Honeywell

Honeywell
301 Plainfield Road
Suite 330
Syracuse, NY 13212
315-552-9700
315-552-9780 Fax

June 9, 2016

To: Harry Warner, NYSDEC, Region 7 (1 bound)
Diane Carlton, NYSDEC, Region 7 (1 PDF)
Holly Sammon, Onondaga County Public Library (1 bound)
Samuel Sage, Atlantic States Legal Foundation (1 bound)
Mary Ann Coogan, Camillus Town Hall (1 bound)
Stephen Weiter, Moon Library (1 bound)
Joseph J. Heath, Esq. (1 bound)
Melissa Lewandowski, Solvay Public Library (1 bound)

Re: Letter of Transmittal – Onondaga Lake Repository Addition

The below document has been approved by the New York State Department of Environmental Conservation (NYSDEC) and is enclosed for your document holdings:

- Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design, Modified Protective Cap Areas RA-C2 Design Revision
May 2016

Sincerely,

John P. McAuliffe

John P. McAuliffe, P.E.
Program Director, Syracuse

Enc.

cc: Timothy J. Larson, P.E., NYSDEC Project Manager
Chris Fitch, Brown and Sanford (ecopy)

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Division of Environmental Remediation, Remedial Bureau D
625 Broadway, 12th Floor, Albany, NY 12233-7013
P: (518) 402-9676 I F: (518) 402-9773
www.dec.ny.gov

May 12, 2016

Mr. John P. McAuliffe, P.E.
Program Director, Syracuse
Honeywell
301 Plainfield Road, Suite 330
Syracuse, NY 13212

Re: Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design, Modified Protective Cap RA-C2 Design Revision, Dated May 2016

Dear Mr. McAuliffe:

We have received and reviewed the above-referenced document, a copy of which was attached to Edward Glaza's May 11, 2016 email to my attention, and the revised version of the document appropriately addresses our previous comments. Therefore, the Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design, Modified Protective Cap RA-C2 Design Revision, dated May 2016, is hereby approved. Please see that copies of the approved document, including this approval letter, are sent to the distribution list selected for this site as well as the document repositories selected for this site.

Sincerely,

Timothy J. Larson, P.E.
Project Manager

ec: B. Israel, Esq, - Arnold & Porter
J. Davis - NYSDOL, Albany
M. Schuck - NYSDOH, Albany
M. McDonald – Honeywell
R. Nunes - USEPA, NYC
M. Sergott - NYSDOH, Albany
E. Glaza - Parsons

Honeywell

Honeywell
301 Plainfield Road
Suite 330
Syracuse, NY 13212
315-552-9700
315-552-9780 Fax

June 3, 2016

Mr. Timothy J. Larson
New York State Department of Environmental Conservation
Division of Environmental Remediation
Remedial Bureau D
625 Broadway, 12th Floor
Albany, NY 12233-7016

RE: Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design, Modified Protective Cap RA-C2 Design Revision May 2016

Dear Mr. Larson:

Enclosed you will find one bound copy and one electronic (PDF and original) of the Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design, Modified Protective Cap RA-C2 Design Revision, dated May 2016.

Please feel free to contact Ed Glaza at 315-451-9560 or me if you have any questions.

Sincerely,

John P. McAuliffe

John P. McAuliffe, P.E.
Program Director, Syracuse

Enclosure

cc: Robert Nunes, USEPA (1 bound, 1 PDF)
Argie Cirillo, USEPA (Cover letter only)
Mike Spera, AECOM (1 bound, 1 PDF)
Bob Montione, AECOM (1 bound, 1 PDF)
Tara Blum, NYSDEC (1 bound, 1 PDF)
Kenneth Lynch, NYSDEC (1 bound)
Margaret Sheen, Esq. NYSDEC (Cover Ltr Only)
Harry Warner, NYSDEC (1bound, 1 PDF)
Mark Sergott, NYSDOH (1 PDF)
Norman Spiegel, Env. Protection Bureau (Cover Ltr Only)
Andrew Gershon, Env. Protection Bureau (Cover Ltr Only)
John Davis, Env. Protection Bureau (1 bound, 1 PDF)
Joseph Heath, Esq. (ec Cover letter only)
Thane Joyal, Esq. (1 PDF)

cc: (Continued)

Curtis Waterman (1 PDF)
Alma Lowry, Esq. (1 PDF)
Jeanne Shenandoah, Onondaga Nation (1 bound Plus ec Cover letter only)
Bill Hague, Honeywell (ec Cover Ltr Only)
Brian Israel, Arnold & Porter (1 PDF)
Steve Miller, Parsons (1 PDF)
Edward Glaza, Parsons (1 bound)
Joe Detor, Anchor QEA (1 PDF)

ONONDAGA LAKE CAPPING, DREDGING, HABITAT AND PROFUNDAL ZONE (SMU 8) FINAL DESIGN

MODIFIED PROTECTIVE CAP RA-C-2 DESIGN REVISION

Prepared for:

Honeywell

301 Plainfield Road, Suite 330
Syracuse, NY 13212

Prepared by:

PARSONS

301 Plainfield Road, Suite 350
Syracuse, NY 13212

ANCHOR QEA

290 Elwood Davis Road, Suite 318
Liverpool, NY 13088

MAY 2016

SUMMARY OF DESIGN REVISION

This cap design revision pertains to a portion of Remediation Area C (RA-C) where geotechnical investigations completed subsequent to the Final Design identified soft (low strength) sediment on relatively steep slopes. These sediments are softer than was identified during the Pre-design Investigation (PDI), and therefore a design revision is required in this area to allow for stable placement of the caps. For a capping project of the scale of Onondaga Lake Remediation, it is not unusual to expect to incur field conditions in minor areas throughout the implementation that may require adjustments to the cap system to achieve the remedial goals for the project.

The MPC designs shown in Figure 1 were determined to be stable based on substantial geotechnical data collected in this area subsequent to the Final Design and detailed geotechnical analysis, as presented in Attachment 1. This analysis incorporates the results from field investigations performed with equipment that is both more accurate than that used during the 2005 to 2008 pre-design investigation (PDI) and capable of assessing conditions in the deeper water portions of the lake where softer sediments have been identified. This included cone penetrometer testing (CPT), full flow penetrometer (FFP), and additional vane sheer testing (VST). In addition to the improved accuracy of these measurements, the use of these methods in areas of the site with previously placed cap materials has allowed an assessment of cap placement induced strength gain (from consolidation) in the sediment, which has been a key consideration in the slope stability assessments in some cap areas.

The evaluation of strength data collected between 2012 and 2015 indicate that the sediments in portions of the remediation areas are significantly softer than anticipated based on the PDI conducted prior to 2012. Comparison between the estimated strength parameters from the field VST data (from the PDI) and the post-PDI VST data conducted after 2012 indicates that, in general, the PDI data showed higher shear strengths for the shallow sediments than the recent (post-2012) data. The technical report titled “Development of Geotechnical Design Parameters for Lakebed Sediments in Onondaga Lake Capping Areas” (Geosyntec, October 2015) presents a comparison of the PDI and post-PDI sediment strength data.

The MPC designs were optimized to maximize the total thickness of the cap while still meeting the required factor of safety based on geotechnical considerations. The thickness and composition of the various layers comprising the MPCs are shown below as well as on Figure 1. Chemical isolation modeling was completed to determine the granular activated carbon (GAC) application rates that will be result in MPCs that are protective for isolation of organic contaminants for at least 1000 years, consistent with the evaluation timeframe used in the Final Design, as documented in Attachment 2. Modeling also verified that the MPCs will be protective for isolation of mercury for at least 1000 years; the minor exception to this may be portions of the small direct amendment application area, as discussed below following the bullets. The thickness and composition of the various layers comprising the MPCs, including the updated GAC application rates based on the modeling, are listed below.

RA-C-2A (less than 4 feet) (Multi-layer Cap) - GAC application rate of 0.1 lbs/sf

- 12-inch minimum coarse gravel habitat/erosion protection layer
- 9-inch minimum sand/GAC chemical isolation layer
- 3-inch minimum of sand/siderite chemical isolation layer
- 3-inch minimum of sand/siderite mixing layer

RA-C-2A (4 to 10 feet) (Multi-layer Cap) - GAC application rate of 0.1 lbs/sf

- 10-inch minimum fine gravel habitat/erosion protection layer
- 4.5-inch minimum sand/GAC/siderite chemical isolation layer
- 3-inch minimum of sand/siderite mixing layer

RA-C-2A (10 to 30 feet): (Multi-layer Cap) - GAC application rate of 0.1 lbs/sf

- 12-inch minimum sand habitat/erosion protection layer
- 4.5-inch minimum sand/GAC/siderite chemical isolation layer
- 3-inch minimum sand/siderite mixing layer

RA-C-2A Cap Transition Area - GAC application rate of 0.1 lbs/sf

- One to four layers as the cap transitions between RA-C-2A and RA-C-2B, as shown in Attachment 1. Where present, the layers within the transition zone will be consistent with the layers within adjacent RA-C-2A.

RA-C-2B (20 to 30 feet) (Mono-layer Cap) - GAC application rate of 0.1 lbs/sf

- 2-inch average sand/GAC/siderite

RA-C-2C: (Multi-layer Cap Conservatively Modeled as Mono-Layer Cap) - GAC application rate of 0.1 lbs/sf

- 4.5-inch average sand habitat/erosion protection layer
- 9-inch average sand/siderite/GAC layer

RA-C-2D (Direct Amendment Application) - GAC application rate of 0.1 lbs/sf

- GAC and siderite direct application. Will include a volume of sand during placement approximately equal to 0.5 inches to facilitate placement

The area where GAC will be directly applied to the surface of the sediments in RA-C-2D is very small (approximately 0.3 acres), which represents only about 0.07 % of the total capped area. As documented in Attachment 1, the recommended approach in this area is direct application of GAC to the sediment surface because geotechnical stability considerations limit placement of a sand cap in this small area. The GAC will mix with the surface sediments through bioturbation, as discussed in Attachment 2. Mechanical mixing of GAC with the surface sediments is not considered practical because it could disturb the sediments sufficiently to result in potential slope instability. Bioturbation has proven to be effective at other sediment remediation sites in mixing amendments such as GAC throughout the biologically active upper layer of sediment. The GAC will adsorb the organic contaminants of concern within the sediment porewater and prevent them from being available to small organisms within the surface sediments or migrating into the water column. As detailed in Attachment 2, sufficient GAC will be applied to achieve protection for at least 1000 years.

Mercury concentrations in surface sediments in sediment cores collected during the PDI within or along the outer edge of MPC-C-2D were:

- OL-VC-20164 3.0 mg/kg
- OL-VC-20136 7.1 mg/kg
- OL-VC-20137 0.28 mg/kg
- OL-VC-20138 0.63 mg/kg

Two of these four samples exceed the mercury sediment probable effects concentration (PEC) criteria of 2.2. Mercury concentrations in this area, which represents approximately 0.07% of the total area capped within the littoral zone, will be higher than anticipated in the Final Design for the lake. However, the bioaccumulation-based sediment quality value (BSQV) of 0.8 mg/kg will continue to be met in this portion of the lake. Also, it is not anticipated that this will effect achievement of remedial goals relating to mercury levels in fish in the lake due to the small areal extent of RA-C-2D compared to overall capped areas within the lake littoral zone. This area is in water depths less than 20 feet and therefore would not be considered net depositional; however, surface concentrations are expected to be reduced over time in this small area as new cleaner sediments deposit and mix with the existing surface sediments. Amendment application in this area also includes siderite, which was found to significantly reduce mercury concentrations in porewater. Mercury concentrations in porewater were reduced by over two orders of magnitude and mercury was absent in porewater in PDI leachate testing or was detected at low estimated values when siderite was combined with site porewater, as detailed in Appendix I of the Final Design (Parsons and AnchorQEA, 2012).

The area of RA-C-2D was delineated taking into consideration shoreline area conditions. The lake-bottom along the shoreline in this area consists of fill such as slag, sand and gravel from Crucible Specialty Metals. Sampling of the shoreline lake bottom fill material in this area was completed as part of the Preliminary Site Assessment for the Lake Pump Site (C&S, 2003). Results from two surface sediment samples in this area do not exceed the lake cleanup criteria. GAC direct application in this area will include all areas where soft sediments are present. Based on prior investigations and probing completed in 2016, this will conservatively include the area of the lake bottom in this area that is below a water depth of five feet, although much of the lake bottom in the area between 5 and 10 feet in water depth in this area also consists of fill material. The bathymetry in this area will be resurveyed to verify the 5-foot bathymetry boundary and adjusted as appropriate prior to GAC direct application in this area.

The siderite layer has already been placed in RA-C-2A, including the transition zone. The presence of the intact siderite layer will be verified in these areas prior to placement of additional cap layers. Siderite will be incorporated into all of the RA-C-2 MPCs, including the direct amendment application area, to neutralize high pH and thus promote biodegradation of organic contaminants. Biodegradation of organic contaminants is expected to occur in the multi-layer and mono-layer caps, including the area of direct amendment application. However, the GAC application rate in these areas were conservatively developed through modeling assuming there was no biological decay. The siderite ore application rate (specified in lbs/sf) will be consistent with the Final Design in all of the RA-C-2 MPCs, including the direct application area. The siderite percent by weight within the sand/siderite mixture will be increased to account for the thinner sand/siderite layers (when less than 6 inches) as compared to the Final Design. The revised design as it pertains to the pH neutralization provides a level of protection that is equivalent to that of the original design even though the cap thickness over which the siderite is distributed will be decreased in some areas, as detailed in the Modified Protective Cap RA-D-1 Design Revision (Parsons and Anchor QEA 2015).

It is anticipated that the GAC and siderite will be placed in the RA-C-2D direct application area using the same equipment and methods (hydraulic spreader barge) that have been successfully used throughout the program to place finer-grained cap material, including sand/GAC/siderite mixtures. Based on the demonstrated ability to uniformly place sand/GAC/siderite mixtures, similar success is anticipated in directly placing GAC and siderite without sand. However, to provide consistency with the application methods used in other areas, a low volume of sand (equivalent to approximately 0.5 inches of sand placement on average) will be mixed with GAC during the direct application process to promote GAC distribution and settlement, as well as provide increased stability of the GAC following placement prior to its expected mixing with the sediment via bioturbation. A comprehensive Construction Quality Assurance Plan (CQAP) (Parsons and Anchor QEA, 2012) has been developed and implemented to ensure that the cap is constructed consistent with the Final Design, including thickness and amendment application rate requirements. The construction verification methods will be revisited as necessary to ensure the MPCs, including the GAC direct amendment area, are constructed consistent with this design modification.

Post-construction monitoring and maintenance of the capped areas throughout the lake, inclusive of the MPC areas addressed in this design revision, will be performed to verify that the overall integrity of the cap is maintained so that it remains physically stable (i.e., does not erode) and chemically protective over time. Long-term monitoring of the caps will include physical monitoring to verify stability and sampling of the caps to verify their chemical integrity, as summarized below. Long-term monitoring will also include macrobenthic community sampling and documentation of vegetation recovery, as appropriate. Details of the monitoring methods, frequencies, and procedures and response actions will be developed based on joint discussions with NYSDEC and will be presented in the Onondaga Lake Monitoring and Maintenance Scoping document (OLMMS).

Physical monitoring of the capped areas, including the MPC areas included in this design revision, will involve verifying that the various layers of cap material placed are stable and intact using a combination of methods including bathymetric surveys, sediment probing and coring, and/or other geophysical methods. The cap integrity will be monitored routinely and following wind/wave, tributary inflow, ice scour or seismic events that exceed a threshold design magnitude that may impact a specific cap area, consistent with USEPA (2005) recommendations. The frequency of routine monitoring will be greater initially after construction (e.g., multiple monitoring events within the first 5 to 10 years), and reduced over time once the monitoring is able to establish a consistent pattern of cap performance.

Chemical monitoring will involve measuring chemical concentrations within the caps to verify that contaminants are not moving through or accumulating within the cap at rates and concentrations that exceed specified remedy success metrics. Samples will also be collected within the MPC areas as the different cap configurations in these areas will likely result in different monitoring approaches, depths, and compliance points. The frequency of routine monitoring may be reduced over time once the monitoring is able to establish a consistent pattern of cap performance. Details of the chemical monitoring methods, frequencies, locations, sampling intervals, procedures, and response actions will be developed based on joint discussions with NYSDEC and will be presented in the OLMMS for NYSDEC review and approval.

Monitoring of the RA-C-2D GAC direct application area will also be completed as part of the long-term cap monitoring program described above. Long-term monitoring will be implemented to verify that the GAC/sand remains in place and is protective. Compliance with criteria in the GAC direct application areas will be verified by sampling of the porewater within the biologically active portion of the surface sediments. Specific monitoring methods applicable to this area will be developed.

In the event that the monitoring plan discussed above identifies areas where the cap may not be performing consistent with expectations, follow-up assessments and/or response actions will be implemented. Follow-up assessments/actions may include additional investigation to further evaluate potential deficiencies, continued monitoring and assessment of overall remedy effectiveness over time, and/or placement of additional cap materials. Cap maintenance and response actions will be detailed in the OLMMS.

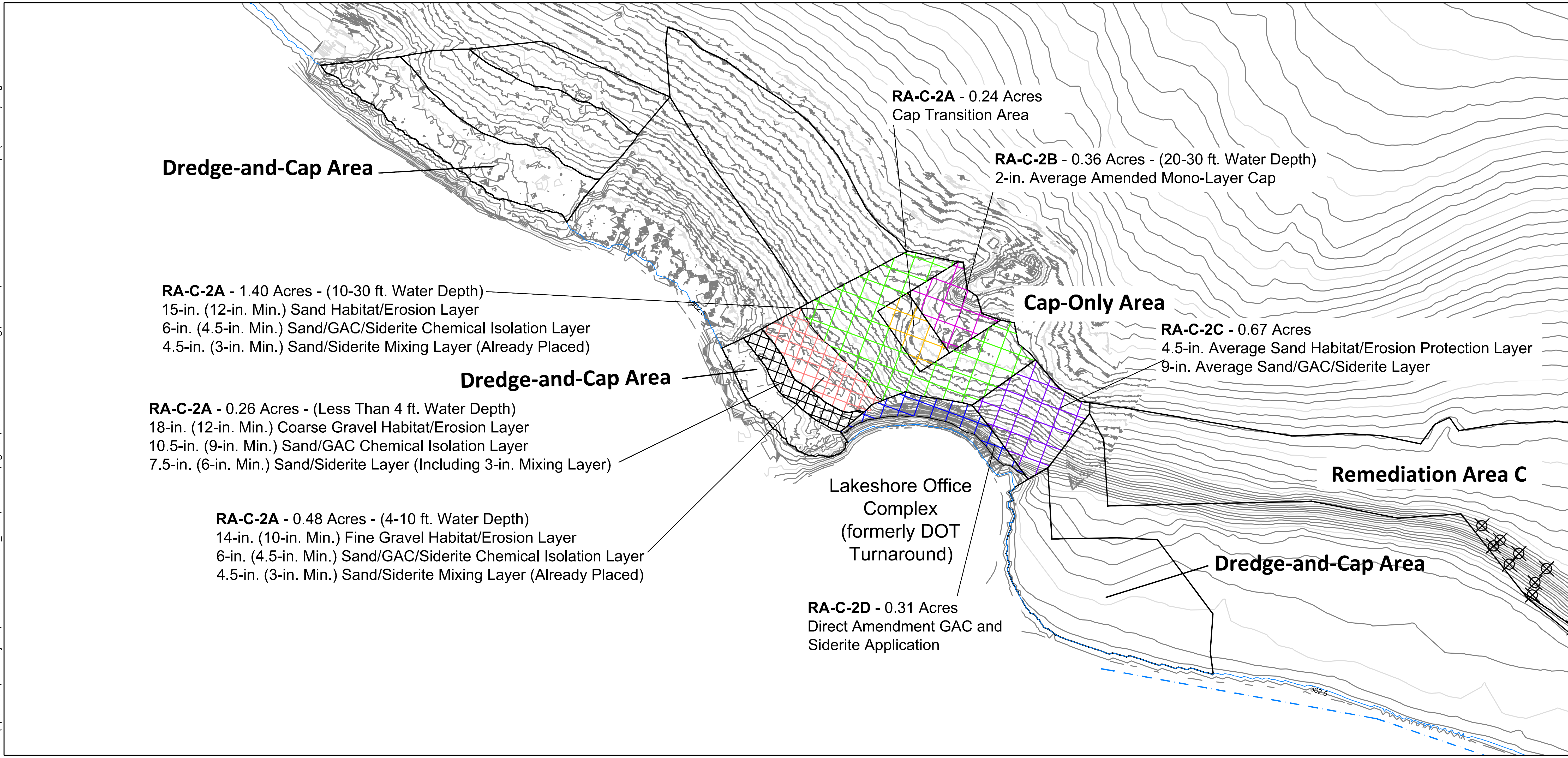
REFERENCES

C&S, 2003. Preliminary Site Assessment Report, Lake Pump Site, Town of Geddes, New York. C&S Companies. July 2003.

