Changed Pages

Part III, Appendix III-D.5-4

Landfill Foundation Settlement, Waste Settlement, and Soil Liner Strain Analyses
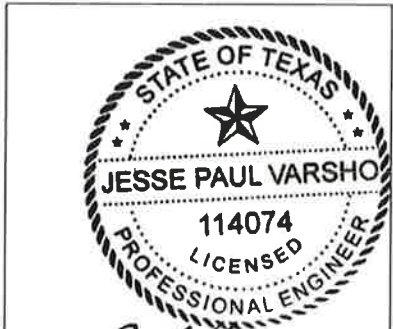
LANDFILL FOUNDATION SETTLEMENT, WASTE SETTLEMENT, AND SOIL LINER STRAIN ANALYSES

This document is released for the purpose of permitting only under the authority of Michael W. Oden, P.E. #67165. It has been Updated in August 2017 to match the current landfill configuration. It is not to be used for bidding or construction. Texas Registered Engineering Firm F-5650.

This document is released for the purpose of permitting only under the authority of Jesse P. Varsho, P.E. #114074. It is not to be used for bidding or construction. Texas Registered Engineering Firm F-5650

Appendix III-D.5-4, Landfill Foundation Settlement, Waste Settlement, and Liner Strain Analyses
- Updated calculations to match new landfill geometry

	Client Name:	Rancho Viejo Waste Management, LLC		
	Project Name:	Pescadito Environmental Resource Center	**Project No.:**	155145
	Modified by:	O. Covert	**Date Modified:**	8/1/17
	Reviewed by:	P. Thomas	**Date Reviewed:**	8/7/17

TITLE: LANDFILL FOUNDATION SETTLEMENT, WASTE SETTLEMENT, AND SOIL LINER STRAIN ANALYSES

Problem Statement

Determine the consolidation settlement of 1) the landfill foundation, and 2) the waste; and determine the strain on the soil liner due to the foundation settlement. The consolidation due to waste placement at critical locations is evaluated to determine the differential settlement between these locations. The calculations are performed to demonstrate that the leachate collection system will maintain a positive slope, and the final cover system and soil liner will not be damaged due to differential settlement.

References

The referenced literature cited below is provided in the attached pages. Referenced site specific information is provided within the Application as stated below.

1. Mass excavation grades, liner grades, and final landform grades presented on plan drawings contained in Design Drawing Set of this Application.
2. Summary of Geotechnical Design Parameters contained in **Appendix III-D.5-1** of this Report.
3. The site Geology Report (dated 2015) contained in this Application — as it pertains to subsurface investigative data (i.e., potentiometric levels) refer to Appendix III-E.1 of the Geology Report.
4. Figures 1 and 2 presenting locations of analyzed settlement points (attached pages).
5. Microsoft Excel foundation and waste settlement calculation spreadsheets (attached pages).
6. Coduto, Donald P. (2001). "Foundation Design Principles and Practices." Prentice-Hall, 2nd Edition, 2001.
7. Sharma, H.D., and Anirban, D. (2007). "Municipal Solid Waste Landfill Settlement: Postclosure Perspectives." Journal of Geotechnical and Geoenvironmental Engineering, 133(6), 619-629.
8. Qian, X., Koerner, R.M., and Gray, D.H. (2002). "Geotechnical Aspects of Landfill Design and Construction. Prentice-Hall, 2001.

Assumptions

Locations Analyzed for Foundation Settlement

To analyze potential impacts due to differential settlement of the landfill liner / leachate collection system, locations of where the largest differential settlement would occur were evaluated. From this evaluation, the largest differential settlement of the landfill liner system / foundation is expected to occur in the South Unit landfill between foundation settlement points **F1** and **F2** (as shown on **Figure 1** in **Reference No. 4**) for the following reasons:

- Foundation settlement point F1 is located over the maximum waste column over the leachate collection pipe and point F2 is located where the minimum waste column thickness occurs over the leachate collection pipe; and

- Foundation settlement point F1 is located just south of the maximum elevation for the final landform and point F2 is located where the lowest elevation for the leachate collection system grades occurs.

Settlement point **F1** is located approximately **214 feet west** of settlement point **F2**. The base elevation difference of the two settlement points is controlled by the **0.50%** gradient leachate pipe run (see Drawing No. III-D.3-1).

Client Name:	Rancho Viejo Waste Management, LLC		
Project Name:	Pescadito Environmental Resource Center	**Project No.:**	155145
Modified by:	O. Covert	**Date Modified:**	8/1/17
Reviewed by:	P. Thomas	**Date Reviewed:**	8/7/17

TITLE: LANDFILL FOUNDATION SETTLEMENT, WASTE SETTLEMENT, AND SOIL LINER STRAIN ANALYSES

Table 1 on the following page provides the elevations of the foundation settlement points, and the elevations and thicknesses of the relevant landfill system layers. The foundation settlement point locations are presented on **Figure 1 (Reference No. 4)**.

The leachate collection system (LCS) grades will settle as the compacted low permeable soil liner settles. The analysis that follows in this section, calculates the settlement in the compressible layers beneath the LCS:

- The compacted low permeable soil liner (3-ft); and
- Native soils that lie 50-ft beneath the proposed landfill bottom (i.e., 50-ft below the compacted low permeable soil liner).

*Note, the native soils were determined to be overconsolidated (**Reference No. 2**) and the overburden pressure that will be due to the final landform (i.e., complete landfill build-out) at the point of maximum waste column thickness (approximately 241 feet) will be significantly less than the preconsolidation pressure that was calculated (**Reference No. 2**). Therefore the assumption that the native soils 50-ft beneath the landfill bottom will settle is conservative for the purposes of this settlement calculation.*

Locations Analyzed for Waste Settlement

To analyze potential impacts due to differential settlement on the final cover system, locations of where the largest differential settlement of the waste would occur were evaluated. From this evaluation, the largest differential settlement of waste is expected to occur between the point of maximum waste thickness and the point of minimum waste thickness (at the edge of the landfill) or:

- Maximum waste thickness of **241 feet** at waste settlement point **W1**, and
- Minimum waste thickness of **0 feet** at the edge of the landfill at waste settlement point **W2**.

The horizontal distance between the waste settlement points **W1** and **W2** is approximately **553 feet**. **Table 1** below provides the elevations of the waste settlement points, and the elevations and thicknesses of the relevant landfill system layers. The waste settlement point locations are presented on **Figure 2. (Reference No. 4)**.

