GEOSYNTEC CONSULTANTS

COMPUTATION COVER SHEET

Client: Honeywell **Project:** Onondaga Lake ILWD Stability **Project/Proposal #:** GJ4204 **Task #:** 14-05

TITLE OF COMPUTATIONS **STATIC SLOPE STABILITY ANALYSES**

COMPUTATIONS BY: Signature Fan Zhu 1/17/2011 DATE
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APPROVED BY: (PM or Designate) Signature 17 JAN 2011 DATE
Printed Name and Title: Jay Beech, Principal

APPROVAL NOTES: ______________________

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

Written by:	**Fan Zhu**	Date:	**1/14/2011**	Reviewed by:	**Ming Zhu/R. Kulasingam/Jay Beech**	Date:	**1/14/2011**
Client:	**Honeywell**	Project:	**Onondaga Lake ILWD Stability**	Project/ Proposal No.:	**GJ4204**	Task No.:	**14-05**

STATIC SLOPE STABILITY ANALYSES

INTRODUCTION

This calculation package was prepared as part of the Remediation Area D geotechnical stability analysis for the Onondaga Lake Bottom Site. Specifically, the purpose of this package is to present static slope stability analyses for Remediation Area D after dredging, during capping, and after capping. Remediation Area D, which is also referred to as the In-Lake Waste Deposit (ILWD), is shown in Figure 1. Remediation Area D consists predominantly of Sediment Management Unit (SMU) 1 with limited portions of SMUs 2 and 7. The static slope stability was evaluated for (i) overall general cross sections along the ILWD slope, and (ii) localized areas that have relatively steep slopes. Analyses were performed for both undrained and drained cases under the interim condition after dredging, the interim condition during the potential phases of capping, and the final condition after capping.

It should be noted that the cap configurations used in the analyses presented herein are consistent with the mean cap thickness, as documented in the main text of the *Capping, Dredging, and Habitat Design.* For the purpose of the analyses presented herein, the maximum potential difference in cap thickness during the capping phases was assumed, as described later in this package.

Seismic slope stability analyses for the Remediation Area D after capping were performed and are presented in a separate calculation package titled "*Seismic Slope Stability Analyses*" in Appendix H.4 of the *Capping, Dredging, and Habitat Design*.

METHODOLOGY

<u>Static Slope Stability</u>

Static slope stability analyses were performed using Spencer's method [Spencer, 1973], as implemented in the computer program SLIDE, version 5.0 [Rocscience, 2006]. Spencer's method, which satisfies both vertical and horizontal force equilibrium and moment equilibrium, is considered to be more rigorous than other methods, such as the simplified Janbu method [Janbu, 1973] and the simplified Bishop method [Bishop, 1955].

In general, selection of a slope stability method depends on the accuracy of the analytical derivation of the method as well as the numerical implementation in a slope stability program. SLIDE 5.0 offers nine separate methods to analyze slope stability. Ordinary or Fellenius and

Simplified Bishop methods satisfy only force equilibrium in one direction and moment equilibrium. Janbu's simplified, Corps of Engineers' (#1 and #2), and Lowe-Karafiath methods satisfy only force equilibrium in two directions. Janbu's corrected method as implemented in SLIDE uses a modification factor to correct the factor of safety to indirectly account for moment equilibrium. Spencer's, General Limit Equilibrium (GLE), and Morgenstern-Price methods satisfy force equilibrium in two directions and moment equilibrium. The implementation of GLE method in SLIDE is essentially the same as Morgenstern-Price method. Based on the number of equilibrium equations satisfied, Spencer's and GLE/Morgenstern-Price methods are the most rigorous methods available. GLE/Morgenstern-Price method is generally not available in many slope stability programs due to the complexity of numerical implementation, and therefore the experience of applying this method in general practice is significantly less than that for Spencer's method. For this reason, Spencer's method is the preferred method in standard practice for analyzing general circular slip surfaces. Therefore, Spencer's method was chosen as the standard method for performing slope stability analyses for potential circular failure surfaces.

Rotational type failure mode (i.e., circular slip surfaces) was considered to assess the slope stability factor of safety (FS) at the selected cross sections. The SLIDE program generated several potential circular slip surfaces, calculated the FS for each of these surfaces, and identified the most critical slip surface (i.e., the slip surface with the lowest FS). Wedge type slip surfaces were not considered applicable for Remediation Area D because they generally only apply when known weak layers or interfaces are present. Regardless, an independent analysis was performed assuming wedge type slip surfaces. The results indicated that the FSs calculated using the wedge type slip surfaces were greater than those calculated using the circular slip surfaces. Therefore, only circular slip surfaces were evaluated and presented in this package.

Information required for the analyses included:

- geometry of the slope;
- subsurface soil stratigraphy;
- water table;
- properties of subsurface materials; and
- external loading and support conditions, if any.

Target Factor of Safety

The Statement of Work (SOW) attachment of the Consent Decree (CD) provided guidelines for evaluating the stability of the ILWD. A FS of 1.5 is required for the long-term static condition. This is consistent with target FS values used in general engineering practice for the long-term condition [Hammer and Blackburn, 1977; USACE, 2003]. A minimum required FS of 1.3 was selected for the interim condition [USACE, 2003].

SUBSURFACE STRATIGRAPHY

Detailed information regarding the subsurface stratigraphy is presented in Appendix H.1 of the *Capping, Dredging, and Habitat Design* in a calculation package titled "*Summary of Subsurface Stratigraphy and Material Properties*" (referred to as the Data Package). In summary, the subsurface stratigraphy primarily consists of the following materials: Solvay Waste (SOLW), Marl, Silt and Clay, Silt and Sand, Sand and Gravel, Till, and Shale. In isolated areas of the ILWD, thin silt layers are present over the SOLW. The elevation of the lake water surface in the ILWD was assumed to be El. 363 feet above mean sea level (NAVD88), as presented in the Data Package.

The subsurface profile of the ILWD was developed based on the elevation of each layer from the boring logs provided by Parsons. As explained in the Data Package, the deeper surfaces (e.g., bottom of Silt and Clay, bottom of Silt and Sand) that were below the depth of the shallow borings were developed based on a limited number of deeper borings in the ILWD. Since critical slip surfaces identified in the analyses are generally located within depths that were covered by the shallower borings (i.e., borings that terminated in or above the Silt and Clay layer), this is not expected to affect the static slope stability evaluation.

ANALYZED CROSS SECTIONS

As shown on the proposed dredging plan in Figure 1, eight cross sections were selected for the stability analyses. The dredging plan was developed by Anchor QEA and provided to Geosyntec by Parsons. Cross Sections 1 through 5 were selected to represent the overall general slope of the ILWD bottom. Cross Sections A to C were selected to represent potentially critical localized steep slopes. The geometries of Cross Sections 1 through 5 and Cross Sections A through C after dredging are presented in Figures 2 to 9.

As documented in the main text of the *Capping, Dredging, and Habitat Design*, the total cap thickness varies with the water depth. The minimum and mean thicknesses of each cap component correspond to several ranges in water depths. The following potentially critical conditions during and after capping were analyzed:

- <u>Overall General Slopes during Capping:</u> The potential condition where only the cap in 0 to 3 ft of water near the shoreline is constructed and the cap has a mean (with overplacement) total thickness of 4.4 ft was considered to be the most critical condition based on a preliminary analysis. As an example, the analyzed geometry of Cross Section 1 during capping is shown in Figure 10.
- <u>Localized Steep Slopes during Capping:</u> The potential condition where only the cap in the shallower water zone (i.e., upslope side of the cross section) is constructed and the cap has the mean (with overplacement) total thickness corresponding to the water depth was considered to be the most critical condition based on a preliminary analysis. As an example, the analyzed geometry of Cross Section A during capping is shown in Figure 11.
- <u>Overall General Slopes and Localized Steep Slopes after Capping of Remediation Area D:</u> The potential condition where the cap in 10 to 30 ft of water has the minimum total thickness, while the caps in other areas have the mean (with overplacement) total thicknesses was considered to be the most critical condition based on a preliminary analysis. The same cap configuration for the overall general slopes was applied to the localized steep slopes. As examples, the analyzed geometry of Cross Sections 1 and A after capping are shown in Figures 12 and 13, respectively.

MATERIAL PROPERTIES

Detailed information related to the selection of subsurface material properties was presented in the Data Package. Table 1 summarizes the properties (i.e., unit weights, undrained and drained shear strengths) of each subsurface material and the cap material (i.e., the sand) used in the slope stability analyses.

It should be noted that to model the condition immediately after capping when the excess pore water pressure due to the cap has not yet dissipated and no shear strength gain has yet been achieved, the undrained shear strength ratios of the Marl and the Silt and Clay were manually adjusted (i.e., reduced as compared to the ratios used for the other conditions) in the slope stability program (i.e., SLIDE). This adjustment was necessary because the program automatically adds the effective cap loading to the vertical effective stress before calculating the undrained shear strength values. The reduced undrained shear strength ratios were selected so that the calculated undrained shear strengths are approximately the same before and immediately after cap placement. The calculation of the reduced undrained shear strength ratios for Marl and Silt and Clay are presented in Attachment 1 of this package. For the condition during dredging, the program automatically considers the reduction of undrained shear strength of the Marl and the Silt and Clay due to the reduction in vertical effective stress caused by dredging.

RESULTS AND CONCLUSIONS

The static slope stability of Remediation Area D after dredging, during capping and after capping was evaluated for five overall general slopes (i.e., Cross Sections 1 through 5) and three localized steep slopes (i.e., Cross Sections A through C). The results of the static slope stability analyses are summarized in Table 2. As examples, the critical circular slip surfaces for Cross Sections 4 and C are shown in Figures 14 through 25.

Under the interim condition after dredging, the calculated FSs for the selected eight cross sections range from 2.6 to 9.0 for the undrained case and 2.2 to 3.9 for the drained case. Under the interim condition during capping, the calculated FSs for the eight selected cross sections range from 2.1 to 2.5 for both the undrained and the drained cases. Under the final condition after capping, the calculated FSs for the eight selected cross sections range from 2.1 to 2.9 for both the undrained and the drained cases. The results indicate that the selected cross sections have acceptable calculated FSs.

Additional analyses were performed to evaluate the sensitivity of slope stability to the undrained and drained shear strengths of SOLW. One of the critical cross sections, i.e., Cross Section 3, was selected for the sensitivity analyses. In the sensitivity analyses, the SOLW shear strength values were reduced to represent the mean minus one standard deviation (i.e., 165 psf for the undrained shear strength) or lower value (i.e., 29 degrees for the drained friction angle), which were calculated based on the laboratory tests. The sensitivity analysis results indicate that (i) for the interim condition after dredging, the calculated FS is 2.4 for the undrained case and 1.6 for the drained case; (ii) for the interim condition during capping, the calculated FS is 1.8 for the undrained case and 2.5 for the drained case; and (iii) for the final condition after capping, the calculated FS is 1.8 for the undrained case and 2.5 for the drained case. Therefore, the calculated FSs are greater than the target FSs for the critical cross section using the reduced shear strengths for SOLW.

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Janbu, N., "Slope Stability Computations," Embankment Dam Engineering, Casagrande Memorial Volume, R. C. Hirschfield and S. J. Poulos, Eds., John Wiley, New York, 1973, pp. 47-86.

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Spencer, E., "The Thrust Line Criterion in Embankment Stability Analysis," *Géotechnique*, Vol. 23, No. 1, pp. 85-100, March 1973.

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Tables

Table 1. Summary of Material Properties for Slope Stability Analyses

Material	Unit Weight (pcf)	Drained Shear Strength, ϕ' (degrees)	Undrained Shear Strength used for analysis after dredging	Undrained Shear Strength used for analysis during and after capping
Cap-Sand[1]	120	32	N/A	N/A
Silt[2]	98	32	N/A	N/A
SOLW	81	37	240 psf	240 psf
Marl	98	32	$S_u/\sigma_v'=0.35$	$S_u/\sigma_v'=0.24$[3],[4]
Silt and Clay	108	30	$S_u/\sigma_v'=0.35$	$S_u/\sigma_v'=0.26$[3],[4]
Silt and Sand	120	32	N/A	N/A
Sand and Gravel	120	32	N/A	N/A
Till	120	40	N/A	N/A
Shale	120	40	N/A	N/A

Notes:

[1]. For the purpose of the slope stability analysis, the relatively thin layer of gravel in the proposed cap was not modeled. The gravel material is expected to have a larger friction angle than the sand. Therefore, not modeling the gravel component of the cap in the slope stability analysis was considered to be conservative.

[2]. The unit weight and the drained shear strength of Marl were used for Silt overlying the SOLW in certain areas of the ILWD.

[3]. The undrained shear strength ratios of Marl and Silt and Clay below the cap were manually reduced in the SLIDE program to avoid the increase of undrained shear strengths of Marl and Silt and Clay due to the additional load from cap. For the portion of cross section without cap, the original ratio of 0.35 was applied to Marl and Silt and Clay.

[4]. The reduced undrained shear strength ratios were calculated as described in Attachment 1.

