Appendix C –Lookout Slough Tidal Habitat Restoration and Flood Improvement Project: 65% Geotechnical Basis of Design Report, Blackburn Consulting 2019.

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Appendix B.2

Draft 65% Geotechnical Basis of Design Report

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DRAFT GEOTECHNICAL BASIS OF DESIGN REPORT 65% DESIGN

LOOKOUT SLOUGH TIDAL HABITAT RESTORATION AND FLOOD IMPROVEMENT PROJECT

Prepared For:

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BCI File No. 3195.x
September 26, 2019

Mr. David Urban
Director of Operations
Ecosystem Investment Partners
5550 Newbury Street
Baltimore, MD 21209

Subject: **DRAFT GEOTECHNICAL BASIS OF DESIGN REPORT – 65% Design**
Lookout Slough Tidal Habitat Restoration and Flood Improvement Project
Solano County, California

Dear Mr. Urban,

Blackburn Consulting (BCI) is pleased to submit this Draft Geotechnical Basis of Design Report (Draft GBODR) for 65% Levee Design associated with the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project in Solano County, California. This Draft GBODR replaces BCI's May 2019 Draft 60% GBODR for the Project.

The findings and recommendations in this report are draft, intended for 65%-level design, and should not be relied on for final design or construction. Findings and recommendations may change as design progresses. Subsequent 90% and/or 100% updates of this report prepared by BCI will contain findings and recommendations for final design and construction.

Thank you for including BCI on your team for this important project. Please call if you have questions or require additional information.

Sincerely,

BLACKBURN CONSULTING

Prepared by:

Nicole C. Hart, P.E.
Senior Project Engineer

Reviewed by:

REGISTERED PROFESSIONAL ENGINEER
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Robert B. Lokteff, G.E., P.E.
Principal

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1 INTRODUCTION

1.1 Purpose and Scope

Blackburn Consulting (BCI) prepared this Draft Geotechnical Basis of Design Report (Draft GBODR) for 65% Levee Design associated with the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (Lookout Slough THRFIP) in Solano County, California. BCI prepared this Draft GBODR for Ecosystems Investment Partners (EIP) to support the design-build team's 65% design of the Lookout Slough THRFIP. This report updates and replaces the May 2019 DRAFT 60% Design GBODR BCI prepared for the Lookout Slough THRFIP.

This 65% Draft GBODR contains relevant information and analysis results from the May 2019 DRAFT 60% GBODR and updated information and analysis results based on the following:

- The September 2019 Draft Geotechnical Data Report (GDR) prepared by BCI that contains site topography, geology and geomorphology, historical explorations, and BCI's exploration and laboratory testing program for the Duck Slough Setback Levee (DSSL) completed to date.
- Review of geotechnical evaluations prepared by others including descriptions of the existing levees within the project area, past performance and levee improvements to those levees, and explorations and laboratory tests performed by others that are relevant to the Lookout Slough THRFIP.
- Several meetings with EIP and the design-build team to discuss and obtain consensus regarding 65% geotechnical design parameters and methodology.
- Preliminary comments provided by the USACE, the Safety Assurance Panel (SAR), and the Department of Water Resources (DWR) on the Draft 30% GBODR.
- Preliminary comments provided by the SAR panel and the DWR on the Draft 60% GBODR.
- The April 2019 Draft Hydrologic and Hydraulic System Analysis, Lookout Slough Tidal Habitat Restoration and Flood Improvement Project (H&H Analysis), prepared by Environmental Science Associates (ESA).
- The September 2019 Draft Geotechnical Borrow Report (Borrow Report) prepared by BCI and submitted under separate cover. The Draft Borrow Report presents a summary of BCI's evaluation of on-site borrow performed to date for the Lookout Slough THRFIP.
- Updated Geotechnical Plan and Profile sheets that reflect the new 65% design centerline location and stationing, levee geometry, and information from exploratory borings and laboratory tests.
- Seepage, slope stability and settlement analysis updated with 65% design information.
- Seismic vulnerability evaluation for the DSSL.
- Preliminary information from explorations drilled in August 2019 at the DSSL tie-in locations (laboratory testing in progress).