Client Name:	Rancho Viejo Waste Management, LLC		
Project Name:	Pescadito Environmental Resource Center	Project No.:	155145
Modified by:	O. Covert	Date Modified:	8/1/17
Reviewed by:	P. Thomas	Date Reviewed:	8/7/17

TITLE: LANDFILL FOUNDATION SETTLEMENT, WASTE SETTLEMENT, AND SOIL LINER STRAIN ANALYSES

Settlement Point Locations	Elevation of Top of Final Landform / Final Cover	Final Cover Thickness	Waste Column Thickness	Elevation of Top of Protective Soil Cover	Protective Soil Cover Thickness	Elevation of Top of Compacted Low Permeable Soil Liner	Compacted Low Permeable Soil Liner Thickness
Table 1 — Elevations of Material Layers at Foundation and Waste Settlement Points							
Foundation Settlement Points:							
F1	703 -ft.MSL	3 -ft	241	459 -ft.MSL	2 -ft	457 -ft.MSL	3 -ft
F2	659 -ft.MSL	3 -ft	198	458 -ft.MSL	2 -ft	456 -ft.MSL	3 -ft
Waste Settlement Points:							
W1	703 -ft.MSL	3 -ft	241	459 -ft.MSL	2 -ft	457 -ft.MSL	3 -ft
W2	575 -ft.MSL	3 -ft	0	572 -ft.MSL	2 -ft	570 -ft.MSL	3 -ft

Note:
Maximum waste column thickness of 241 feet (occuring near approximate center of landfill) was conservatively assumed in settlement calculations.

Initial Site Conditions

Table 2 on the following page summarizes the geologic site stratigraphy prior to landfill development. Native soils will be excavated down to mass excavation grades (i.e., bottom of compacted soil liner elevation) — specifically, to elevations **454-ft.MSL** and **453-ft.MSL** at points **F1** and **F2**, respectively. The average potentiometric surface was assumed to be at elevation **538 ft. MSL** (**Reference No. 3**).

Final Site Conditions

Table 2 on the following page summarizes the stratigraphy of the landfill system layers at the time of complete landfill build-out. Inside the landfill, the potentiometric surface is assumed to be at the top of the LCS drainage geocomposite or approximately 1 inch above the compacted low permeable soil liner. Materials that are below the assumed potentiometric surface are assumed to be saturated.

Client Name:	Rancho Viejo Waste Management, LLC		
Project Name:	Pescadito Environmental Resource Center	**Project No.:**	155145
Modified by:	O. Covert	**Date Modified:**	8/1/17
Reviewed by:	P. Thomas	**Date Reviewed:**	8/7/17

APTIM

TITLE: LANDFILL FOUNDATION SETTLEMENT, WASTE SETTLEMENT, AND SOIL LINER STRAIN ANALYSES

Table 2 Descriptions of Site Stratigraphy At Foundation Settlement Points (F1, F2) BEFORE and AFTER Landfill Development				
Geologic and Landfill System Layer Descriptions	**Top Elevation of Layer**	**Thickness**	**Moist Unit Weight**	**Saturated Unit Weight**
At Point F1: BEFORE Landfill Development				
Stratum II-III-IV (excavated, dry)	555 -ft.MSL	17 -ft	129 pcf	132 pcf
Stratum II-III-IV (excavated, saturated)	538 -ft.MSL	84 -ft	129 pcf	132 pcf
Stratum II-III-IV (compressible, saturated)	454 -ft.MSL	50 -ft	129 pcf	132 pcf
Stratum II-III-IV (incompressible, saturated)	404 -ft.MSL	-	-	-
At Point F1: AFTER Landfill Development				
Final Cover System	703 -ft.MSL	3 -ft	129 pcf	132 pcf
Waste Fill	700 -ft.MSL	241 -ft	65 pcf	65 pcf
Protective Soil Cover	459 -ft.MSL	2 -ft	129 pcf	132 pcf
Compacted Low Permeable Soil Liner	457 -ft.MSL	3 -ft	129 pcf	132 pcf
Stratum II-III-IV (compressible, saturated)	454 -ft.MSL	50 -ft	129 pcf	132 pcf
Stratum II-III-IV (incompressible, saturated)	404 -ft.MSL	-	-	-
At Point F2: BEFORE Landfill Development				
Stratum II-III-IV (excavated, dry)	556-ft.MSL	18 -ft	129 pcf	132 pcf
Stratum II-III-IV (excavated, saturated)	538 -ft.MSL	85 -ft	129 pcf	132 pcf
Stratum II-III-IV (compressible, saturated)	453 -ft.MSL	50 -ft	129 pcf	132 pcf
Stratum II-III-IV (incompressible, saturated)	403 -ft.MSL	-	-	-
At Point F2: AFTER Landfill Development				
Final Cover	659-ft.MSL	3 -ft	129 pcf	132 pcf
Waste	656 -ft.MSL	198 -ft	65 pcf	65 pcf
Protective Soil Cover	458 -ft.MSL	2 -ft	129 pcf	132 pcf
Compacted Low Permeable Soil Liner	456 -ft.MSL	3 -ft	129 pcf	132 pcf
Stratum II-III-IV (compressible, saturated)	453 -ft.MSL	50 -ft	129 pcf	132 pcf
Stratum II-III-IV (incompressible, saturated)	403 -ft.MSL	-	-	-

Client Name:	Rancho Viejo Waste Management, LLC
Project Name: Pescadito Environmental Resource Center	**Project No.:** 155145
Modified by: O. Covert	**Date Modified:** 8/1/17
Reviewed by: P. Thomas	**Date Reviewed:** 8/7/17

TITLE: LANDFILL FOUNDATION SETTLEMENT, WASTE SETTLEMENT, AND SOIL LINER STRAIN ANALYSES

Liner / Foundation Settlement Equations

Consolidation is divided into three categories: 1) immediate settlement, 2) primary consolidation settlement, and 3) secondary settlement. Immediate settlement is caused by the elastic deformation of soils without any change in the moisture content. Primary consolidation in saturated fine-grained soils occurs due to the expulsion of water in response to an increase in effective stress. Following primary consolidation under a constant effective stress is secondary consolidation. Primary and secondary consolidations are calculated for the compacted low permeable soil liner. It was determined that the native soils below the low permeability soil liner are overconsolidated (**Reference No. 2**).