Table 2. Summary of Static Slope Stability Analysis Results

Analyzed Scenario	Cross Section	Interim-Condition (after dredging)			Interim-Condition (during capping)			Final-Condition (after capping)			Note
		Calculated Minimum FS	Target FS	Is FS OK?	Calculated Minimum FS	Target FS	Is FS OK?	Calculated Minimum FS	Target FS	Is FS OK?	
Undrained	1	7.09	1.3	Yes	2.50	1.3	Yes	2.63[1]	1.5	Yes	
	2	2.64	1.3	Yes	2.50	1.3	Yes	2.64[1]	1.5	Yes	
	3	2.64	1.3	Yes	2.40	1.3	Yes	2.40[1]	1.5	Yes	
	4	7.30	1.3	Yes	2.51	1.3	Yes	2.86[1]	1.5	Yes	Results shown in Figures 14, 16 and 18
	5	7.16	1.3	Yes	2.33	1.3	Yes	2.33[1]	1.5	Yes	
	A	9.01	1.3	Yes	2.50	1.3	Yes	2.58[1]	1.5	Yes	
	B	4.63	1.3	Yes	2.12	1.3	Yes	2.12[1]	1.5	Yes	
	C	2.94	1.3	Yes	2.50	1.3	Yes	2.58[1]	1.5	Yes	Results shown in Figures 20, 22 and 24
Drained	1	3.23	1.3	Yes	2.50	1.3	Yes	2.63	1.5	Yes	
	2	2.64	1.3	Yes	2.32	1.3	Yes	2.64	1.5	Yes	
	3	2.15	1.3	Yes	2.50	1.3	Yes	2.50	1.5	Yes	
	4	2.16	1.3	Yes	2.51	1.3	Yes	2.86	1.5	Yes	Results shown in Figures 15, 17 and 19
	5	2.18	1.3	Yes	2.50	1.3	Yes	2.50	1.5	Yes	
	A	3.85	1.3	Yes	2.39	1.3	Yes	2.58	1.5	Yes	
	B	2.78	1.3	Yes	2.12	1.3	Yes	2.12	1.5	Yes	
	C	2.94	1.3	Yes	2.50	1.3	Yes	2.58	1.5	Yes	Results shown in Figures 21, 23 and 25

Note:

[1].The FSs were calculated using the reduced undrained shear strength ratios of Marl and Silt and Clay.

Figures

Written by:	Fan Zhu	Date:	1/14/2011	Reviewed by:	Ming Zhu/R. Kulasingam/Jay Beech	Date:	1/14/2011
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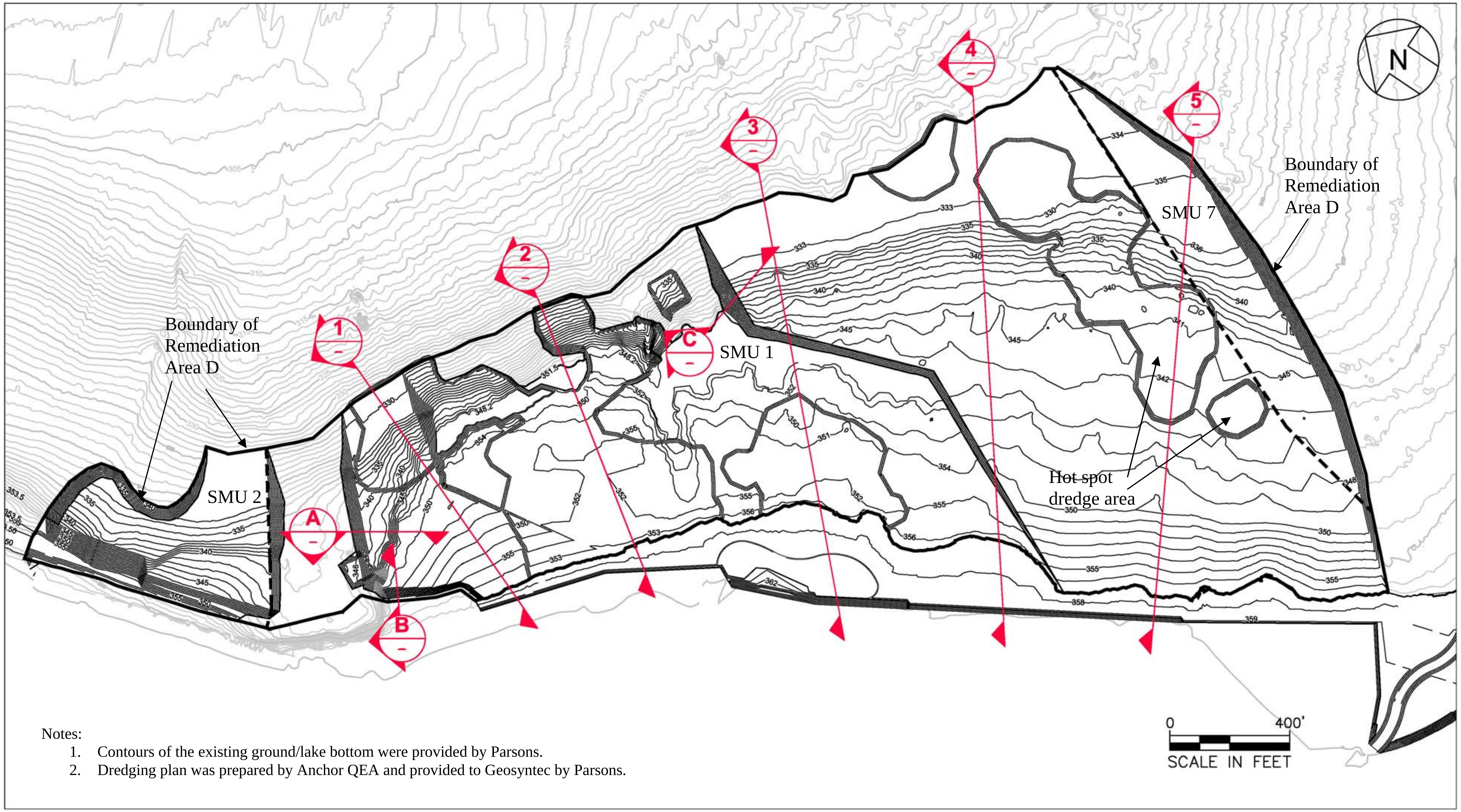

Figure 1. Locations of Selected Cross Sections on Dredging Plan
(Dredging plan was prepared by Anchor QEA and provided to Geosyntec by Parsons)

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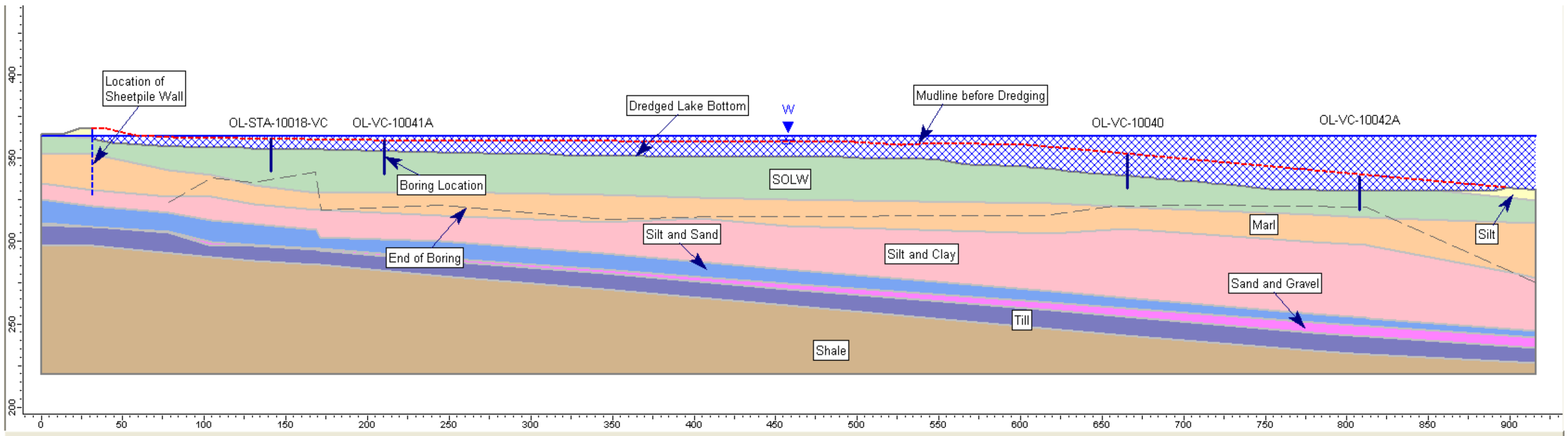

Figure 2. Geometry of Cross Section 1

Notes:

1. Axes show distances and elevations in feet.
2. Subsurface profiles below the line of end of boring were estimated based on information from deeper borings located elsewhere in Remediation Area D.
3. At several locations, the borings shown in the figure are offset from the cross section line. As a result, the end of the boring at these locations does not match exactly the line of end of boring.
4. The above notes apply to Figures 3 through 6.

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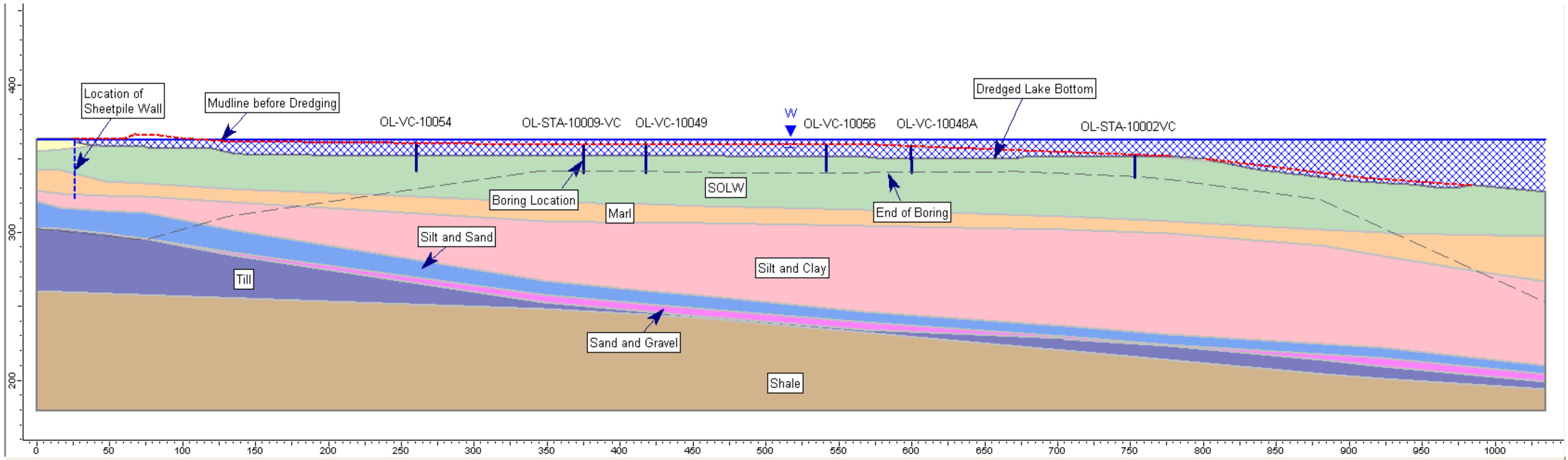

Figure 3. Geometry of Cross Section 2

Notes:
1. See notes for Figure 2.