Parsons and AnchorQEA. 2012. "*Construction Quality Assurance Plan Onondaga Lake Capping, Dredging and* Habitat"

Parsons and AnchorQEA. 2015. "*Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design Modified Protective Cap RA-D-1 Design Revision*"

United States Environmental Protection Agency. 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites.* EPA-540-R-05-012. OSWER 9355.0-85. Office of Solid Waste and Emergency Response. December 2005.



H:\Syracuse1\CAD Projects\010139-ONONDAGA_LAKE\01013902\Figures\Construction Monitoring\FCF RA-C\RA-C-2 Modified Protective Caps (05-10-16).dwg RA-C

BATHYMETRY SOURCE:
Filename: EXG-Lake (Performed by: CR ENVIRONMENTAL, 2005) and RAC Pro_101114 (Performed by Sevenson, 10-2014)
HORIZONTAL DATUM: New York State Plane, Central Zone, North American Datum 1983 (NAD83), U.S. Feet
VERTICAL DATUM: North American Vertical Datum 1988 (NAVD88)

LEGEND:
Shoreline (elev. 362.5')
20-foot Depth Contour (elev. 342.5')

0 200
Scale in Feet

May 10, 2016 9:49am cyard

ANCHOR QEA

Figure 1
Modified Protective Cap Area RA-C-2
Onondaga Lake

ATTACHMENT 1

MODIFIED PROTECTIVE CAP RA-C-2
GEOTECHNICAL ANALYSIS

Written by:	C. Carlson/M. Erten	Date:	5/11/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/11/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-C-2	Project No.:	GD5837	Task No.:	03

SLOPE STABILITY ANALYSIS
FOR CAP PLACEMENT IN MODIFIED PROTECTIVE CAP AREA RA-C-2

This report evaluates the geotechnical aspects of a modified protective cap (MPC) in the western portion of Remediation Area C (RA-C) for various sequential cap lift placement configurations. The results of slope stability analyses showed that a MPC design in this area would consist of various cap thicknesses, as shown in Figure 8. The slope stability analyses presented herein accounts for the increase in strength of soft shallow sediments in a normally consolidated state with time due to consolidation under the cap loading. Therefore, one or two week waiting periods between placements of the lifts was evaluated in this analysis which is required during construction. The strength and stability of the underlying sediment will continue to increase over time following construction. However, longer wait time (i.e., 2 to 4 weeks) between cap lift placements would minimally improve the undrained shear strength of deeper sediments (where the controlling critical slip surfaces pass through) and therefore would not increase the calculated factor of safety. The MPC design in RA-C offshore of the DOT Turnaround (RA-C-2) will be protective consistent with the intent of the Remedial Design, which will be documented in a separate submittal to the New York State Department of Environmental Conservation (NYSDEC).

INTRODUCTION

For a capping project of the scale of Onondaga Lake Remediation, it is not unusual to expect previously unforeseen field conditions in small areas that may warrant adjustments to the cap system to achieve the remedial goals for the project. Evaluation of recently collected sediment strength data in RA-C indicates that the sediments in portions of RA-C are significantly softer than anticipated based on pre-design investigations [Geosyntec, 2015]. Therefore, modification of the cap designs detailed in the *Onondaga Lake Capping, Dredging, Habitat, and Profundal Zone Final Design* (Final Design) submittal in March 2012 is appropriate in small portions of RA-C.

This slope stability calculation package was prepared in support of the cap stability evaluations and development of MPCs in the DOT Turnaround Area of RA-C. The location of RA-C in Onondaga Lake is shown in Figure 1. The area where MPCs are being developed in this area is referred to as RA-C-2.

Sediment capping operations have been underway in Onondaga Lake since August 2012. The primary functions of the cap materials are to provide chemical and physical isolation for contaminated sediments and to reconstruct the habitat layer on the lake bottom. A portion of the contaminated materials in RA-C have been dredged prior to capping to provide adequate post-construction water depth to achieve habitat objectives; these areas are referred to as "dredge and cap areas." The remainder of the contaminated materials in RA-C are to be capped without performing any dredging; these areas are referred to as "cap-only areas."

This report evaluates the interim geotechnical slope stability condition of the cap after each lift of cap material is placed under a variety of cap placement configurations in the cap-only and dredge and cap areas. For the purposes of the slope stability analyses, each of the cap placement configurations was considered technically feasible and practical. Practical cap lift thicknesses based on input from the capping operations team which are included in this evaluation include:

- an average of 2-in. lift of sand;
- an average 4.5-in., 6-in., 7.5-in., or 9-in. lift of sand (i.e., minimum of 3-in., 4.5-in., 6-in. or 7.5-in lifts, respectively) including a typical 1.5 in. of over-placement;
- an average 10-in. lift of fine gravel (i.e., minimum of 6-in. lift) including a typical 4 in. of over-placement; and
- an average 12-in. lift of coarse gravel (i.e., minimum of 6-in. lift) including a typical 6 in. of over-placement.

In this analysis, original Cap Type J includes a minimum of 6 inches of siderite mixed with medium sand, 9 inches of granular activated carbon (GAC) mixed with medium sand, and 12 inches of medium sand.

The original Cap Type H includes a minimum of 6 inches of siderite mixed with medium sand, 9 inches of GAC mixed with medium sand, and 18 inches of fine gravel.

The original Cap Type L includes a minimum of 6 inches of siderite mixed with medium sand, 9 inches of GAC mixed with medium sand, 12 inches of coarse gravel, and 12 inches of fine gravel.

SLOPE STABILITY ANALYSES

The slope stability analyses were performed using Janbu's simplified method [Janbu, 1973] for block failure slip surfaces and Spencer's method [Spencer, 1973] for the circular slip surfaces, as implemented in the computer program SLIDE, version 6.026 [Rocscience, 2013]. Spencer's method, which satisfies vertical and horizontal force equilibrium and moment equilibrium, is considered to be more rigorous than other methods, such as Janbu's simplified method [Janbu, 1973] and the simplified Bishop's method [Bishop, 1955]. However, Spencer's method often encounters numerical convergence difficulties when considering block slip surfaces. Therefore, Spencer's method was used for the circular slip surfaces, while Janbu's method was used for block slip surfaces.

The rotational and block modes of slope stability analyses are consistent with the methods presented in the RA-C-1 Report [Geosyntec, 2016].

Target Factor of Safety

Consistent with the RA-C-1 Report [Geosyntec, 2016], a target factor of safety (FS) of 1.5 was selected for the analyses presented herein. The target FS (1.5) for the slope stability analysis of the cap is consistent with the target FS selected for previous slope stability analyses, including the FS used for stability analysis of the In-lake Waste Deposit (ILWD) area included as Appendix H to the Final Design. The FS of 1.5 for the ILWD stability analysis was specified in the Statement of Work included as part of the Remedial Design/Action Consent Decree for the lake. Given the potential implications of additional cap movement, as demonstrated by the prior areas of cap movement, a FS of 1.5 is appropriate for this analysis consistent with prior stability analysis associated with the remediation design.

Subsurface Stratigraphy

Because the sediments in RA-C are soft, undisturbed samples could not be collected in the field and tested in the laboratory for measuring the shear strength and consolidation properties. Therefore, the information regarding the subsurface stratigraphy was obtained from in situ field testing techniques, including the Cone Penetrometer Test (CPT) and Full-Flow Penetrometer Test (FFP). It should be noted that the FFP is generally more accurate than the CPT for assessing the low shear strength of soft sediments. Therefore only the results of FFP tests are presented in this report.

In selection of the shear strength profiles and subsurface stratigraphy, the effect of creep behavior, as stated in Geosyntec (2015), was considered. The effect of creep behavior on slope stability was addressed within the target FS of 1.5 and the selection of lower bound values for undrained shear strength of the sediments. The target FS and lower shear strength values are expected to result in relatively low stress levels (induced by capping load) along the predicted failure surfaces and reduce the likelihood of the creep behavior and reduction in the undrained shear strength with time.

The locations of in situ tests within RA-C are presented in Figure 2. These in situ tests provided information to characterize the in situ shear strength and consolidation properties of the soft sediments within different regions of RA-C. In 2012, ten FFPs and CPTs (OL-CPT-01 to OL-CPT-10) were advanced. In 2013, two FFPs (OL-FFP-C1 and OL-FFP-C2) were advanced. In May 2015, twelve FFPs (FFP-15-C1 to C12), three CPTs (FFP-15-C2-CPT, C6-CPT, and C9-CPT), and two vibracores (FFP-15-C8-VC and C10-VC) were conducted in the cap-only area of RA-C. The FFP results and selected shear strength profiles for slope stability analyses are shown in Figures 3 and 4. The other collected FFP data, west of RA-C where full cap thickness is proposed, are provided in Attachment A.

For Cross Section 1, the stability of the cap is mainly controlled by presence of soft sediments in relatively shallow slopes as reflected in collected FFP-15-C8, FFP-15-C1, and FFP-15-C9 (Figure 3). The shear strength profile from FFP-15-C8, which is closer to the cross section compared to FFP-15-C1 or FFP-15-C9, was used. The slope stability of cap is sensitive to the strength of shallow sediments in top 2 ft. FFP-15-C9, FFP-15-C1, and FFP-15-C8 have verified the presence of soft shallow sediments. Also the collected FFP (OL-CPT-12) in the upslope area of Cross Section 1 is shown in Figure 3.

For Cross Section 2, the shear strength profile from FFP-15-C1 and FFP-15-C9, which are closer to the cross section compared to FFP-15-C8, were used. Also significant decrease of the shear strength of the sediments with depth was considered. The shear strength of sediments (as observed in most of the investigation locations in Onondaga Lake) commonly increases with depth. The reason for the decrease in shear strength with depth in Cross Section 2 is unknown. Therefore, a conservative approach was considered appropriate while developing the subsurface stratigraphy model and assigning the shear strength profiles in RA-C-2. The deep weak layer appeared to be extended throughout the RA-C-2A, as FFP-15-C4 and FFP-15-C5 in the adjacent area (Attachment A) exhibited the weak layer.

GEOTECHNICAL STABILITY EVALUATION

Shear Strength Gain

The shear strength gain caused by an increase in vertical effective stress (in this case, as a result of cap placement) is proportional to the degree of consolidation. The shear strength gain considered in the analyses for RA-C-2 was consistent with the method described in the report titled "Development of Geotechnical Design Parameters for Lakebed Sediments in Onondaga Lake Capping Areas"[Geosyntec, 2015].

In general, the strength gain of sediments deeper than 4 ft below the lake bottom was neglected due to long drainage path and negligible degree of consolidation in practical few-week wait time between placements of cap lifts.

The normally consolidated and over-consolidated state of the lakebed sediments were considered in slope stability analyses and developed based on the method described in Geosyntec [2015]. The normally and over-consolidated sediments are noted in Figures 3 to 4.

Geotechnical Parameters

The material properties used for the geotechnical slope stability analyses in this report are presented in Table 1 and Figures 3 and 4. In summary, the subsurface materials in the modified protective cap area RA-C-2 consist of three strata: Soft Sediments, Marl, and Silt and Clay. Soft Sediments extend to depths of about 10 to 20 ft. Marl lies between depths of 20 and 60 ft. Silt and Clay is below depths of 60 ft.

Geotechnical parameters of lakebed sediments are described in Geosyntec report [2015].

ANALYZED CROSS SECTIONS

Two cross sections shown in Figure 2 were evaluated for slope stability analyses in RA-C-2. Cross Section 1 was considered representative for the stability considerations in RA-C-2C and RA-C-2D and Cross Section 2 was considered representative cross section for the stability conditions in the RA-C-2A and RA-C-2B. Figures 3 and 4 show the bathymetry, subsurface conditions, and selected strength profiles for Cross Sections 1 and 2, respectively.

RESULTS OF SLOPE STABILITY ANALYSES

Figures 5 and 6 show the calculated failure surfaces and minimum FS for Cross Sections 1 and 2, respectively, in the existing condition (i.e., prior to cap placement) and after each lift of cap is placed.

For Cross Section 1, predicted failure surfaces are shown in Figure 5 and the minimum calculated FS for placement of Cap Type J are listed in the table below.

Lift	Existing	Lift 1	Lift 2	Lift 3		Lift 4
Average Cap Thickness (in.)	-	4.5	4.5	4.5	6.0	4.5
Wait Time (week)	-	1	1	1	1	1
Extension Beyond Cap Only (ft)*	-	80	60	40	40	20
Calculated Minimum FS	2.20	1.57	1.53	1.54	1.43	1.44
Recommended Placement	-	X	X	X	-	-
Depth of Failure Surface (ft)	2	2	2	4	2	4

*The cap is extended beyond the cap boundary in order to provide buttressing effect and increase the FS.

Based on the calculated FS, it is recommended that three lifts of cap materials with an average lift thickness of 4.5 inches per lift be placed in RA-C-2C. It should be noted that this recommendation resulted from the presence of shallow soft sediments over the relatively steeper slopes along this cross section, as shown in Figure 3. In general, the calculated failure surfaces as presented in table above are within the upper zone of the soft sediments (i.e., depths of 2 feet). Since the calculated slip surfaces are large and the slopes are relatively steep, placement of additional cap materials in this area (with thinner lift, larger feathering, and practical longer wait time) results in calculated FS less than target FS of 1.5.

For Cross Section 2, predicted failure surfaces are shown in Figure 6 and the minimum calculated FS for placement of Cap Type J are listed in the table below.

Lift	Existing	Lift 1			Lift 2	Lift 2	Lift 3*	Lift 4*
Average Cap Thickness (in.)	-	4.5	4.5*	2.0**	6.0*	2.0**	6.0	9.0
Wait Time (week)	-	-	-	-	1	2	1	1
Feathering or Setback (ft)	-	-	100	-	20	20	20	30
Calculated Minimum FS	1.88	1.23	2.01	1.51	1.91	1.44	1.81	1.53
Recommended Placement	-	-	X	X	X	-	X	X
Depth of Failure Surface (ft)	8	2	12	2	14	2	14	2

* The lift thickness and calculated FS are for the area upslope of the 100-ft setback in Figure 6.

** The thickness and calculated FS are for the area within the 100-ft wide setback, shown in Figure 6.

Therefore, for Cap Type J, four lifts of cap (one average 4.5-in. + two average 6.0-in. + one average 9.0-in. thick lifts) with one-week wait times between lifts and setbacks presented in the table above and Figure 6 are recommended. With the exception of the 100-ft wide setback discussed below, the setbacks shown in Figure 6 for Cross-Section 2 are also applicable for the areas of RA-C-2A east and west of the area of the RA-C-2B 2-in placement. In these areas, all four layers will be placed up to the edge of SMU 8 and the setbacks will extend into SMU 8.

One average 2-in. thick lift will be placed in a 100-ft wide area as detailed in Figure 6. The 100-ft setback for placing the first 4.5-in. lift in Cross Section 2 is due to the presence of a deep water depression around Station 500 ft (Figure 6) and presence of soft sediments along the steeper portion of this depression (Figure 4). This setback includes 40-ft offset from the crest surrounding the depression to prevent instability due to the cap placement upslope and sideslope of the depression area.

For Cap Type H, three lifts of cap (one average 4.5-in. + one average 6.0-in. + one average 14-in. thick lifts) with one-week wait times between lifts are recommended. Placement of additional cap in Cap Type H in this section results in calculated FS that are less than the target FS of 1.5.

For Cap Type L, four lifts of cap (one average 7.5 in. sand/siderite + one 10.5 in. of granular activated carbon (GAC) + one average 18 in. of coarse gravel + one average 16 in. of fine gravel lifts) are recommended. It should be noted that the required setback of 40 ft for Lift 4 resulted from the presence of a deep weak layer with undrained shear strength of 50 psf along this cross section, as shown in Figure 4. Since the calculated failure surfaces are deep, the strength gain for slope stability analysis is considered negligible.

For this cross section, the calculated failure surfaces as presented in the table above are within the upper zone of the soft sediments (i.e., depths of 2 to 4 feet) or deeper weak layer of soft sediments (i.e., depths of 8 to 14 ft).

The cap placement procedure in RA-C-2 includes a verification of successful placement of each cap layer as required by the Construction Quality Assurance Plan (CQAP) through methods such as coring, prior to proceeding with the subsequent layer. However, the monitoring and verification of successful layer placement will not provide information regarding whether additional lift placements would be stable; rather, it only verifies that it was stable for what was already placed. Therefore, real time monitoring would not allow additional cap material to be placed.

Other engineering methods to improve stability and allow additional cap material placement, such as toe berms and keyways, were considered. The critical slip surfaces are large and deep along the relatively continuous steep slope areas in RA-C-2, thus, these engineering methods could not potentially be suited for this area.

It should be noted that the potential for creep behavior (as stated in Geosyntec 2015) would be offset by the strength gain due to consolidation with time, resulting in an increase in the calculated FS over time. Additional long-term analysis of slope stability for a representative cross section (Cross Section 2) was conducted. The calculated FS for the long-term condition (after consolidation of sediments under the cap loading is completed) in Cross Section 2 is 2.35 (compared to the calculated FS of 1.5, immediately after the cap placement). Also, the long-term presence and performance of the cap throughout the lake, including the MPC areas, will be verified as part of the long-term cap monitoring program.

Construction of a cap on the steep slope adjacent to the DOT Turnaround area (nearshore portion on Cross Section 1) would require installation of a berm at the base of the slope to provide a stable base upon which the slope cap could be constructed. Without construction of the toe berm, it is anticipated that placed cap material would slough and accumulate at the base of the slope until an equivalent toe berm/buttress formed naturally. Based on the very soft nature of the sediments that currently exist at the toe of the slope and out into deeper water adjacent to the DOT Turnaround, it is anticipated that an adequate toe berm could not be constructed without resulting in a condition where the FS would be less than 1.5. Figure 7 shows the results of the stability analysis performed for the construction of a berm following the placement of the recommended three lifts of cap materials with an average lift thickness of 4.5 inches per lift in the downslope area (RA-C-2C); the predicted FS for this scenario is less than 1. The results of slope stability analysis show that only three thin lifts of cap material can be placed in RA-C-2C and no additional cap placement is recommended over the nearshore steep area (RA-C-2D in Figure 8). Other cap configurations (e.g., thinner caps on the steep slope) were considered, but each of these configurations would require (or naturally result) in a toe berm at the base of the steep slope. Therefore, capping is not recommended on the steep portion of the slope adjacent to the NYSDOT turnaround (RA-C-2D).