1.2 Project Overview

The Lookout Slough THRFIP will create more than 3,000 acres of habitat for listed and vulnerable native species within a portion of Reclamation District 2068 (RD 2068) including upland, tidal, subtidal, and floodplain habitat for Delta Smelt, Longfin Smelt, Steelhead Salmon, Splittail, Giant Garter Snake, and other species. In addition to habitat creation, the Lookout Slough THRFIP would provide 40,000 to

50,000 acre-feet of seasonal floodplain storage. A Lookout Slough THRFIP Vicinity Map is presented as Figure 1.

To create tidal, subtidal, and floodplain habitat, the Lookout Slough THRFIP will breach the Shag Slough Levee (SSL) at several locations and construct the new DLLS to maintain Yolo Bypass flood protection to areas outside of the Lookout Slough THRFIP area. EIP retained BCI to perform geotechnical engineering services associated with DSSL design, borrow material evaluation within the site area, and design of PG&E tower access roads that extend to the distribution towers located within the site area. Geotechnical recommendations for the PG&E towers are presented in separate Technical Memorandums prepared by the design-build team. In addition, the design-build team is preparing a separate Hass and Cache Slough Levee Technical Memorandum that provides an evaluation of possible impacts the Lookout Slough THRFIP may have on the existing Hass and Cache Slough levees. Figure 2 presents the Lookout Slough THRFIP site limits and includes the DSSL alignment, PG&E distribution tower alignment with proposed access road locations, and proposed SSL breach areas.

1.3 Project Datum

BCI references the Elevations in this report in feet based on the North America Vertical Datum of 1988 (NAVD88). The horizontal datum is based on California State Plane Zone 2.

1.4 Geotechnical Data

The 65% Draft GDR contains the geotechnical data compiled to date to support the Lookout Slough THRFIP geotechnical levee analysis and recommendations. The data includes information from BCI's subsurface evaluations, field explorations, and laboratory tests. To date, BCI has completed forty-three (43) exploratory borings and five (5) cone penetrometer tests to support design and meet the USACE criteria regarding the number of explorations needed for levee design evaluation.

The USACE and Central Valley Flood Protection Board (CVFPB) approved the 408 permit on August 8, 2019, which included the Drilling Program Plan (DPP) to drill explorations on the SSL and the Hass and Cache Slough East Levees. After approval, BCI drilled four exploratory borings in August 2019 for DSSL tie-in analysis; two explorations on the Hass Slough East Levee at the southern tie-in, and two explorations on the SSL at the northern tie-in. BCI also drilled two exploratory borings on the Hass and Cache Slough East Levee to obtain information for the Hass and Cache Slough Levee Technical Memorandum. Additional CPTs are planned along the Hass and Cache Slough East Levee in early October 2019. Laboratory testing for the above exploratory borings is in progress. Test results will be included in subsequent GDR reports completed for the project.

2 RELEVANT EVALUATIONS BY OTHERS

2.1 Available Reports

BCI obtained relevant information regarding the existing levees within the Lookout Slough THRFIP area from the following available reports:

- April 2011 *Geotechnical Assessment Report, North NULE Project Study Area, Volume 1 of 6, Non-Urban Levee Evaluations Project Contract 4600008101, Task Order U104,* (2011 NULE) prepared by URS;

- August 2011, *Remedial Alternatives and Cost Estimates Report (RACER), North NULE Study Area, Non-Urban Levee Evaluations Project, Contract 4600008101, Task Order U107,* (2011 RACER), prepared by URS;
- January 2011, *Final Geomorphology Technical Memoranda and Maps, North NULE Area Geomorphic Assessments, Non-Urban Levee Evaluations Project, Contract 4600008101,* (2011 Geomorphology TM), prepared by URS.
- May 1986, *Right Bank Yolo Bypass and Left Bank Cache Slough near Junction Yolo Bypass and Cache Slough, Levee Construction, General Design, Supplement No. 1 to Design Memorandum No. 13*, prepared by the USACE.
- November 1988, *Levee Construction Right Bank Yolo Bypass & Left Bank Cache Slough,* prepared by the USACE, Sacramento District.
- February 1993, *Attachment B Basis of Design Geotechnical Evaluation of Levees for Sacramento River Flood Control System Evaluation, Lower Sacramento River Area, Phase IV,* (1993 USACE BODR Attachment B), prepared by the USACE. Attachment B contains the Initial Appraisal Report – Lower Sacramento Area. BCI could not obtain a copy of the full 1993 USACE BODR.