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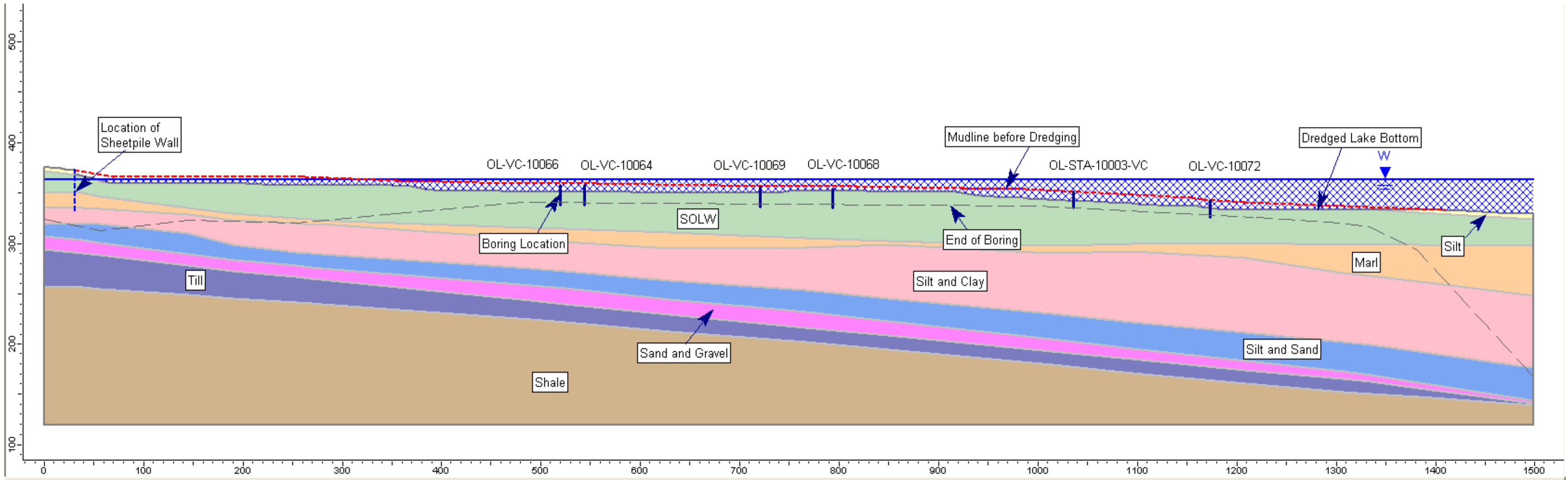

Figure 4. Geometry of Cross Section 3

Notes:

1. See notes for Figure 2.

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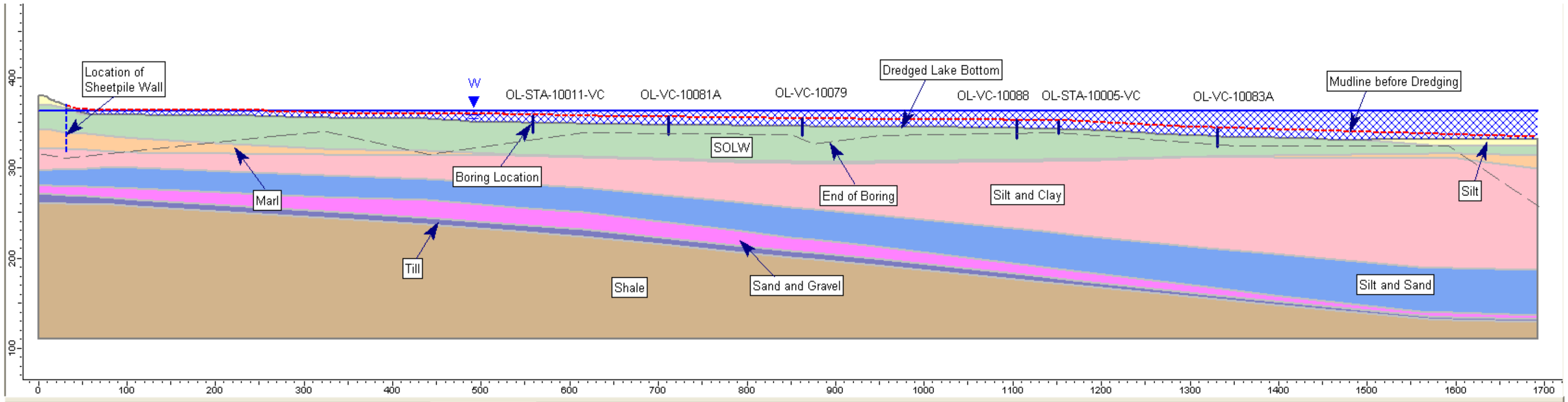

Figure 5. Geometry of Cross Section 4

Notes:

1. See notes for Figure 2.

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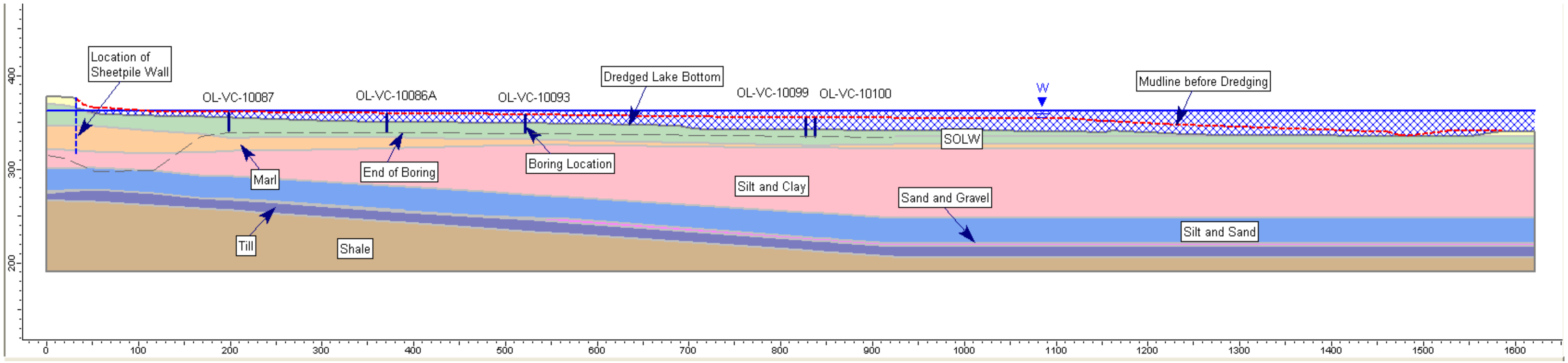

Figure 6. Geometry of Cross Section 5

Notes:

1. See notes for Figure 2.
2. The subsurface layer boundaries (i.e., the boundaries below the original mudline and the dredged lake bottom) were extended horizontally beyond the station of 850 ft for the purpose of slope stability analysis.

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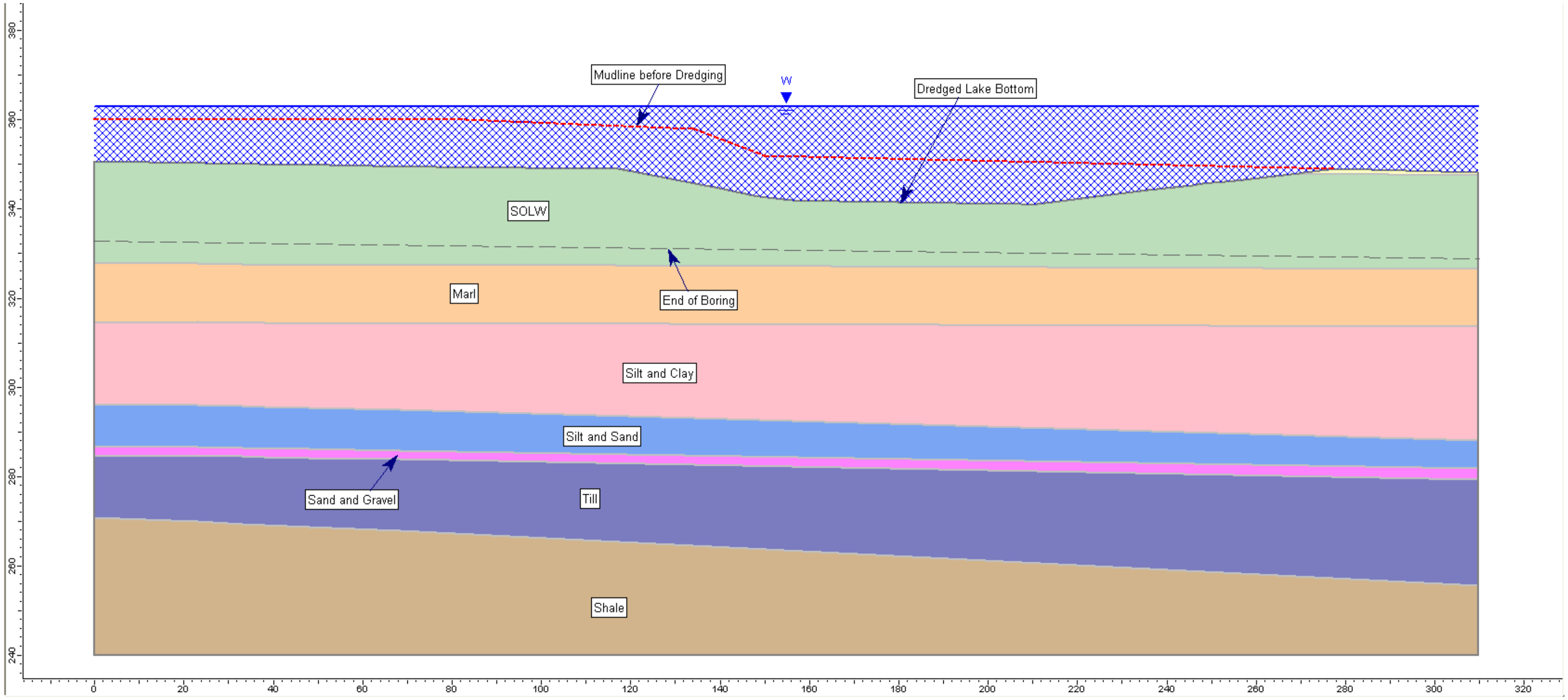

Figure 7. Geometry of Cross Section A

Notes:

1. Axes show distances and elevations in feet.
2. Subsurface profiles below the line of end of boring were estimated based on information from deeper borings.
3. The above notes apply to Figures 8 and 9.

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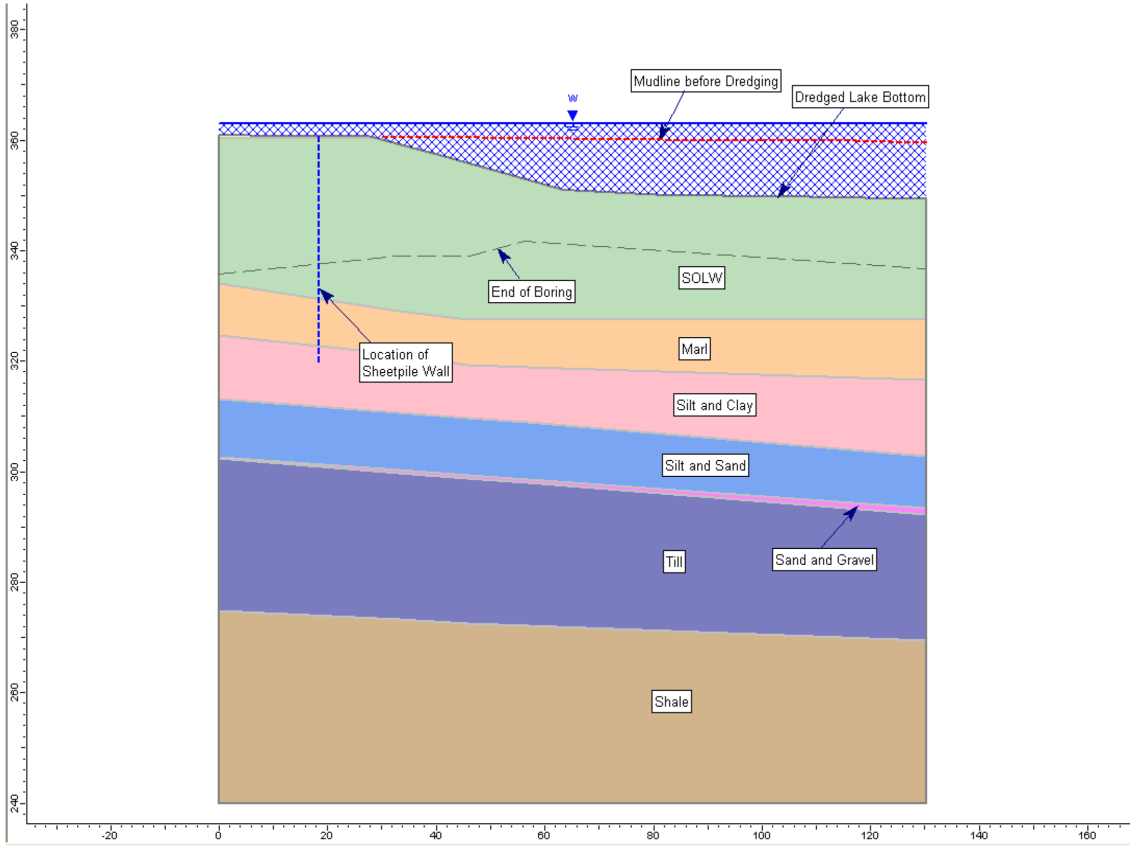

Figure 8. Geometry of Cross Section B

Notes:

1. See notes for Figure 7.

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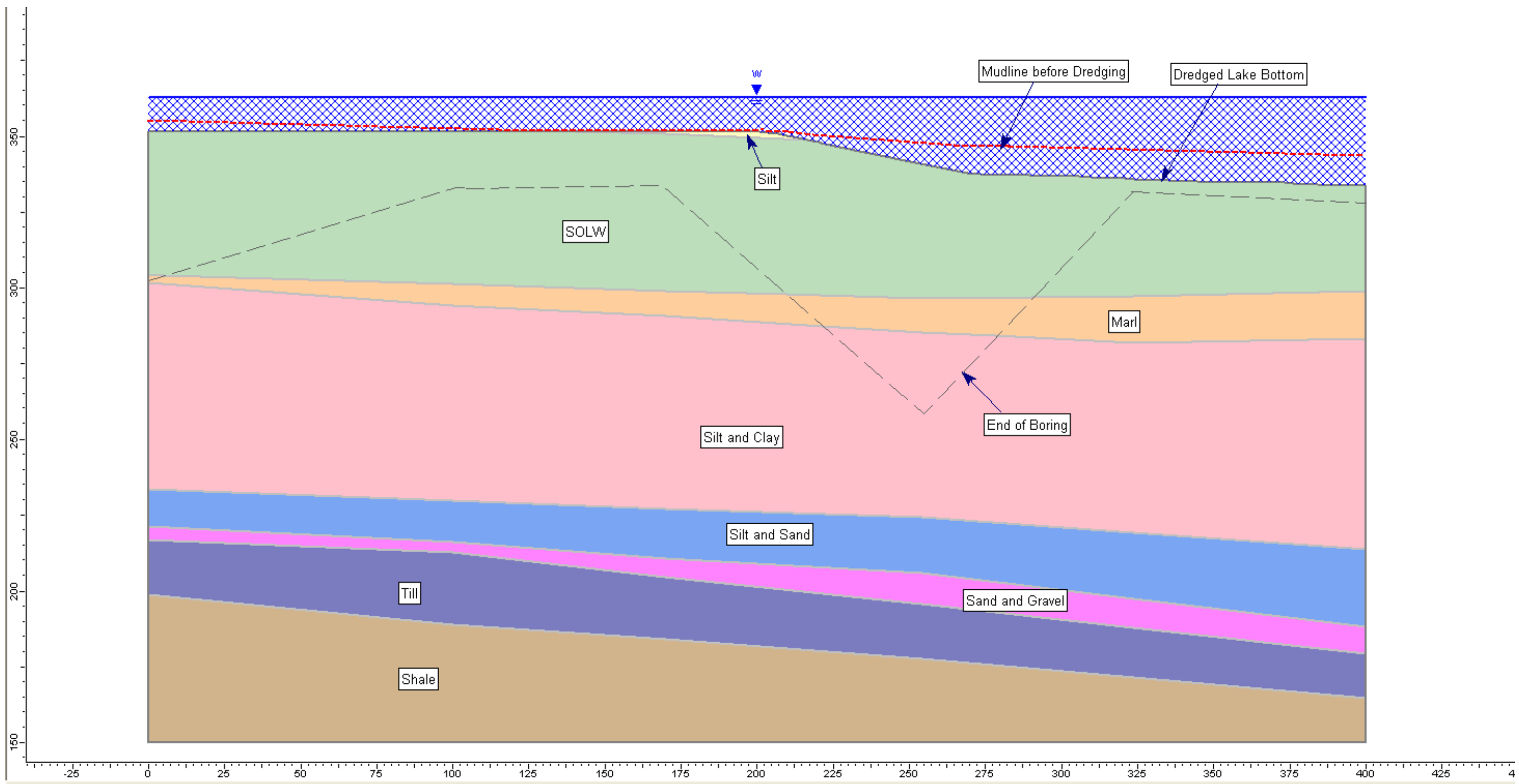

Figure 9. Geometry of Cross Section C

Notes:

1. See notes for Figure 7.

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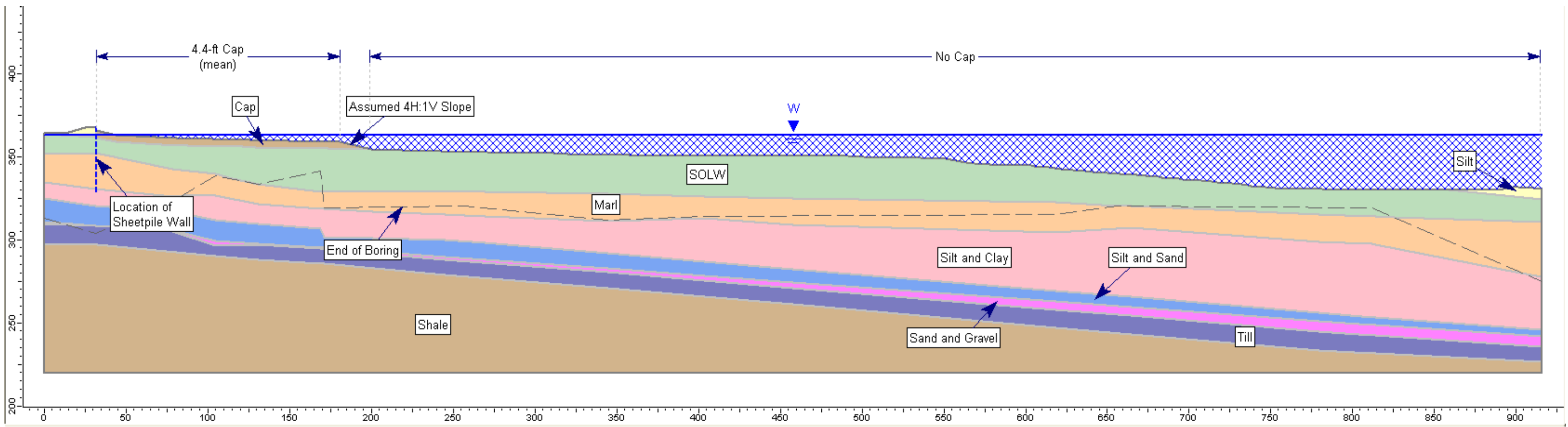

Figure 10. Analyzed Geometry of Cross Section 1 during Capping

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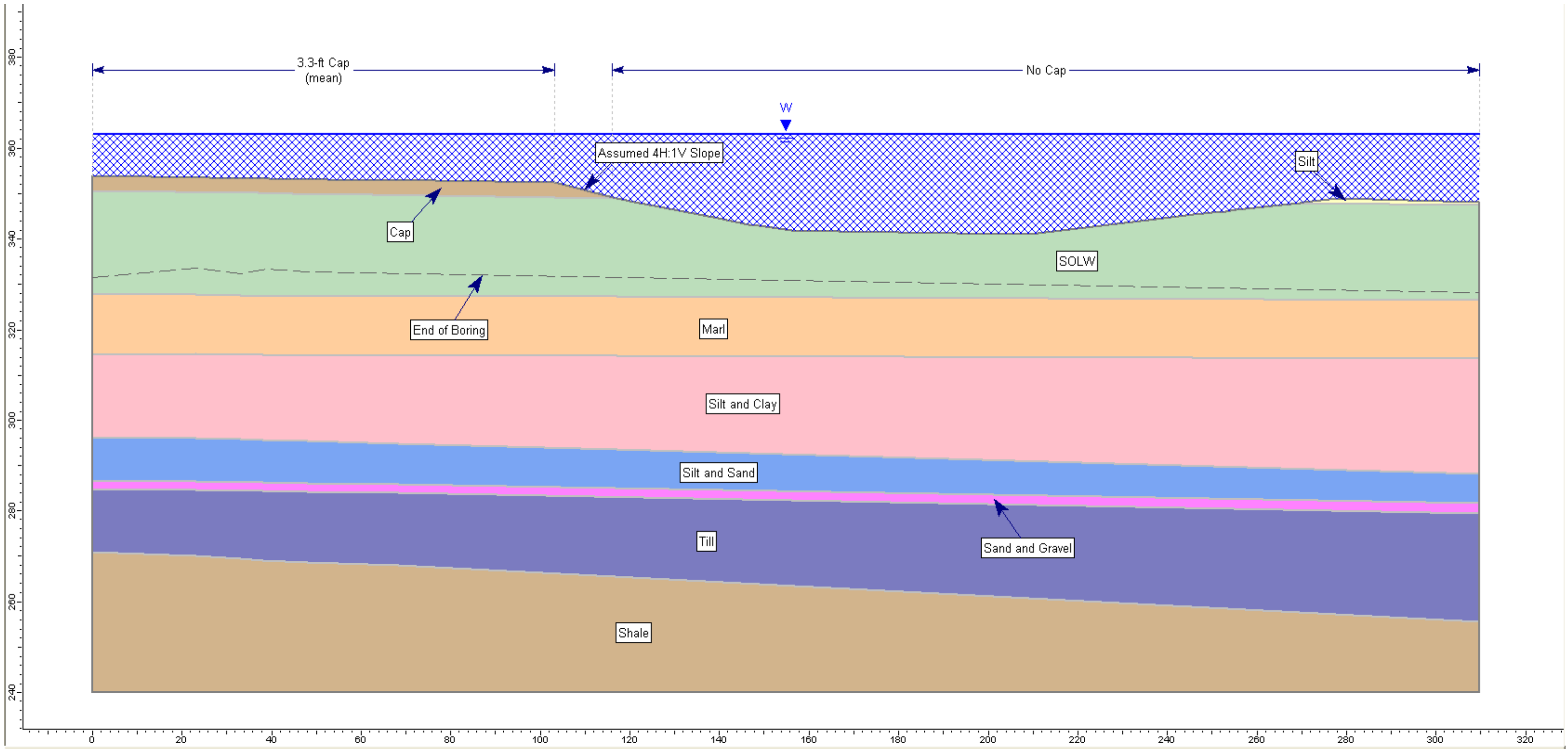

Figure 11. Analyzed Geometry of Cross Section A during Capping

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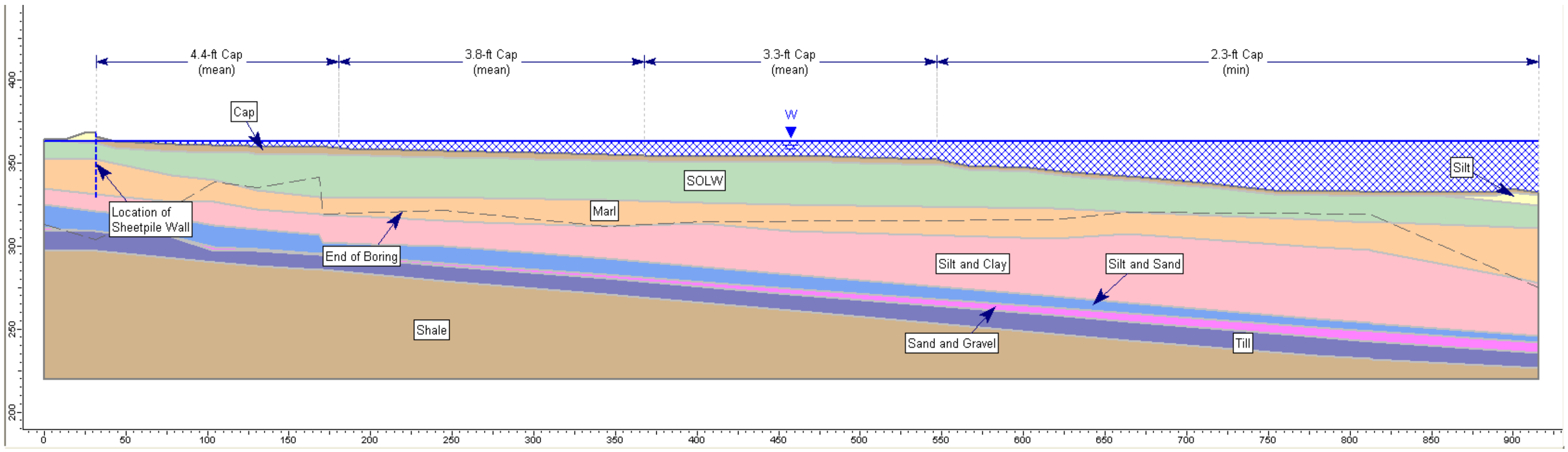

Figure 12. Analyzed Geometry of Cross Section 1 after Capping

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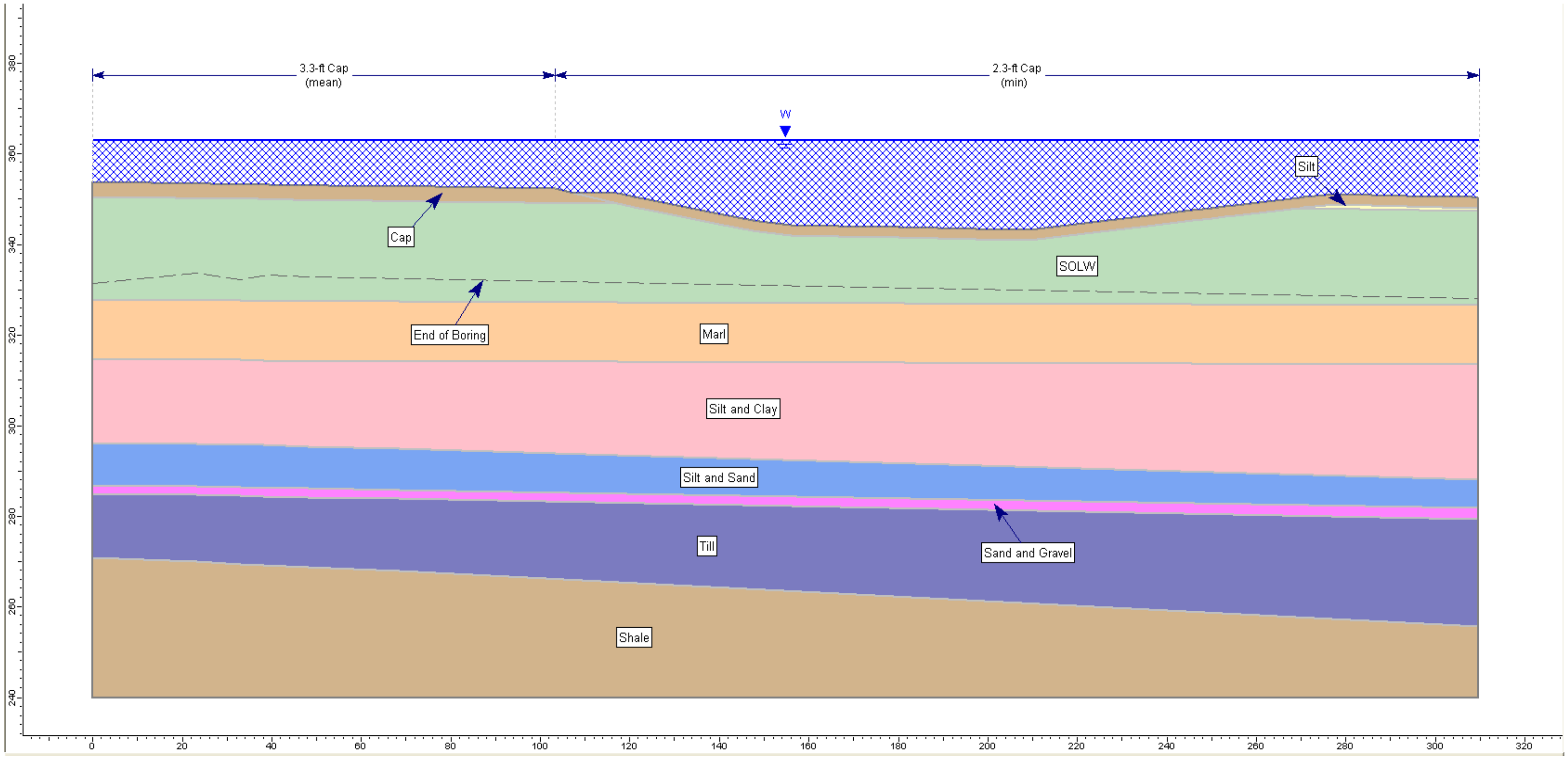