Primary Settlement

For overconsolidated soils, where $\Phi'_o < \Phi'_f \leq \Phi'_p$, primary settlement is determined using the following equation:

$$S_p = \frac{C_r}{1 + e_0} * H * \log\left(\frac{\sigma'_f}{\sigma'_o}\right)$$

Where,

- S_p = Primary Settlement, feet
- C_r = Recompression Index
- H = Thickness of the layer, feet
- e_o = Initial void ratio
- σ'_o = Initial vertical effective stress, psf
- σ'_f = Final vertical effective stress, psf

Consolidation parameters have been summarized in **Appendix III-D.5-1** of this Report (**Reference No. 2**).

Secondary Settlement

It is conservatively assumed that primary consolidation is complete subsequent to final cover placement. Secondary consolidation is calculated using the following equation.

$$S_s = \frac{C_\alpha}{1 + e_p} * H * \log\left(\frac{T_2}{T_1}\right)$$

Where:

- S_S = Secondary settlement, feet
- C_α = Secondary compression index
- H = Thickness of Layer, feet
- e_p = Void Ratio at end of primary consolidation
  = e_o (to be conservative)
- T_1 = Time at start of secondary compression, years
- T_2 = Time at end of observation period, years

Values of C_α used in the settlement analyses have been summarized in **Appendix III-D.5-1** of this Report (**Reference No. 2**).

	Client Name:	Rancho Viejo Waste Management, LLC		
APTIM	Project Name:	Pescadito Environmental Resource Center	Project No.:	155145
	Modified by:	O. Covert	Date Modified:	8/1/17
	Reviewed by:	P. Thomas	Date Reviewed:	8/7/17

TITLE: LANDFILL FOUNDATION SETTLEMENT, WASTE SETTLEMENT, AND SOIL LINER STRAIN ANALYSES

Final Cover / Waste Settlement Equations

The waste settlement calculations are based on Terzaghi's theory of one-dimensional consolidation in which the primary settlement, time of primary settlement, and secondary settlement are evaluated. However waste will not experience primary consolidation in the manner of a saturated soil. Waste will undergo initial and primary compression. Both types of compression occur rapidly and are grouped together. The primary settlement is calculated incrementally for nineteen (19) fill lifts of waste and one lift for the final cover placement for one landfill cell. It is assumed that each lift of waste is 20-feet thick and each lift will take 3 months to complete. The estimate for primary settlement assumes that as each lift (or load) is placed large settlements will occur rapidly with no pore pressure build up.

The time of primary compression is estimated to be completed within 2 to 30 days following loading. From this estimate, we can assume that the final cover will only be subjected to the primary settlement from the final lift of the landfill plus secondary settlement that will occur during post-construction / post-closure. The waste settlement calculations focus on the post-closure settlement to evaluate the potential for damage to the final cover system.

The secondary settlement was calculated based on Terzaghi's time-settlement relationship. Because it is assumed that secondary settlement occurs by the self-weight of each fill lift, the secondary settlement is calculated for each lift individually, and then summed to provide a total value for secondary settlement.

Liner / Foundation Settlement Calculations

The equations presented on the previous page were used to estimate the foundation settlement at Points **F1** and **F2**. The thickness of waste at points **F1** and **F2** are **241 feet** and **198 feet**, respectively. The final effective overburden stress and settlement vary accordingly.

Initial Effective Stress. The initial effective stress of the in-situ materials is the average effective stress prior to excavation and waste placement. The initial effective stress for the compacted low permeable soil liner was calculated as the weight of itself. The effective stress is calculated at the center of each geologic unit / layer (please refer to the attached spreadsheets for calculations, provided as **Reference No. 5**).

Final Effective Stress. The final effective stress is the effective stress following final cover placement and varies for settlement points **F1** and **F2**. The effective stress is calculated at the center of each geologic unit / layer (please refer to the attached spreadsheets for calculations, provided as **Reference No. 5**). The effective stress values for initial and final conditions, for each geologic / landfill layer are summarized on **Tables 3** and **4** on the following page.

APTIM	**Client Name:** Rancho Viejo Waste Management, LLC		
	Project Name: Pescadito Environmental Resource Center	**Project No.:** 155145	
	Modified by: O. Covert	**Date Modified:** 8/1/17	
	Reviewed by: P. Thomas	**Date Reviewed:** 8/7/17	

TITLE: LANDFILL FOUNDATION SETTLEMENT, WASTE SETTLEMENT, AND SOIL LINER STRAIN ANALYSES

Table 3 Initial and Final Effective Stresses				
Geologic Unit / Landfill Layer	**Initial Effective Stress**		**Final Effective Stress**	
	Point F1	**Point F2**	**Point F1**	**Point F2**
Compacted Low Permeable Soil Liner	104.4 psf	104.4 psf	16,191.7 psf	13,630.1 psf
Stratum II-III-IV	9,779.4psf	9,978.0 psf	18,269.5 psf	15,474.5 psf

Primary and Secondary Consolidation Settlement

Table 4 below summarizes the calculated settlement at foundation settlement points **F1** and **F2**. Detailed spreadsheets providing a breakdown of the calculations are provided in the attached pages (**Reference No. 5**).

Table 4 Liner / Foundation Settlement			
Landfill Layer	**Primary Settlement**	**Secondary Settlement**	**TOTAL Settlement**
Settlement at Point F1:			
Compacted Low Permeable Soil Liner	0.244101422 –ft	0.018588267 -ft	0.262689689 -ft
Stratum II-III-IV	0.503937507 -ft	0.309804455 -ft	0.813741962-ft
TOTAL:	0.748038929 -ft	0.3289392722 -ft	1.076431652-ft
Settlement at Point F2:			
Compacted Low Permeable Soil Liner	0.235767069 -ft	0.018588267 -ft	0.254355336 -ft
Stratum II-III-IV	0.353931844 -ft	0.309804455 -ft	0.663736299 -ft
TOTAL:	0.589698913 -ft	0.328392722 -ft	0.918091636 -ft

Total Liner / Foundation Settlement. The total settlement of the foundation soils is equal to the summation of the settlement of each geologic unit. The elevation of the top of the compacted low permeability soil liner after settlement will be approximately:

- At Settlement Point F1: (EL. 457-ft MSL) - (1.076431652-ft) = **EL.455.924-ft MSL**
- At Settlement Point F2: (EL. 456-ft MSL) - (0.918091636-ft) = **EL. 455.082-ft MSL**