The above reports refer to Hass Slough as Haas Slough. We have therefore kept consistent with this nomenclature when referring to the historical information.

2.2 Existing Levee Information for the Lookout Slough THRFIP Area

The 2011 NULE presents information with sub-area segments. Area 5, West Delta Levees, includes the levees within the Lookout Slough THRFIP area. These levee segments include:

- Levee Segment 153, located along the right bank of the Yolo Bypass (or Shag Slough),
- Levee Segment 313, located along the left bank of Cache Slough, and
- Levee Segment 312, located along left bank of Haas Slough (the southern end within the Lookout Slough THRFIP Area).

Based on the 2011 NULE, limited information exists on levee construction and assumes that soil adjacent to the levee segments was used for levee construction. The 2011 NULE infers that the subsurface stratigraphy below the levee segments consists of fine-grained material, interbedded in localized areas, with Delta peat and mud.

The 1986 USACE Levee Construction report addressed the 2.4-mile section of the southern tip of the Liberty Farm mitigation measures. This report refers to a departure from the original project plan, which had proposed mitigating the 2.4-mile southern tip. Instead, the selected alternative included a new cross levee connecting the SSL to the Cache Slough East Levee. The 1988 plans show this alternative.

The 1993 USACE BODR Attachment B provides subsurface information collected at the site with an evaluation of pre-1986 borings, and borings performed in 1990 and 1991. Within this report, the USACE states that the levee and foundation systems are extremely complex.

It is important to note that the 2011 NULE report includes the cross levee presented on the 1988 USACE plans in Levee Segment 153 (Right Bank Shag Slough) as discussed below in Sections 2.2.1. However, the USACE National Levee Database (NLD) instead places this levee segment in RD 2098 – Cache Slough-Haas Slough – Unit 2, Cache Slough. BCI therefore provides a separate section for the Cross Levee in

Section 2.2.4 below and includes the cross levee in the SSL section as it pertains to information provided in the 2011 NULE.

BCI summarizes the information provided in the 2011 NULE and the USACE reports and plans in Sections 2.2.1 through 2.2.4 below. Where available, specific Levee Segment information is provided. Appendix A of this report contains figures extracted from the 2011 NULE that show the respective levee mile identifications for each Segment discussed below. Appendix A also contains a Past Performance Map that presents Reported Levee Performance Events summarized in the 2011 NULE.

2.2.1 SSL

The 2011 NULE describes the SSL as Levee Segment 153, which extends from Liberty Island Road, south for 3.6 miles. From levee mile (LM) 3.6 to LM 4.43, the 2011 NULE states that a new levee mile system was implemented with the construction of a new cross levee. The new levee mile system begins at the Yolo Bypass, and extends west for 0.55 miles to the intersection with Cache Slough. The 2011 NULE separates this segment into Reach 1, from LM 0.0 to LM 3.18, and Reach 2, from LM 3.18 to LM 3.6 and LM 0.0 to LM 0.55. Reach 2 is the Cross Levee, described in Section 2.2.4.

The 2011 NULE further states that historical documents indicate that Segment 153 levees were originally constructed in the 1900s predominantly of organic clay and clay dredged from adjacent sloughs and channels. Levee geometry included 3H:1V riverside and 2H:1V landside slopes. USACE widened and raised the levees in 1961 with borrow material dredged from the Deep-Water Ship Channel and borrow along Cache Slough. New levee geometry included 3H:1V landslide and waterside slopes with a 40-foot berm on each side. Due to several failed PL 84-99 repair attempts, USACE reconstructed this levee in 1976. For several years, construction repair work continued to bring the Lookout Slough THRFIP levee to design grade.

The 2011 NULE states that historical performance included multiple erosion sites, and significant subsidence and stability problems during construction of the Reach 2 levee system (Cross Levee). Foundation material consists of clay, silt and sand within Reach 1 and compressible peat and organic material within Reach 2.

