Equivalency of Double Liner System for Florida Coal Ash Landfills

TAG Meeting 2

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Motivation - 1

- Federal and state regulations are requiring new Coal Combustion Residuals (CCR) landfills, new CCR surface impoundments, and all lateral expansions be constructed **with a composite liner.**
- The composite liner must consist of two components;
  - An upper component consisting of **a geomembrane liner** … and
  - GM components should consist of **(HDPE) and** must be at least **60-mil** thick.
  - The GM … must be installed in **direct and uniform contact** with the compacted soil
  - a lower component consisting of **at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than 1 x 10^{-7} cm/sec**

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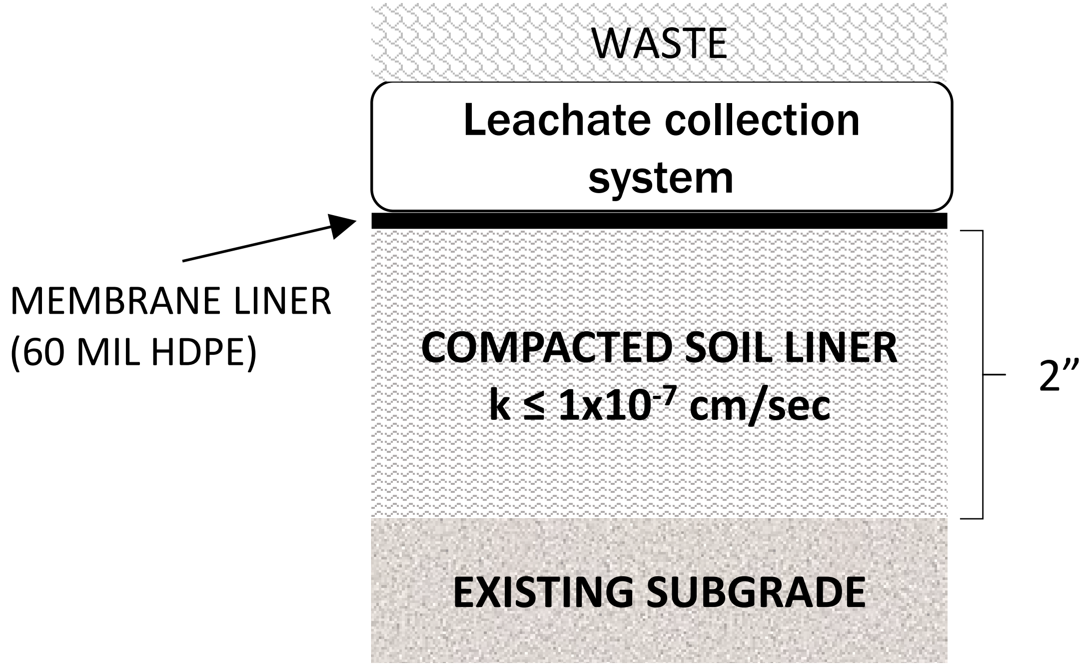

EPA Required Liner System

Motivation - 2

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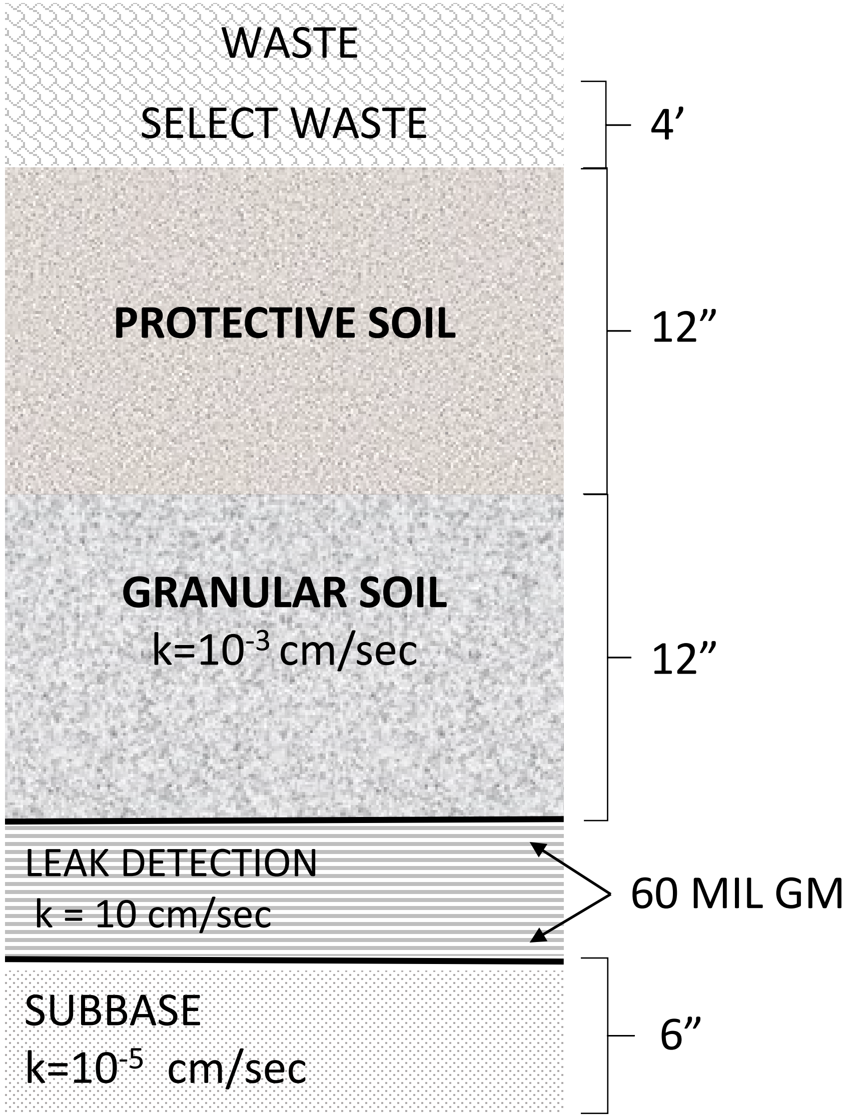
- On April 15, 2015, in the preamble to EPA coal ash rule, EPA considered that Florida's double liner system design **may not be appropriate for coal ash landfills** and stated:
- **"Florida's double-liner system does not meet the level of performance** achieved by EPA's composite liner system or the alternative liner system option."



Double Liner Option

OBJECTIVES: Two simple objectives

1. Assess the equivalency of the **Florida Double Liner System** to **EPA's composite liner system using more than 30 yrs of Leak Detection System (LDS) data (Let the data speak!!!!)**

"For instance, **it is not evident if the EPA has compared performance of the Florida double liner system, as a whole, but rather they compared the theoretical performance of its different components.**"

Our 2020-2021 Project is a step toward the overall objectives

2. Determine if the state of the art, from the literature and from current knowledge about landfill barriers, support the EPA conclusions.