	Client Name: Rancho Viejo Waste Management, LLC	
APTIM	**Project Name:** Pescadito Environmental Resource Center	**Project No.:** 155145
	Modified by: O. Covert	**Date Modified:** 8/1/17
	Reviewed by: P. Thomas	**Date Reviewed:** 8/7/17

TITLE: LANDFILL FOUNDATION SETTLEMENT, WASTE SETTLEMENT, AND SOIL LINER STRAIN ANALYSES

Differential Settlement

The differential settlement between Points **F1** and **F2** are calculated as follows:

$$S_{diff} = \frac{|S_{pt.F1} - S_{pt.F2}|}{Horizontal\ Distance_{pt.F1/pt.F2}} \times 100\%$$

$$S_{diff} = \frac{|1.076431652\ ft - 0.918091636\ ft|}{214\ ft} = \textbf{0.07399\%}$$

Slope of Leachate Collection System

The leachate collection system (LCS) is designed with a **slope of 0.50%** (slope along LCS collection pipe). During waste placement and post-closure care, differential settlement will occur. At the end of the post-closure care period, the final slope between points **F1** and **F2** will be:

$$Slope_{diff} = \frac{Elev_{pt.F1} - Elev_{pt.F2}}{Horizontal\ Distance_{pt.F1/pt.F2}} \times 100\%$$

$$Slope_{diff} = \frac{(455.924\ ft - 455.082\ ft)}{214\ ft} \times 100\% = \textbf{0.39346\%}$$

Compacted Low Permeable Soil Liner Strain

The maximum strain (ε) the compacted low permeable soil liner will experience from the foundation settlement will be equal to **0.0003178%** which is deemed within acceptable limits for a compacted clay soil, and therefore the soil liner integrity will not be compromised due to cracking (**Reference No. 8**).

$$\varepsilon_{F1,F1} = \frac{\left|\left(L_{F1,F2}\right)_{Final} - \left(L_{F1,F2}\right)_{Initial}\right|}{\left(L_{F1,F2}\right)_{Initial}} \times 100\%$$

$$\left(L_{F1,F2}\right)_{Initial} = \sqrt{(El.\,457ft - El.\,456ft)^2 + (214ft)^2} = 214.002336ft$$

$$\left(L_{F1,F2}\right)_{Final} = \sqrt{(El.\,455.924ft - El.\,455.082ft)^2 + (214ft)^2} = 214.001656ft$$

$$\varepsilon_{F1,F2} = \frac{|(214.001656ft) - (214.002336ft)|}{(214.002336ft)} \times 100\%$$

$$\varepsilon_{F1,F2} = \textbf{0.0003178\%}$$

	Client Name:	Rancho Viejo Waste Management, LLC	
APTIM	**Project Name:**	Pescadito Environmental Resource Center	**Project No.:** 155145
	Modified by: O. Covert		**Date Modified:** 8/1/17
	Reviewed by: P. Thomas		**Date Reviewed:** 8/7/17

TITLE: LANDFILL FOUNDATION SETTLEMENT, WASTE SETTLEMENT, AND SOIL LINER STRAIN ANALYSES

A summary of the differential settlement, soil liner strain, and the initial and final LCS slopes between the foundation settlement point locations analyzed (i.e., F1 and F2) is presented below on **Table 5**.

Table 5 Summary of Foundation Differential Settlement, Initial and Final LCS Slopes, and Soil Liner Strain				
Location	**Foundation Differential Settlement**	**Initial LCS Slope**	**Final LCS Slope**	**Compacted Low Permeable Soil Liner Strain**
Between Settlement Points F1 and F2	0.07399%	0.5%	0.39346%	0.0003178%

Final Cover / Waste Settlement Calculations

The calculated settlement at settlement point **W1** is calculated to be approximately **27.54 feet** (refer to attached spreadsheets in **Reference No. 5**):

$$S_{pt.W1} = (\Delta S_p due\ to\ Final\ Cover\ Placement) + (\ 3S_s\ following\ post\ construction, 30yrs.)$$

$$S_{pt.W1} = (1.10ft + 26.44ft) = \textbf{27.54} ft$$

Differential settlement between points **W1** and **W2** was calculated using a value of **27.54 feet**. At point **W2**, settlement is **0 feet**; therefore, the differential settlement between Points **W1** and **W2** is approximately **4.98 percent**:

$$S_{diff} = \frac{|S_{pt.W1} - S_{pt.W2}|}{Distance_{pt.W1/pt.W2}} \times 100\%$$

$$S_{diff} = \frac{|27.54\ ft - 0.00\ ft|}{553\ ft} = \textbf{4.98}\%$$

Results

Foundation Settlement

The estimated maximum differential settlement of the landfill foundation is approximately 0.0007399 ft/ft. This settlement value is deemed negligible and will not cause failure of the liner or leachate collection system. The slope of the leachate collection system at the end of the post-closure care period will be approximately 0.39% which will allow for proper leachate drainage and collection.

Waste Settlement

The estimated maximum differential settlement of the landfill final slopes due to waste settlement is approximately 0.0498 ft/ft. This value is considered to be negligible and will not cause or contribute to the failure of the final cover system.