CONCLUSIONS

The results of the slope stability analyses for the placement of multiple lifts of cap with one or two-week waiting periods between lifts show that, in general:

- the calculated minimum FS for the existing condition in various areas of RA-C-2 varies between 2.20 and 1.88; and

- in RA-C-2, a reduction in cap thickness in Cap Type J, H, and L from that detailed in the Final Design is required to achieve a calculated FS that can be considered acceptable.

Figure 8 shows the recommendation for cap placement in the modified protective cap area RA-C-2.

REFERENCES

Bishop, A. (1955), "*The Use of the Slip Circle in the Stability Analysis of Slopes*," Geotechnique, Volume 5, No. 1, Jan 1955, pp. 7-17.

Geosyntec Consultants (2016), "*Slope Stability Analysis for Cap Placement in Modified Protective Cap Area RA-C-1*," Prepared for submittal to NYSDEC, April 25, 2016, 25 pages.

Geosyntec Consultants (2015), "*Development of Geotechnical Design Parameters For Lakebed Sediments in Onondaga Lake Capping Areas*," Prepared for submittal to NYSDEC, October 12, 2015, 38 pages.

Janbu, N. (1973), "*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.

Mayne, P.W. (2007), "*Cone Penetration Testing, A Synthesis of Highway Practice*," NCHRP Synthesis 368, Transportation Research Board, Washington, D.C.

Rocscience (2013), "*SLIDE – 2-D Limit Equilibrium Slope Stability for Soil and Rock Slopes*," User's Guide, Rocscience Software, Inc., Toronto, Ontario, Canada, 2013.

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

Written by:	C. Carlson/M. Erten	Date:	5/11/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/11/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-C-2	Project No.:	GD5837	Task No.:	03

Table 1. Summary of material properties used for the slope stability analyses in Modified Protective Cap area RA-C-2.

Material	Total Unit Weight (pcf)	Undrained Shear Strength, s_u (psf)
Soft Sediments	85	Selected as shown in Figures 3 and 4
Marl	100	220, for depth < 30 ft 440, for depth ≥ 30 ft
Silt and Clay	110	$\frac{s_u}{\sigma_v'} = 0.3$

Written by:	C. Carlson/M. Erten	Date:	5/11/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/11/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-C-2	Project No.:	GD5837	Task No.:	03

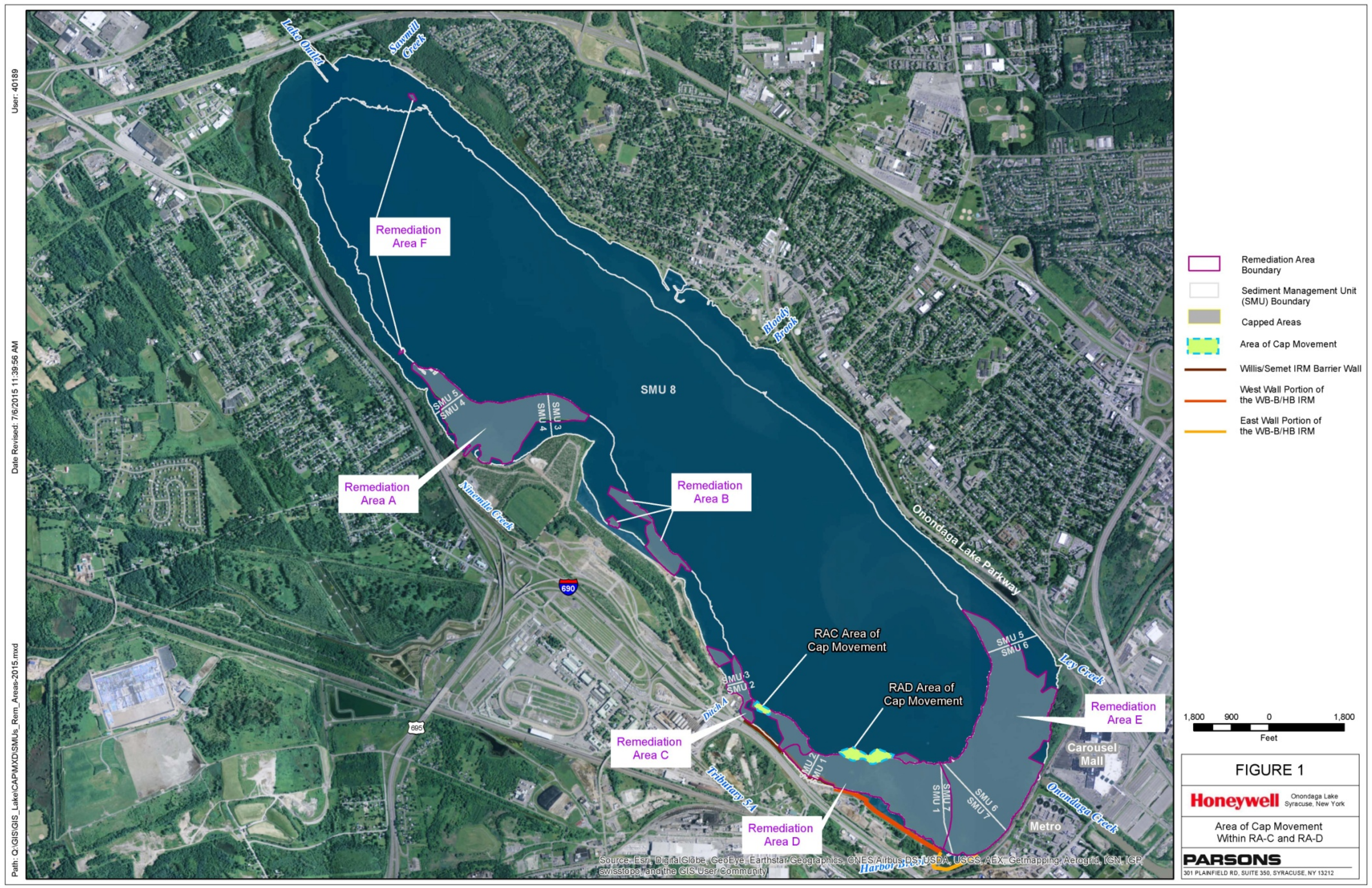


Figure 1. Remediation Area C (RA-C) among other Remediation Areas in the Onondaga Lake Capping Project

Written by:	C. Carlson/M. Erten	Date:	5/11/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/11/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-C-2	Project No.:	GD5837	Task No.:	03

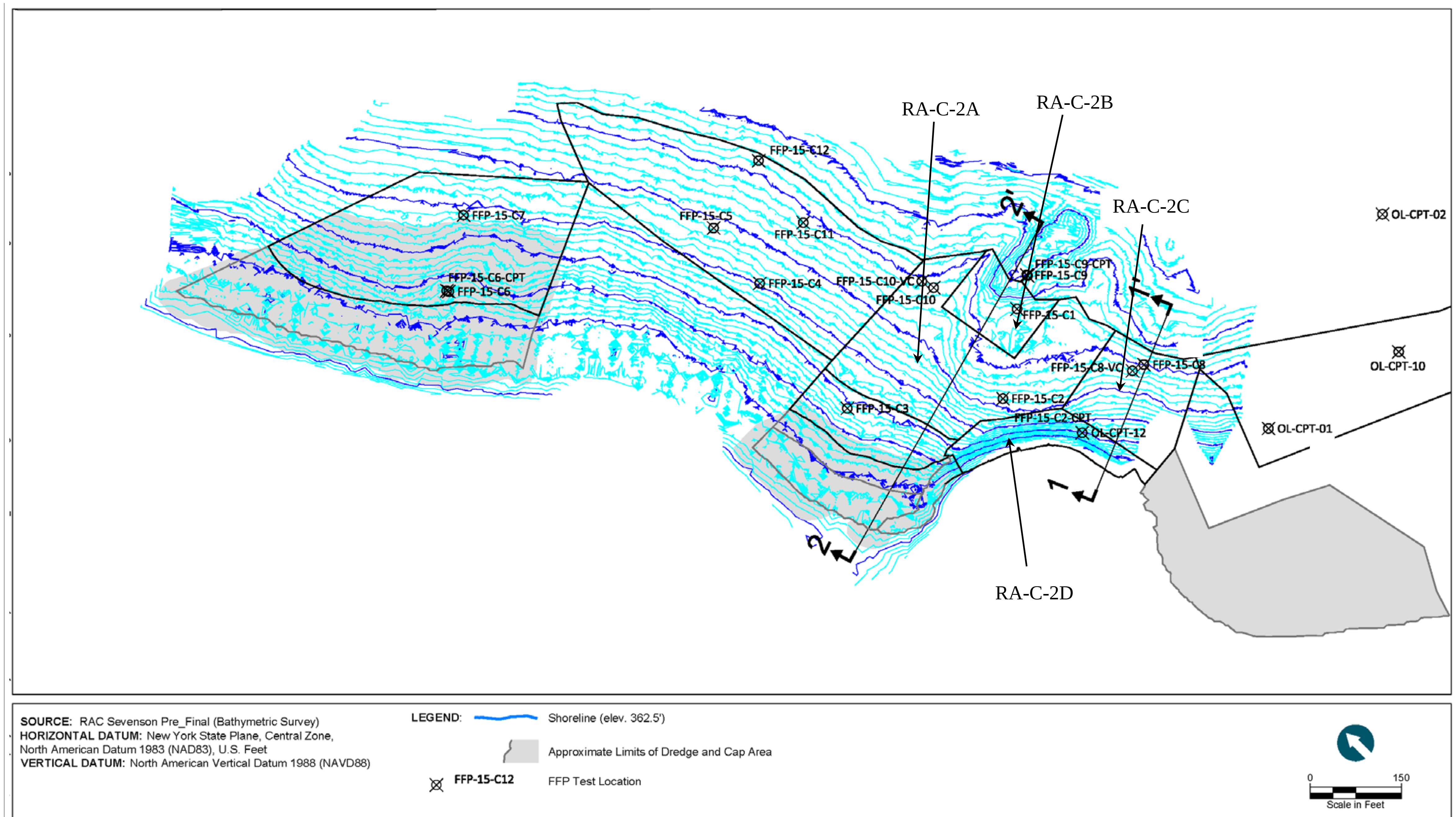


Figure 2. Map of modified protective cap area RA-C-2. This map also shows locations of in situ FFP and CPT tests and the two analyzed cross sections.

Written by:	C. Carlson/M. Erten	Date:	5/11/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/11/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-C-2	Project No.:	GD5837	Task No.:	03

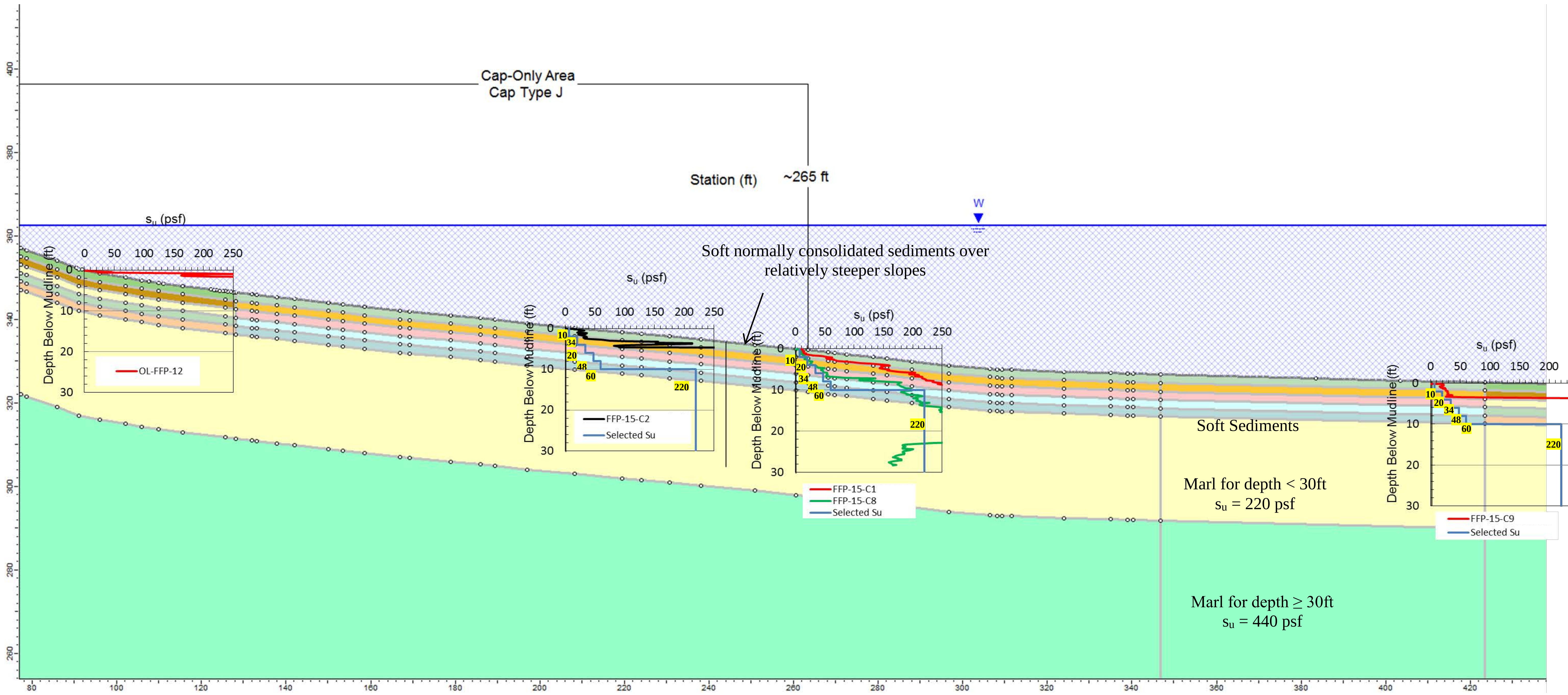


Figure 3. Subsurface stratigraphy and shear strength (s_u) profiles developed from the FFPs collected near Cross Section 1.

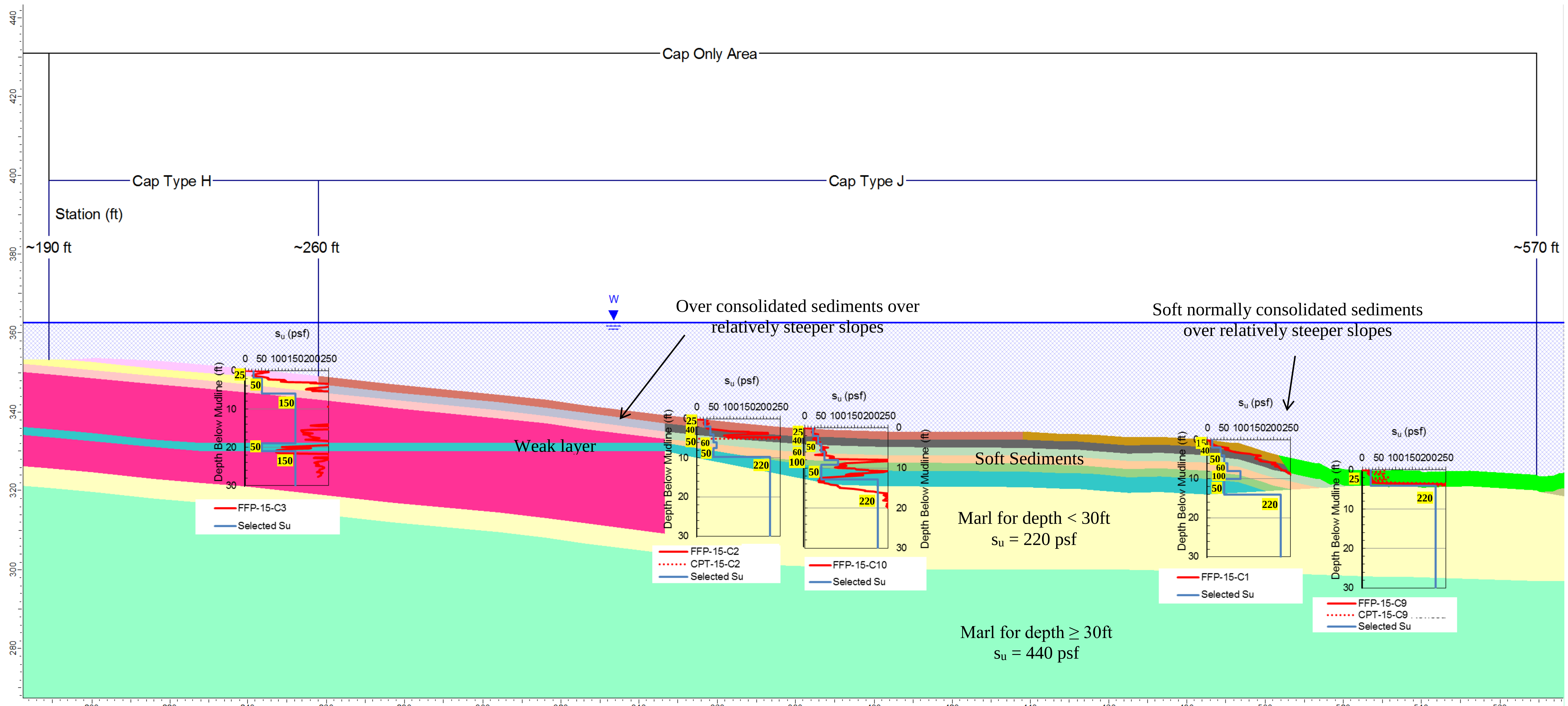


Figure 4. Subsurface stratigraphy and shear strength (s_u) profiles developed from the FFPs collected near Cross Section 2.

