad for solid waste with a maximum leachate head of 1 ft, and 1000 gpad for ponds. Since that time 20 gpad has typically been adopted by state regulators throughout the USA for municipal solid waste landfills. This seems to have worked quite well. For example, as shown in Figure 3, the LDS of a new landfill cell had an ALR of 20 gpad, but leak flow rates were about 40 gpad spiking to over 130 gpad after precipitation events. The offending leak(s) had to be located and repaired. A geoelectric survey was performed on the surface of the sand drainage layer of the geomembrane. Several holes were located, excavated, and repaired, and the leak flow rate decreased to about 10 gpad - an acceptable level. The rate did not go to zero and probably would not have ever gone to zero however many repair attempts were made. But note clearly that this is not leakage into the ground but is leakage collected by and removed from the secondary liner.

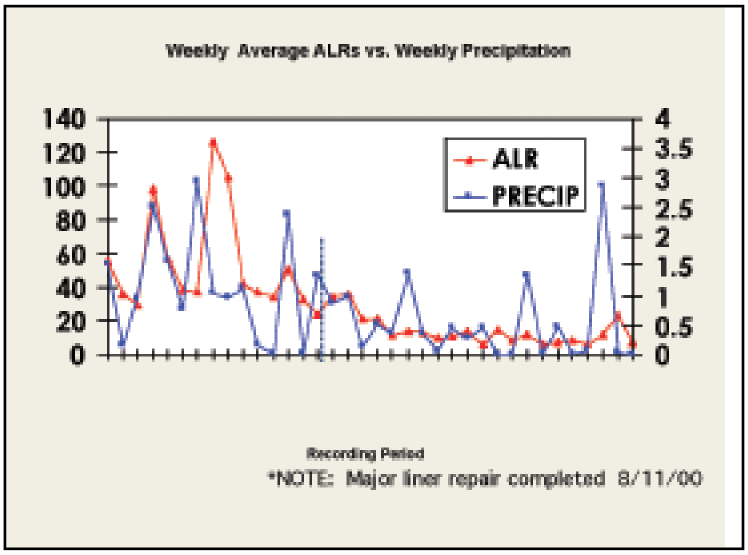

Figure 3. Leak flow rate (red). Precipitation (blue). Courtesy of R. Phaneuf, NYSDEC

If we return to our reference 70 acre evaporation pond, when it was half filled the leak flow rate was about 450 gpd, or ~13 gpad. This is quite low for a pond of that size and depth. The state ALR (50 gpd) used previously for "small" ponds was being applied to this very large pond. Note, that is 50 gpd, not 50 gpad! Thus a small 1 acre pond is allowed an ALR of 50 gpad, but the 70 acre pond is expected to have an ALR of 0.7 gpad! The ALR of 50 gpd simply cannot be met by a large pond. Clearly an ALR should be expressed as a function of liner area. Then, in fairness, it should also be expressed as a function of average head, but this may be expecting a little too much.

In 1989 Giroud and Bonaparte published two very useful tables, as presented here. Table 1 for the permeation rate ("di minimis" leakage) of water as function of head through a 0.040 in. liner that has no physical holes, and Table 2 for leakage rates through different sized holes as a function of head, and size of hole. For our full 70 acre evaporation pond averaging ~30 ft deep the di-minimis leakage rate is ~1960 gpd which far exceeds the actual specified ALR of 50 gpd. Zero is theoretically impossible. Of course that depends on whether the permeated water vapor remains as a vapor and is expelled through air vents or whether it re-condenses into a liquid within the LDS and is removed.

Calculated Unitized Leakage Rates due to Permeation of Water Through an HDPE Geomembrane

	Water depth on top of the geomembrane, h_w					
	0 m (0 ft)	0·003 m (0·01 ft)	0·03 m (0·1 ft)	0·3 m (1 ft)	3 m (10 ft)	>10 m (>30 ft)
Coefficient of migration, m_g (m²/s)	0	9×10^{-20}	9×10^{-18}	9×10^{-16}	9×10^{-14}	3×10^{-13}
Unitized leakage rate, q_g						
(m/s)	0	9×10^{-17}	9×10^{-15}	9×10^{-13}	9×10^{-11}	3×10^{-10}
(lphd)	0	8×10^{-5}	0·008	0·8	80	260
(gpad)	0	8×10^{-6}	0·0008	0·08	8	28

Table 1.