Figure 13. Analyzed Geometry of Cross Section A after Capping

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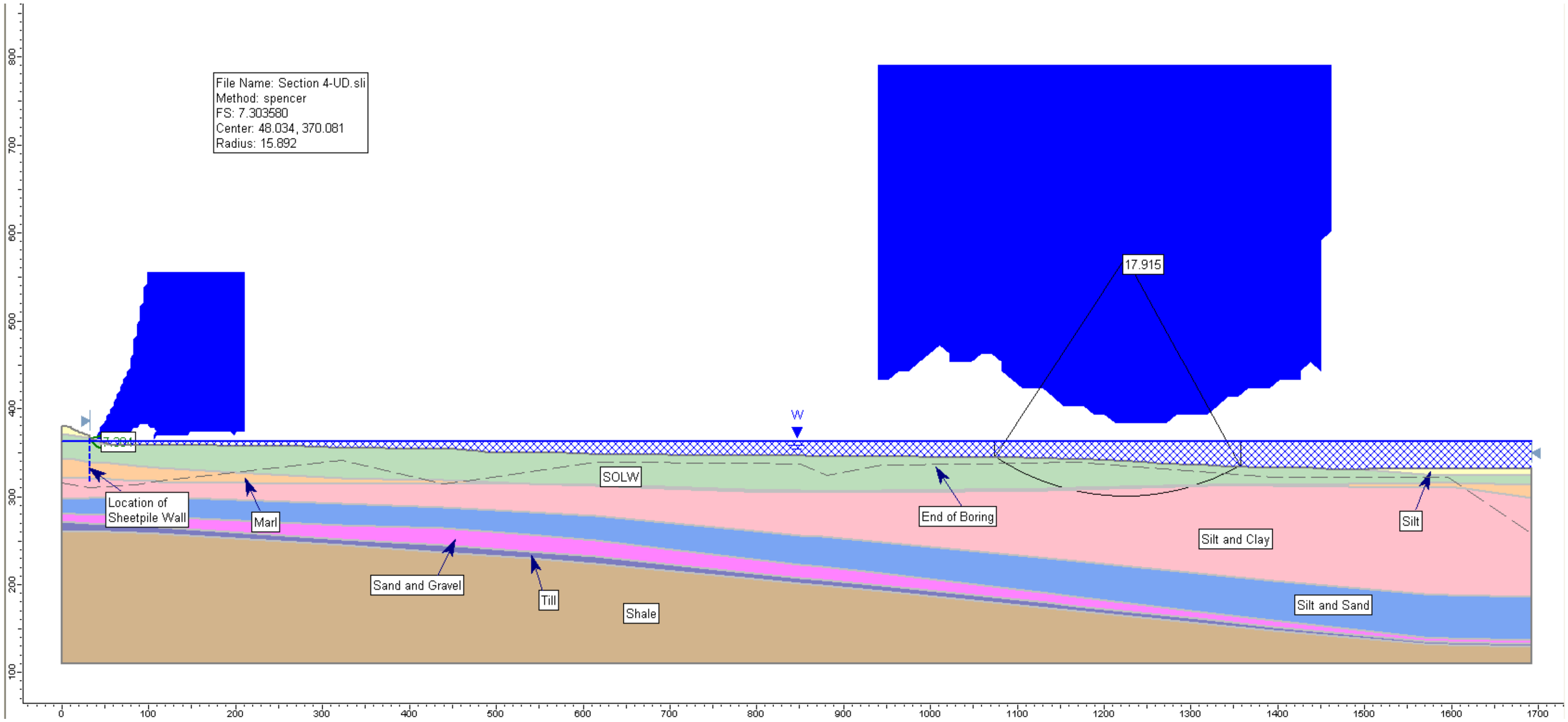

Figure 14. Slope Stability Analysis Result for Cross Section 4 under Interim Condition after Dredging (Undrained)

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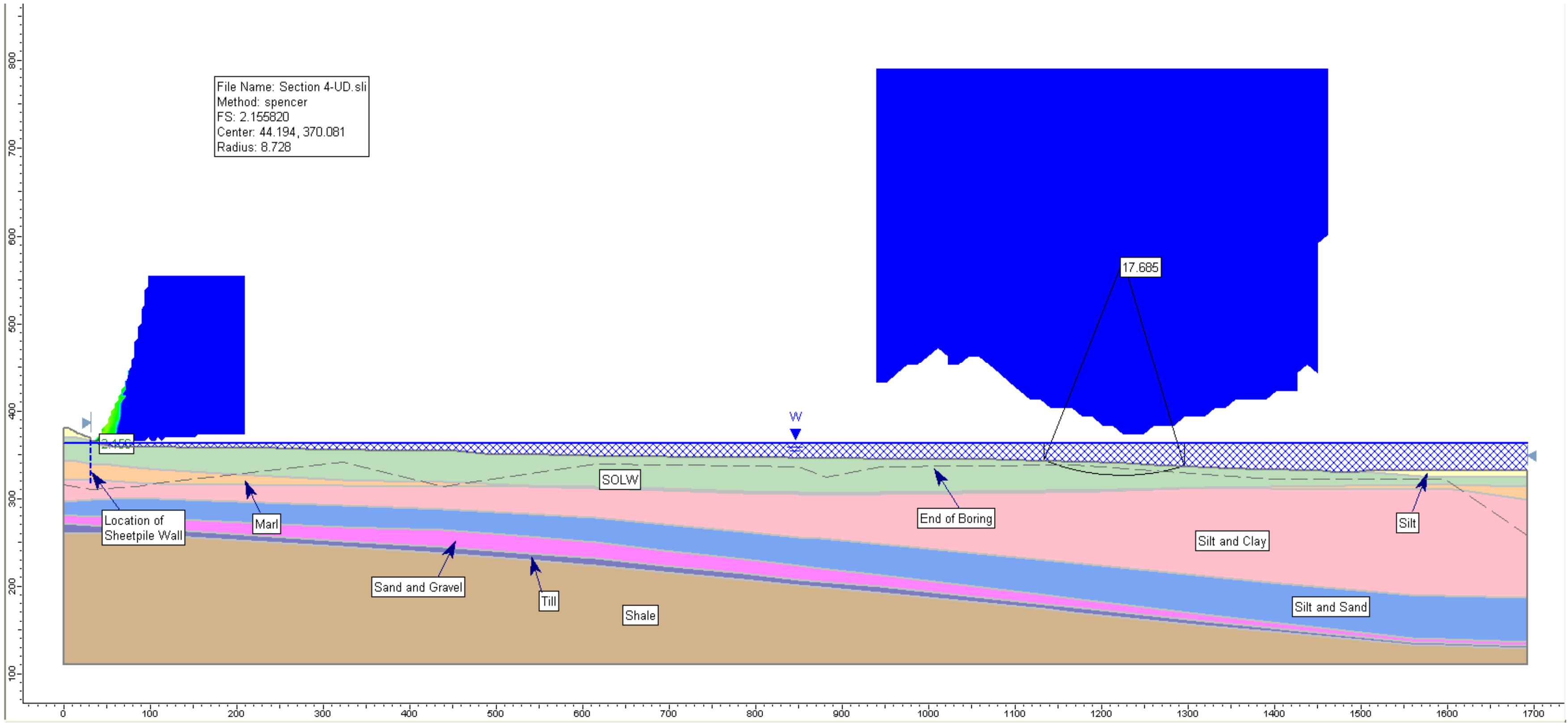

Figure 15. Slope Stability Analysis Result for Cross Section 4 under Interim Condition after Dredging (Drained)

Written by:	**Fan Zhu**	Date:	**1/14/2011**	Reviewed by:	**Ming Zhu/R. Kulasingam/Jay Beech**	Date:	**1/14/2011**

Client:	**Honeywell**	Project:	**Onondaga Lake ILWD Stability**	Project/ Proposal No.:	**GJ4204**	Task No.:	**14-05**

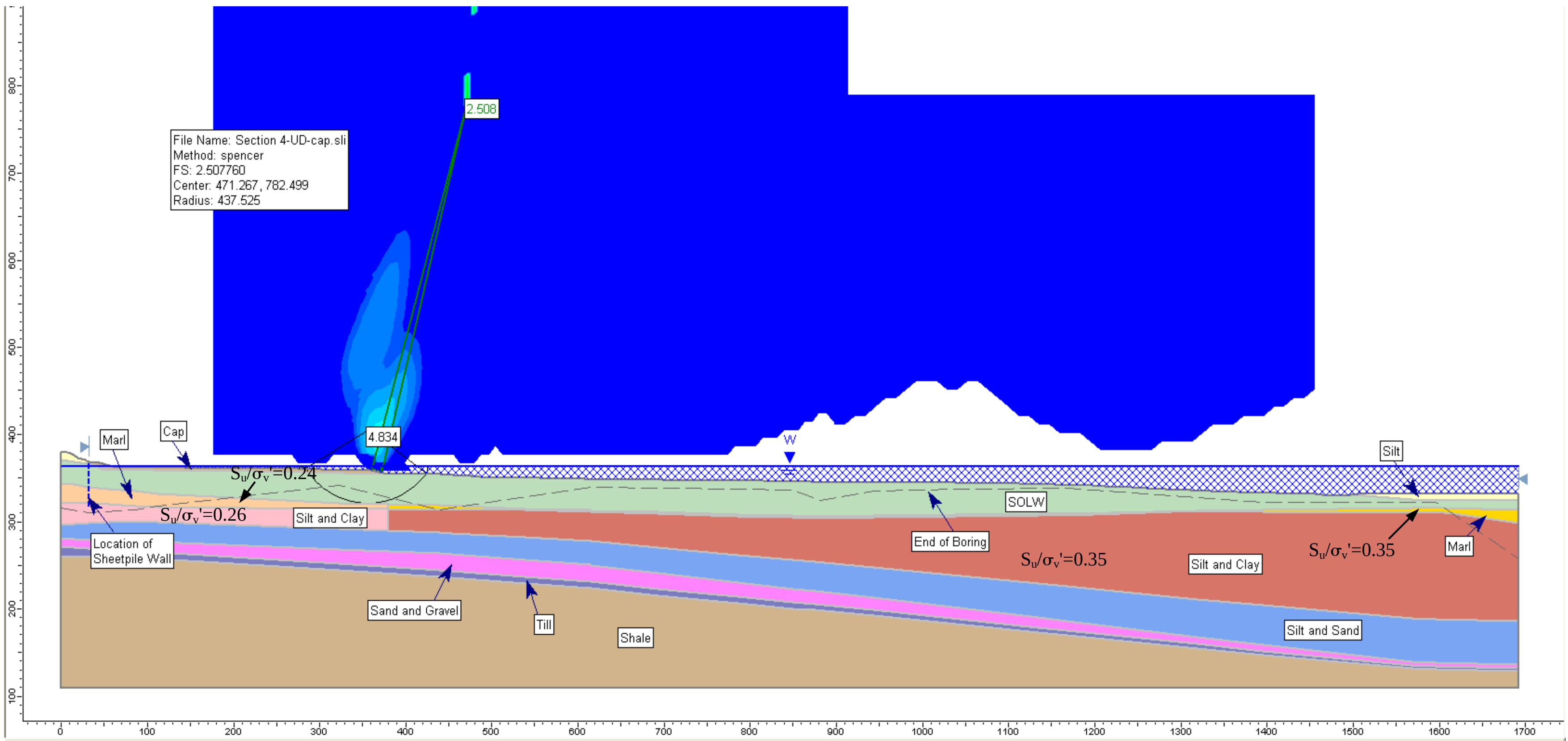

Figure 16. Slope Stability Analysis Result for Cross Section 4 under Interim Condition during Capping (Undrained)