Reference No. 4

Figures 1 and 2
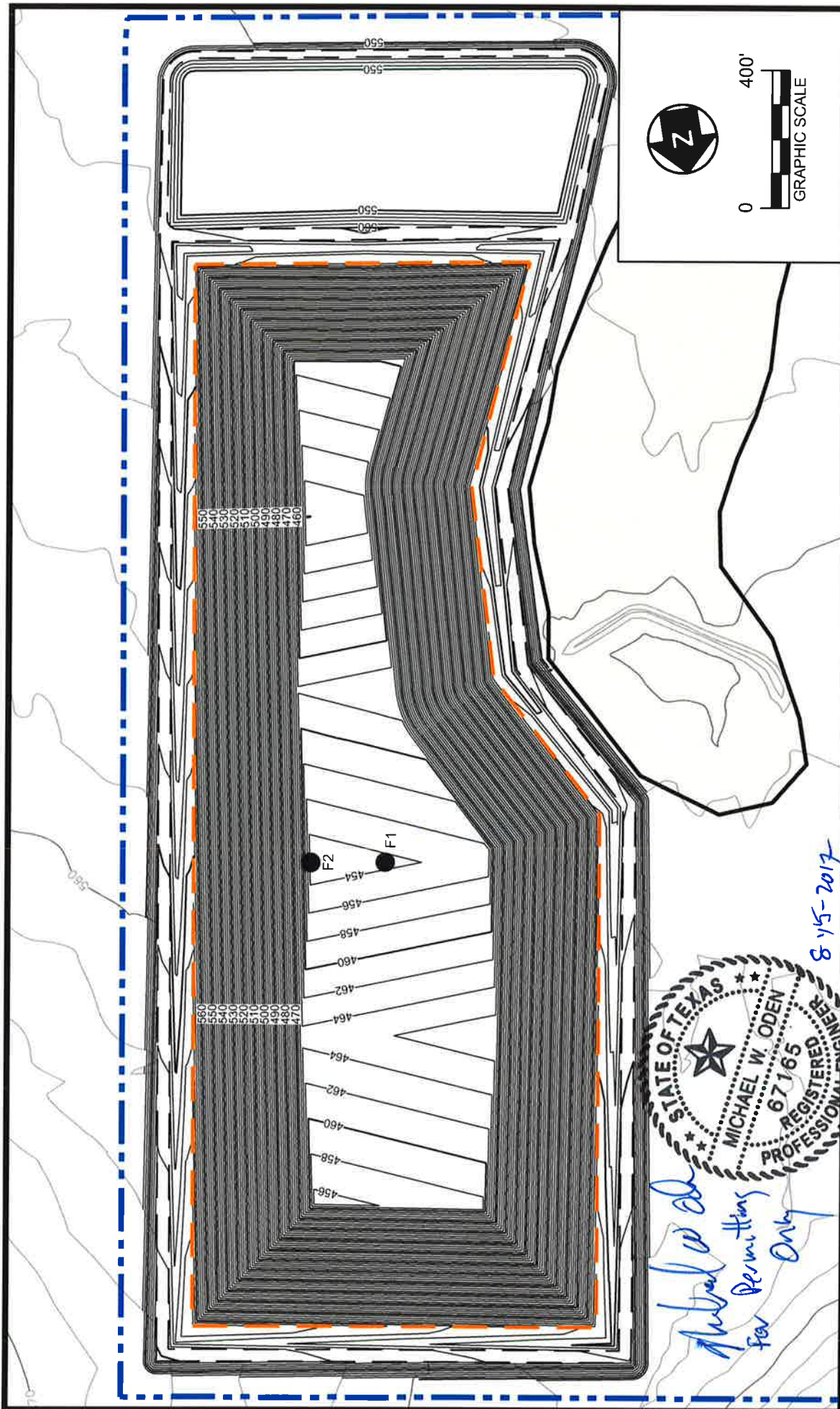
PESCADITO ENVIRONMENTAL RESEARCH CENTER
WEBB COUNTY, TEXAS (MSW 2374)

APPENDIX III-D.5-4, FIGURE 1
LOCATION OF FOUNDATION SETTLEMENT POINTS
SHOWN ON TOP OF MASS EXCAVATION GRADES

APTIM Environmental & Infrastructure, Inc.

(f/k/a/ CB&I Environmental & Infrastructure, Inc.)
TBPE FIRM F-5650

APTIM Environmental & Infrastructure, Inc. has prepared this document for a specific project or purpose. All information contained within this document is copyrighted and remains intellectual property of APTIM Environmental & Infrastructure, Inc. This document may not be used or copied, in part or in whole, for any reason without expressed written consent by APTIM Environmental & Infrastructure, Inc.

APTIM

| DRAWN BY: | ORC | APPROVED BY: | MWO | PROJ. NO.: | 155145 | DATE: | AUGUST 2017 |

GRAPHIC SCALE

0   400'

STATE OF TEXAS
MICHAEL W. ODEN
67165
REGISTERED
PROFESSIONAL ENGINEER

8-15-2017

For Permitting Only

F1
F2

N

GRAPHIC SCALE

0   400'