The 2011 NULE presents subsurface information from the USACE borings extending 25 feet below the ground surface conducted in 1959 and 30- to 40-feet deep borings along Reach 2. These explorations confirm relatively stiff clay within the northern portion of Reach 1 and organic clay up to 30 feet deep in the southern portion of this Segment.

The USACE drilled four explorations, 2 F-91-9, 9A and 2F-91-10, 10A, along this levee segment in 1991. These explorations indicate the levee and foundation materials consist of fat clay and organic clay.

2.2.2 Cache Slough East Levee

The 2011 NULE describes the Cache Slough East Levee as Levee Segment 313, which extends from Reach 2 of Levee Segment 153 (LM 7.2) to the confluence of Haas Slough and Cache Slough to the north (LM 5.3). As discussed above, the NLD reports the Cross Levee as part of the Left Bank Cache Slough Levee. See Section 2.2.4 for a discussion on the Cross Levee based on information from the USACE reports.

Original construction of these levees occurred in the early 1900s with soil most likely obtained from adjacent sloughs. The 2011 NULE states that the original levees were deficient in grade and did not include patrol roads. Similar to Levee Segment 153, sometime between the 1930s and 1960s, USACE improved this levee segment with borrow material generated from the Deep-Water Ship Channel and local borrow areas along Cache Slough. The 2011 NULE LiDAR survey data indicated that the landside slopes vary from 2H:1V to 3.2H:1V. The waterside slopes vary from 1.3H:1V to 3H:1V.

The 2011 NULE reported that, similar to Reach 2 of Levee Segment 153, these improved levees experienced significant distress and subsidence including erosion and landside slumps. Continuous repairs from 1974 to 1980 resulted in similar distress. Some of the landside slumps involved the entire landside slope and, at times, the levee crown.

The USACE drilled five explorations, 2F-91-13, 2F-91-14, 2F-91-15, 5F-62-7, and 5F-62-8, along this levee stretch. The explorations indicate the levee and foundation material generally consist of lean- to fat clay with some interbedded peat layers.

2.2.3 Haas Slough East Levee

The 2011 NULE describes Haas Slough East Levee as Levee Segment 312, which extends along the left bank of Haas Slough from the confluence of Cache Slough then continues north 1.9 miles along Haas Slough, north of the Lookout Slough THRFIP. The section adjacent to the Lookout Slough THRFIP extends from the confluence of Cache Slough to the confluence with Duck Slough. Segment 312 levees were constructed in the early 1900s using dredge material from adjacent sloughs, so the levee likely consist of lean- to fat clay and organic clay. The subsurface conditions below the levees also consists of lean- to fat clay.

Similar to other levees in the area described above, the USACE improved this levee system in the 1930s and 1960s using borrow from dredging operations in the Deep-Water Ship Channel and borrow areas near Cache Slough. The 2011 NULE LiDAR indicates landside slopes from 2H:1V to 5H:1V, with the majority being 2.5H:1V or flatter. Waterside slopes vary but are as steep as 1.5H:1V.

The 2011 NULE states that this levee section experienced landside sloughing at multiple locations during the 1997-1998 flood, both along the waterside and landside slopes.

The USACE drilled three explorations, 2F-91-11,11A, and 2F-91-12, within this levee segment adjacent to the Lookout Slough THRFIP. The explorations indicate the levee and foundation material generally consists of lean- to fat clay with some interbedded peat layers, similar to that encountered in Levee Segment 313.

2.2.4 Cross Levee

The 1986 USACE report presents project background and history that led to the construction of the cross levee at the southern end of the Lookout Slough THRFIP. The southern end of Liberty Farm, along the SSL, experienced substantial subsidence and sloughing both during and after construction improvements in 1961. Through 1973, remedial repair and upgrade construction occurred annually. Repair continued until 1981 when the USACE decided to design a more permanent fix along this levee stretch.

The 1986 report concentrates on the initial selected plan which included 6-feet of freeboard by improving and enhancing the existing levee. Due to cost considerations, the USACE deviated from the proposed plan and selected an alternative plan to construct a cross levee to join Shag Slough to Cache Slough. The existing levees north of the remediation location were also to be widened and/or modified to provide a 20-foot-wide levee crown, 3(H):1(V) waterside levee slopes and 2(H):1(V) landside levee slopes.