RESEARCH TASKS (100%)

Task 1: Collected Most Relevant Documents – Composite Liner Leakage Rate

We used the following to estimate leakage rate through Composite Liner:

(This is the leakage rate any Equivalent Liner System must beat)

- *Rowe, R.K.* ***(2012).*** *Short and Long-term Leakage Through Composite Liners, 7th Arthur Casagrande Lecture, Canadian Geotechnical Journal, Vol. 49, pp. 141-169.*
- *Rowe, R.K.* ***(2005).*** *Long-term Performance of Containment Barrier Systems. Fourth Rankine Lecture. Geotechnique 55, No. 9, pp. 631-678.*
- *Rowe, R.K., and Booker, J.R.* ***(1998).*** *Theoretical Solutions for Calculating Leakage Through Composite Liner System. Geotechnical Research Center Report GEOT-18-98.*
- *Giroud, J.P., 1997. Equations for calculating the rate of liquid migration through composite liners due to geomembrane defects. Geosynthetics International 4 (3/4), 335-348*

RESEARCH TASKS (100%)

Task 2:

We determined leakage rates calculations and their different equations for alternative liner systems:

- *Bonaparte, R., Giroud, J.P., and Gross B.A. (1989). Rates of Leakage Through Landfill Liners. Proceedings of Geosynthetics, San Diego, CA, IFAI, St. Paul, MN, Vol. I, PP. 18-28.*
- *Fluent, J.E., Jr., Badu-Tweneboah, K., and Khatami, A. (1992). A Review of Geosynthetic Liner System Technology, Waste Management and Research, Copenhagen, Denmark, Vol. 10, No. 1, pp. 47-65.*
- *Giroud, J.P., and Bonaparte, R. (1989). Leakage Through Liners Constructed with Geomembranes, Part I: Geomembrane Liners. Geotextiles and Geomembranes, Vol. 8, No. 1, pp. 27-67.*
- *Giroud, J.P., and Bonaparte, R. (1989). Leakage Through Liners Constructed with Geomembranes, Part II: Composite Liners. Geotextiles and Geomembranes, Vol. 8, No. 2, pp. 71-111.*
- *Giroud, J.P., Khatami, A., and Badu-Tweneboah, K. (1989). Evaluation of the Rate of Leakage Through Composite Liners, Geotextiles and Geomembranes, Vol. 8, No. 4, pp. 337-340.*
- *Giroud, J.P., Soderman, K.L., Khire, M.V. & Badu-Tweneboah, K. 1998. New developments in landfill liner leakage evaluation. Proc. of 6th intern. conf. on geosynthetics, Atlanta, Industrial Fabrics Association International.*

RESEARCH TASKS (100%)

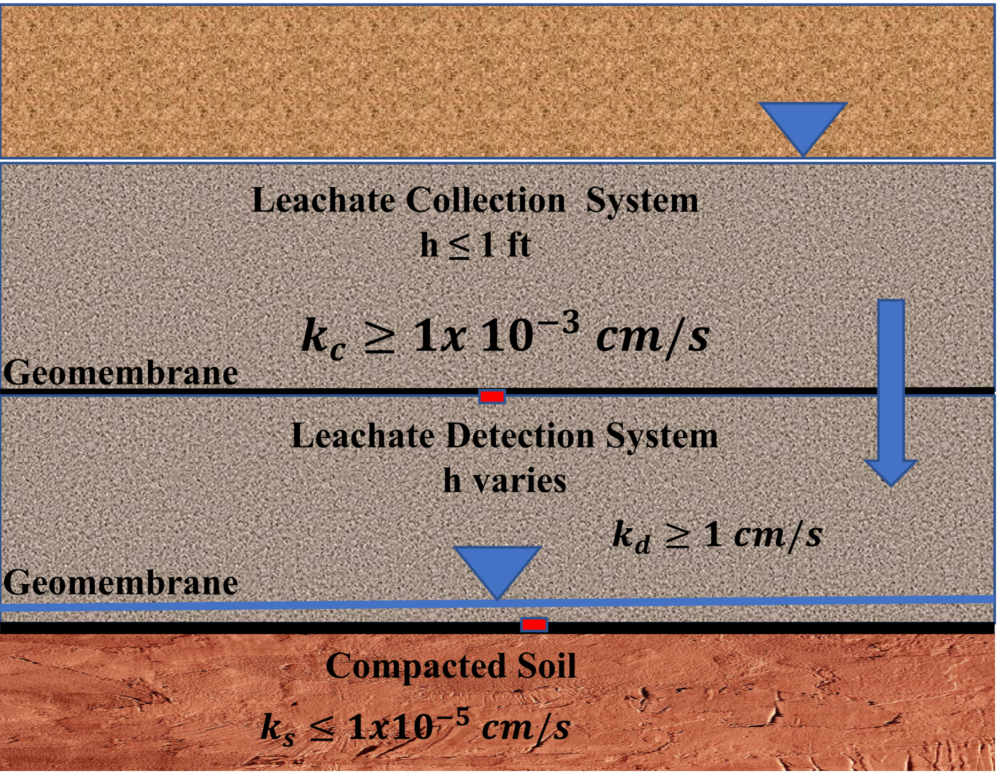
Task 3:

Recalculate theoretical leakage flow rates through Florida double liner systems and Composite Liner Systems

- *Florida Department of Environmental Protection (1995). Report on Leakage Flow Rates from Double-Lined Landfills in Florida, June 7th 1995. FDEP Solid Waste Section, 2600 Blair Stone Road, Tallahassee, FL. 32399-2400.*
- *Tedder, R., 1997, "Evaluating the Performance of Florida Double-Lined Landfills," Geosynthetics '97 Conference Proceedings, Vol. 1, IFAI, Long Beach, California, USA, March 1997, pages 425 -438.*

Theoretical Leakage Rates: Florida and EPA liner systems

Leakage Through FL Double Liner



Min thickness Varies depending on K_s and h

$$B_{ave} = \frac{2\sqrt{\frac{Q_1}{k_d}}}{\sin\alpha} * \sqrt{1 + \frac{2X_{ave}\sin\alpha}{\sqrt{\frac{Q_1}{k_d}}}}$$

Leakage Through Primary Liner

$$Q_1 = 3\ a^{0.75}h^{0.75}{k_d}^{0.5}$$

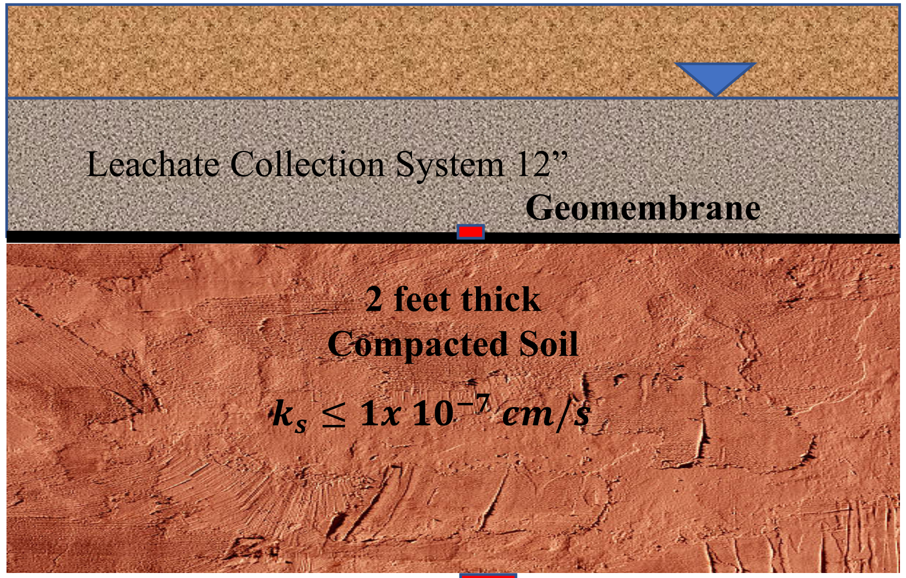
When there is a sand layer above or below Primary Liner

$$Q_1 = CC_B a\sqrt{2gh}$$

Leakage Through Secondary Liner

$$Q_2 = \beta_c(1 + 2\left(\frac{D_{ave}}{L_s}\right)^{0.95})a^{0.1}{D_{ave}}^{0.9}{k_s}^{0.74}$$