W2   W1

To Perm Hrg Ab
8-15-2017

STATE OF TEXAS
MICHAEL W. ODEN
67165
REGISTERED
PROFESSIONAL ENGINEER
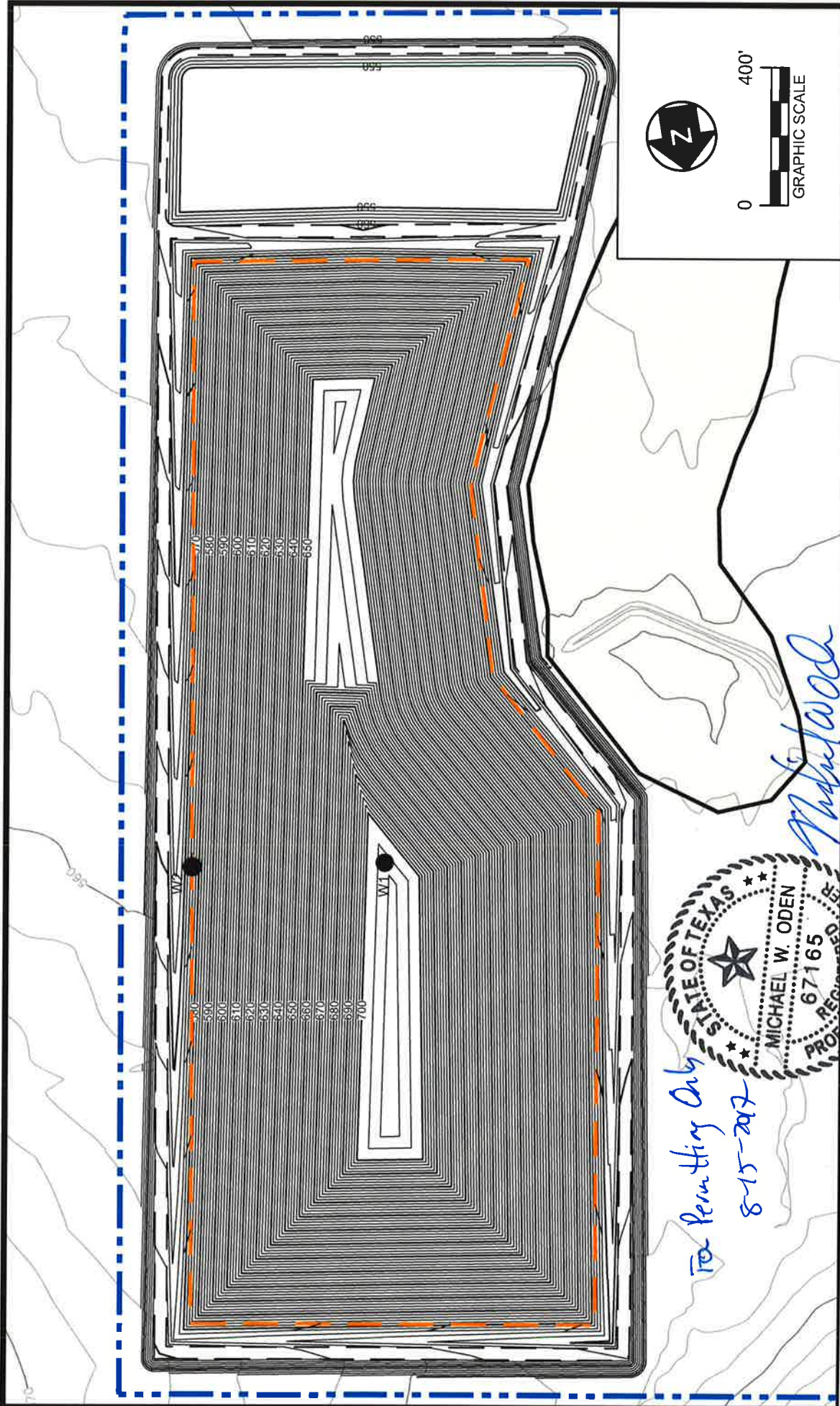
APTIM

APTIM Environmental
& Infrastructure, Inc.

(f/k/a/ CB&I Environmental & Infrastructure, Inc.)
TBPE FIRM F-5650

APTIM Environmental & Infrastructure, Inc. has prepared this document for a specific project or purpose. All information contained within this document is copyrighted and remains intellectual property of APTIM Environmental & Infrastructure, Inc. This document may not be used, reproduced, in part or in whole, for any reason without expressed written consent by APTIM Environmental & Infrastructure, Inc.

PESCADITO ENVIRONMENTAL RESEARCH CENTER
WEBB COUNTY, TEXAS (MSW 2374)

APPENDIX III-D.5-4, FIGURE 2
LOCATION OF WASTE SETTLEMENT POINTS
SHOWN ON TOP OF FINAL LANDFILL GRADES

| DRAWN BY: | ORC | APPROVED BY: | MWO | PROJ. NO.: | 155145 | DATE: | AUGUST 2017 |

Reference No. 5

Foundation and Waste Settlement Calculation Spreadsheets

This document is released for the purpose of permitting only under the authority of Michael W. Oden, P.E. #67165. It has been Updated in August 2017 to match the current landfill configuration. It is not to be used for bidding or construction. Texas Registered Engineering Firm F-5650.

This document is released for the purpose of permitting only under the authority of Jesse P. Varsho, P.E. #114074. It is not to be used for bidding or construction. Texas Registered Engineering Firm F-5650

Appendix III-D.5-4, Landfill Foundation Settlement, Waste Settlement, and Liner Strain Analyses
- Updated calculations to match new landfill geometry

Stress concentrations through cross section of a Landfill

Company Name	APTIM
Project Name	Pescadito Landfill
Project Number	155145
Date	7/26/2017

Units: English

Make sure that the cross sections for both the before and after landfill line up at the bottom geological units under the landfill liner.

Cross Section before landfill development
Settlement Point F1

Unit	Classification	Interval	Thickness (ft)	Relative Density (%)	Unit Weights (pcf)		Mid-Layer Stresses (psf)		Bottom-Layer Stresses (psf)	
					γsat	γbuoyant	σ' (effective)	σ (total)	σ' (effective)	σ (total)
Example	EX	0-2	2		0	0	0.00	0.00	0.00	0.00
Stratum II-III-IV (excavated, dry)	CH	El. 555-538	17		129	129	1,096.50	1,096.50	2,193.00	2,193.00
Stratum II-III-IV (excavated, saturated)	CH	El. 538-454	84		132	69.6	5,116.20	7,737.00	8,039.40	13,281.00
Stratum II-III-IV (compressible, saturated)	CH	El. 454-404	50		132	69.6	9,779.40	16,581.00	11,519.40	19,881.00
Stratum II-III-IV (incompressible, saturated)	CH	El. 404-								

APTIM
August 2017

Stress concentrations through cross section of a Landfill

Company Name	APTIM
Project Name	Pescadito Landfill
Project Number	155145
Date	7/26/2017

Units: English

Cross Section after Landfill
Settlement Point F-1

| Unit | Classification | Interval | Thickness (ft) | Unit Weights (pcf) | | Mid-Layer Stresses (psf) | | Bottom-Layer Stresses (psf) | |
				γ_{sat}	$\gamma_{buoyant}$	σ' (effective)	σ (total)	σ' (effective)	σ (total)
Example	EX	0-2	2	0	0	0.00	0.00	0.00	0.00
Final Cover	CH	El. 703-700	3.083	129	129	198.85	198.85	397.71	397.71
Waste	-	El. 700-459	241	65	65	8,230.21	8,230.21	16,062.71	16,062.71
Protective Cover Soil	CH	El. 459-457	2	129	129	16,191.71	16,191.71	16,320.71	16,320.71
Compacted Low Permeable Soil Liner	CH	El. 457-454	3	132	69.6	16,425.11	16,518.71	16,529.51	16,716.71
Stratum II-III-IV (compressible, saturated)	CH	El. 454-404	50	132	69.6	18,269.51	20,016.71	20,009.51	23,316.71
Stratum II-III-IV (incompressible, saturated)	CH	El. 404-							

Settlement Analysis for the base of a Landfill

Enter data into the necessary white cells
Data must be entered into all the columns that contain comments

Company Name: APTIM

Project Name: Pescadito Landfill
Project Number: 155145
Date: 7/26/2017

Units: English

Life of Landfill (yrs): 6.5
Post-closure care period + Life of Landfill (yrs): 36.5
Total Settlement (ft): 1.07643