The two most often applied primary ALRs are the 20 gpad for landfill primary liners and the 500 gpad specified in "Recommended Standards for Wastewater Facilities " (2004) by 10 northern states and one Canadian province for liners under 6 ft of water in waste water treatment plants. In May 2009 the Geosynthetic institute published a white paper on ALRs in different facilities in different states throughout the USA. For instance, in Oregon existing lined ponds observe an ALR of 3400 gpad but new ones must have zero leakage. As previously indicated, this is not practical. In South Dakota there is a staged ALR program for mine pond liners. No action is required up to 20 gpad. Up to 200 gpad daily monitoring is increased, the area of the leak(s) should be sought, and a written action plan initiated. From there to 500 gpad, the leak(s) should be located, the water level lowered below the leak(s), and a formal action plan submitted. Over 500 gpad, the leak(s) must be repaired.

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The highest state ALR is 6800 gpad, which is far too high.

If 20 gpad for landfills is extended to a 6 ft head in Table 2, the ALR at a 6 ft head would be between 50 and 120 gpad, significantly less than the 500 gpad required by the "Ten States" rules. Personally, I believe that 250 gpad seems a reasonable number for heads of about 10 ft.

Calculated Leakage Rates due to Pinholes and Holes in a Geomembrane

	Defect diameter	Water depth on top of the geomembrane, h_w: 0·003 m (0·01 ft)	0·03 m (0·1 ft)	0·3 m (1 ft)	3 m (10 ft)	30 m (100 ft)
Pinholes	0·1 mm (0·004 in)	0·006 (0·0015)	0·06 (0·015)	0·6 (0·15)	6 (1·5)	60 (15)
	0·3 mm (0·012 in)	0·5 (0·1)	5 (1)	50 (13)	500 (130)	5 000 (1 300)
Holes[a]	2 mm (0·08 in)	40 (10)	130 (30)	400 (100)	1 300 (300)	4 000 (1 000)
	11·3 mm (0·445 in)	1 300 (300)	4 000 (1 000)	13 000 (3 000)	40 000 (10 000)	130 000 (30 000)

Values of leakage rate in liters/day (gallons/day)

Table 2.

In another case a double lined 5000 m^2 pond 4.5 m deep was leaking 2l/hr and it was required that the leak(s) be found and repaired. The leakage rate was ~100 lphd or 10 gpad. This is very low for a 4.5 m deep pond, so the leakage should simply have been captured and returned into the pond. Attempting to find and repair the leak(s) would likely just increase the rate. Note from Table 2 that a leak rate of 50l/h under a 4.5 m head can be generated by a ~ 0.005 in. (0.15 mm) diameter hole. Very small and difficult to locate even with geoelectrical methods.

The hole producing 450 gpd in our 70 acre evaporation pond liner could be only ~0.012 in. diameter, also small, difficult, and unnecessary to find. In fact the owner of the evaporation pond has spent two years and many hundreds of thousands of dollars trying to find this miniscule leak. This has benefited no one.

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Note that the data generated in the GSI survey may be individual facility ALRs and not uniform ALRs applied state-wide to all containment facilities. Several states work with engineers to determine ALRs on a site specific basis depending on local groundwater conditions and the nature of the contained liquid. This is a very sensible approach. To the contrary, any agency expecting or

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specifying absolutely zero leakage is not taking a practical approach. This can only lead to arguments, wasted time and efforts, and unnecessary expenses that gain nothing.

In summary, all geomembrane-lined liquid containment facilities should have specified ALRs for the primary liner of double lining systems. The ALR should not be zero. It should exceed the "diminimis" permeation rate. It should not be lower than the liner integrity achievable by state-of-practice installation technology followed by a geoelectric survey over the complete liner area. And it should not be high enough that it will allow poor quality liner installation without geoelectric integrity surveys.

The most comprehensive ALR will be expressed as a function of unit area and, for ponds, as a function of average liquid depth.

Accept some leakage through an individual geomembrane liner but deal with it safely such that no further damage to the liner and subgrade occurs. Specify a Maximum Allowable or Action Leakage Rate for all geomembrane liners. **L&W**

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