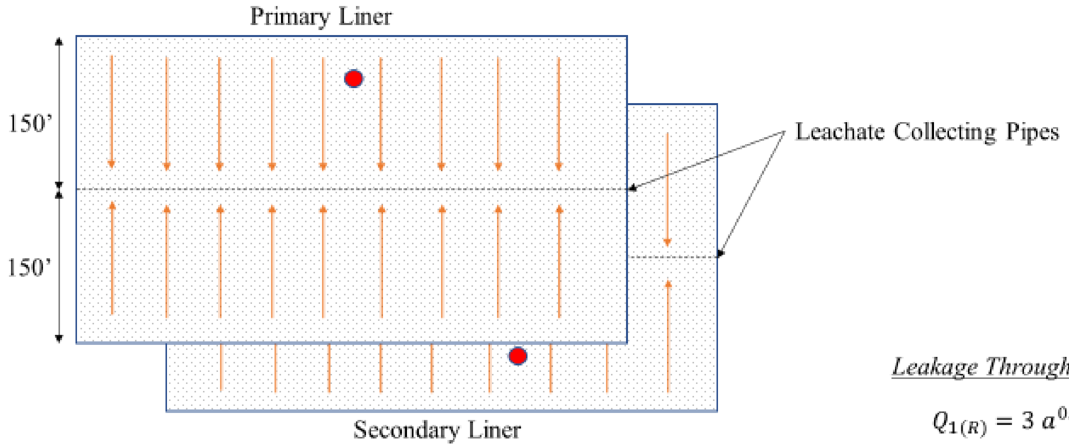
Leakage Through Composite Liner



β_c=0.21 Good Contact
=1.15 Poor Contact

$$Q = \beta_c(1 + 2\left(\frac{h_w}{L_s}\right)^{0.95})a^{0.1}{h_w}^{0.9}{k_s}^{0.74}$$

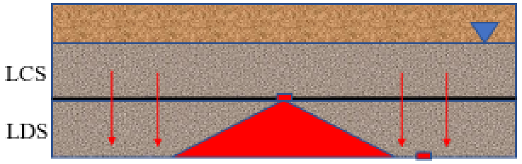
“..it is not evident if the EPA has compared performance of the Florida double liner system, as a whole, but rather they compared the theoretical performance of its different components….”



Leakage Through Primary Liner

$$Q_{1(R)} = 3\, a^{0.75} h^{0.75} k_d^{\,0.5}$$

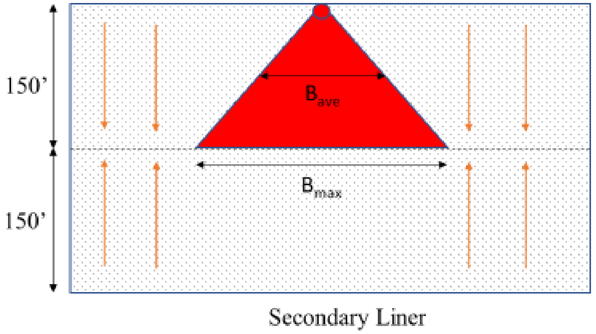
When there is a sand layer above or below Primary Liner

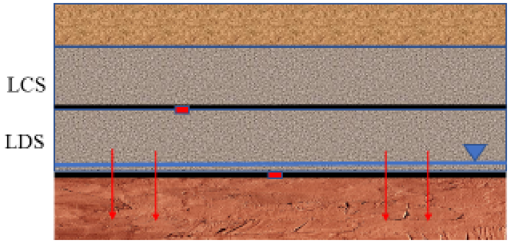


$$Q_1 = C C_B a \sqrt{2gh}$$

When free-flow through primary liner (occurs when there is geonet above and below geomembrane)

- Trying to figure out reasons on how did the EPA reach such a conclusion. How did they handle the theoretical calculations for the FL system.
- Still working on different ways of calculating theoretical leakage





Width of wetted area beneath hole in primary liner

$$B_{ave} = \frac{2\sqrt{\frac{Q_1}{k_d}}}{\sin\alpha} * \sqrt{1 + \frac{2X_{ave}\sin\alpha}{\sqrt{\frac{Q_1}{k_d}}}}$$

Average Depth of Flow in LDS

$$D_{ave} = \frac{Q_1}{B_{ave}\, k_d \sin\alpha}$$

Leakage Through Secondary Liner

$$Q_2 = \beta_c\left(1 + 2\left(\frac{D_{ave}}{L_s}\right)^{0.95}\right) a^{0.1} D_{ave}^{\;0.9} k_s^{\;0.74}$$

RESEARCH TASKS (75%)

Task 4:

- Collected actual leachate flow rates into the leak detection system (LDS) at Florida's active and closed double-lined landfills
- Data from FDEP database not as useful as previously assumed
  - Not as available, only few sites report were found
  - No systematic way of storage of the data. Leakage data location is somehow arbitrary at best
  - When available, in PDF
  - When available LCS and LDS are not always separated

QUARTERLY LEACHATE QUANTITY REPORT

[redacted]

Quarter 2nd Quarter 2013

Leachate Quantities									
Month	Precipitation (inches)	Open Acres	Intermediate Acres	Closed Acres	Class I Collected (gallons)	Class III Collected (gallons)	Stored (gallons)	Cell Dust Control (gallons)	Treated/Disposed Off-site (gallons)
April	3.25	21.9	24.6	0.0	117,066	85,147	143,810	180,000	0
May	5.95	21.9	24.6	0.0	150,830	99,085	137,110	108,000	132,166
June	7.12	32.1	24.6	0.0	186,779	270,011	221,840	0	400,030
TOTALS	16.32				454,675	454,243		288,000	532,196

quantity stored at the end of each month

Detection Zone					
Month	Days	Class I Acres	Secondary Pump hours	Detection Zone (gallons)	Leakage Rate* (gal/ac/day)
April	30	14.5	0	0	0.00
May	31	14.5	0	0	0.00
June	30	24.7	0	0	0.00
TOTALS	91	14.8	0	0	0.00

* Action Leakage Rate = 100 gal/ac/day (Section 9.4 of Engineering Report)