Method for Non-Cohesive Soils
Mark X in the correct box
Classical: X
Peck

Settlement Point F1 Unit	Classification	Cohesion or Non-Cohesion (C or N)	Interval	Thickness (ft)	Liquid Limit LL	Corrected Standard Penetration Count N60	Void Ratio e_o	Compression Index Cc	Recompression Index Cr	Secondary Compression Index Ca	Preconsolidation Stress (psf) $\sigma'c$	Mid-Layer Stresses (psf) σ' (initial)	Mid-Layer Stresses (psf) σ' (final)	Primary Settlement	Secondary Settlement	Settlement
Example	EX	C	0-2	2			0	0	0	0	-	1.00	1.00	0	0	0.000000
Compacted Low Permeable Soil Liner	CH	C	El. 457-454	3	58		0.64	0.0609	0.0609	0.0136	-	104.40	16,191.71	0.244101422	0.018588267	0.262689689
Stratum II-III-IV (compressible, saturated)	CH	C	El. 454-404	50	58		0.64	0.4240	0.0609	0.0136	114,763.00	9,779.40	18,269.51	0.503937507	0.309804455	0.813741962
Stratum II-III-IV (incompressible, saturated)	CH	C	El. 404-													

Settlement$_{LINER}$ = 0.244101422 0.018588267 0.262689689
Settlement$_{SUBGRADE}$ = 0.503937507 0.309804455 0.813741962
Totals = 0.748038929 0.326392722 1.076431662

Note:

The compression index (Cc) for the low permeable soil liner was set equal to the recompression index (Cr) since there is no preconsolidation stress.

APTIM
August 2017

Stress concentrations through cross section of a Landfill

Company Name	APTIM
Project Name	Pescadito Landfill
Project Number	155145
Date	7/26/2017

Units: English

Make sure that the cross sections for both the before and after landfill line up at the bottom geological units under the landfill liner.

Cross Section before landfill
Settlement Point F2

Unit	Classification	Interval	Thickness (ft)	Relative Density (%)	Unit Weights (pcf)		Mid-Layer Stresses (psf)		Bottom-Layer Stresses (psf)	
					γsat	γbuoyant	σ' (effective)	σ (total)	σ' (effective)	σ (total)
Example	EX	0-2	2		0	0	0.00	0.00	0.00	0.00
Stratum II-III-IV (excavated, dry)	CH	El. 556-538	18		129	129	1,161.00	1,161.00	2,322.00	2,322.00
Stratum II-III-IV (excavated, saturated)	CH	El. 538-453	85		132	69.6	5,280.00	7,932.00	8,238.00	13,542.00
Stratum II-III-IV (compressible, saturated)	CH	El. 453-403	50		132	69.6	9,978.00	16,842.00	11,718.00	20,142.00
Stratum II-III-IV (incompressible, saturated)	CH	El. 403-								

Stress concentrations through cross section of a Landfill

Company Name	APTIM
Project Name	Pescadito Landfill
Project Number	155145
Date	7/26/2017

| Units | English |

Cross Section after development of landfill
Settlement Point F2

Unit	Classification	Interval	Thickness (ft)	Unit Weights (pcf) γsat	Unit Weights (pcf) γbuoyant	Mid-Layer Stresses (psf) σ' (effective)	Mid-Layer Stresses (psf) σ (total)	Bottom-Layer Stresses (psf) σ' (effective)	Bottom-Layer Stresses (psf) σ (total)
Example	EX	0-2	2	0	0	0.00	0.00	0.00	0.00
Final Cover	CH	EL. 659-656	3.083	129	129	198.85	198.85	397.71	397.71
Waste	-	El. 656-458	198	65	65	6,832.71	6,832.71	13,267.71	13,267.71
Protective Cover Soil	CH	El. 458-456	2	129	129	13,396.71	13,396.71	13,525.71	13,525.71
Compacted Low Permeable Soil Liner	CH	El. 456-453	3	132	69.6	13,630.11	13,723.71	13,734.51	13,921.71
Stratum II-III-IV (compressible, saturated)	CH	El. 453-403	50	132	69.6	15,474.51	17,221.71	17,214.51	20,521.71
Stratum II-III-IV (incompressible, saturated)	CH	El. 403-							

Settlement Point F2
(Page 3 of 3)

Settlement Analysis for the base of a Landfill

Enter data into the necessary white cells
Data must be entered into all the columns that contain comments

Company Name: APTIM

Units: English

Method for Non-Cohesive Soils — Mark X in the correct box

Project Name: Pescadito Landfill

Project Number: 148866
Date: 7/26/2017

Life of Landfill (yrs): **65**
Post-closure care period + Life of Landfill (yrs): **36.5**
Total Settlement (ft): **0.91809**

Classical: **X**
Peck:

Settlement Point F2 Unit	Classification	Cohesion or Non-Cohesion (C or N)	Interval	Thickness (ft)	Liquid Limit LL	Corrected Standard Penetration Count N60	Void Ratio e_o	Compression Index Cc	Recompresion Index Cr	Secondary Compression Index Ca	Preconsolidation Stress (psf) $\sigma'c$	Mid-Layer Stresses (psf) σ' (initial)	Mid-Layer Stresses (psf) σ' (final)	Primary Settlement	Secondary Settlement	Settlement
Example	EX	C	0-2	2			0	0	0	0	-	1.00	1.00	0	0	0.000000
Compacted Low Permeable Soil Liner	CH	C	El. 456-453	3	58		0.64	0.0609	0.0609	0.0136		104.40	13,630.11	0.235767069	0.018588267	0.254355336
Stratum II-III-IV (compressible, saturated)	CH	C	El. 453-403	50	58		0.64	0.4204	0.0609	0.0136	114,763.00	9,978.00	15,474.51	0.353931844	0.309804455	0.663736299
Stratum II-III-IV (incompressible, saturated)	CH	C	El. 403-													

Settlement$_{LINER}$ = 0.235767069   0.018588267   0.254355336
Settlement$_{SUBGRADE}$ = 0.353931844   0.309804455   0.663736299

Totals =   0.589698913   0.328392722   0.918091636

Note:
The compression index (Cc) for the low permeable soil liner was set equal to the recompression index (Cr) since there is no preconsolidation stress.