Written by:	Fan Zhu	Date:	1/14/2011	Reviewed by:	Ming Zhu/R. Kulasingam/Jay Beech	Date:	1/14/2011

Client:	Honeywell	Project:	Onondaga Lake ILWD Stability	Project/ Proposal No.:	GJ4204	Task No.:	14-05

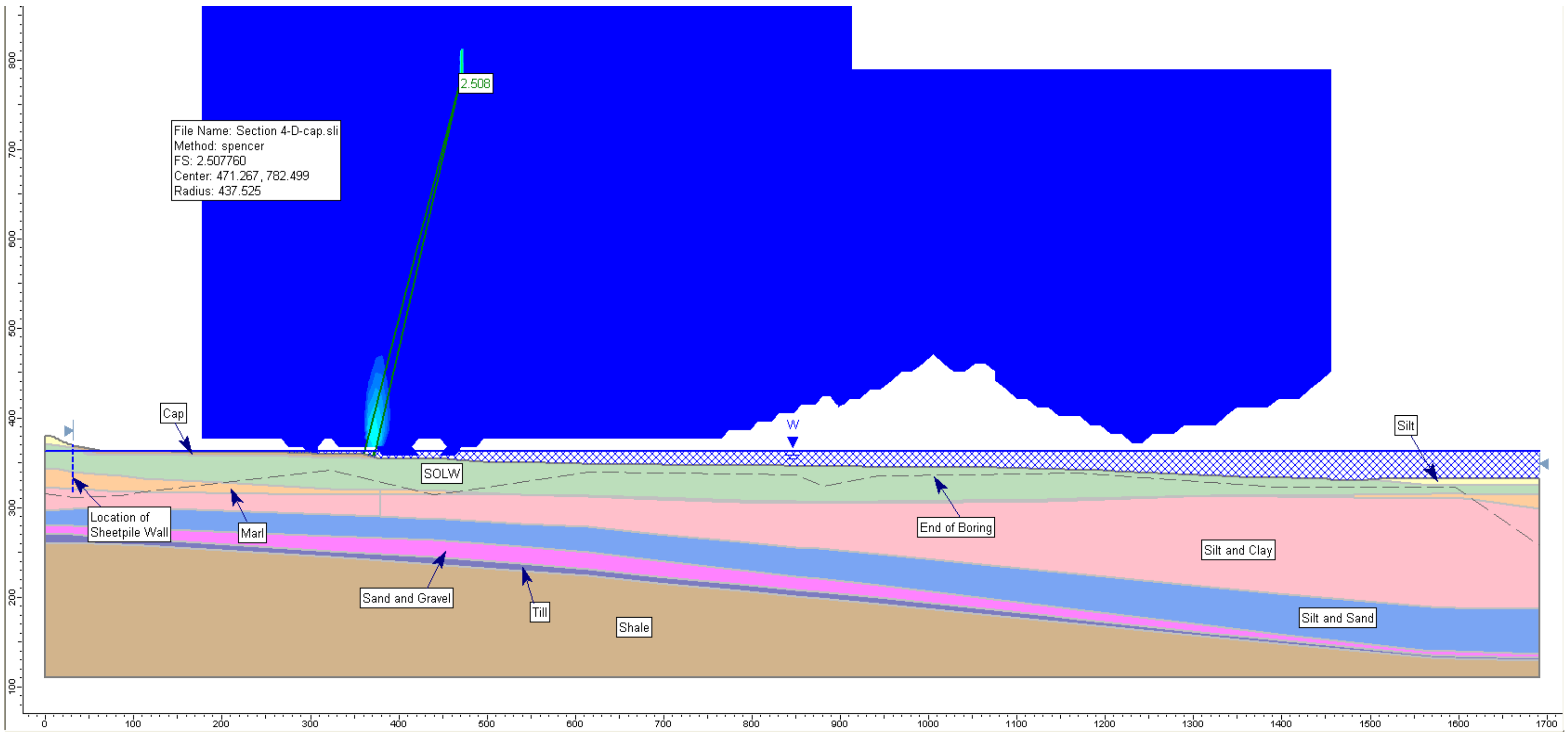

Figure 17. Slope Stability Analysis Result for Cross Section 4 under Interim Condition during Capping (Drained)

Written by:	**Fan Zhu**	Date:	**1/14/2011**	Reviewed by:	**Ming Zhu/R. Kulasingam/Jay Beech**	Date:	**1/14/2011**

Client:	**Honeywell**	Project:	**Onondaga Lake ILWD Stability**	Project/ Proposal No.:	**GJ4204**	Task No.:	**14-05**

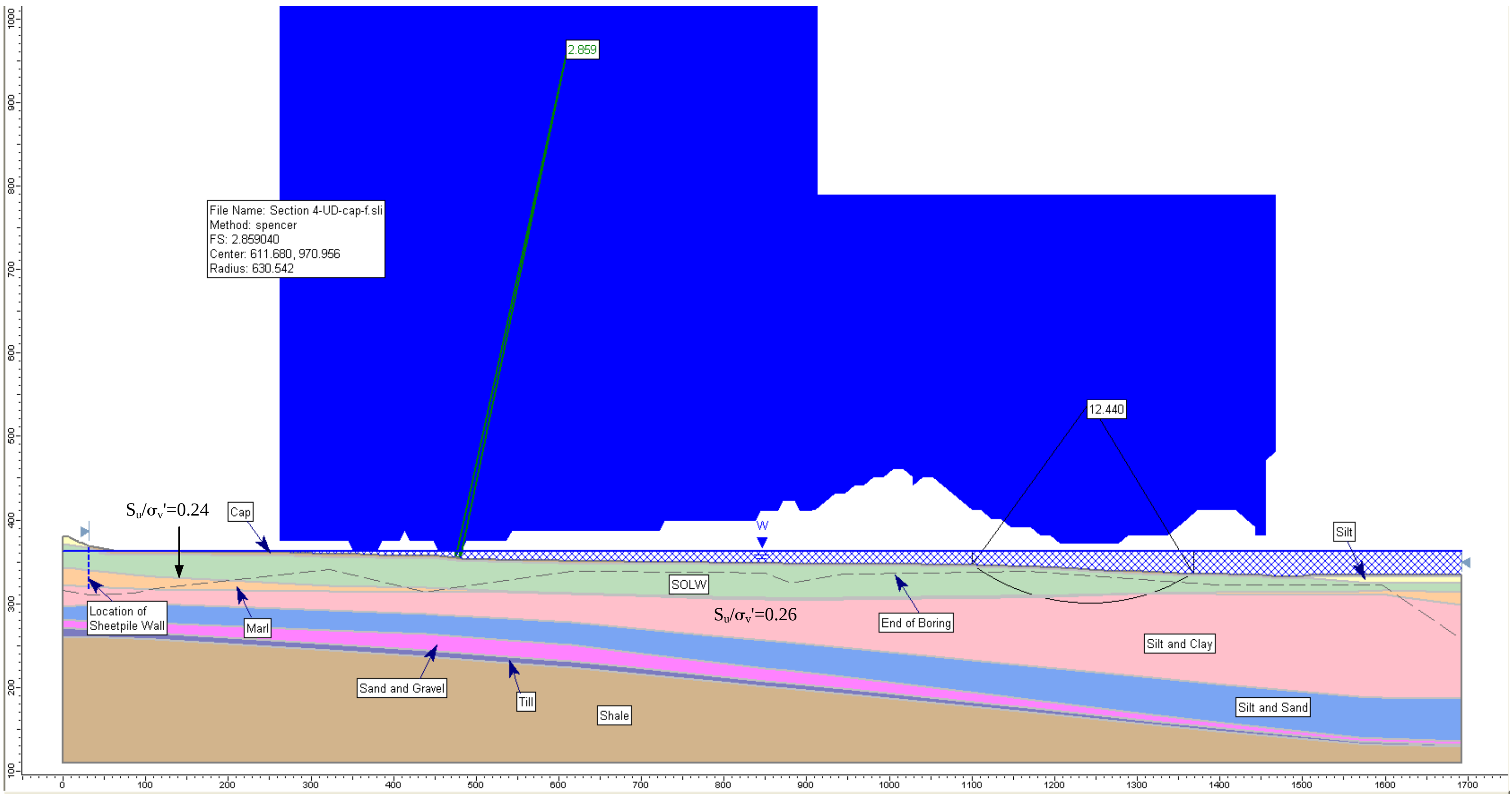

Figure 18. Slope Stability Analysis Result for Cross Section 4 under Final Condition after Capping (Undrained)

Written by: **Fan Zhu** Date: **1/14/2011** Reviewed by: **Ming Zhu/R. Kulasingam/Jay Beech** Date: **1/14/2011**

Client: **Honeywell** Project: **Onondaga Lake ILWD Stability** Project/ Proposal No.: **GJ4204** Task No.: **14-05**

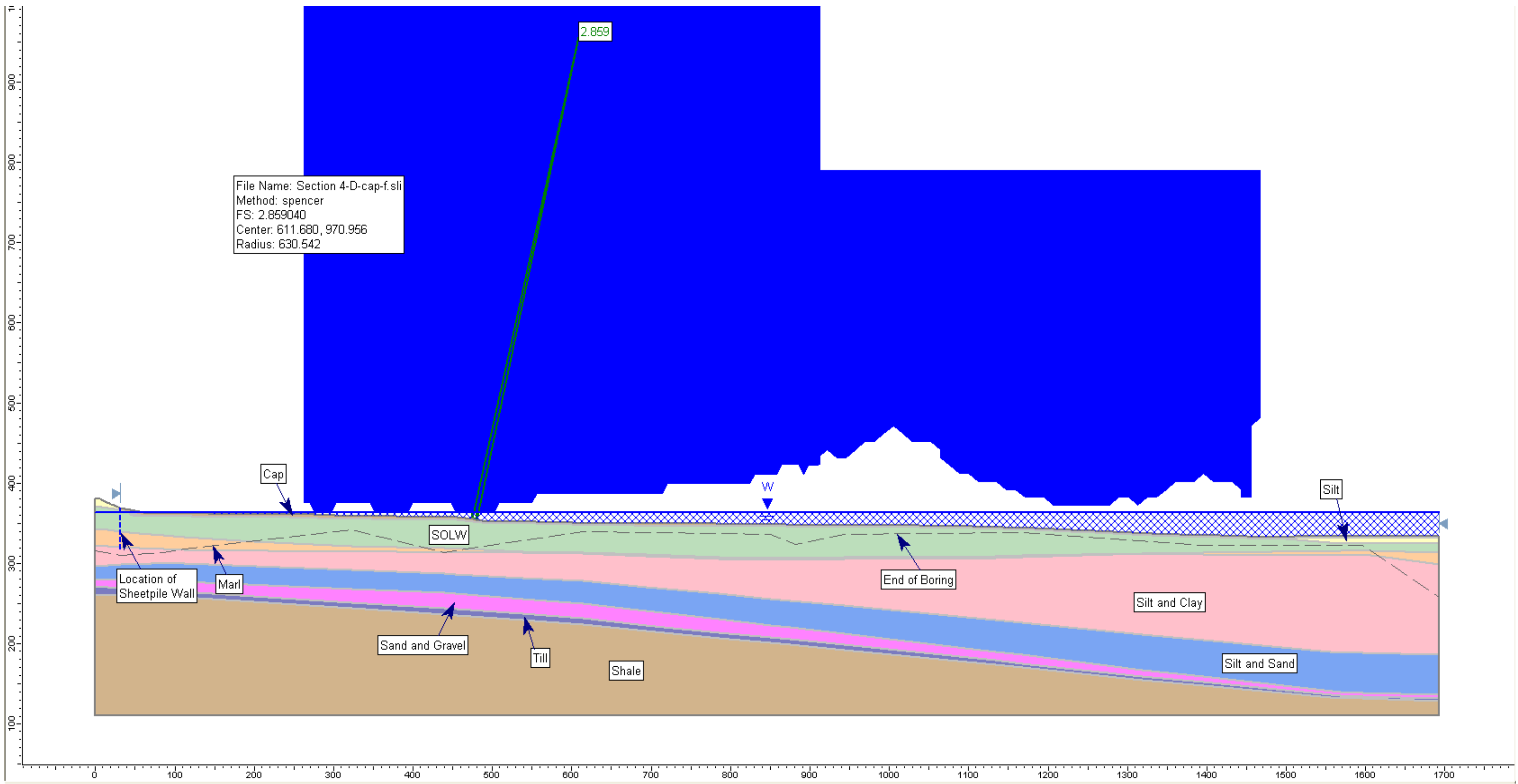

Figure 19. Slope Stability Analysis Result for Cross Section 4 under Final Condition after Capping (Drained)

Written by:	Fan Zhu	Date:	1/14/2011	Reviewed by:	Ming Zhu/R. Kulasingam/Jay Beech	Date:	1/14/2011

Client:	Honeywell	Project:	Onondaga Lake ILWD Stability	Project/ Proposal No.:	GJ4204	Task No.:	14-05