Leachate Management System

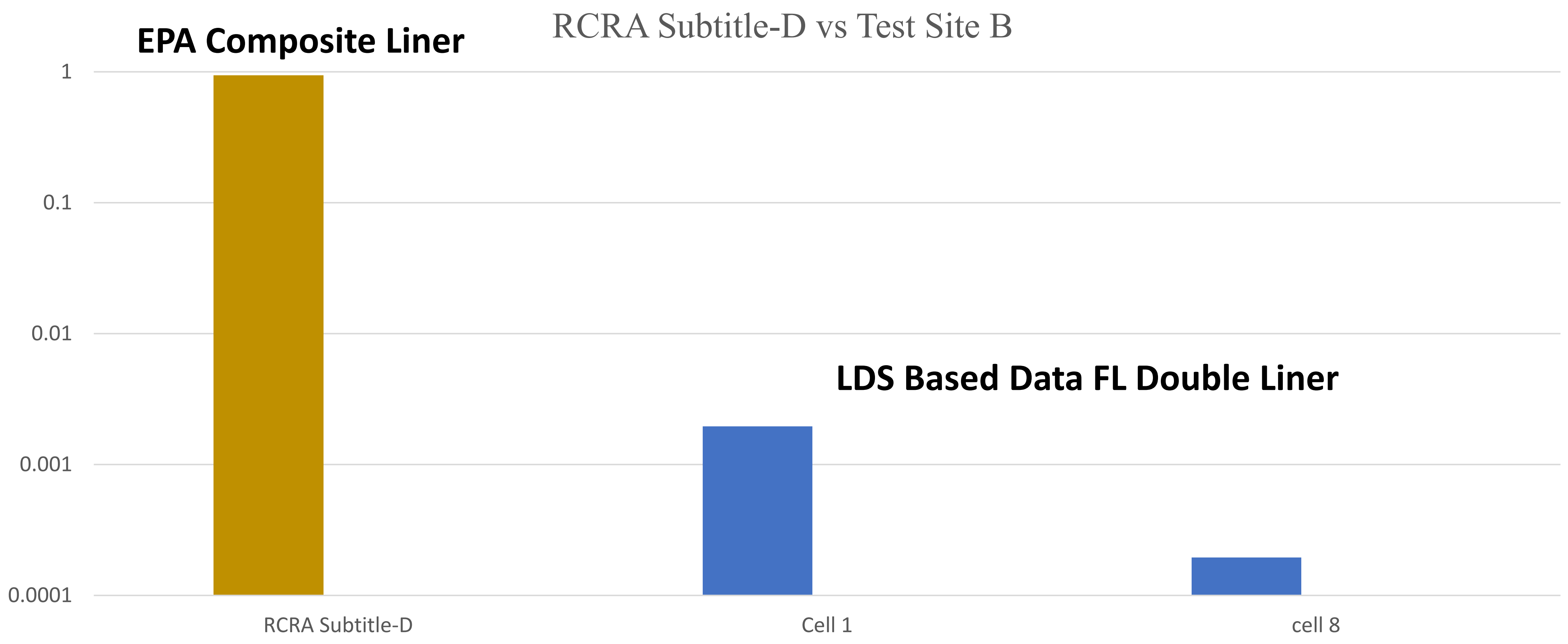
Operation Log

		LEACHATE COLLECTION SYSTEM			BASIN LEAK COLLECTION SYSTEM	
DATE	TIME	METER READING	FLOW (GAL.)	TOTAL GAL.	METER READING	FLOW (GAL.)
		194336	169247		4515	6330
1	8Am	194355	169435	1880	4515	6330
2	11Am	194377	169651	2160	4515	6330
3						
4						
5						
6	8Am	194459	170373	7220	4515	6330
7	8Am	194484	170615	2420	4515	6330
8	8Am	194506	170829	2140	4515	6330
9	8Am	194531	171071	2420	4515	6330
10						
11						
12	11Am	194600	171744	6730	4515	6330
13	8Am	194619	171932	1850	4515	6330
14	8Am	194638	172120	1040	4515	6330
15	8Am	194651	172320	2000	4515	6330
16	4Pm	194682	172550	2300	4515	6330
17						
18						
19	8Am	194731	173028	4780	4515	6330
20	8Am	194749	173215	1870	4515	6330
21	8Am	194765	173375	1600	4515	6330
22	4Pm	194786	173588	2130	4515	6330
23	8Am	194799	173721	1330	4515	6330
24						
25						
26	8Am	194865	[illegible]	4550	4515	6330
27	8Am	194867	174337	1610	4515	6330
28	8Am	194873	174471	1340	4515	6330
29	8Am	194894	174658	1870	4519	6363
30						
31						
TOTAL				54110		

Task 4: **RESEARCH TASKS (75%)**

- Data Collected from 25 Landfills. Mainly through personal contacts and
- Especially **our TAG Members – Very grateful**
- Multiple Cells from each landfill, for multiple yrs
- Might be largest dataset of actual landfill field performance
- Might have significant impact on designing with Geomembranes and GCLs
- Might receive more data in the next few months.
- COVID made the task harder
- ALL data show much less leakage rate from FL double lined landfills than EPA composite liner system (Next Slides)
- Currently collecting other pertinent or relevant data:
  - For each cell LDS historic records, we need:
    - Exact Liner Profile
    - Active period, interim cover period, final cover period, etc.
    - Using FDEP database and contacting landfills
    - Might plan trips to selected landfills (with best data)
    - Task will continue with Year 2 of the project

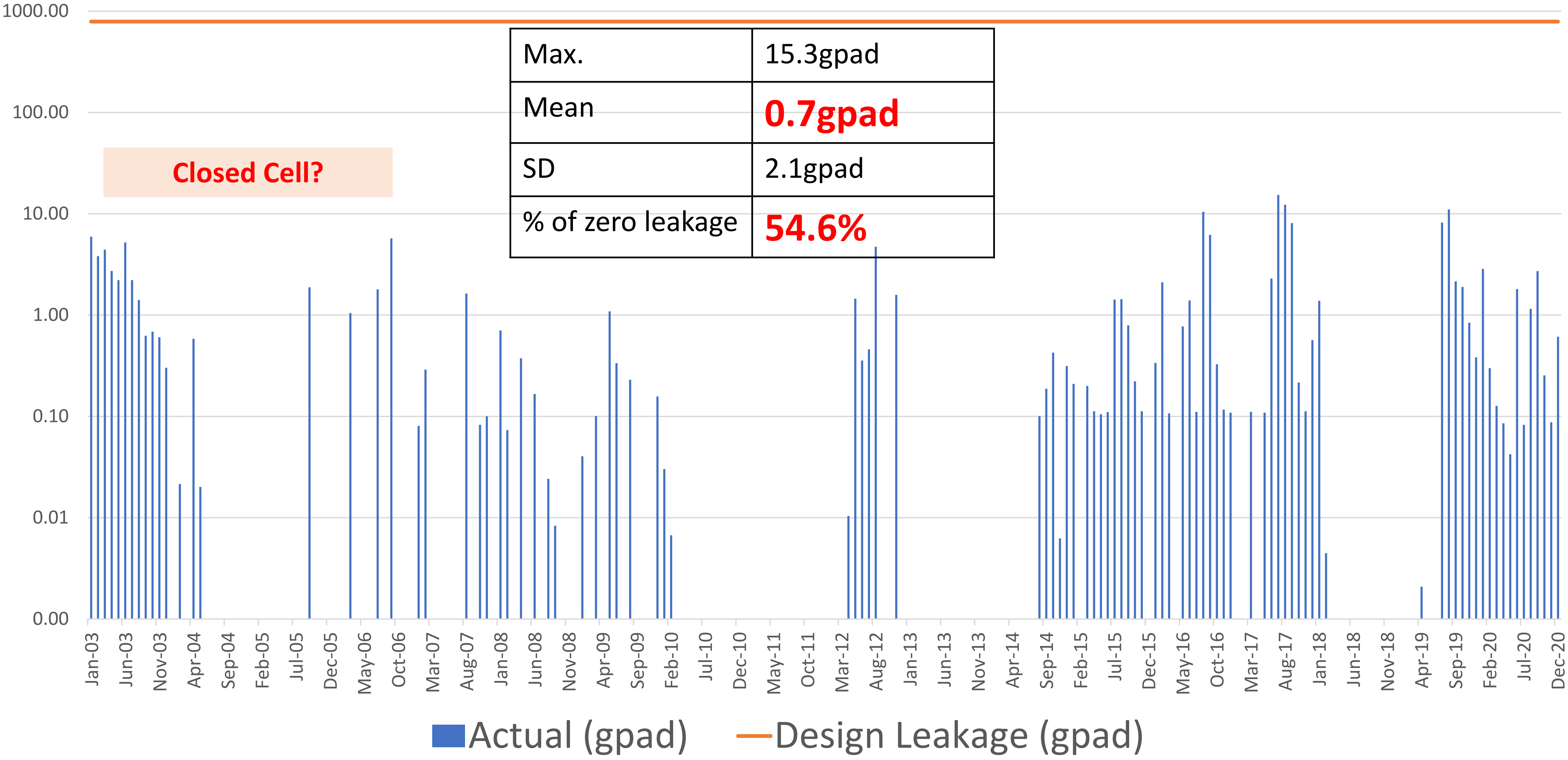
“Over All” Florida LDS Data Based Leakage Rate vs EPA Composite Liner Leakage