APTIM
August 2017

Pescadito Landfill - Primary Waste Settlement Calculation

August 2017

Given:

Primary Settlement Eqtn.	$S_p = H \times C'_c(\log((\sigma'_{zo} + \sigma'_{zf})/\sigma'_{zo}))$
	$C'_c = 0.25$
	H_{waste} = height of waste fill lift
	Maximum waste height of cell = 241 feet
	Waste is placed in twelve (12) lifts at 20 feet each and one lift at 1 foot
	$\gamma_{waste\,(pcf)} = 65$
	Each lift takes 3 months to complete
Final Cover	$H_{final\,cover}$ (ft) = 3
	$\gamma_{final\,cover}$ (pcf) = 129
	Assume 3 months to complete construction of final cover
Stresses	σ'_{zo} = initial effective stress (psf)
	σ'_{zf} = final effective stress (psf)
Other Information	Each lift takes 3 months to complete (conservative)
	Life of landfill is assumed to be 6.5 years

Mid-Lift Stresses (psf)

Placement of Lift (mos.)	Lift No.	Depth of Fill Lift (ft)	Total Depth of Fill (ft)	L1 σ'zo	L1 σ'zf	L2 σ'zo	L2 σ'zf	L3 σ'zo	L3 σ'zf	L4 σ'zo	L4 σ'zf	L5 σ'zo	L5 σ'zf	L6 σ'zo	L6 σ'zf	L7 σ'zo	L7 σ'zf	L8 σ'zo	L8 σ'zf	L9 σ'zo	L9 σ'zf	L10 σ'zo	L10 σ'zf	L11 σ'zo	L11 σ'zf	L12 σ'zo	L12 σ'zf	L13 σ'zo	L13 σ'zf	L14 σ'zo	L14 σ'zf	Total Primary Settlement "Sp" (ft)	Incremental Primary Settlement "Sp" (ft)
3	1	20	20	650	650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	1.51
6	2	20	40	650	1,300	650	650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.51	2.39
9	3	20	60	650	1,950	650	1,300	650	650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.89	3.01
12	4	20	80	650	2,600	650	1,950	650	1,300	650	650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.90	3.49
15	5	20	100	650	3,250	650	2,600	650	1,950	650	1,300	650	650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.40	3.89
18	6	20	120	650	3,900	650	3,250	650	2,600	650	1,950	650	1,300	650	650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.29	4.23
21	7	20	140	650	4,550	650	3,900	650	3,250	650	2,600	650	1,950	650	1,300	650	650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.51	4.52
24	8	20	160	650	5,200	650	4,550	650	3,900	650	3,250	650	2,600	650	1,950	650	1,300	650	650	-	-	-	-	-	-	-	-	-	-	-	-	23.03	4.77
27	9	20	180	650	5,850	650	5,200	650	4,550	650	3,900	650	3,250	650	2,600	650	1,950	650	1,300	650	650	-	-	-	-	-	-	-	-	-	-	27.80	5.00
30	10	20	200	650	6,500	650	5,850	650	5,200	650	4,550	650	3,900	650	3,250	650	2,600	650	1,950	650	1,300	650	650	-	-	-	-	-	-	-	-	32.80	5.21
33	11	20	220	650	7,150	650	6,500	650	5,850	650	5,200	650	4,550	650	3,900	650	3,250	650	2,600	650	1,950	650	1,300	650	650	-	-	-	-	-	-	38.01	5.40
36	12	20	240	650	7,800	650	7,150	650	6,500	650	5,850	650	5,200	650	4,550	650	3,900	650	3,250	650	2,600	650	1,950	650	1,300	650	650	-	-	-	-	43.40	0.33
39	13	1	241	650	7,833	650	7,183	650	6,533	650	5,883	650	5,233	650	4,583	650	3,933	650	3,283	650	2,633	650	1,983	650	1,333	650	683	33	33	-	-	43.73	1.10
42	final cover	3.000	244.000	650	7,930	650	7,280	650	6,630	650	5,980	650	5,330	650	4,680	650	4,030	650	3,380	650	2,730	650	2,080	650	1,430	650	780	33	130	98	98	44.84	(Σ Sp = 44.84)

Notes:

Incremental settlement is the difference of the total primary settlement number and the previous total primary settlement number.

Pescadito Landfill - Secondary Waste Settlement Calculation
August 2017

Given:	
Waste	**Secondary Settlement Eqtn:** $S_s = [(C'_\alpha) * (H_o) * (\log(t_2/t_1))]$ $\quad C'_\alpha = 0.051$ Maximum height of cell = 241 ft. (waste) + 3 ft. (cover) = 244 ft. Waste is placed in twelve (12) lifts at 20 ft. each and one lift at one foot $\quad H_o =$ height of lifts 1-12 = 20 feet lift 13 = 1 feet Assume 3 months to complete each lift: $t_1 =$ 0.25 yrs
Final Cover	**Secondary Settlement Eqtn:** $S_s = [(C_\alpha)/(1+e_o)] * (H_o) * (\log(t_2/t_1))]$ $\quad e_o = 0.064$ $\quad C_\alpha = 0.0136$ $\quad H_o =$ height of final cover = 3 feet Assume 3 months to complete construction of final cover
Other Information	Landfill life conservatively assumed = 6.5 years Post Closure monitoring period = 30 years $t_1 =$ time of pseudo-primary settlement to occur after completion of fill (years) $t_2 =$ time after placed fill and post-closure (years) = (30 + 30 - ($\sum t_x$))

Lift No.	(A) Total Time in Months to Complete Filling of Lifts	(B) Total Time in Years to Complete Filling of Lifts ($\sum t_x$)	(C) t_1 (yrs)	(D) t_2 (yrs)	t_2/t_1	S_s (ft)
1	3	0.25	0.25	36.25	145	2.205
2	6	0.50	0.25	36.00	144	2.202
3	9	0.75	0.25	35.75	143	2.198
4	12	1.00	0.25	35.50	142	2.195
5	15	1.25	0.25	35.25	141	2.192
6	18	1.50	0.25	35.00	140	2.189
7	21	1.75	0.25	34.75	139	2.186
8	24	2.00	0.25	34.50	138	2.183
9	27	2.25	0.25	34.25	137	2.179
10	30	2.50	0.25	34.00	136	2.176
11	33	2.75	0.25	33.75	135	2.173
12	36	3.00	0.25	33.50	134	2.170
13	39	3.25	0.25	33.25	133	0.108
final cover	42	3.50	0.25	33.00	132	0.081
					Σ Settlement =	26.44

Notes:

(A) = 3 months + time for filling previous lifts

(B) = Col.(A) / 12

(C) = (3 mos.) x (1 yr./12mos.) = 0.25

(D) = 30 + 30 - Col.(B)

Pescadito ERC – Part III, Appendix III-D.5-4, Ref. 5
Foundation Settlement, Waste Settlement,
and Soil Liner Strain   Page 8 of 8

APTIM
August 2107