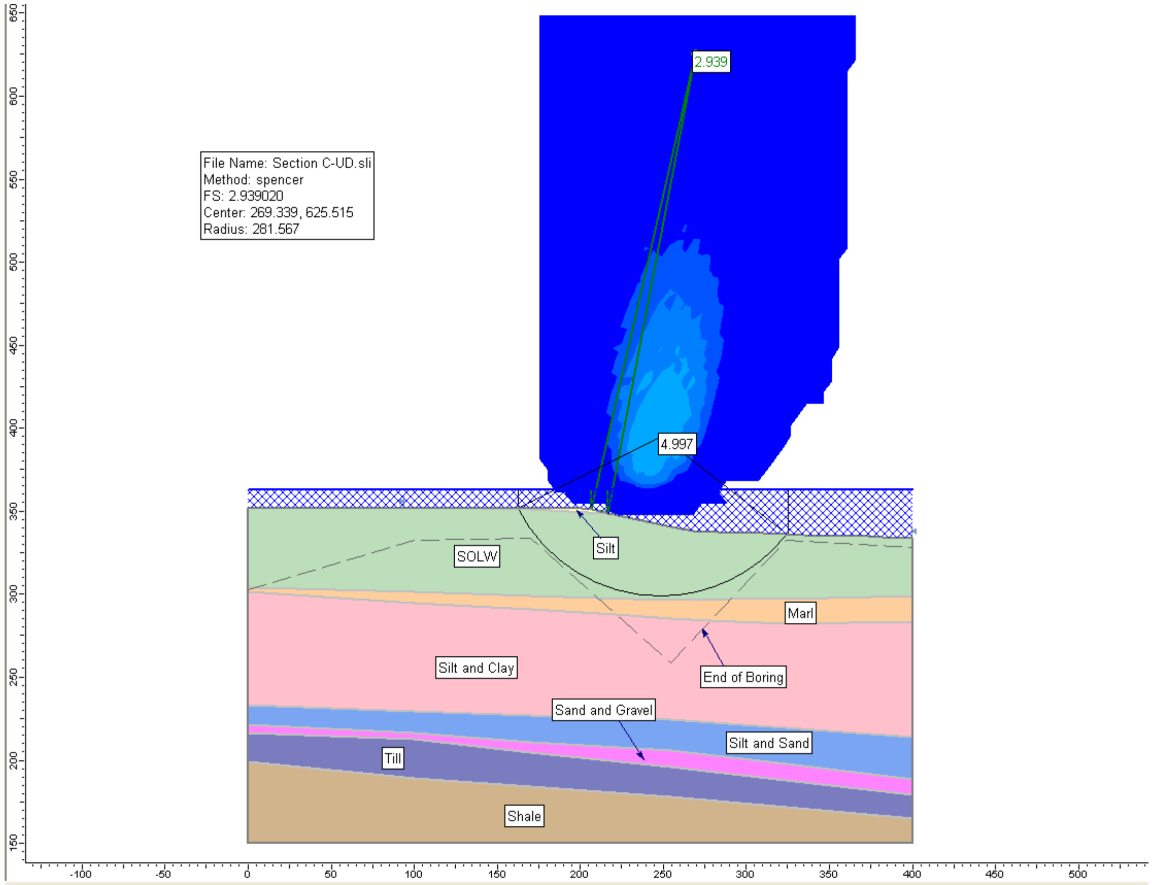

Figure 20. Slope Stability Analysis Result for Cross Section C under Interim Condition after Dredging (Undrained)

Written by:	Fan Zhu	Date:	1/14/2011	Reviewed by:	Ming Zhu/R. Kulasingam/Jay Beech	Date:	1/14/2011

Client:	Honeywell	Project:	Onondaga Lake ILWD Stability	Project/ Proposal No.:	GJ4204	Task No.:	14-05

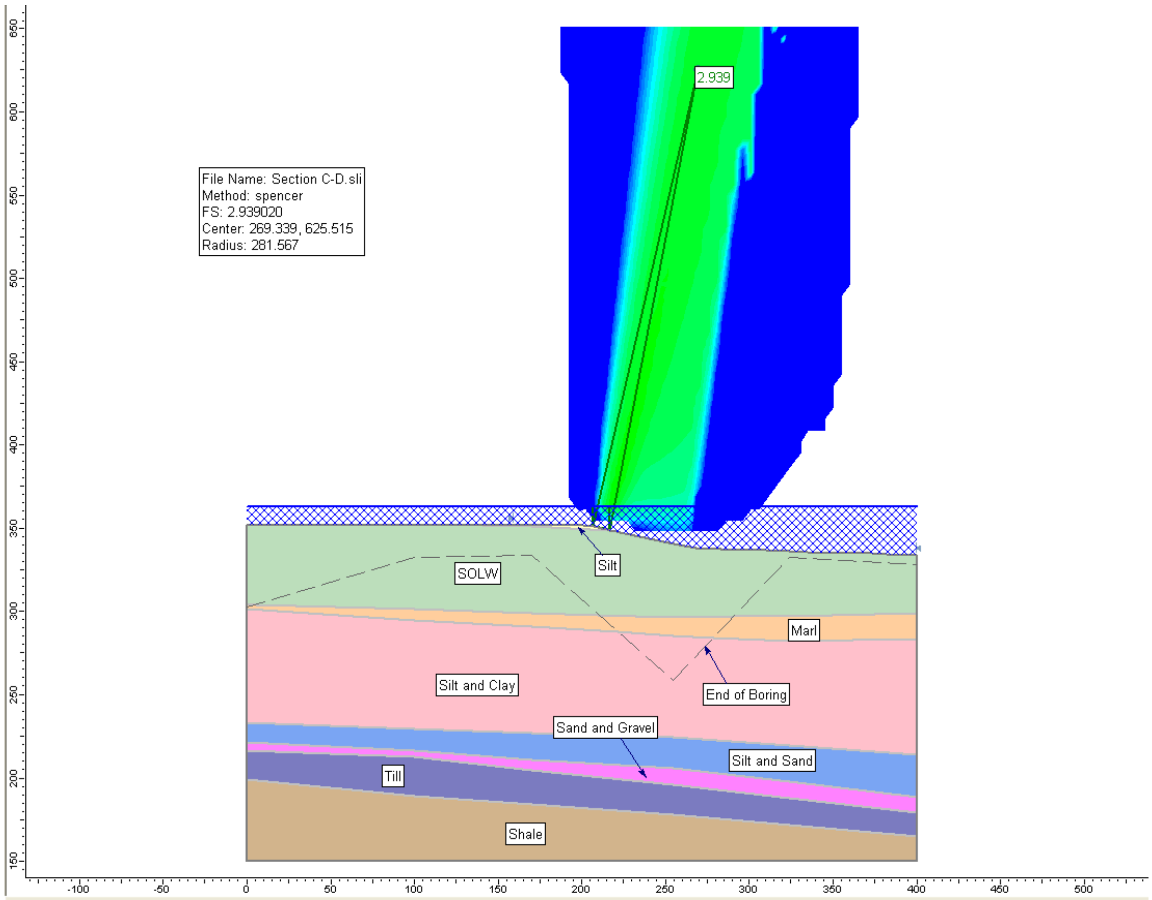

Figure 21. Slope Stability Analysis Result for Cross Section C under Interim Condition after Dredging (Drained)

Written by:	Fan Zhu	Date:	1/14/2011	Reviewed by:	Ming Zhu/R. Kulasingam/Jay Beech	Date:	1/14/2011
Client:	Honeywell	Project:	Onondaga Lake ILWD Stability	Project/ Proposal No.:	GJ4204	Task No.:	14-05

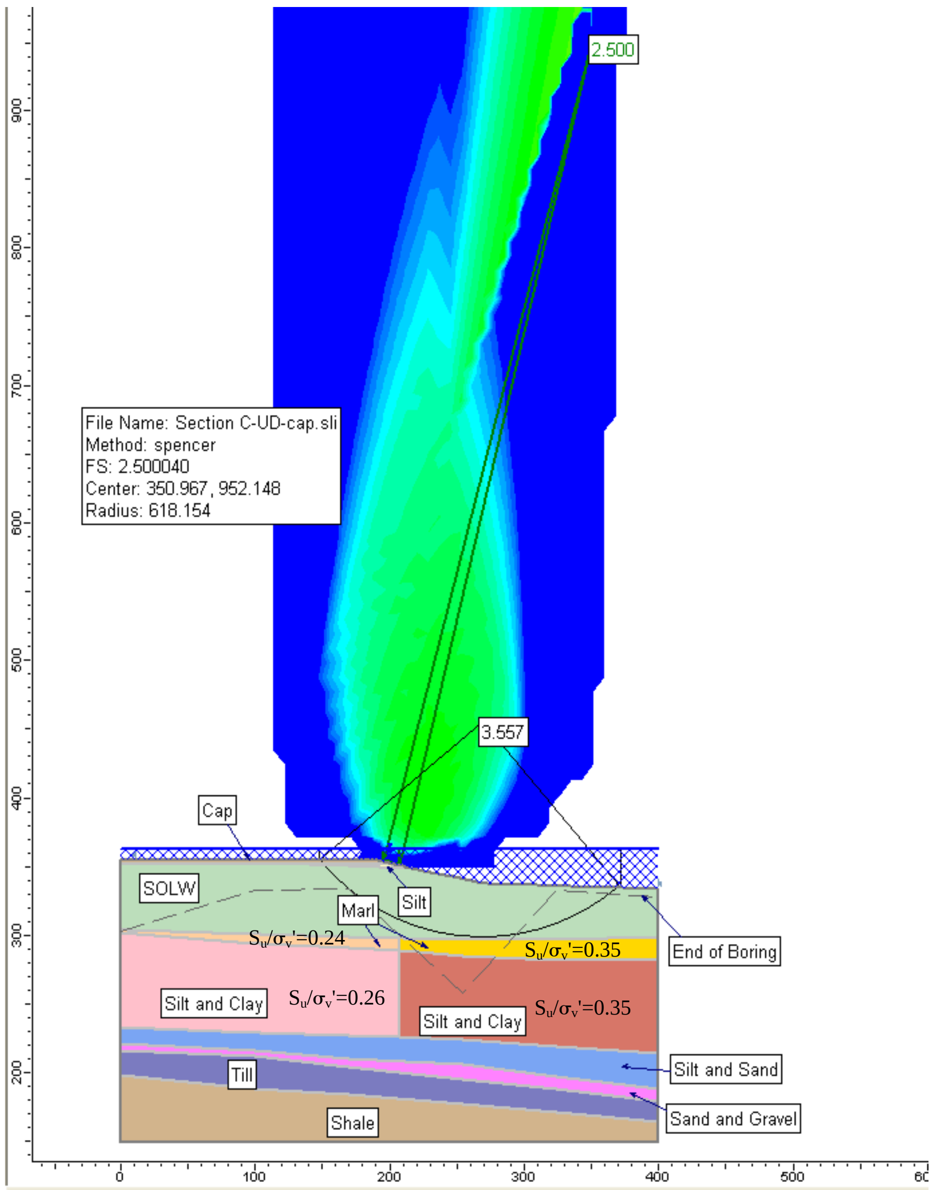

Figure 22. Slope Stability Analysis Result for Cross Section C under Interim Condition during Capping (Undrained)

Written by:	Fan Zhu	Date:	1/14/2011	Reviewed by:	Ming Zhu/R. Kulasingam/Jay Beech	Date:	1/14/2011

Client:	Honeywell	Project:	Onondaga Lake ILWD Stability	Project/ Proposal No.:	GJ4204	Task No.:	14-05