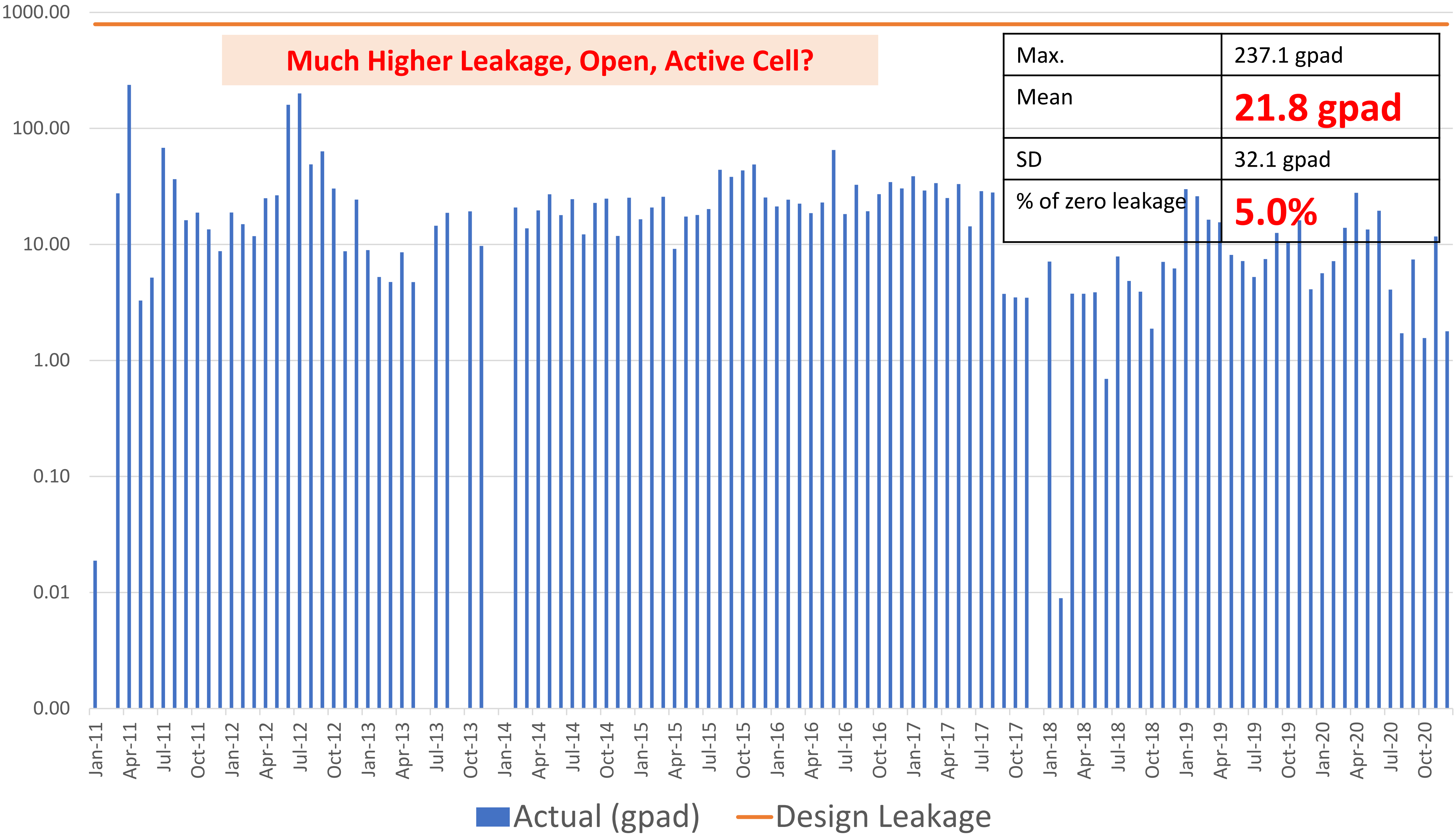
Few examples to discuss

Monthly Leakage Rate into LDS for [redacted] Landfill- Cell 2

Max.	15.3gpad
Mean	**0.7gpad**
SD	2.1gpad
% of zero leakage	**54.6%**



Leakage into LDS for [redacted] Landfill- Cell 3

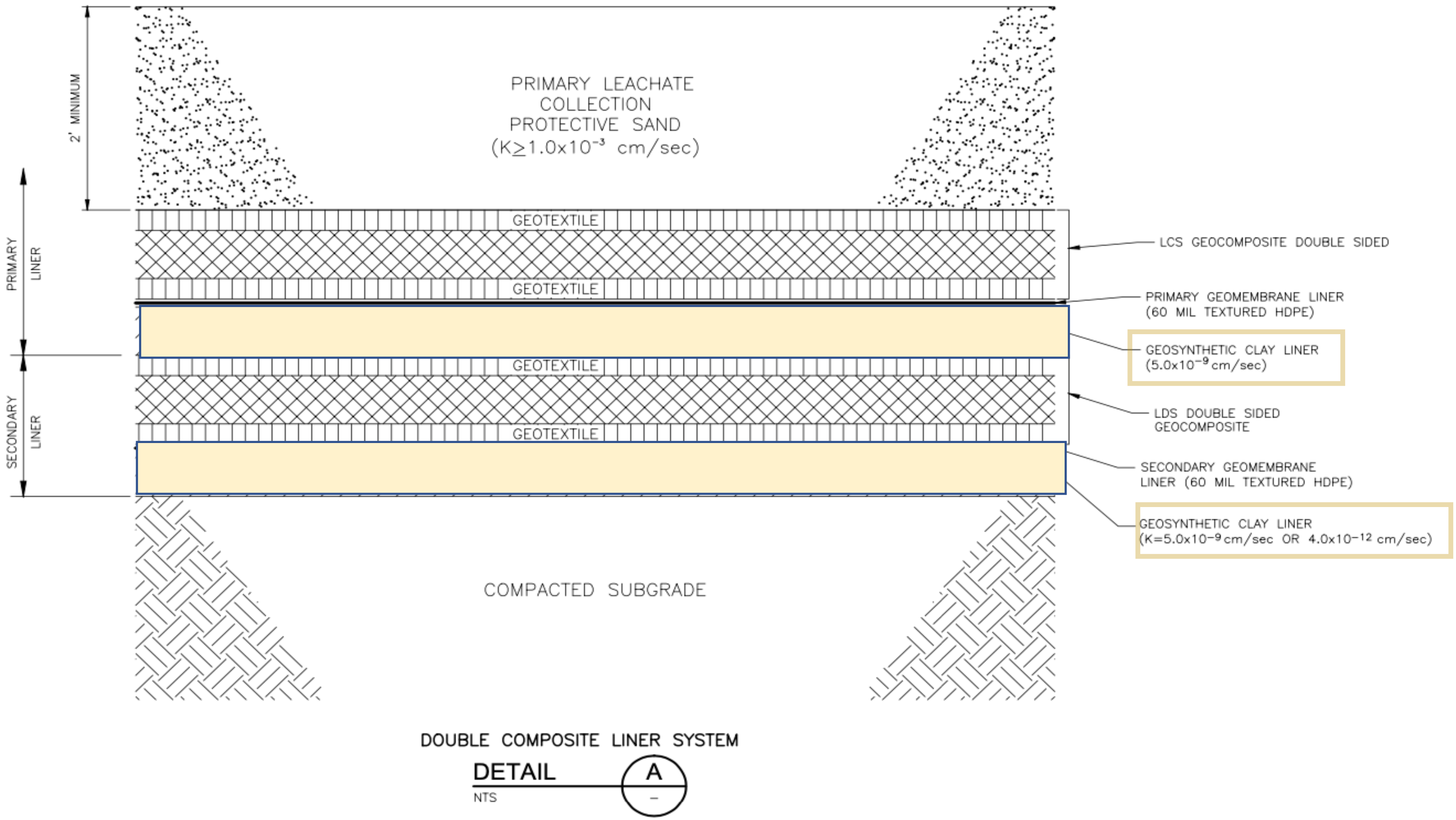


Max.	237.1 gpad
Mean	**21.8 gpad**
SD	32.1 gpad
% of zero leakage	**5.0%**

Intellectual/Engineering value of LDS data:

- Re-develop and/or update equations for leakage data from primary to secondary leachate collection systems.
  - Under different configuration?
    - **Case 1** Free Flow: Geonet Drainage Layer on both sides of Geomembrane
    - **Case 2** Leakage through Geomembrane overlaying a highly Permeable Layer: Geonet below geomembrane and sand above Geomembrane
    - **Case 3** Same as Case 2, but with Restricted Flow in the LDS: Can only be used if hydraulic conductivity of layer below geomembrane is less than 10^{-4} cm/sec, and Head of liquid on top of geomembrane is less than the thickness of layer below geomembrane
  - Under different operational conditions
    - Active cell
    - Interim covered cell
    - Final covered cell

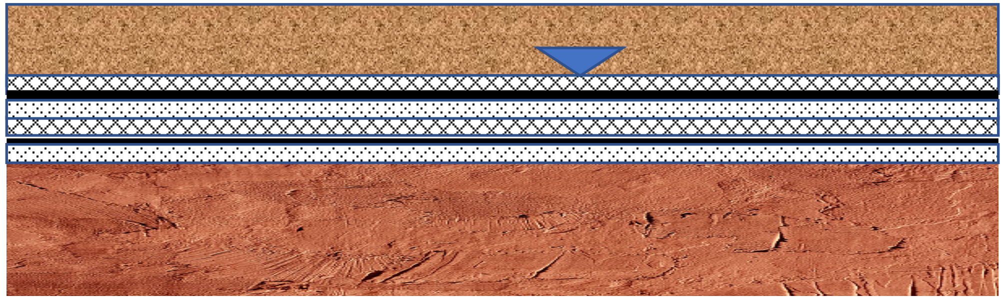
Two landfills with data: Double-Composite



LDS Data are basically: Field Scale Evaluation of GCL Performance at a very large scale and through a long period of performance.

We identified these two sets of Data and are preparing a technical paper on their data.

Double Composite Liner System

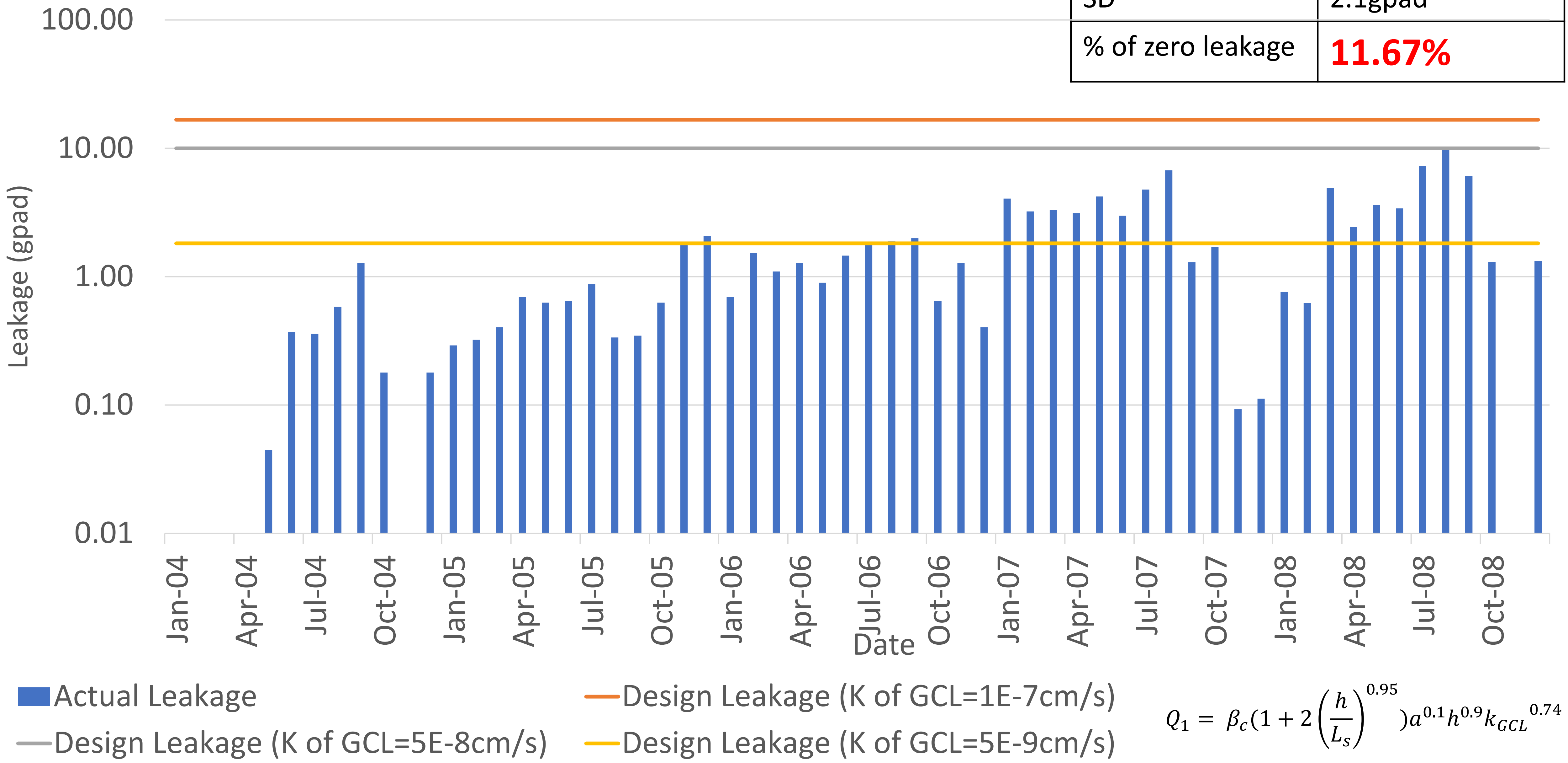


Leakage Through Primary Liner

$$Q_1 = \beta_c\left(1 + 2\left(\frac{h}{L_s}\right)^{0.95}\right)a^{0.1}h^{0.9}k_{GCL}{}^{0.74}$$