Written by:	C. Carlson/M. Erten	Date:	5/11/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/11/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-C-2	Project No.:	GD5837	Task No.:	03

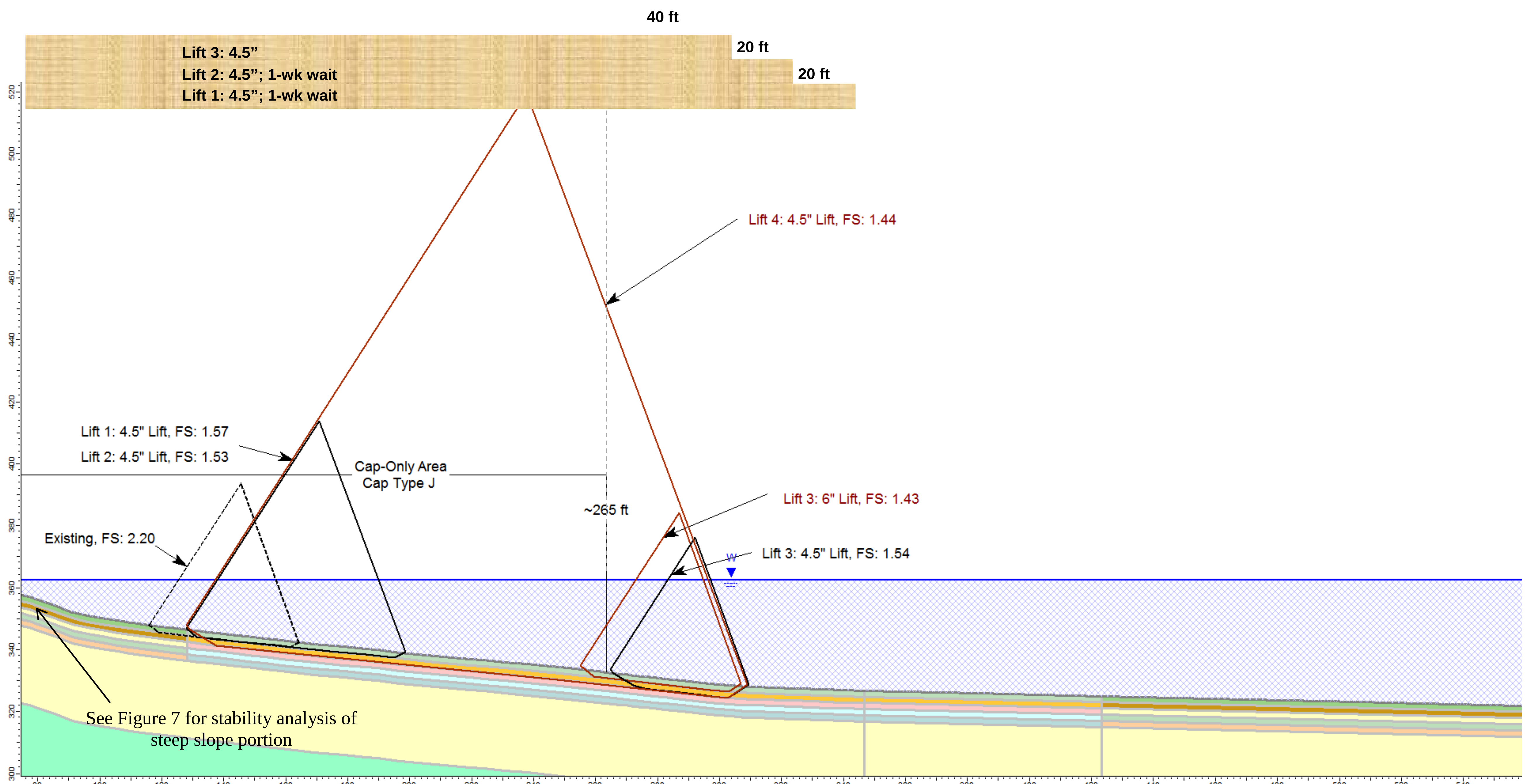


Figure 5. Calculated factors of safety and critical slip surfaces for Cross Section 1.

Written by:	C. Carlson/M. Erten	Date:	5/11/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/11/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-C-2	Project No.:	GD5837	Task No.:	03

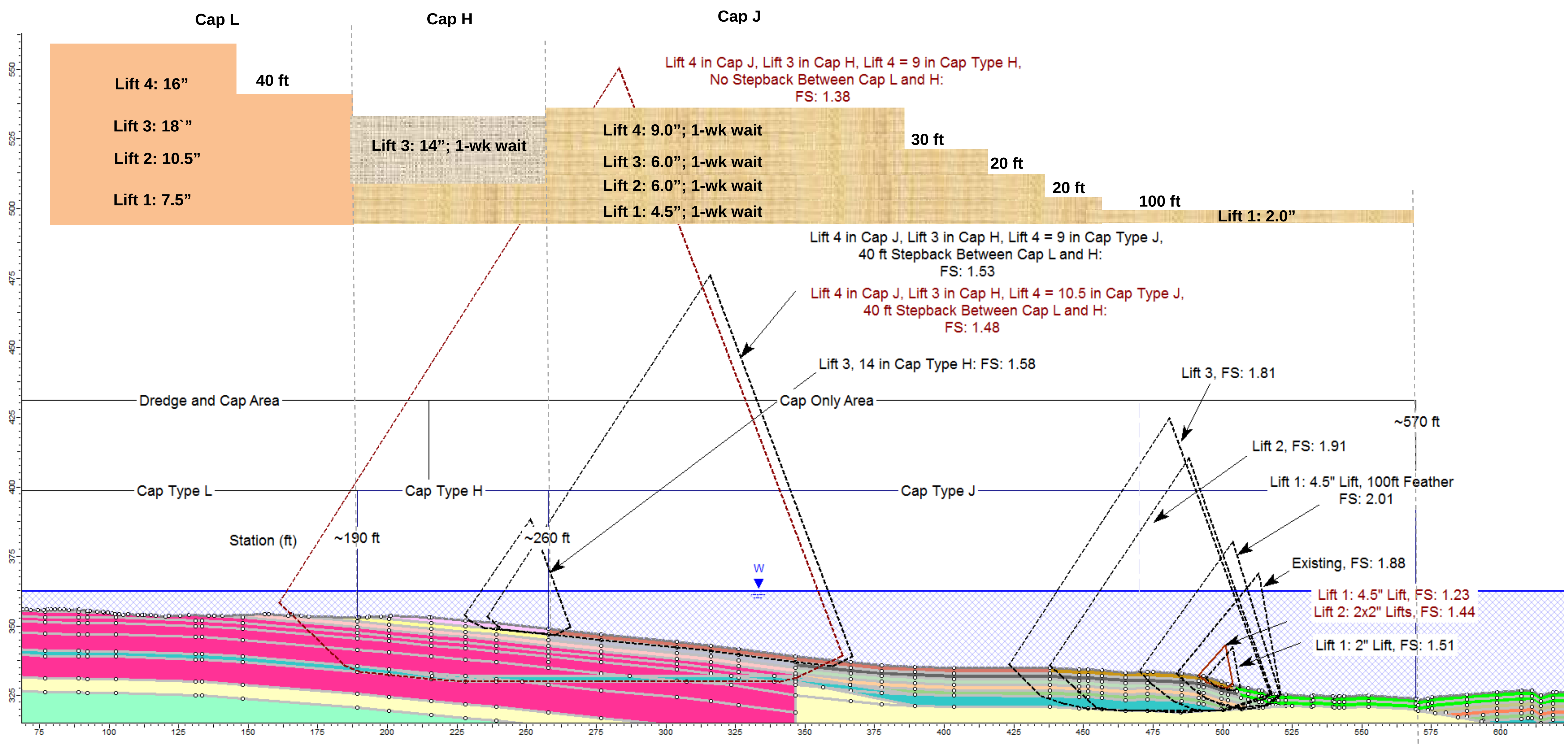
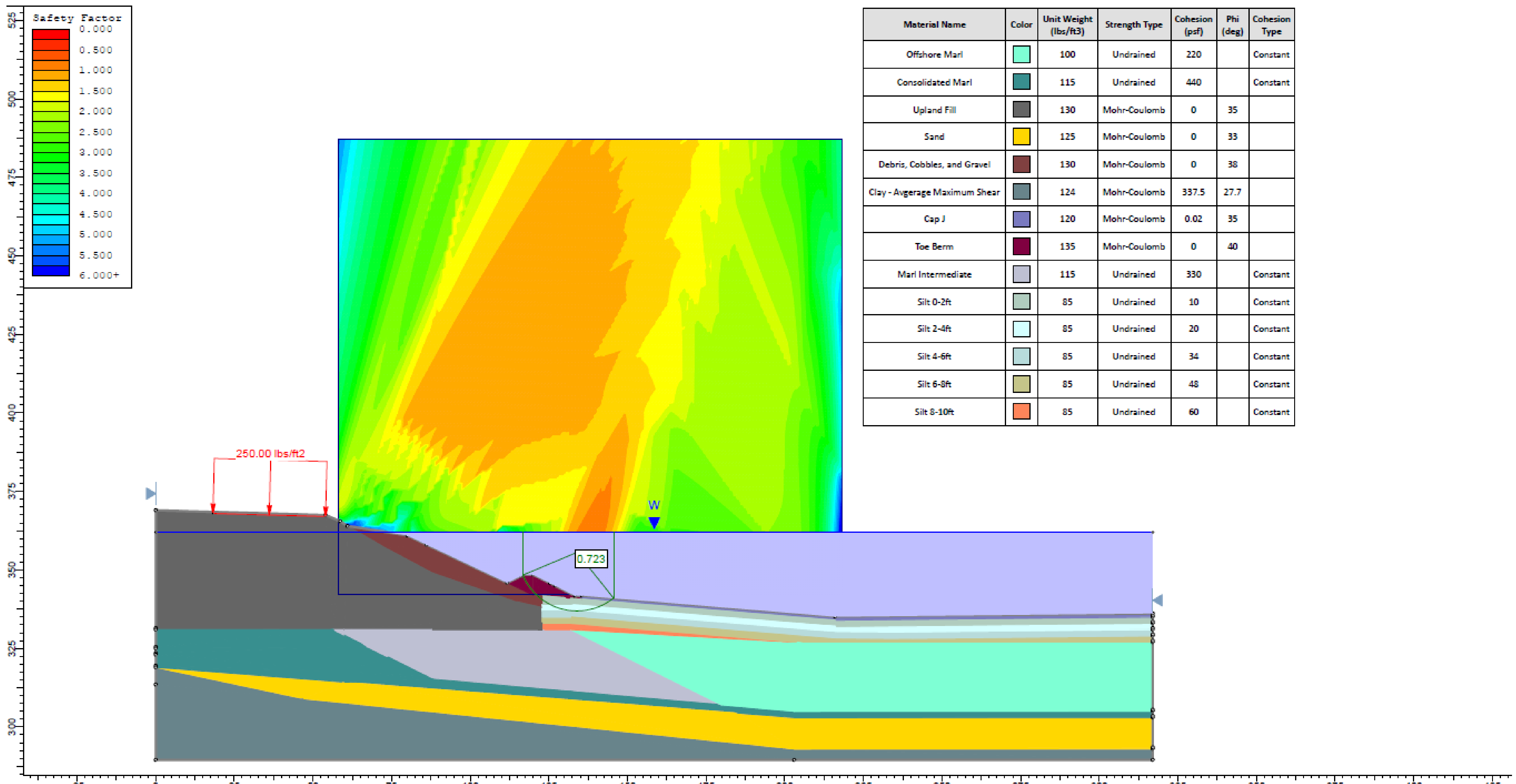


Figure 6. Calculated factors of safety and critical slip surfaces for Cross Section 2.

Written by:	C. Carlson/M. Erten	Date:	5/11/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/11/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-C-2	Project No.:	GD5837	Task No.:	03



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type
Offshore Marl		100	Undrained	220		Constant
Consolidated Marl		115	Undrained	440		Constant
Upland Fill		130	Mohr-Coulomb	0	35	
Sand		125	Mohr-Coulomb	0	33	
Debris, Cobbles, and Gravel		130	Mohr-Coulomb	0	38	
Clay - Avgerage Maximum Shear		124	Mohr-Coulomb	337.5	27.7	
Cap J		120	Mohr-Coulomb	0.02	35	
Toe Berm		135	Mohr-Coulomb	0	40	
Marl Intermediate		115	Undrained	330		Constant
Silt 0-2ft		85	Undrained	10		Constant
Silt 2-4ft		85	Undrained	20		Constant
Silt 4-6ft		85	Undrained	34		Constant
Silt 6-8ft		85	Undrained	48		Constant
Silt 8-10ft		85	Undrained	60		Constant

Figure 7. Calculated factors of safety and critical slip surface for installation of a berm at the base of the steep slope portion of Cross Section 1.

Written by:	C. Carlson/M. Erten	Date:	5/11/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/11/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-C-2	Project No.:	GD5837	Task No.:	03

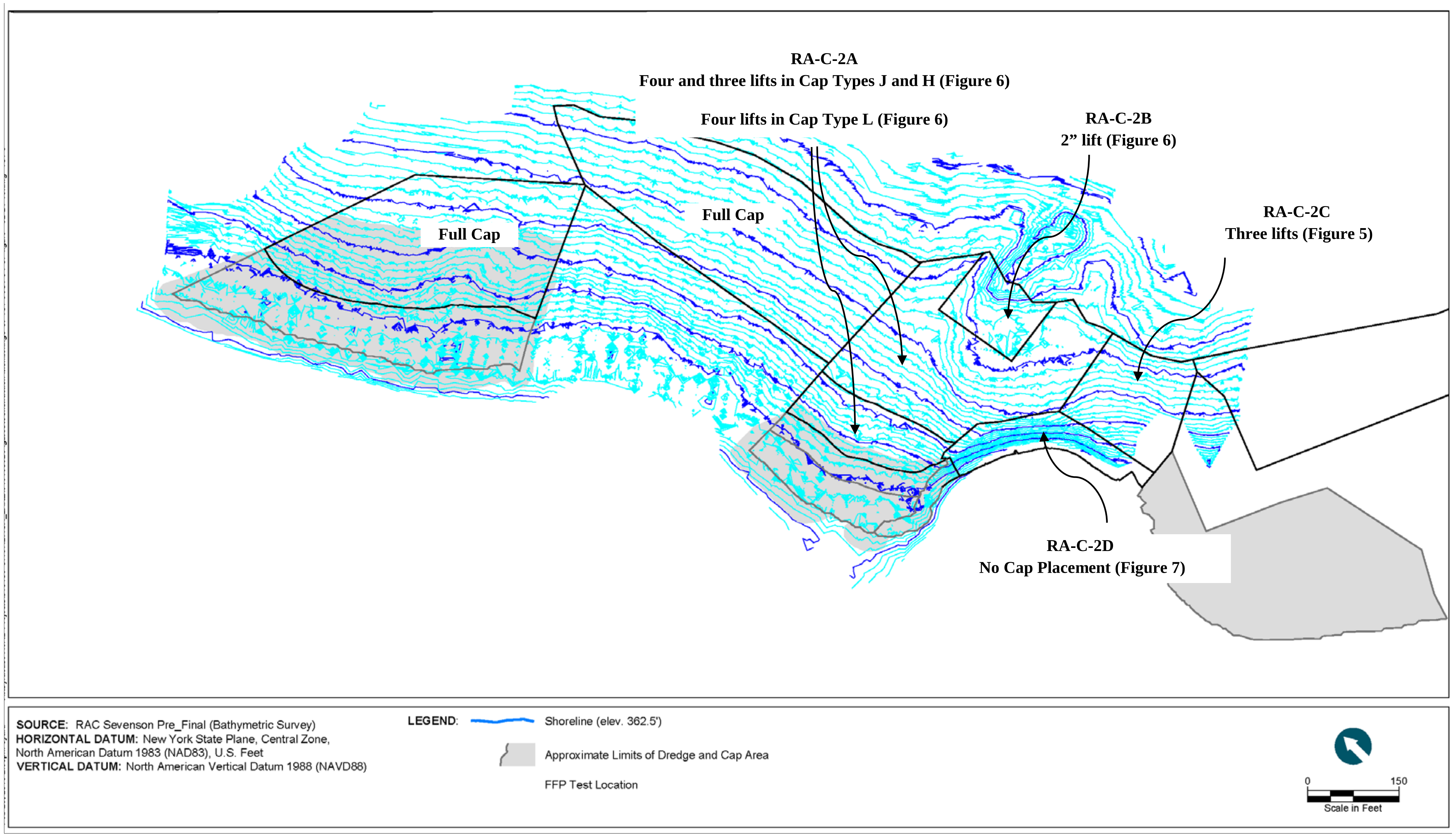
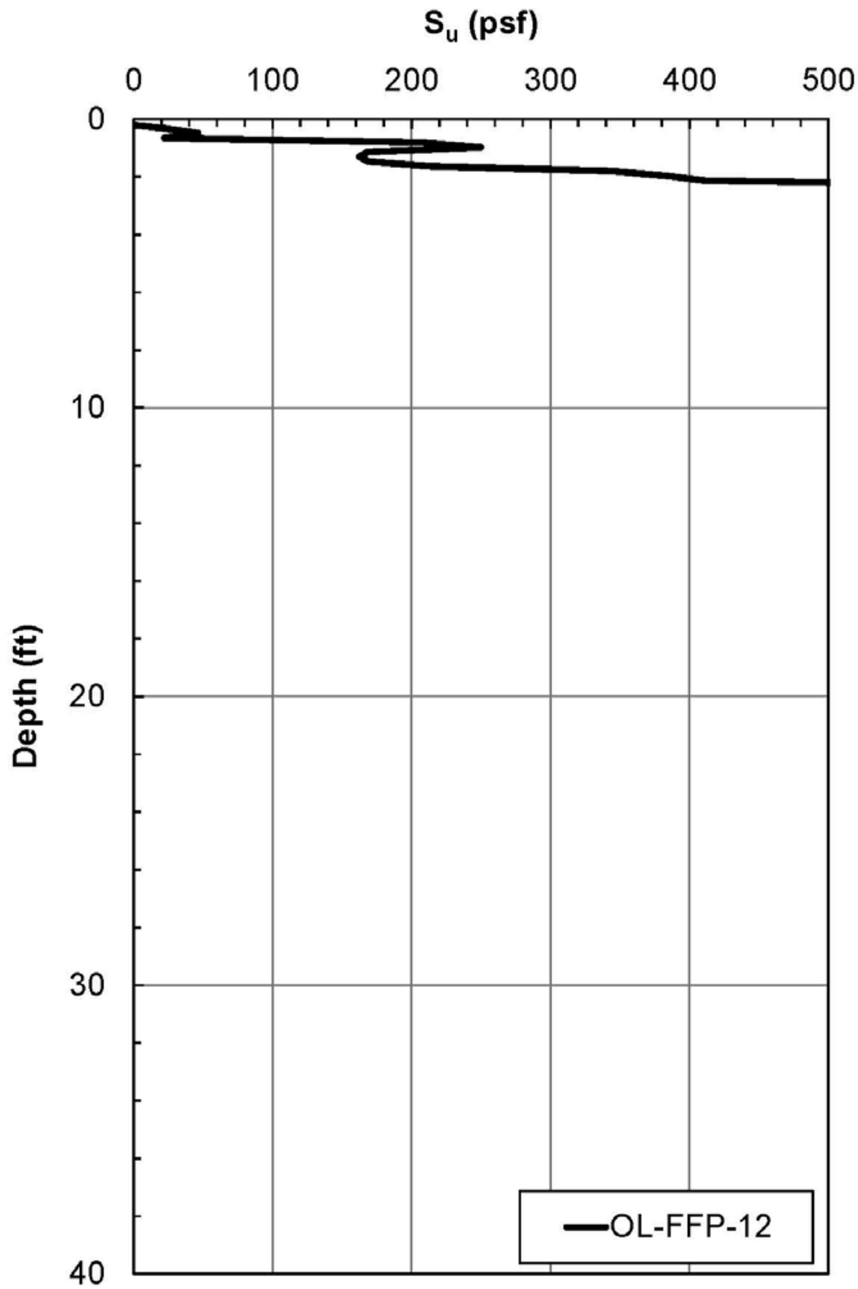
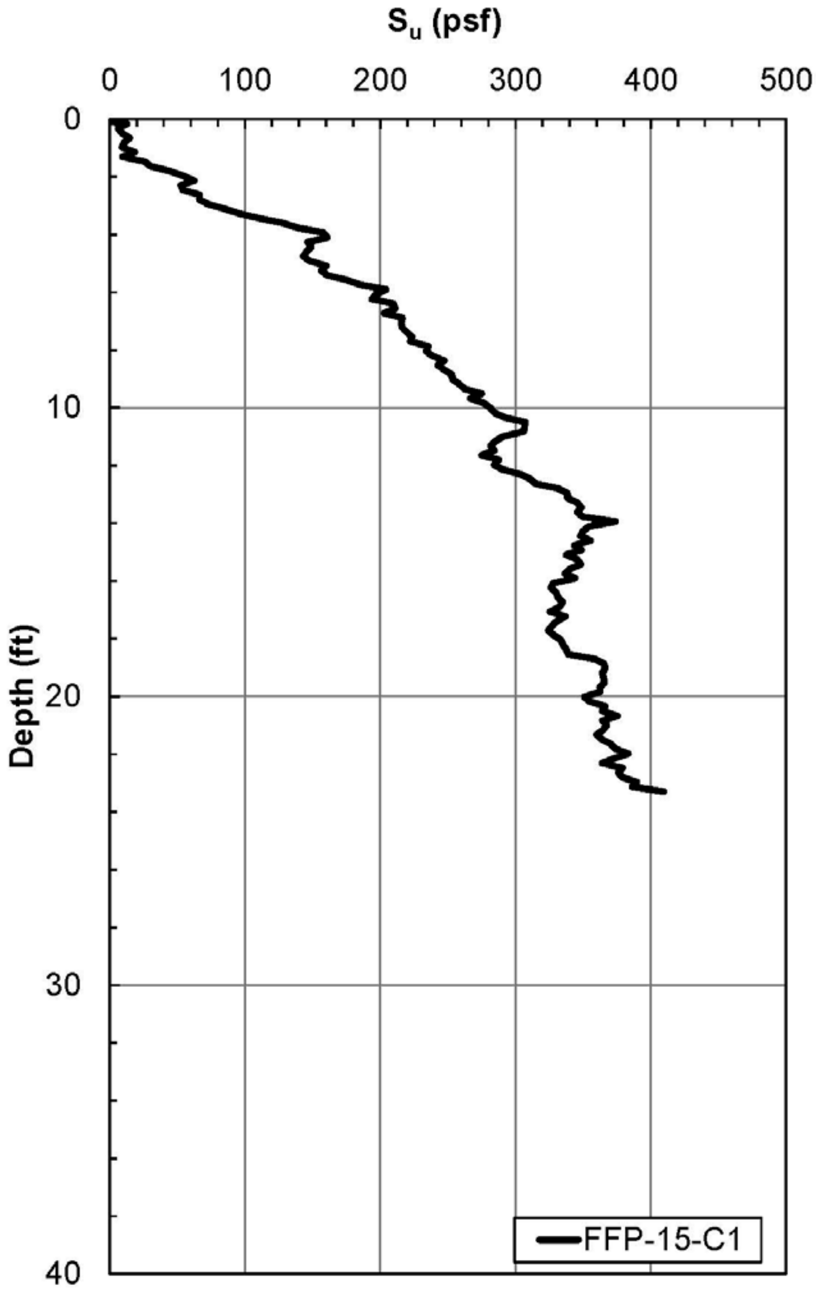


Figure 8. Recommended cap placement in modified protective cap area RA-C-2.