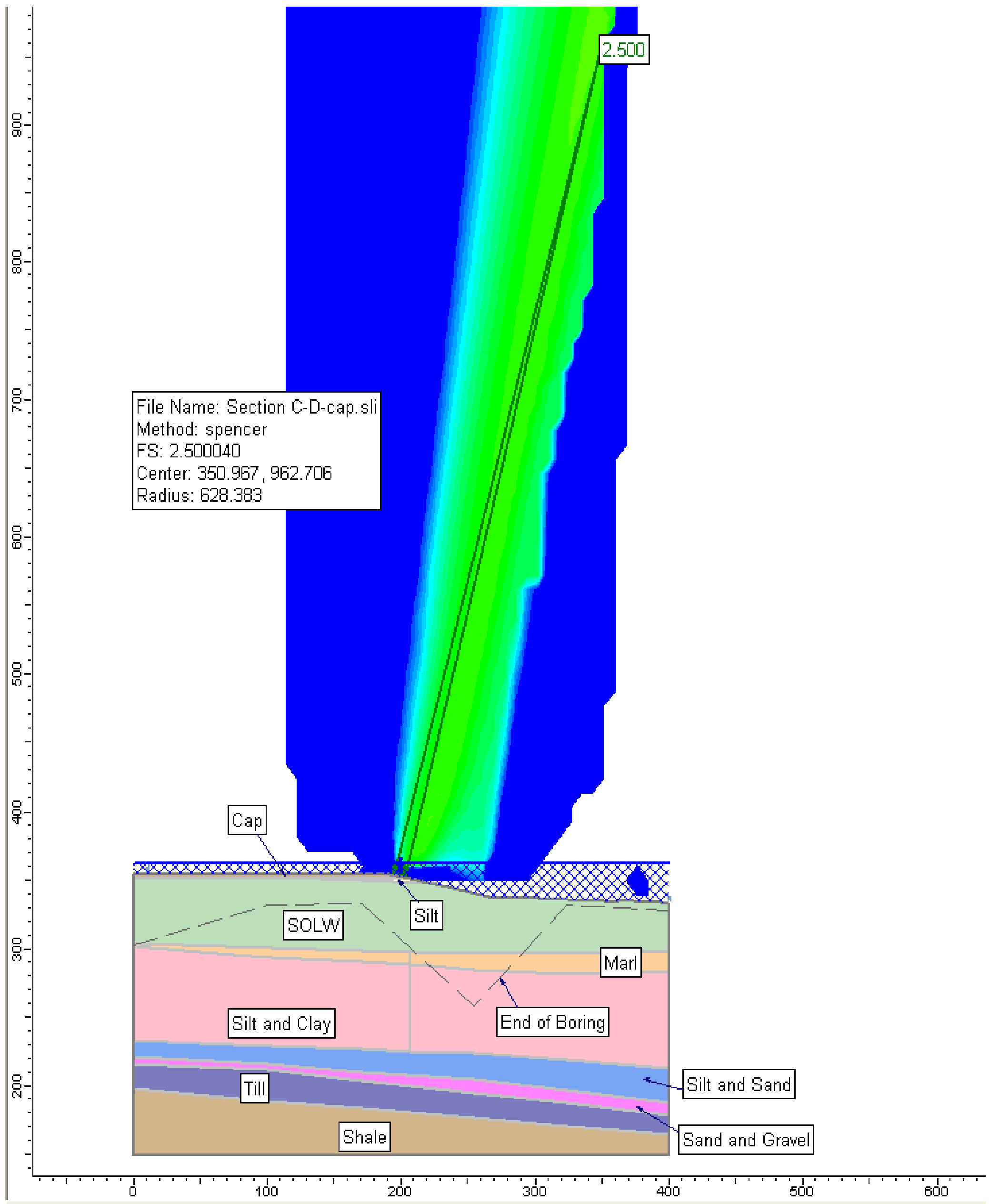

Figure 23. Slope Stability Analysis Result for Cross Section C under Interim Condition during Capping (Drained)

Written by:	**Fan Zhu**	Date:	**1/14/2011**	Reviewed by:	**Ming Zhu/R. Kulasingam/Jay Beech**	Date:	**1/14/2011**

Client:	**Honeywell**	Project:	**Onondaga Lake ILWD Stability**	Project/ Proposal No.:	**GJ4204**	Task No.:	**14-05**

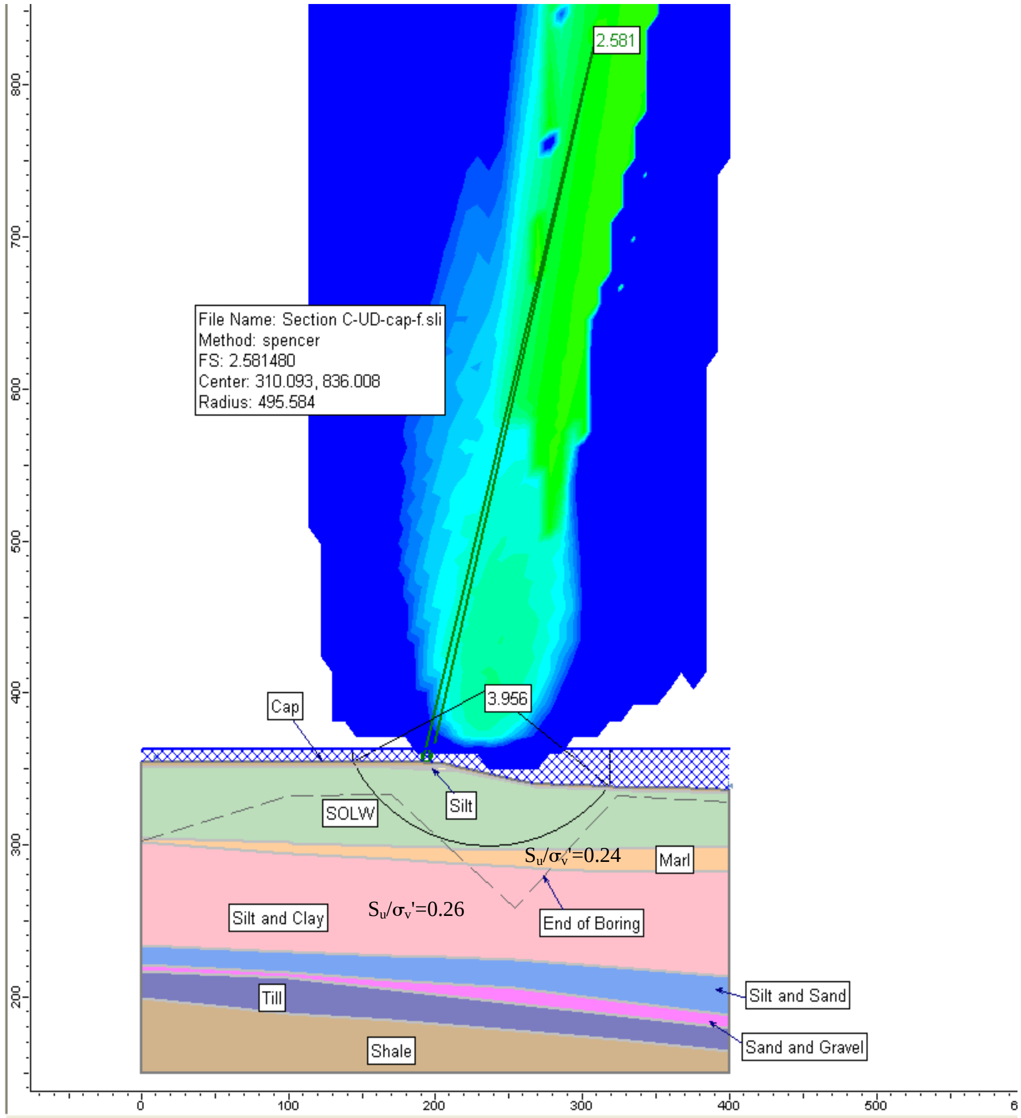

Figure 24. Slope Stability Analysis Result for Cross Section C under Final Condition after Capping (Undrained)

Written by:	Fan Zhu	Date:	1/14/2011	Reviewed by:	Ming Zhu/R. Kulasingam/Jay Beech	Date:	1/14/2011
Client:	Honeywell	Project:	Onondaga Lake ILWD Stability	Project/ Proposal No.:	GJ4204	Task No.:	14-05

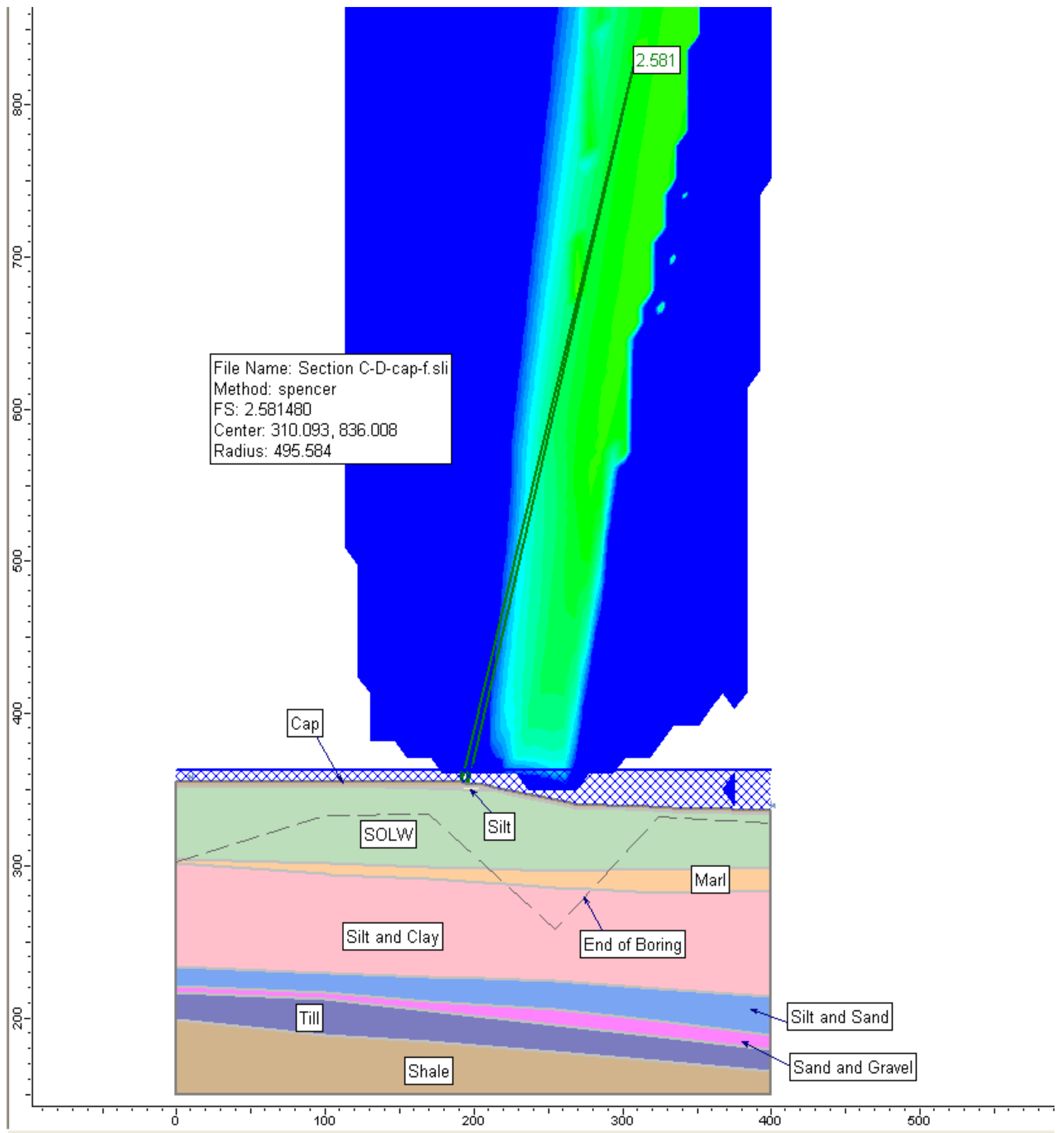

Figure 25. Slope Stability Analysis Result for Cross Section C under Final Condition after Capping (Drained)

Written by:	**Fan Zhu**	Date:	**1/14/2011**	Reviewed by:	**Ming Zhu/R. Kulasingam/Jay Beech**	Date:	**1/14/2011**
Client:	**Honeywell**	Project:	**Onondaga Lake ILWD Stability**	Project/ Proposal No.:	**GJ4204**	Task No.:	**14-05**

Attachment 1

Calculation of Reduced Undrained Shear Strength Ratios

The reduced undrained shear strength ratios of Marl and Silt and Clay were calculated as follows:

a) Assume a representative subsurface profile for ILWD: As presented in Figure 19 in the Data Package, the thicknesses of SOLW and Marl were assumed to be 30 ft and 10 ft, respectively. The unit weights of SOLW and Marl are 81 pcf and 98 pcf, respectively.

b) Select the point at the middle of Marl and the point at the top of Silt and Clay: The undrained shear strength at the middle of Marl before capping is:

$$S_{u1} = 0.35\sigma_v' = 0.35\times[30\times(81\text{-}62.4)+5\times(98\text{-}62.4)] = 258 \text{ psf}$$

The undrained shear strength at the top of Silt and Clay before capping is:

$$S_{u2} = 0.35\sigma_v' = 0.35\times[30\times(81\text{-}62.4)+10\times(98\text{-}62.4)] = 320 \text{ psf}$$

c) The vertical effective stresses at the selected points after capping (assuming a 5.5-ft thick cap consisting of 3.2 ft gravel and 2.3 ft sand) are:

$$\sigma_{v1}' = 3.2\times(125\text{-}62.4)+2.3\times(120\text{-}62.4)+30\times(81\text{-}62.4)+5\times(98\text{-}62.4) = 1069 \text{ psf}$$

$$\sigma_{v2}' = 3.2\times(125\text{-}62.4)+2.3\times(120\text{-}62.4)+30\times(81\text{-}62.4)+10\times(98\text{-}62.4) = 1247 \text{ psf}$$

d) To consider the condition immediately after capping, the undrained shear strength ratios of Marl and Silt and Clay below cap were selected to be:

$$S_u/\sigma_v'_{\text{(Marl)}} = 258/1069 = 0.24$$

$$S_u/\sigma_v'_{\text{(Silt and Clay)}} = 320/1247 = 0.26$$

It is noted that the above undrained strength ratios were calculated assuming that the maximum cap thickness is 5.5 ft. If the actual cap thickness is less than 5.5 ft, the calculated undrained shear strength ratios will be greater. Therefore, it is conservative to use the above calculated undrained shear strength corresponding to a 5.5 ft cap in the slope stability analyses for cases with thinner caps.