Leakage into LDS for [redacted] Landfill

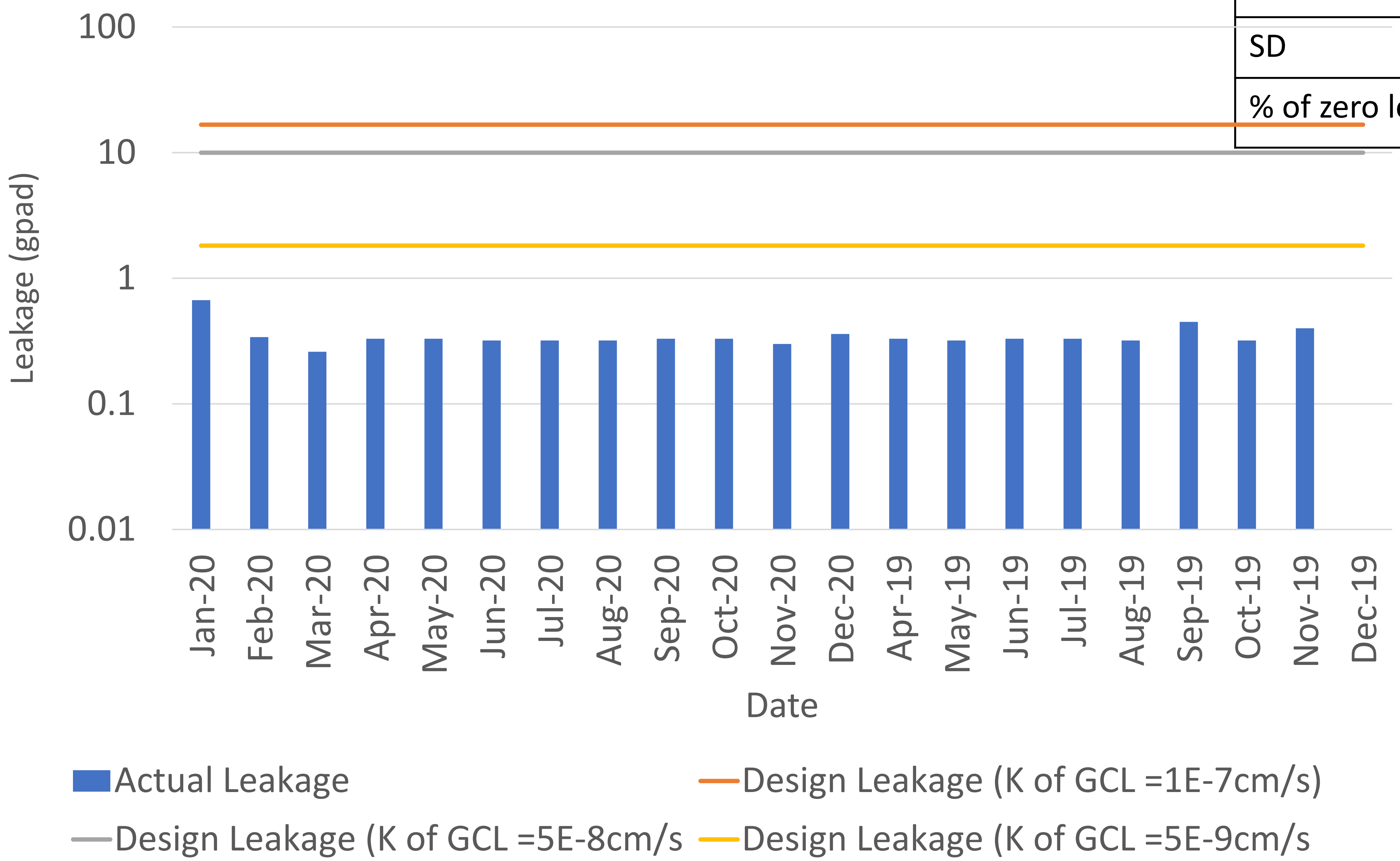
Max.	10.1gpad
Mean	**1.7gpad**
SD	2.1gpad
% of zero leakage	**11.67%**



$$Q_1 = \beta_c(1 + 2\left(\frac{h}{L_s}\right)^{0.95})a^{0.1}h^{0.9}k_{GCL}{}^{0.74}$$

Leachate into LDS for [redacted] Landfill (Cell A1)

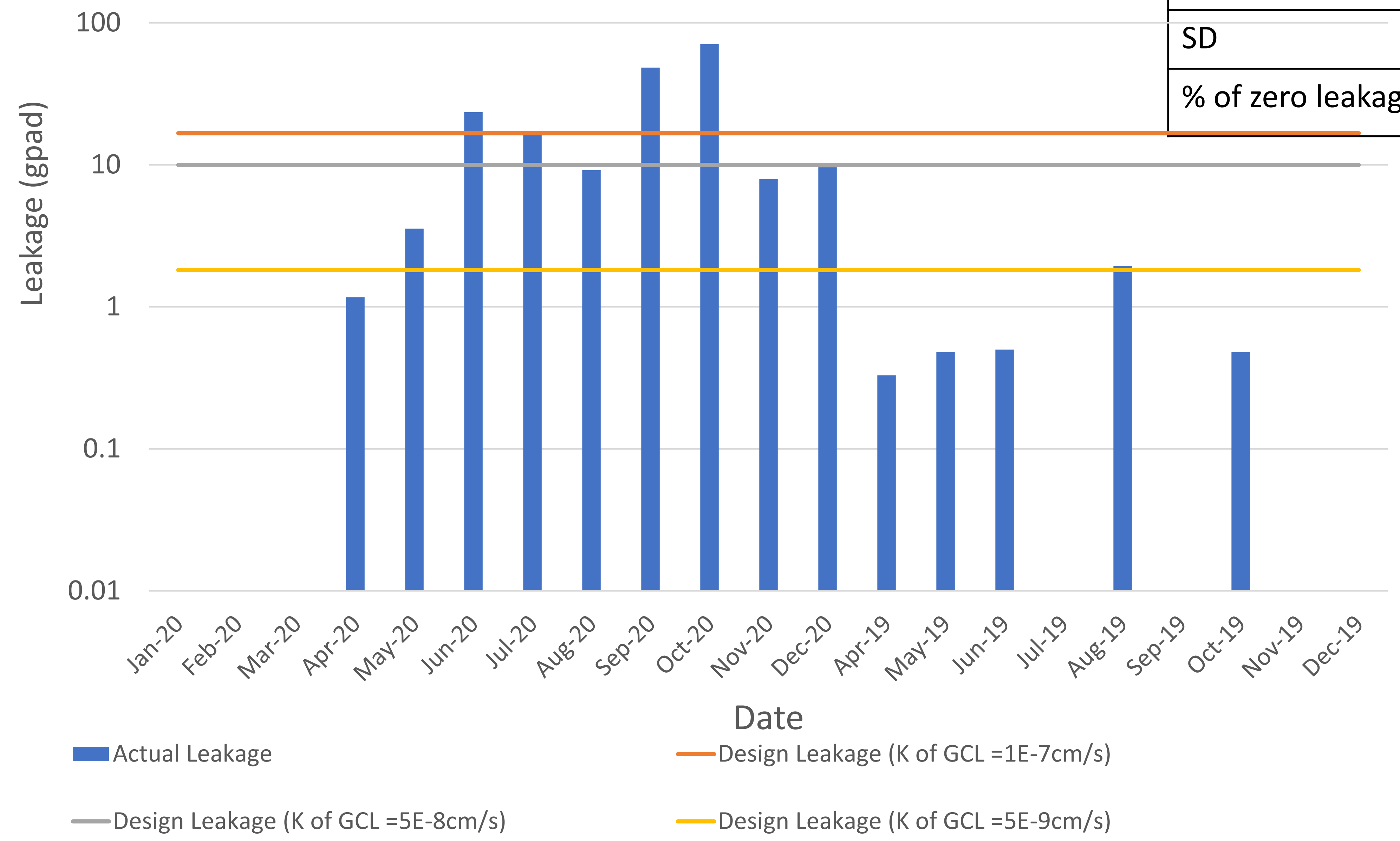
Max.	0.67gpad
Mean	**0.33 gpad**
SD	0.11 gpad
% of zero leakage	**4.76%**



$$Q = \beta_c\left(1 + 2\left(\frac{h_w}{L_s}\right)^{0.95}\right)a^{0.1}{h_w}^{0.9}{k_s}^{0.74}$$

Leachate into LDS for [redacted] Landfill (Cell A4)