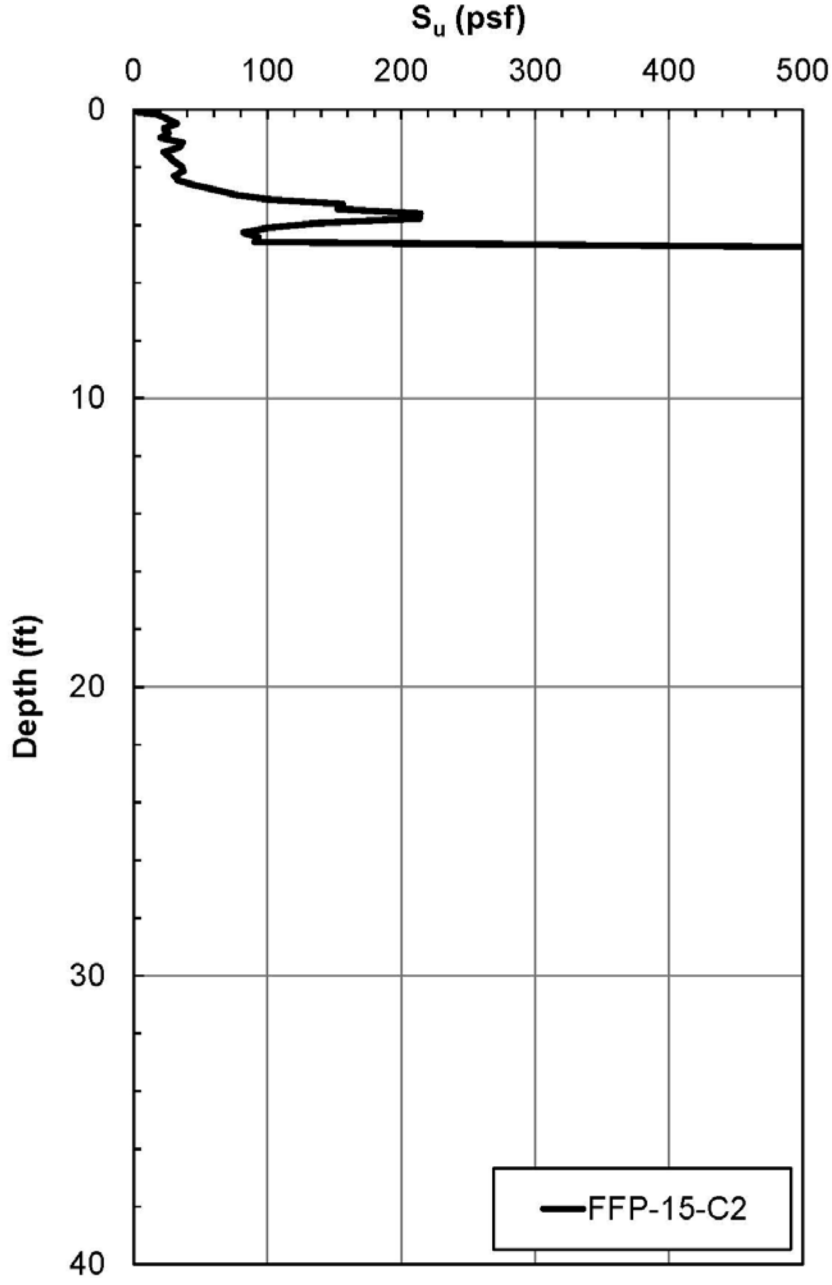
Appendix A
(FFP Data in RA-C-2 and in West of RA-C-2)



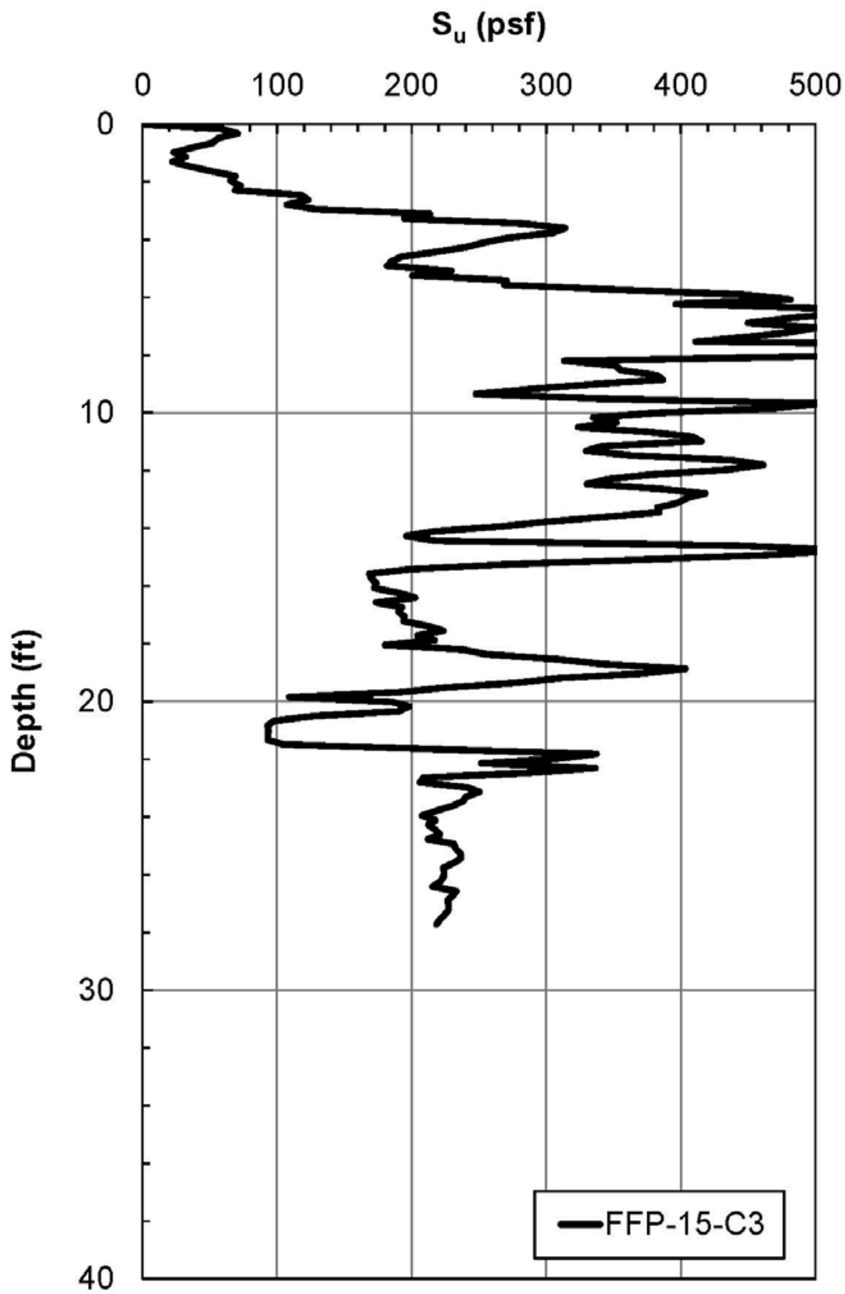
S_u (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
OL-FFP-12



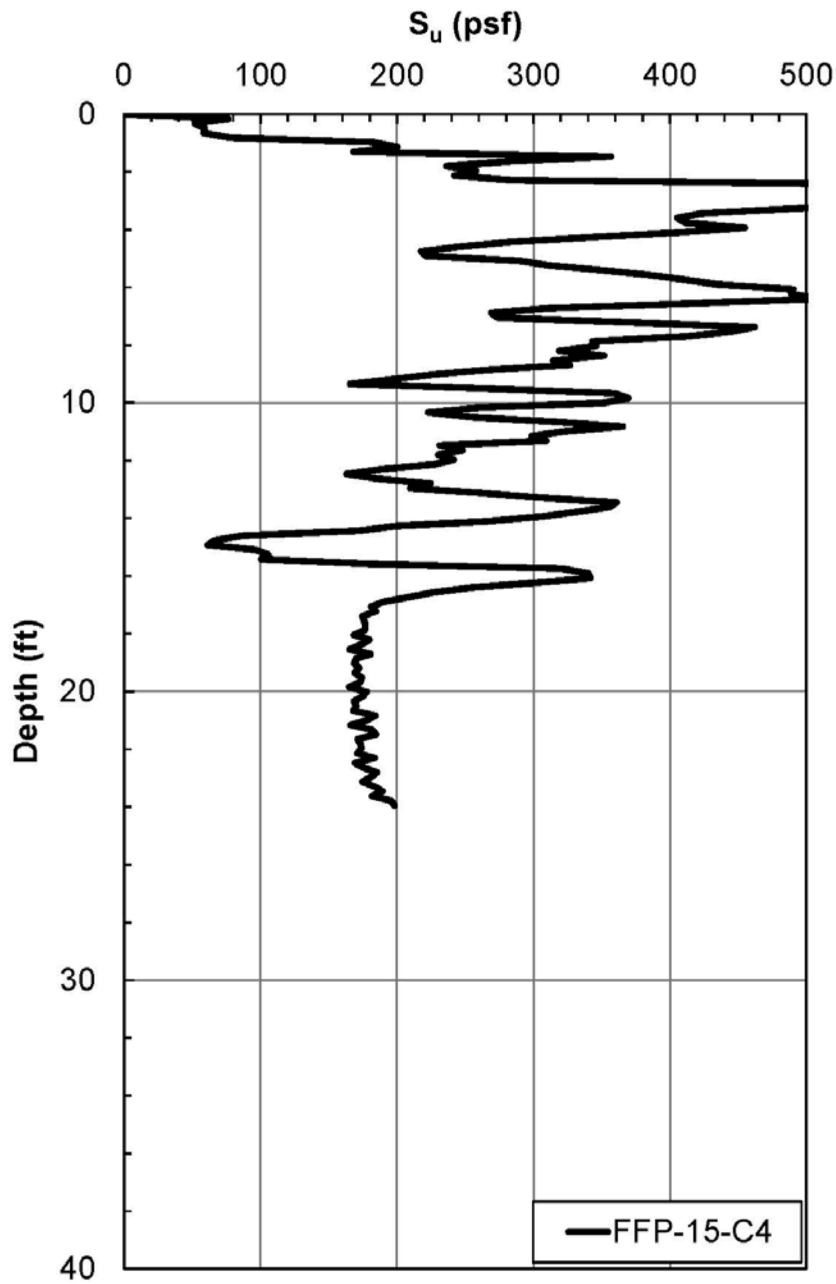
S_u (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
FFP-15-C1



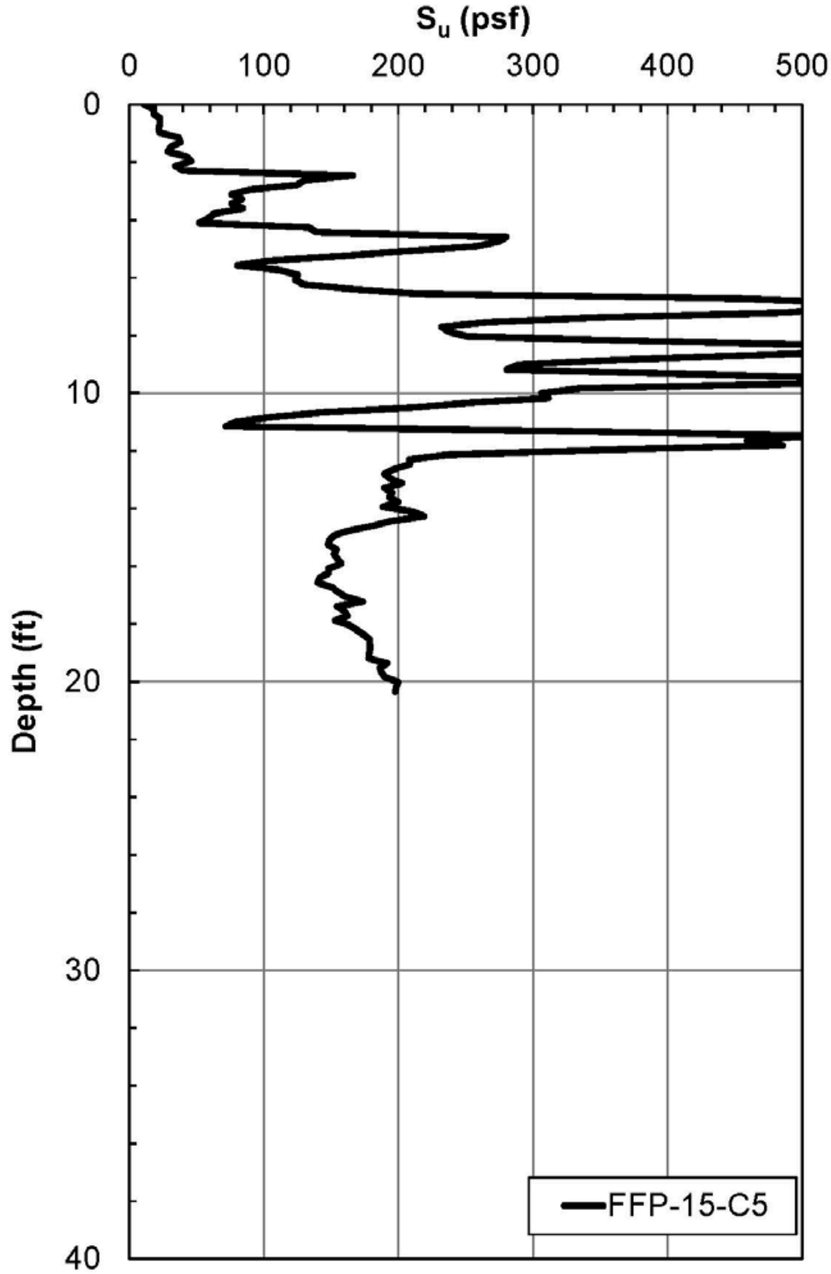
S_u (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
FFP-15-C2



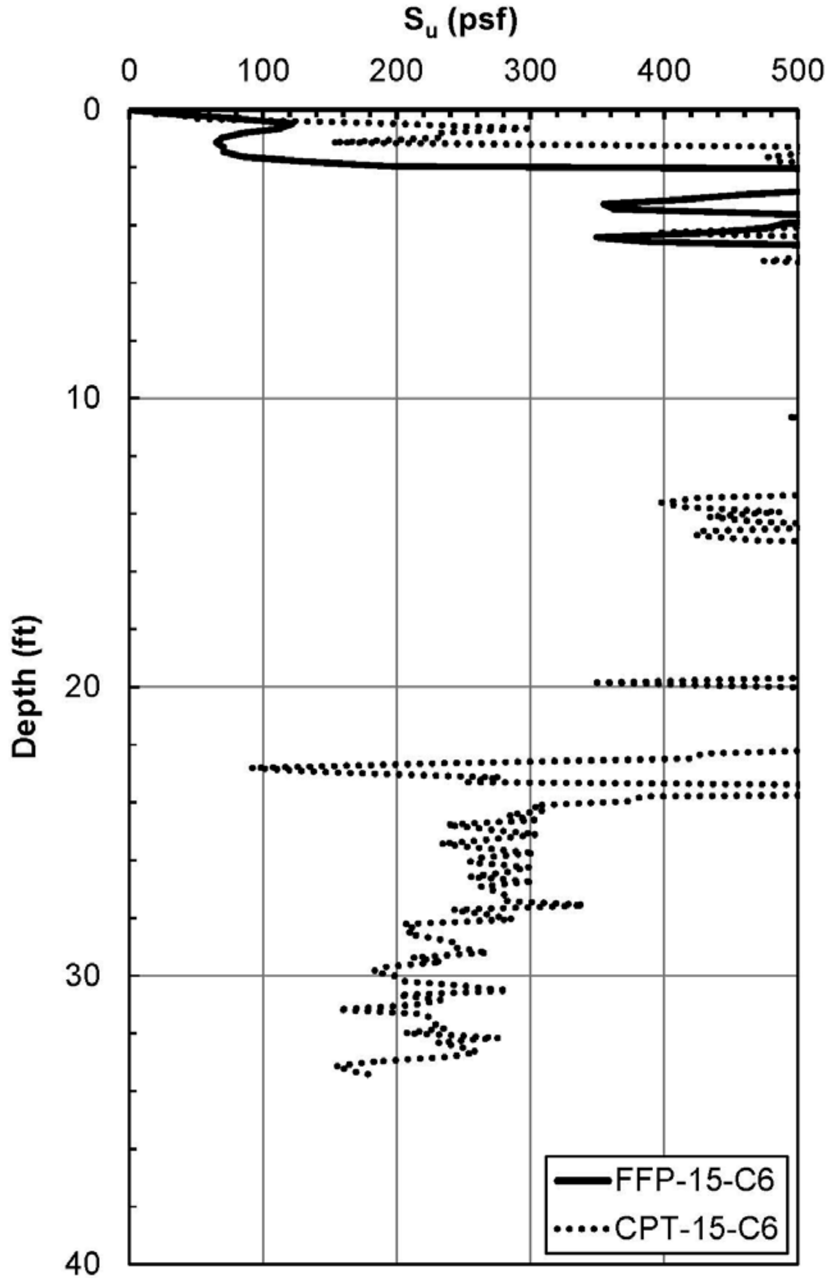
S_u (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
FFP-15-C3