The 1988 USACE plans for the Cross Levee show a 20-foot-wide levee crown and 3(H):1(V) waterside and landside slopes with rip rap protection along the waterside slopes to Elevation 7 feet. It appears that the Cross Levee crest elevations were designed to meet the SSL elevation at the tie-in with Shag Slough and slope down to meet the elevation of the Cache Slough East Levee. Based on information provided in the USACE *Supplement to Standard Operation and Maintenance Manual, Sacramento River Flood Control Project, Unit No. 109, West Levee of Yolo Bypass and East Levee of Cache Slough*, the construction of the Cross Levee was completed on November 1, 1989.

3 TOPOGRAPHY, GEOLOGY, GEOMORPHOLOGY, GROUND WATER AND SUBSURFACE SOIL CONDITIONS

3.1 Topography

The 2011 NULE describes the Area 5, West Delta Levees as located within the low-lying portion of the southwestern Sacramento Valley. Within the project area and surrounding sites, small and large canals with associated levees were constructed to aid in irrigation, prevent flooding, and drain the previously saturated, low-lying deposits. Current ground elevations near the proposed DSSL range from Elevation 8 feet to Elevation 6 feet.

BCI reviewed the following available historical topographic maps within the Lookout Slough THRFIP area to identify if historical sloughs or drainage areas crossed the proposed DSSL alignment:

- Courtland Quadrangle Topography, March 1908 Edition, Reprinted in 1914.
- Cache Slough Quadrangle Topography, 1916 Edition.
- Liberty Island Quadrangle Topography, 1952, Photo revised 1968.

A pond feature is identified on both the 1908 and the 1916 topographic maps. This pond feature aligns with the water feature identified on the geomorphology map, discussed below in Section 3.3. BCI did not identify any other historical sloughs or drainage/irrigation channels crossing the proposed DSSL alignment. Appendix A presents the topographic maps overlain with the project limits and the proposed DSSL alignment.

3.2 Geology

The Lookout Slough THRFIP area is located within the northwestern portion of the approximately 50-mile-wide and 400-mile-long Great Valley Geomorphic Province. The Great Valley province is a depositional basin bounded by the Sierra Nevada to the east, the Coast Ranges to the west, and the Klamath Mountains and Cascade Range to the north. The basin is a broad, elongated, northwest trending, structural trough that has been filled with a thick sequence of sediments as much as 20,000 to 40,000 feet thick.

BCI reviewed both the *Geologic Maps of the Sacramento -San Joaquin Delta,* California, Brian F. Atwater, 1982 (1982 Geologic Map), and the *Geologic Map of the Late Cenozoic Deposits of the Sacramento Valley, Sheet 1,* Edward J. Helley and David S. Harwood, USGS Publication MF-1790, 1985 (1985 Geologic Map). Both Geologic Maps indicate the site as generally underlain by Basin Deposits, Undivided/Flood-basin deposits (Holocene) (Qb). This material consists of fine grained silt and clay. Both maps also identify two localized areas are mapped as Lower Member, Modesto Formation (Qml) (1985 Geologic Map) and Alluvium of Putah Creek, Older Alluvium (Pleistocene) Qop near the proposed DSSL alignment and borrow areas. The Qml formation consists of unconsolidated, slightly weathered gravel, sand, silt and clay. These areas are near the water features identified in the geomorphology map discussed below in Section 3.3.

The 1982 Geology Map identifies the northern border of the property as Younger Alluvium of Putah Creek (Holocene and Pleistocene) (Qyp). The border of Qyp closely follows the border between Basin Deposits and Marsh Deposits identified on the geomorphology map. Peat Deposits (Qp/Qpm) extend into the very lower southeast section of the project site on both geology maps. The southern cross levee is located within this deposit. Peat deposits consist of decaying fresh-water plant remains with minor amounts of silt and clay.

Figure 4 presents the site Geologic Map using the 1982 Geology Map. This map more closely aligns with features identified in the geomorphology map and is more specific to the Delta area.

3.3 Geomorphology

The 2011 Geomorphology TM describes the geology of the project area as the Yolo Flood Basin. During times of flood, slow moving inland seas covered this basin. In the existing information listed in Section 2.1, URS describes deposition in such flood basins resulted from slow moving/standing water, with primary sediments consisting of silt and clay. Higher permeability deposits may be locally interbedded, as well as alluvial fan sediments from west or east flowing streams.