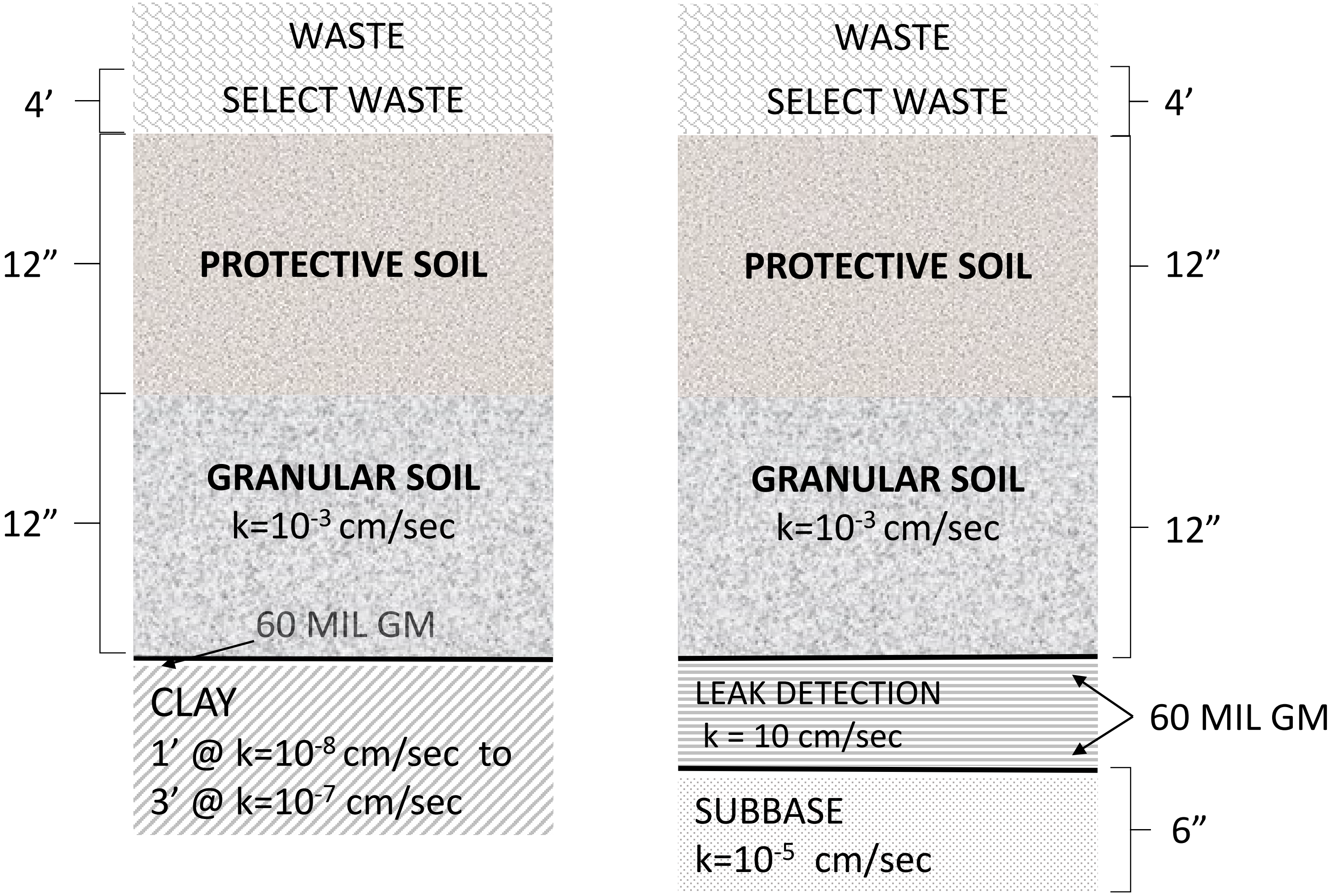
Max.	70.57gpad
Mean	**9.22 gpad**
SD	18.17 gpad
% of zero leakage	**33.33%**



$$Q = \beta_c(1 + 2\left(\frac{h_w}{L_s}\right)^{0.95})a^{0.1}{h_w}^{0.9}{k_s}^{0.74}$$

CURRENT ACTIVITIES

- Use the findings of this study to approach others to continue collecting data from Florida double lined landfills to better resolve the issue of equivalency between the federal composite liner design and the double liner design.
- Use Finite Element Modeling to analyze EPA vs FDEP liner systems to finally put the issue to rest.



Composite Liner Option Double Liner Option

The Equivalency of Florida Double Liner System and Subtitle D Composite Liners for Coal Ash Disposal based on Mass Transport and Chemical Compatibility

Jiannan (Nick) Chen, Assistant Professor, University of Central Florida

Tarek Abichou, Professor, Florida State University

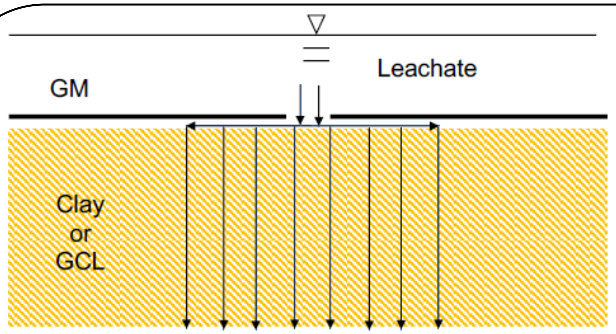
Debra Reinhart, Pegasus Professor, University of Central Florida

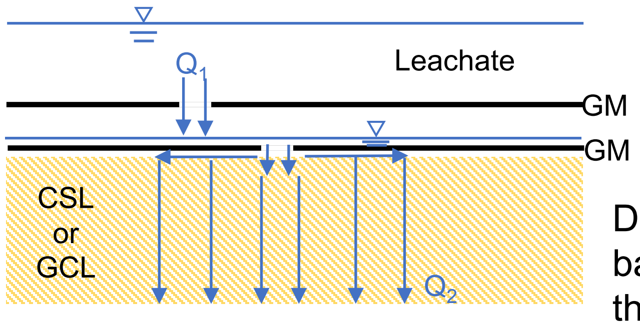
Liner Equivalency Demonstration

Subtitle D Liner

Florida's Double Liner

Equivalency:
Leakage Rate + Mass Transport





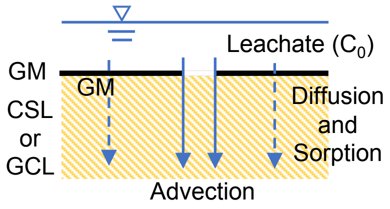
$$Q = C\left[1 + \frac{1}{10}\left(\frac{d_L}{t_L}\right)^{0.95}\right] a^{0.1} d_L^{0.9} K_s^{0.74}$$

Q = leakage rate per hole
a = area of hole
d_L = depth of leachate

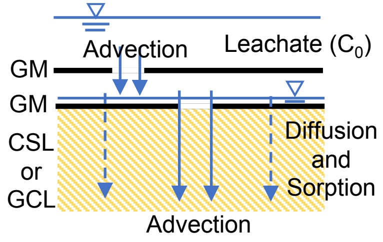
t_L = thickness of liner
K_s = hydraulic conductivity clay
C = contact factor (0.21)

Leakage Rage Calculation

Demonstrate *leakage rate* from base of alternative liner no more than conventional liner – *effective in managing leachate*.



$$R\frac{\partial C_r}{\partial t} = \frac{\partial\left(D_{ij}^{*}\frac{\partial C_r}{\partial x_i}\right)}{\partial x_i} - \frac{\partial (v_{sic} C_r)}{\partial x_i}$$



$$R\frac{\partial C_r}{\partial t} = \frac{\partial\left(D_{ij}^{*}\frac{\partial C_r}{\partial x_i}\right)}{\partial x_i} - \frac{\partial (v_{siD} C_r)}{\partial x_i}$$

R = retardation factor; C_r = resident concentration of solute in the pore water;
t = time; x_i = distance along the respective Cartesian coordinate; D^*_{ij}= effective diffusion coefficient tensor; and v_{siC} and v_{siD} = seepage velocity in the direction x_i of composite liner and double liner.

Mass Transport

Demonstrate *mass discharge* from base of alternative liner no more than conventional liner – *effective in managing contaminants*.

Open Discussion