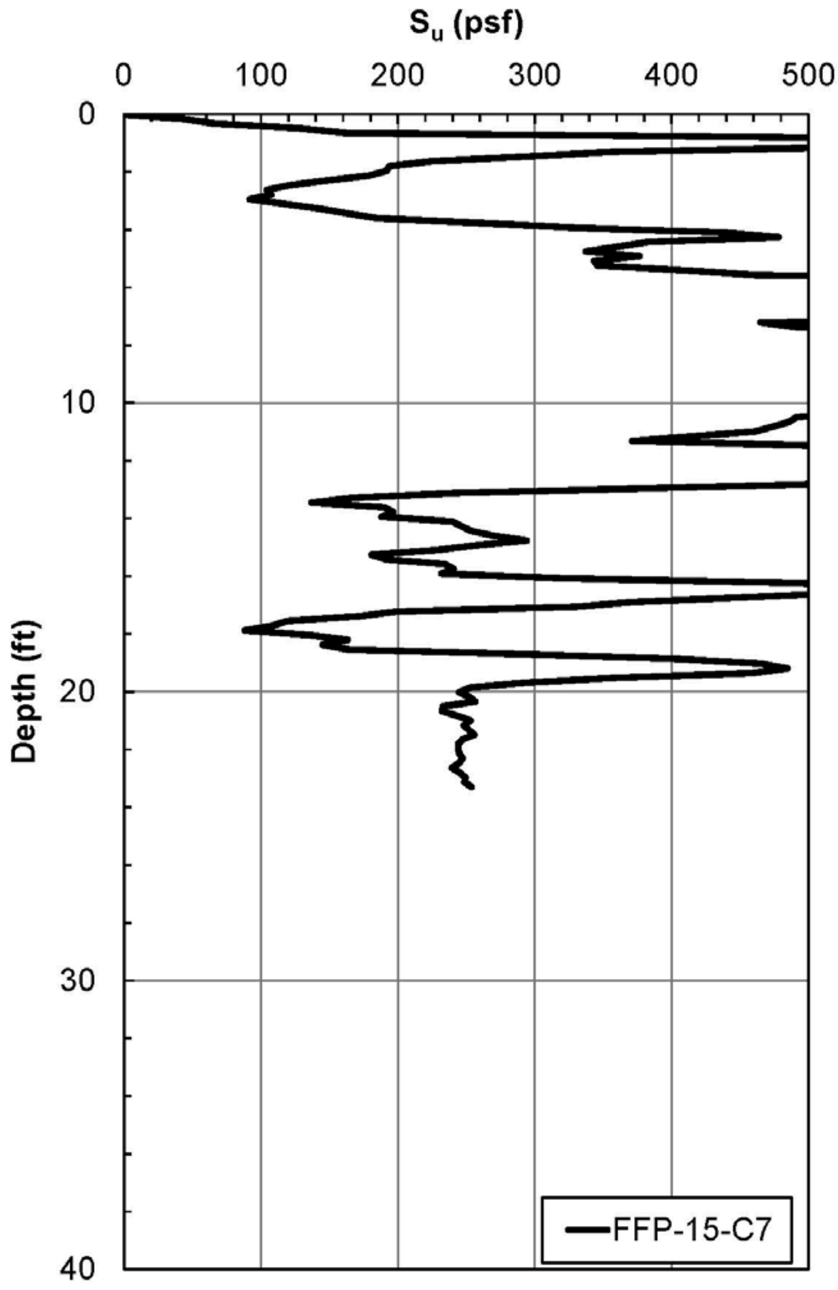
S_u (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
FFP-15-C4



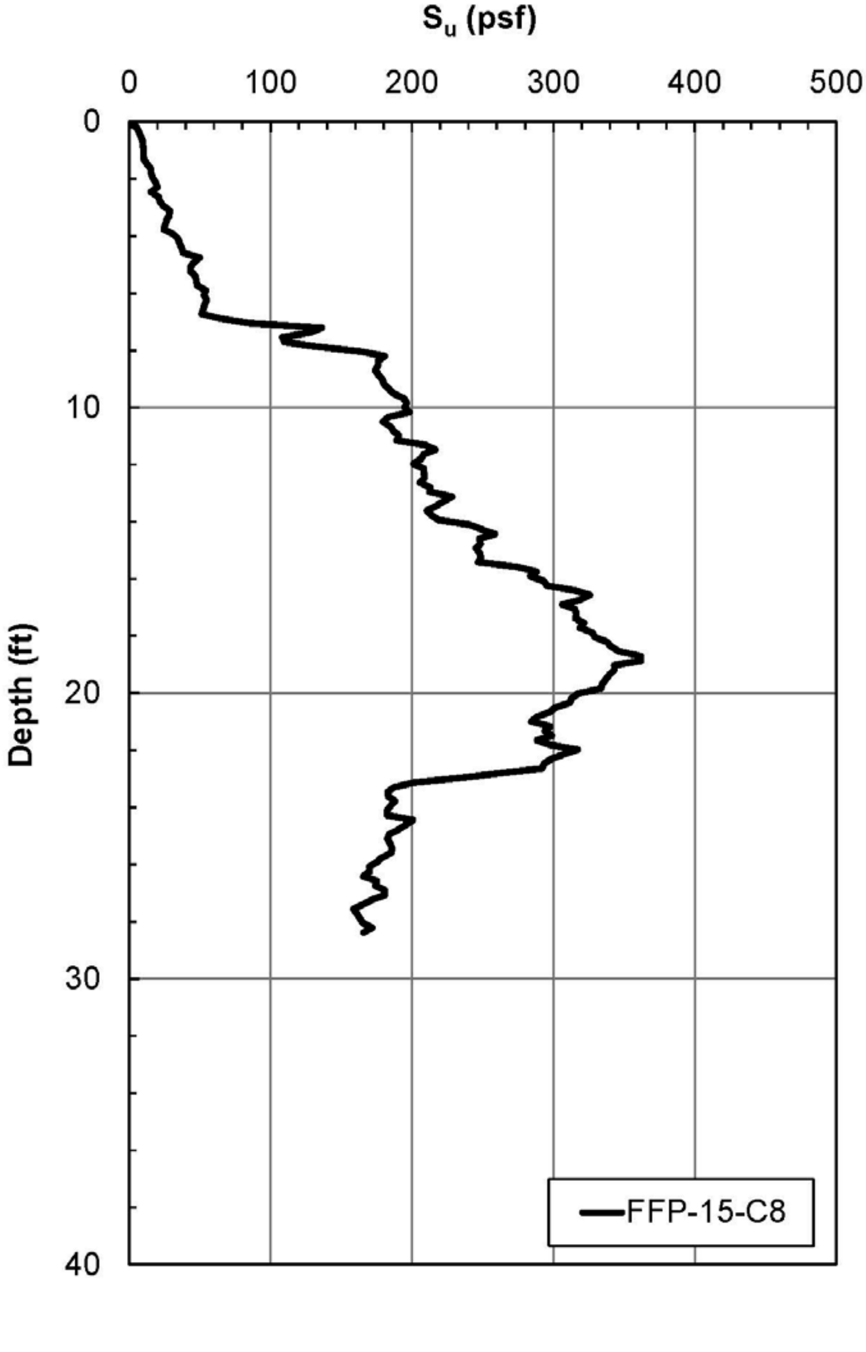
S$_u$ (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
FFP-15-C5



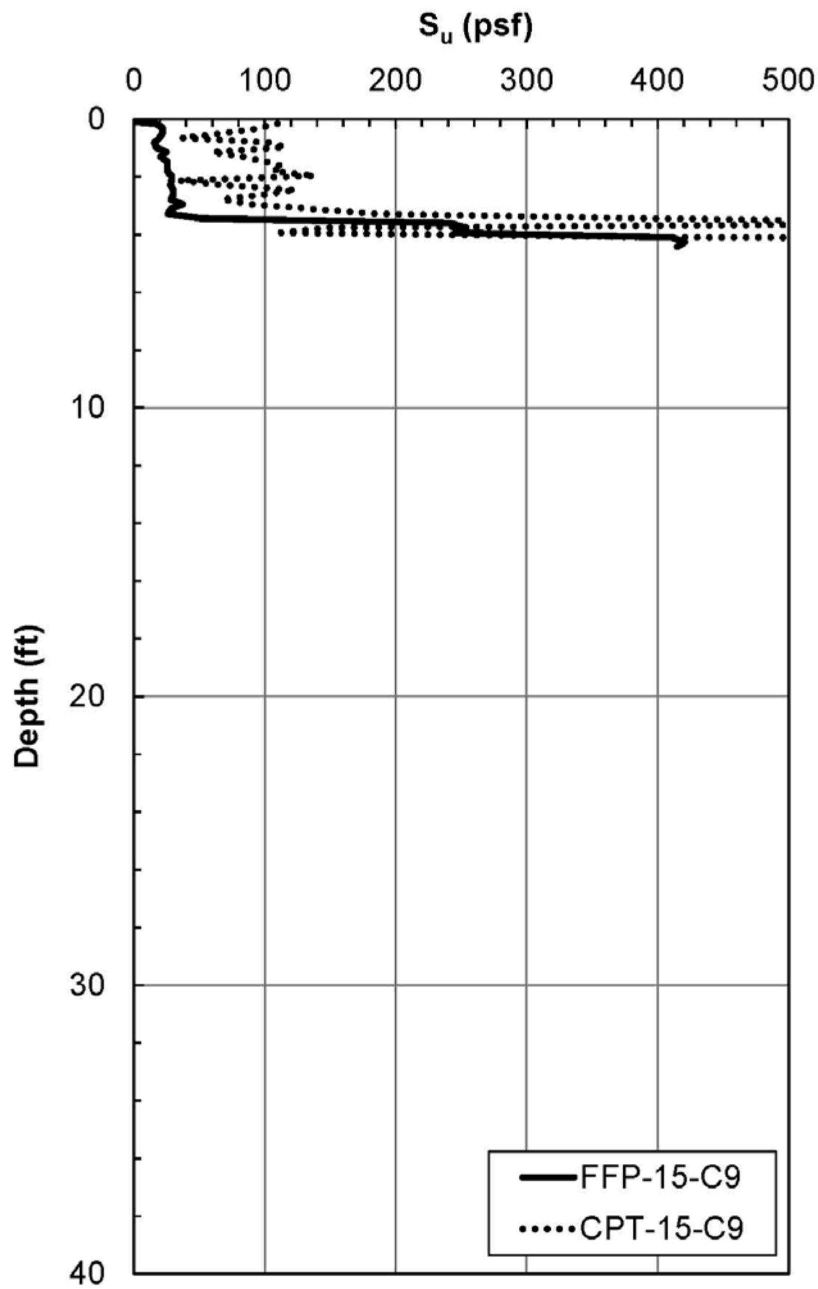
S$_u$ (psf)
0
100
200
300
400
500
Depth (ft)
0
10
20
30
40
FFP-15-C6
CPT-15-C6



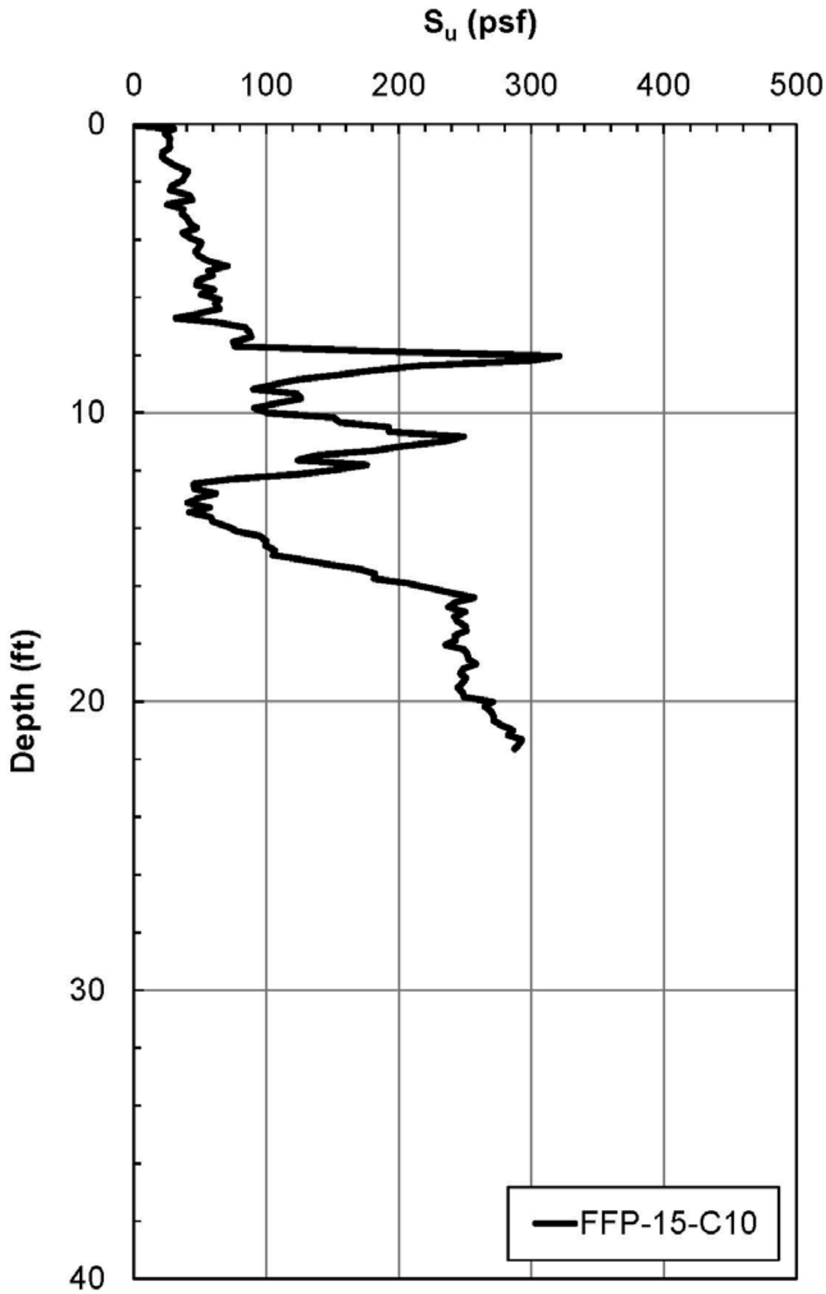
S_u (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
FFP-15-C7



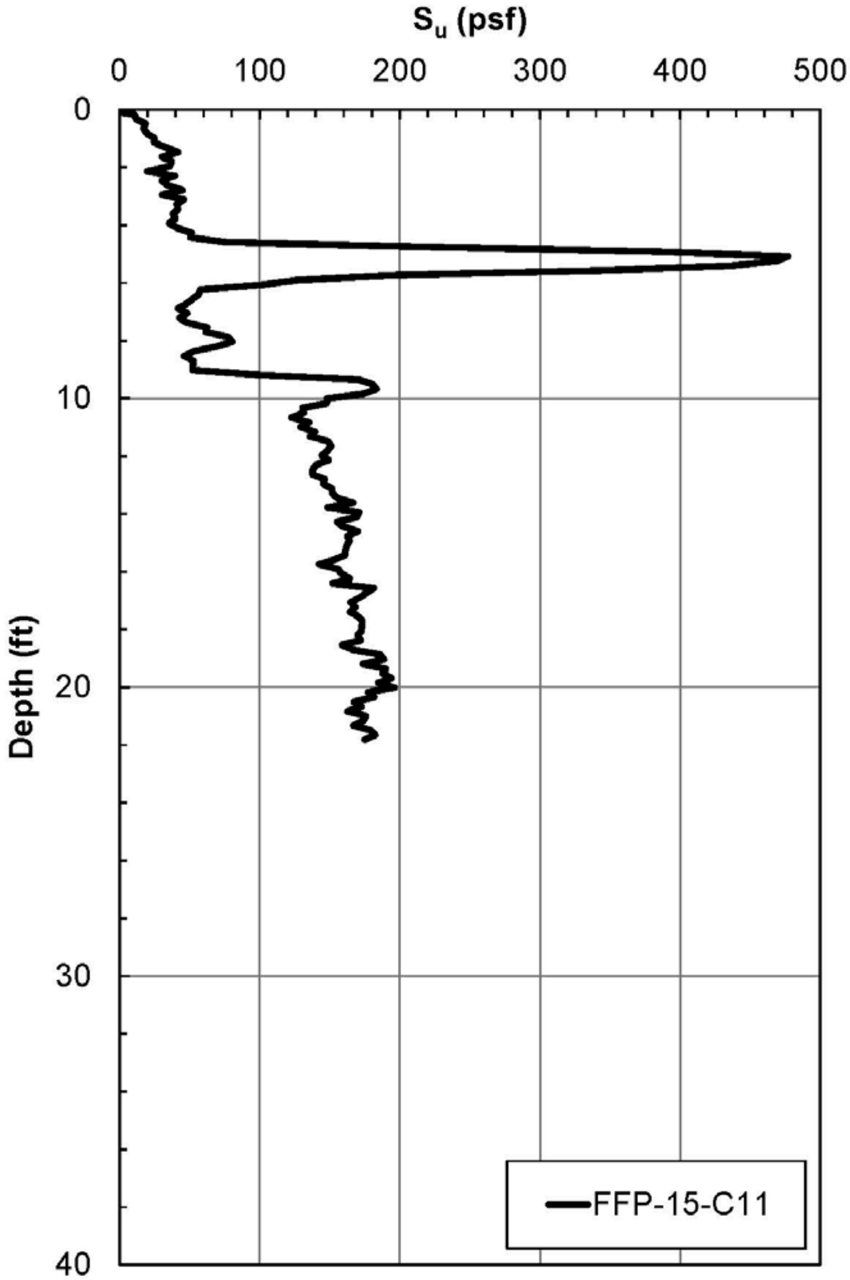
S_u (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
FFP-15-C8



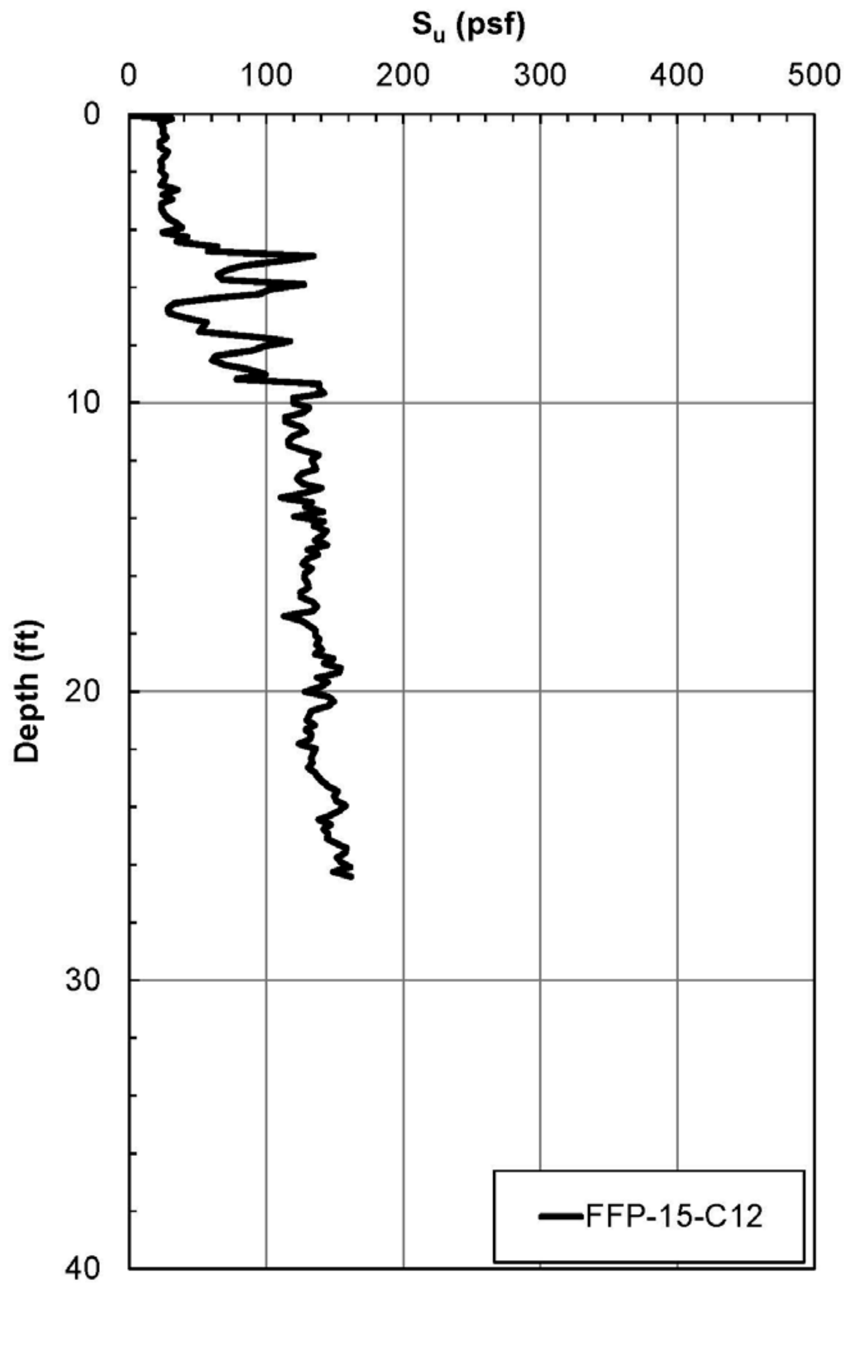
S_u (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
FFP-15-C9
CPT-15-C9



S_u (psf)
0
100
200
300
400
500
Depth (ft)
0
10
20
30
40
FFP-15-C10



S_u (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
FFP-15-C11



S_u (psf)
0
100
200
300
400
500
0
10
20
30
40
Depth (ft)
FFP-15-C12

ATTACHMENT 2

MODIFIED PROTECTIVE CAP RA-C-2
CHEMICAL ISOLATION MODELING

290 Elwood Davis Road, Suite 340
Liverpool, New York 13088
Phone 315.453.9009
Fax 315.453.9010
www.anchorqea.com

REVISED DRAFT MEMORANDUM

To:	Ed Glaza, Parsons	**Date:**	May 11, 2016
From:	Deirdre Reidy and Kevin Russell, Anchor QEA, LLC	**Project:**	E50139-09.02
Cc:	Paul LaRosa and Ram Mohan, Anchor QEA, LLC		
Re:	Cap Modeling in Modified Protective Cap Area RA-C-2		

1 INTRODUCTION

This memorandum documents the numerical modeling conducted for the Modified Protective Caps (MPCs) in Remediation Area (RA) RA-C-2. The numerical modeling was conducted to develop granular activated carbon (GAC) application rates that would be required for these modified caps to be protective for isolation of organic contaminants for more than 1,000 years, consistent with the evaluation timeframe used in the final design. Modeling also verified that the MPCs will be protective for isolation of mercury for at least 1,000 years. The minor exception to this may be portions of the small direct amendment application area, as discussed below.

For a capping project of the scale of Onondaga Lake Remediation, it is not unusual to expect previously unforeseen field conditions in small areas that may warrant adjustments to the cap system to achieve the remedial goals for the project. Subsequent to the cap movements that were observed to have occurred in RA-C and RA-D, additional in situ data collection and geotechnical analyses were conducted in those two remediation areas as well as other portions of the lake. These recent geotechnical stability evaluations have indicated that the cap thicknesses developed as part of the final design (Parsons and Anchor QEA 2012) need to be reduced in the small areas of cap movement, as well as in other small portions of Onondaga Lake RAs where the sediments are softer than previously identified.

This memorandum consists of the following sections:

- Section 2 describes the general modeling approach used to evaluate the various modified cap configurations, as well as the modeling details specific to RA-C-2.

- Section 3 presents the GAC application rate required in each portion of RA-C-2 to meet the target criteria for more than 1,000 years.
- Section 4 presents model sensitivity analyses.
- Section 5 presents a list of references.
- Attachment 1 includes the model files associated with the RA-C-2 MPCs.

2 MODELING APPROACH

2.1 General Approach

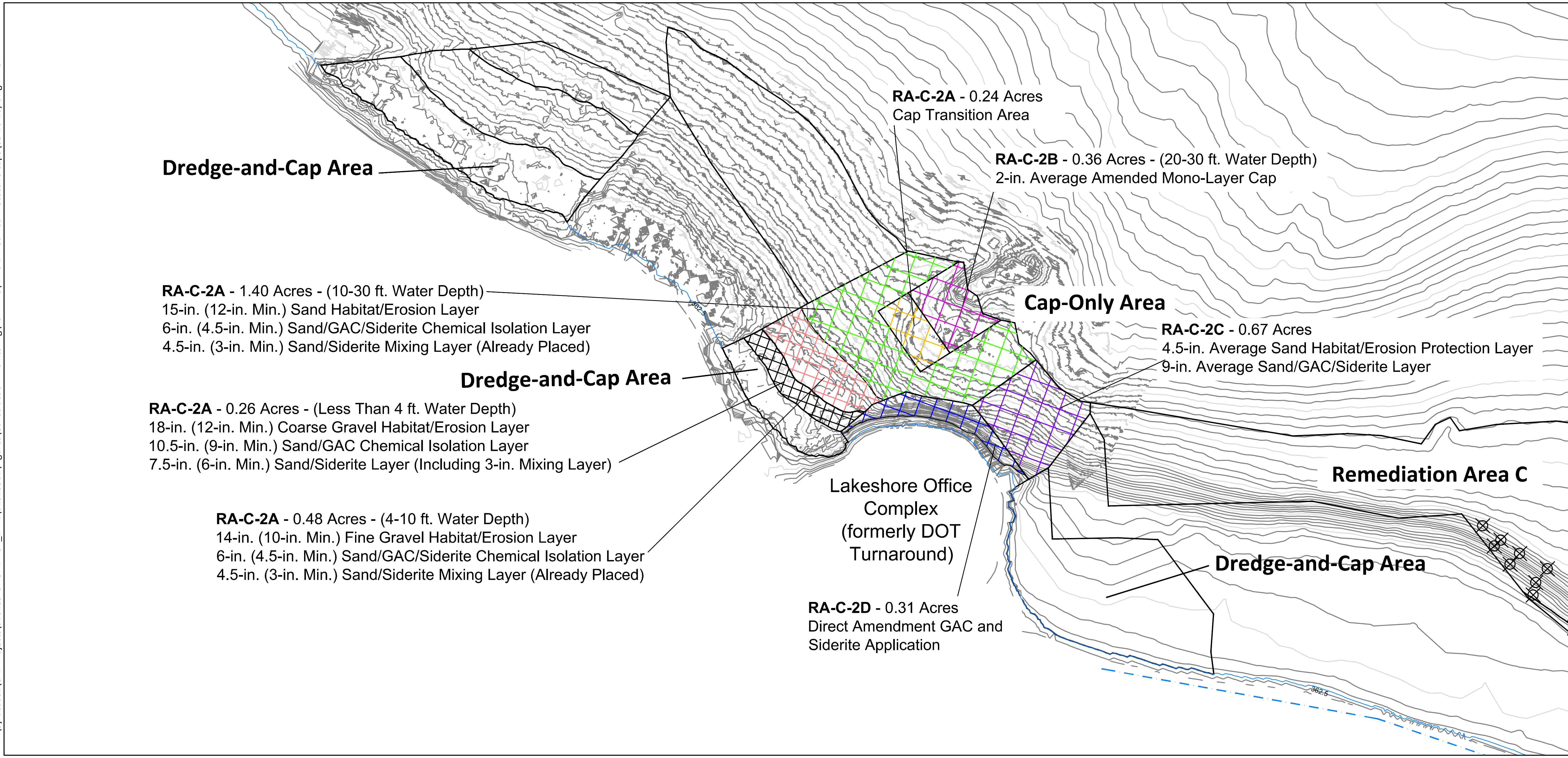
The modeling approaches employed for the proposed MPC configurations identified from the geotechnical analyses can be simplified into the following three basic categories:

1. Multi-layer caps (simulated with the transient numerical model)
2. Mono-layer caps, including direct GAC amendment application (simulated with the transient numerical model)
3. Modeling deposition effects for mercury (simulated with the Sediment Management Unit 8 [SMU 8] monitored natural recovery [MNR] model)

Detailed descriptions of the modeling approach for each of these categories were provided in the first memorandum in this series (Anchor QEA 2015) and are not repeated here. Considerations specific to area RA-C-2 are described in the following subsection. These considerations include the site-specific cap configuration, chemical source term (i.e., initial sediment porewater concentrations), bioturbation depth, and biological decay rate.

2.2 Modeling Approach for RA-C-2 Modified Protective Caps

MPCs were evaluated within four different subareas of RA-C-2, which are located within final design Model Area C2, as depicted in Figure 1. Results of slope stability analyses showed these areas can accommodate a range of MPC configurations, which can be categorized into two general MPC types: multi-layer MPCs and mono-layer MPCs (including direct application of GAC).



H:\Syracuse1\CAD Projects\010139-ONONDAGA_LAKE\01013902\Figures\Construction Monitoring\FCF RA-C\RA-C-2 Modified Protective Caps (05-10-16).dwg RA-C

May 10, 2016 9:49am cyard

BATHYMETRY SOURCE:
Filename: EXG-Lake (Performed by: CR ENVIRONMENTAL, 2005) and RAC Pro_101114 (Performed by Sevenson, 10-2014)
HORIZONTAL DATUM: New York State Plane, Central Zone, North American Datum 1983 (NAD83), U.S. Feet
VERTICAL DATUM: North American Vertical Datum 1988 (NAVD88)

LEGEND: Shoreline (elev. 362.5')
20-foot Depth Contour (elev. 342.5')

0 200
Scale in Feet

ANCHOR QEA

Figure 1
Modified Protective Cap Area RA-C-2
Onondaga Lake

Subarea RA-C-2A, which is a multi-layer MPC, will have sufficient thicknesses based on geotechnical analysis such that there will be separate habitat and chemical isolation layers. This multi-layer MPC was simulated in the model consistent with the final design cap configuration (except using the reduced layer thicknesses as shown in Figure 1). Multi-layer MPCs having a sand/siderite layer placed separately from the GAC-amended chemical isolation layer were evaluated incorporating biological degradation (which is expected to occur over the long term following porewater pH neutralization by siderite), consistent with the final design, as discussed in Section 2.1 of Anchor QEA (2015). However, consistent with the approach discussed in Section 2.2.1 of Anchor QEA (2015), within subarea RA-C-2A, a portion of the siderite is co-mixed with the GAC/sand layer; therefore, biological decay was conservatively excluded from the modeling for this area.

Subareas RA-C-2B, RA-C-2C, and RA-C-2D were evaluated as mono-layer MPCs. Consistent with the approach described in Anchor QEA (2015), subareas identified as mono-layer caps, including areas of direct GAC application, were simulated in a manner consistent with the Modified Erosion Resistant Cap (MERC) that was designed and constructed in the area of the Metro deepwater outfall (Parsons and Anchor QEA 2014). All mono-layer caps were represented in the model using a total 6-inch thickness for the purposes of defining a GAC application rate. This is appropriate even for mono-layer caps that are less than 6 inches thick (including areas of direct application of GAC) because the GAC will be distributed over time by bioturbation (the littoral zone bioturbation depth used in the final design was 6 inches) as detailed in Section 2.2 of Anchor QEA (2015).[1] The model construct assumes that the initial concentration in the cap is zero (i.e., initial cap concentration is not a user input for the model). The upward movement of contaminant mass due to mixing of the underlying sediments with the cap would have an impact on cap concentrations in the near term, but compared to the mass that enters the cap over the timeframe of the model simulation (i.e., 1,000 years), this impact is negligible over the long term. Because siderite will not be placed in a separate layer beneath the sand/GAC material

[1] Studies have shown that toxicity and bioaccumulation in benthic organisms decrease with the addition of GAC to sediments due to reductions in contaminant concentrations in porewater (Janssen and Beckingham 2013). If GAC with adsorbed contaminants is ingested by benthic organisms, it would likely pass through their digestive system with minimal, if any, impact. Organic chemicals strongly bind to GAC and, therefore, would not be assimilated into the organism.

in mono-layer caps, biodegradation was conservatively excluded from the modeling for these cases. Although portions of the 6- to 9-meter zone may be considered net depositional, that process was conservatively not incorporated into the modeling for chemicals other than mercury in certain cases (see below). Compliance with design standards (i.e., porewater-equivalent probable effects concentrations [PECs] and sediment screening concentrations [SSCs]) for mono-layer MPCs was assessed at the mid-point of the bioturbation depth, as detailed in Section 2.2 of Anchor QEA (2015).

2.2.1 Transient Numerical Modeling to Develop GAC Application Rate

Based on the results of the slope stability analysis, MPC configurations for the four subareas of RA-C-2 evaluated in the modeling (Figure 1) are summarized as follows:

- **RA-C-2A**: The following two separate MPCs were simulated in this subarea:
  1) RA-C-2A (4 to 10 feet): A multi-layer MPC consisting of the following:
     - 10 inches minimum of fine gravel (habitat restoration layer)
     - 4.5 inches minimum of sand/GAC/siderite (chemical isolation layer)
     - 3 inches minimum of sand/siderite (which was already placed, and was excluded from modeling due to assumed mixing with underlying sediments) (mixing layer)
  2) RA-C-2A (10 to 30 feet): A multi-layer MPC consisting of the following:
     - 12 inches minimum of sand (habitat restoration layer)
     - 4.5 inches minimum of sand/GAC/siderite (chemical isolation layer)
     - 3 inches minimum of sand/siderite (which was already placed, and was excluded from modeling due to assumed mixing with underlying sediments) (mixing layer)
- **RA-C-2A Cap Transition Area – GAC application rate of 0.1 pound per square foot (lb/sf)**[2]: This subarea includes one to four layers as the cap transitions between RA-C-2A and RA-C-2B, as shown in the geotechnical evaluation memorandum.

[2] Separate modeling was not conducted for the RA-C-2A Cap Transition Area; instead, GAC will be placed in the lower lift(s) of cap material placed in this transition area at a GAC application rate consistent with that of RA-C-2A and RA-C-2B.

Where present, the layers within the Cap Transition Area will be consistent with the layers within adjacent RA-C-2A.

- **RA-C-2B**: This subarea will include a mono-layer cap consisting of an average of 2 inches of cap material, including GAC and siderite.
- **RA-C-2C**: This subarea will include the following layers and was simulated as a mono-layer cap:
  - 4.5 inches average layer of sand
  - 9 inches average layer of sand/GAC/siderite
- **RA-C-2D**: This subarea will include direct application of GAC and siderite to the sediment surface.[3]

Chemical isolation cap modeling using the numerical transient model was conducted to develop the GAC application rate required for each of the MPCs in area RA-C-2 described above. As shown on Figure 1, the habitat/erosion protection layer in RA-C-2A (less than 4 feet) was reduced from 18 inches to 12 inches. The chemical isolation layer in this area was not modified; therefore, this area did not require re-evaluation. No additional sediment or porewater chemistry samples have been collected in RA-C-2 since the final design. Therefore, initial porewater concentrations in these model areas were set to the 95th percentile porewater concentrations used during the final design for Model Area C2. Because the dose of siderite will not be included in a separate sand/siderite layer beneath the sand/GAC material, biodegradation was conservatively excluded from the modeling for RA-C-2.

The MPC thicknesses in RA-C-2 are less than the full-thickness cap that was used as the basis for the final design porewater flux estimates. Therefore, consolidation settlement and porewater flux estimates from the final design are considered conservative for this MPC evaluation.

[3] Subarea RA-C-2D was simulated in the numerical transient model using the same cap configuration, model parameters, and input chemical concentrations as RA-C-2B; therefore, no independent numerical modeling was conducted for RA-C-2D, and results from RA-C-2B are applied to this area for the purposes of assessing the required GAC application rate.

All 25 of the organic chemicals evaluated during final design (i.e., volatile organic compounds, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls) were evaluated with the transient numerical model using deterministic simulations to identify the GAC application rate that would be needed to maintain concentrations below the applicable PECs or SSCs for more than 1,000 years. Mercury was also evaluated with the transient numerical model to evaluate whether concentrations are predicted to be below the applicable PEC for more than 1,000 years in RA-C-2A and RA-C-2C, where the total MPC thickness was at least 6 inches (as detailed in Section 2.3 of Anchor QEA [2015]). Evaluation of mercury for mono-layer MPCs having less than 6 inches total thickness (RA-C-2B) was conducted with the MNR model, as described in Section 2.2.2.

Probabilistic modeling was not conducted for these MPCs. During the final design, although probabilistic modeling was performed for 13 separate modeling areas, the GAC dose was increased in one model area only—WBB1-8, which is not an area of concern for these evaluations. In this area, the GAC application rate increased by less than 10%. These results indicate that the deterministic modeling drives the GAC application rate in nearly all cases and probabilistic modeling is not needed for the MPC evaluations.

2.2.2 MNR Modeling to Evaluate Mercury in RA-C-2B

For mercury, the MPC protectiveness evaluations conservatively assumed adsorption is not enhanced by the presence of GAC, consistent with the final design. Thus, in this modeling approach, the thickness of the cap provides protectiveness for mercury by providing a layer over which adsorption to sand and new sediments and dispersion attenuate porewater concentrations. However, deposition of new material atop the cap also provides an important attenuating mechanism for mercury. Therefore, in the 6- to 9-meter zone where the proposed cap thickness is less than the bioturbation depth of 6 inches, mercury was evaluated with the MNR model. In general, as cap thickness is reduced (i.e., cases in which MPCs are less than 6 inches thick), the effects of this deposition become more significant and are, therefore, important to consider in the effectiveness evaluation, as discussed in Section 2.3 of Anchor QEA (2015). Consideration of deposition is appropriate in RA-C-2B because it is located in water depths greater than 6 meters, which may be considered net depositional as documented in Section 10 of Appendix D in the final design. Because deposition rates have not been measured within the 6- to 9-meter zone, the modeling with the MNR model for areas within the 6- to 9-meter zone was conducted for a range of deposition rates observed in SMU 8. Mercury was, therefore, evaluated with the MNR model (Parsons and Anchor QEA 2014) to verify the protectiveness of the mono-layer MPC in RA-C-2B as described in Section 2.3 of Anchor QEA (2015). In RA-C-2B, concentrations within the model's "mixed layer" were compared to the mercury PEC of 2.2 milligrams per kilogram (mg/kg). The specific inputs for RA-C-2B (2-inch average amended sand cap) are as follows:

- The model "mixed layer" thickness was set to 6 inches.
- The initial concentration of the model "mixed layer" was set to 1.17 mg/kg, which was calculated based on mixing of 2 inches of clean sand with 4 inches of sediment having a concentration of 2.8 mg/kg (see next bullet), accounting for the differences in dry bulk density of the two materials. This configuration was used to represent the long-term mixing over the final design littoral zone bioturbation depth of 6 inches.
- The concentration of the model "buried layer" was set to the surface mercury concentration from sampling location OL-VC-20186 (2.8 mg/kg). This sample location had the maximum mercury concentration measured in surface sediment samples (0 to 12 inches) collected during the pre-design investigation within the 6- to 9-meter zone in the vicinity of this MPC area. These data are specific to the MPC subarea and are direct measurements of the required model input (i.e., the MNR model uses sediment concentration as its input, as compared to the transient cap model, which uses porewater concentration).
- The partitioning coefficient (Kd) for the "mixed layer" and "buried layer" was set to the final design sediment Kd ($10^{2.45}$ liters per kilogram [L/kg]). This is appropriate given that initially the "mixed layer" is a combination of sediment and sand, and over time, additional sediment that settles will be incorporated into the mixing layer.
- The model "mixed layer" porosity was set to 0.58, which was calculated based on the mixing of 2 inches of sand (porosity of 0.4) with 4 inches of sediment having a porosity of 0.74 (see below), accounting for the differences in dry bulk density of the two materials.
- The model "buried layer" porosity was set to 0.74, which is the porosity of sediments used in the final design cap modeling in Model Area C2.

- Sediment deposition rates in the 6- to 9-meter zone have not been measured. Deposition rates reported in Appendix M of the final design indicate the lower end of the range observed in SMU 8 is 0.08 gram per square centimeters per year ($g/cm^2/yr$) and the midpoint of the range observed in SMU 8 is 0.25 $g/cm^2/yr$. Sediment traps deployed at South Deep station in 2012 resulted in deposition rates ranging from 0.1 $g/cm^2/yr$ to 0.62 $g/cm^2/yr$ (average of 0.26 $g/cm^2/yr$, which is similar to the deposition rate of 0.25 $g/cm^2/yr$ used in the MNR modeling for SMU 8 during the final design). Consistent with the approach used for the SMU 8 MNR modeling presented in Appendix M of the final design, it is appropriate to use average deposition rates for long-term simulations. Because the 6- to 9-meter zone may be considered net depositional, it is expected that deposition rates in this area are greater than zero and may be similar to or less than deposition rates measured in SMU 8. Therefore, to capture the range of deposition rates that could be observed, caps within the 6- to 9-meter zone were simulated using an average deposition rate equal to the midpoint of the range observed in SMU 8 (0.25 $g/cm^2/yr$), as well as an average deposition rate of 0.08 $g/cm^2/year$, which is equal to the low end of the range observed in SMU 8 based on the lowest mid-range rate from post-1986 sediment trap and core data, as presented in Appendix M of the Final Design.

The model simulation period for mercury in this area was 500 years (long enough to reach steady-state concentrations).

2.2.3 Mercury in RA-C-2D

Four sediment cores were collected during the Pre-Design Investigation (PDI) within or along the outer edge of RA-C-2D. Mercury concentrations measured in these surface cores were as follows:

- OL-VC-20164 3.0 mg/kg
- OL-VC-20136 7.1 mg/kg
- OL-VC-20137 0.28 mg/kg
- OL-VC-20138 0.63 mg/kg

Two of these four samples exceed the mercury sediment PEC criteria of 2.2. Mercury concentrations in this area, which represent approximately 0.07% of the total area capped within the littoral zone, will be higher than anticipated in the final design for the lake. However, the bioaccumulation-based sediment quality value (BSQV) of 0.8 mg/kg will continue to be met in this portion of the lake. Also, it is not anticipated that this will affect achievement of remedial goals relating to mercury levels in fish in the lake due to the small areal extent of RA-C-2D compared to overall capped areas within the lake littoral zone. This area is in water depths less than 20 feet and, therefore, would not be considered net depositional; however, surface concentrations are expected to be reduced over time in this small area as new cleaner sediments deposit and mix with the existing surface sediments. Amendment application in this area also includes siderite, which was found to significantly reduce mercury concentrations in porewater. Mercury concentrations in porewater were reduced by over two orders of magnitude and mercury was absent in porewater in PDI leachate testing or was detected at low estimated values when siderite was combined with site porewater, as detailed in Appendix I of the final design (Parsons and Anchor QEA 2012).

3 RESULTS

The GAC application rates for the RA-C-2 MPCs consisting of multi-layer caps and mono-layer caps, including areas of direct application of GAC, were developed based on the transient numerical modeling described in the preceding sections. For the RA-C-2A (water depth of 4 to 10 feet) and RA-C-2A (water depth of 10 to 30 feet) multi-layer caps, where a designated habitat restoration layer exists, compliance with the PECs and SSCs was assessed against the maximum concentration within the habitat restoration layer. The transient numerical modeling was conducted starting with the minimal practical GAC application rate of 0.1 lb/sf. Model results indicate that all 26 chemicals meet the target criteria for the duration of the simulation (in this case, more than 1,000 years) with a GAC application rate of 0.1 lb/sf in these multi-layer caps.

The RA-C-2A cap design transitions in a step-wise fashion from its full thickness at the RA-C-2A (water depth of 10 to 20 feet) border to the RA-C-2B boundary in the RA-C-2A Cap Transition Area (Figure 1). The lower lift(s) of cap material placed in the Cap Transition

Area will contain 0.1 lb/sf GAC, based on the transient numerical modeling conducted for RA-C-2A.

For the mono-layer MPCs (RA-C-2B, RA-C-2C, and the direct application of GAC area RA-C-2D), where compliance for organics is assessed within the sand/GAC layer, compliance was assessed against the PEC-equivalent porewater concentrations and SSCs for each of the chemicals evaluated at the midpoint of the 6-inch layer. The transient numerical modeling was conducted starting with the minimal practical GAC application rate of 0.1 lb/sf. Model results indicate that all 25 organic chemicals meet the target criteria for the duration of the simulation (in this case, more than 1,000 years) with a GAC application rate of 0.1 lb/sf in the RA-C-2 mono-layer subareas (including the direct application of GAC area). In RA-C-2C, where the thickness of cap material is 6 inches or greater, the transient model results indicate that mercury meets the target criteria for the duration of the model simulation as well.

For the RA-C-2B MPC, mercury was evaluated with the MNR model and compliance with the PEC of 2.2 mg/kg was assessed over the average concentration within the 6-inch bioturbation zone. MNR model results for mercury in RA-C-2B showed that mercury concentrations within the "mixed layer" remain below the mercury PEC for the duration of the simulation for the range of deposition rates evaluated. Steady-state concentrations were predicted to be 1.03 mg/kg when simulating the midpoint deposition rate of 0.25 $g/cm^2/yr$ and a steady-state mercury concentration of 1.35 mg/kg was predicted when simulating the lower bound deposition rate of 0.08 $g/cm^2/yr$.

As discussed previously, two of the four surface sediment samples in the GAC direct application area (RA-C-2D) exceed the mercury sediment PEC criteria of 2.2. Mercury concentrations in this area, which represent approximately 0.07% of the total area capped within the littoral zone, will be higher than anticipated in the final design for the lake. However, the BSQV of 0.8 mg/kg will continue to be met in this portion of the lake. Also, it is not anticipated that this will affect achievement of remedial goals relating to mercury levels in fish in the lake due to the small areal extent of RA-C-2D compared to overall capped areas within the lake littoral zone. This area is in water depths less than 20 feet and, therefore, would not be considered net depositional; however, surface concentrations are expected to be reduced over time in this small area as new cleaner sediments deposit and mix with the existing surface sediments. Amendment application in this area also includes siderite, which was found to significantly reduce mercury concentrations in porewater. Mercury concentrations in porewater were reduced by over two orders of magnitude and mercury was absent in porewater in PDI leachate testing or was detected at low estimated values when siderite was combined with site porewater, as detailed in Appendix I of the final design (Parsons and Anchor QEA 2012).

4 SENSITIVITY ANALYSES

This section describes sensitivity analyses that were conducted to evaluate select model input parameters.

4.1 Depth of Mixing

The model approach for RA-C-2B (2-inch average mono-layer) and RA-C-2D (direct application of GAC) assumes the GAC placed within the sand/GAC layer will be mixed to a depth of 6 inches, which is the depth of mixing due to bioturbation in the littoral zone. Although bioturbation occurs to a depth of 6 inches, a sensitivity analysis was conducted to evaluate the impacts on model results if the GAC mixed to a depth that is 25% less than the bioturbation depth. To evaluate this scenario, the modeling for the RA-C-2B mono-layer MPC was repeated at a GAC application rate of 0.1 lb/sf and a thickness of 4.5 inches (with all other model settings unchanged, including assessing compliance at the midpoint of the bioturbation depth, or 3 inches)[4]. Results indicated that all chemicals meet the SSCs and porewater-equivalent PECs for more than 1,000 years.

4.2 Mercury Diffusion Coefficient in MNR Model for RA-C-2B

The molecular diffusion coefficient for mercury in the MNR model used to evaluate natural recovery in SMU 8 sediments during the final design was set to 202 square centimeters per yearcm^2/yr) based on literature. The molecular diffusion coefficient for mercury in the cap modeling conducted during final design was 61.8 cm^2/yr, which was also based on literature

[4] Subarea RA-C-2D was simulated in the numerical transient model using the same cap configuration, model parameters, and input chemical concentrations as RA-C-2B; therefore, no independent numerical modeling was conducted for RA-C-2D, and results from RA-C-2B are applied to this area for the purposes of assessing the required GAC application rate.

(but a different source). The mercury molecular diffusion rate of 61.8 cm^2/yr was used to maintain consistency with the final design cap modeling. Therefore, a sensitivity analysis was conducted to evaluate the impact on results from using the molecular diffusion rate of 202 cm^2/yr in the MNR model used to simulate mercury in RA-C-2B. Simulations using this value were conducted for the low-end deposition rate of 0.08 g/cm^2/yr and the midpoint of the range observed in SMU 8 (0.25 g/cm^2/yr). For all scenarios evaluated, the steady-state mercury concentrations meet the PEC of 2.2 mg/kg. The detailed results are as follows:

- RA-C-2B (0.08 g/cm^2/yr): Mercury concentrations remain less than the PEC of 2.2 mg/kg and reach a steady-state mercury concentration of 1.64 mg/kg.
- RA-C-2B (0.25 g/cm^2/yr): Mercury concentrations remain less than the PEC of 2.2 mg/kg and reach a steady-state mercury concentration of 1.40 mg/kg.

5 REFERENCES

Anchor QEA (Anchor QEA, LLC), 2015. *Cap Modeling in Modified Protective Cap Area RA-D-1 and Adjacent Amended Thin-layer Cap in SMU 8.* Prepared for Parsons. October 2015.

Janssen, E.M.L. and B.A. Beckingham, 2013. Biological Responses to Activated Carbon Amendments in Sediment Remediation. *Environ. Sci. Technol.* 470:7595-7607.

Parsons and Anchor QEA, 2012. *Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design. Appendix B – Cap Modeling.* Prepared for Honeywell. March 2012.

Parsons and Anchor QEA, 2014. *Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design Metro Outfall Vicinity Design Addendum. Attachment 2 – Modified Erosion Resistant Cap Chemical Isolation Layer Modeling.* Prepared for Honeywell. October 2014.

ATTACHMENT 1
ONONDAGA LAKE CAP MODELING FILES FOR RA-C-2 MPCs

ATTACHMENT 1: MODEL FILES

This attachment details the files and directory structure associated with the numerical modeling conducted for the Modified Protective Cap (MPC) Area RA-C-2. The cap modeling files are organized into two main folders:

1. Numerical Model
2. MNR Model

The following sections describe the files and subfolders contained in each folder.

Numerical Model

The numerical cap modeling files are contained in two subfolders:

1. Inputs
2. Outputs

The contents of each of these subfolders are described in this section. Please reference Attachment 4 to Appendix B of the final design (Parsons and Anchor QEA 2012[1]) for the numerical model code files and their descriptions. In addition, the structure and formatting of the input and output files for this numerical cap modeling is identical to that from the final design; differences in input values from the final design associated with using the model to represent MPCs are mainly what is described in the subsections that follow.

Numerical Model Inputs

The input files used for simulations with the numerical model are located in the *Numerical_Model\Inputs* folder. Separate input files are used for each of the unique model areas evaluated as part of the RA-C-2 MPC modeling effort:

1. RA-C-2A-1.xls (RA-C-2A [4 to 10 feet] multi-layer MPC)
2. RA-C-2A-2.xls (RA-C-2A [10 to 20 feet] multi-layer MPC)

[1] Parsons and Anchor QEA (Anchor QEA, LLC), 2012. *Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design.* Prepared for Honeywell. March 2012.

3. RA-C-2B.xls (RA-C-2B mono-layer MPC[2])
4. RA-C-2B-45in.xls (RA-C-2B mono-layer MPC modeled as 4.5-inch cap for sensitivity analysis)
5. RA-C-2C.xls (RA-C-2C mono-layer MPC)

These input files are identical in format and layout to those described and included in Attachment 4 to Appendix B of the final design. Each input file contains one tab per chemical modeled, as well as an *Input_Matrix* tab, which specifies the inputs for the various model parameters. Changes made to input values used in the final design for this MPC modeling effort (e.g., cap configuration, decay parameters) are described in detail below.

RA-C-2A-1.xls

The input file titled *RA-C-2A-1.xls* was set up for modeling the RA-C-2A (4 to 10 feet) multi-layer MPC. Changes to this file, as compared to the Model Area C2 final design modeling, are highlighted in orange on the *Input_Matrix* tab, as well as the chemical-specific tabs, where applicable. The following changes were made:

1. The habitat restoration layer thickness was set to a thickness of 25.4 cm.
2. The chemical isolation layer thickness was set to a thickness of 11.43 cm.
3. The foundation/siderite layer thickness was set to a nominal thickness of 1 cm.
4. Decay rates for volatile organic compounds (VOCs) were set to 1E-12 to effectively eliminate the effects of degradation kinetics in the model simulations (1E-12 is used because a non-zero number is necessary for model function).

RA-C-2A-2.xls

The input file titled *RA-C-2A-2.xls* was set up for modeling the RA-C-2A (10 to 20 feet) multi-layer MPC. Changes to this file, as compared to the Model Area C2 final design modeling, are highlighted in orange on the *Input_Matrix* tab, as well as the chemical-specific tabs, where applicable. The following changes were made:

[2] The numerical transient modeling performed for RA-C-2B is also applicable to the RA-C-2D direct application of granular activated carbon (GAC) area (modeled as a mono-layer) because the same transient cap model input parameters and model construct are appropriate for this area, as discussed in the main memorandum. Therefore, no separate transient cap model file was needed for RA-C-2D.

1. The chemical isolation layer thickness was set to a thickness of 11.43 cm.
2. The foundation/siderite layer thickness was set to a nominal thickness of 1 cm.
3. Decay rates for VOCs were set to 1E-12 to effectively eliminate the effects of degradation kinetics in the model simulations (1E-12 is used because a non-zero number is necessary for model function).

RA-C-2B.xls

The input file titled *RA-C-2B.xls* was set up for modeling the RA-C-2B mono-layer MPC. Changes to this file, as compared to the Model Area C2 final design modeling, are highlighted in orange on the *Input_Matrix* tab, as well as the chemical-specific tabs, where applicable. The following changes were made:

1. Decay rates for VOCs were set to 1E-12 to effectively eliminate the effects of degradation kinetics in the model simulations (1E-12 is used because a non-zero number is necessary for model function).
2. Organic carbon fraction in the bioturbation zone was set to a nominally low value of 0.022% (the value used in the final design for cap sand) so that sorption would be negligible.
3. The following inputs for cap configuration were specified to represent the total simulated thickness of 6 inches for the purposes of identifying granular activated carbon (GAC) amendment application rates for mono-layer MPC evaluation, for all chemicals except mercury (which was simulated with the MNR model as described in the last section of this attachment):
   a. The habitat restoration layer thickness was set to a nominal thickness of 1 cm.
   b. The bioturbation zone thickness was set to a nominal thickness of 0.5 cm.
   c. The chemical isolation layer thickness was set to a thickness of 15.24 cm.
   d. The foundation/siderite layer thickness was set to a nominal thickness of 1 cm.

RA-C-2B-45in.xls

The input file titled *RA-C-2B-45in.xls* was set up for modeling the RA-C-2B mono-layer MPC as a 4.5-inch cap. Changes to this file, as compared to the Model Area C2 final design modeling, are highlighted in orange on the *Input_Matrix* tab, as well as the chemical-specific tabs, where applicable. Changes to this file compared to the Model Area C2 final design modeling are the same as those described above for RA-C-2B (*RA-C-2B.xls)* modeling, except the cap thickness. The following inputs for cap configuration were specified to represent the total simulated thickness of 4.5 inches for the purpose of evaluating sensitivity to GAC mixing to a depth that is 25% less than the depth of mixing due to bioturbation:

1. The habitat restoration layer thickness was set to a nominal thickness of 1 cm.
2. The bioturbation zone thickness was set to a nominal thickness of 0.5 cm.
3. The chemical isolation layer thickness was set to a thickness of 11.43 cm.
4. The foundation/siderite layer thickness was set to a nominal thickness of 1 cm.

RA-C-2C.xls

The input file titled *RA-C-2C.xls* was set up for modeling the RA-C-2C mono-layer MPC. Changes to this file, as compared to the Model Area C2 final design modeling, are highlighted in orange on the *Input_Matrix* tab, as well as the chemical-specific tabs, where applicable. Changes to this file compared to the Model Area C2 final design modeling are the same as those described above for RA-C-2B (*RA-C-2B.xls)* modeling, with the exception of the exclusion of mercury. Because a minimum of 6 inches of cap material will be placed, it was appropriate to model mercury with the transient cap model; therefore, mercury was included in the *RA-C-2C.xls* model file.

Numerical Model Outputs

The numerical model output files are located in the *Numerical_Model\Outputs\Det_Output* folder. Within this folder, outputs for each model area are contained in separate folders. The outputs are saved in comma-delimited format (*.csv). Output file names used the same naming convention from the final design, which helps to understand the model scenario:

"Output_"<Model Area>"_"<Chemical Name Abbreviation>"_"<GAC application rate>"-"<Initial Concentration Type>

For file-naming purposes, the GAC application rate component of the file name does not include a decimal point. It should be understood that the decimal place is located between the first and second digits. For example, *Output_RA-C-2A-1_EB_01-C95_UT2.csv* is the file containing outputs from the model simulation of ethylbenzene using the 95th percentile porewater concentrations in Model Area RA-C-2A (4 to 10 feet) multi-layer MPC with a 0.1 lb/sf GAC application rate.

MNR Model

The MNR model was used to simulate mercury for mono-layer MPCs located in water depths greater than 6 meters and having less than 6 inches total cap thickness (RA-C-2B). The model is based on the SMU 8 MNR model used in the final design, with slight modifications to allow for the simulation of organic chemicals. These changes are described in Attachment 1 to Anchor QEA (2015)[3]. Model input settings specific to RA-C-2B (*MNR_Modeling_RA-C-2_Mercury_Revised_V2.xlsm*) are as follows:

1. The "mixed layer" was configured to initially represent mixing of the 2 inches of placed cap material (i.e., sand) with 4 inches of underlying sediments by setting the initial concentration to an average concentration based on differences in mercury concentration and dry bulk density of the two materials. Additionally, the mixed layer porosity was set to 0.58, which accounts for the porosity of the mixed layer of sand and sediment.
2. The "buried layer" in the MNR model was set to the sediment concentrations that will be present beneath the placed cap material, based on available sediment sampling data.
3. The sediment deposition rate was set to 0.25 g/cm^2/year. Model simulations were also conducted using the lower rate of 0.08 g/cm^2/year.
4. Chemical-specific properties such as partition coefficients and diffusion coefficients were set to those used in the transient cap modeling. A sensitivity analysis was performed to evaluate the impact of using the diffusion coefficient that was previously used in the MNR model during the final design evaluation of SMU 8 natural recovery (202 cm^2/year).

Everything else associated with this model file works similar to the SMU 8 MNR model from the final design (e.g., the "Run Model" button executes the code to run the model and

[3] Anchor QEA, 2015. *Cap Modeling in Modified Protective Cap Area RA-D-1 and Adjacent Amended Thin-layer Cap in SMU 8.* Prepared for Parsons. October 2015.

outputs are generated for each simulated chemical; see “Instructions” worksheet for more detail).