The Delta geomorphic domain generally consists of fluvial channels and tidal sloughs. Delta island deposits are late Holocene, unconsolidated and fine-grained organic-rich silt and clay with high water content and peat. Directly adjacent to watercourses, Sacramento River supratidal alluvium and sloughs overlie Delta islands of peat and mud. Natural levee deposits and peat and mud deposits interfinger in the subsurface and create vertical interbedded layers of silt and sand with organic-rich material. The deposits in the Delta are moderately permeable.

The geomorphology underlying the proposed DSSL alignment and extending into the proposed borrow areas generally consists of Basin Deposits (Hn) comprised of fine sand, silt and clay. A localized water area is mapped generally between Station 38+00 to Station 48+00 of the proposed DSSL alignment, and localized Alluvial Fan deposits (Pf) are mapped in the northern portion of the site, generally waterside of the proposed levee alignment. A Holocene Slough Deposit (Hsl) is mapped to extend into the upper northeast corner of the site.

The remainder of the site is generally mapped as Marsh Deposits (Hs) which consist of silt and clay and possible organic rich deposits. Similar to the mapped Qp of the Helley and Harwood Geologic Map, Peat and Muck (Qpm) is mapped in the very lower southwest section of the Lookout Slough THRFIP, near the southern cross levee, but not under the proposed new DSSL alignment. This material consists of interbedded peat and organic-rich silt and clay. Both Historical and Holocene Slough Deposits (Rsl and Hsl respectively) which consist of silt, clay and sand, low-energy channel deposits extend into the Lookout Slough THRFIP predominantly along the western border, apparently originating from Hass and Cache Slough. Refer to Figures 3A and 3B.

3.4 Ground Water

Ground water elevations encountered during recent subsurface explorations are shown on the exploratory borings and test pits logs in the GDR and Borrow Report prepared for this project. This information indicates free ground water from 3 to 20 feet below the existing ground surface (bgs) (approximate Elevation 3 feet to Elevation -7 feet) near the proposed DSSL alignment and landside borrow area. In some explorations, it appears that water was seeping from within the clay blanket layer, while in others, the water appeared to be within discontinuous, thin clayey sand lenses. During test pit excavations, BCI observed ground water seeping from the side walls into the test pit, fluctuating between 5.5 feet to 9 feet bgs. We interpret that the ground water we encountered is a combination of perched water from heavy winter rains, irrigation flooding from ranching operations, and seepage from the nearby canals, sloughs, ditches and the bypass within disconnected sandy clay layers that are more pervious than the overlying and underlying clay.

3.5 Subsurface Conditions Underlying the DSSL Alignment

In general, from Station 0+00 to Station 32+00 and from Station 53+00 to Station 152+00, BCI's subsurface explorations to date indicate that the soil conditions underlying the DSSL alignment consist of a relatively thick (about 35 feet) layer of medium stiff to hard lean-to fat clay to sandy clay, overlying a variable dense to medium dense sand, gravel, silty sand, clayey sand aquifer. We generally encountered the top of the aquifer at an elevation of -30 feet MSL or deeper. In some explorations, we did not encounter an aquifer to the depth explored; and in other explorations, the relatively thick surface clay layer contains variable, discontinuous, relatively thin (less than 5-foot-thick) zones of higher permeability dense to very dense clayey sand, sand with silt and clay, silt and silty sand within the upper 20 feet.

Between Station 32+00 to Station 53+00, the subsurface conditions generally consist of a 5-foot-thick layer of medium stiff to hard lean-to fat clay to sandy clay underlain by relatively permeable layers of medium dense to very dense poorly-to well-graded sand with silt and clay, silty sand, and poorly-to well-graded gravel with sand and clay, up to depths of about 32 feet. The depth to the top of the permeable layers varies. BCI encountered ground water at a depth of about 3 to 7 feet below the surface within this area.

Figures 5A through Figures 5G present the Lookout Slough THRFIP Plan and Geotechnical Profile Figures. These figures present the subsurface soil conditions along the entire levee alignment.

4 DESIGN DSSL WATER SURFACE ELEVATIONS, GEOMETRY AND COMPOSITION

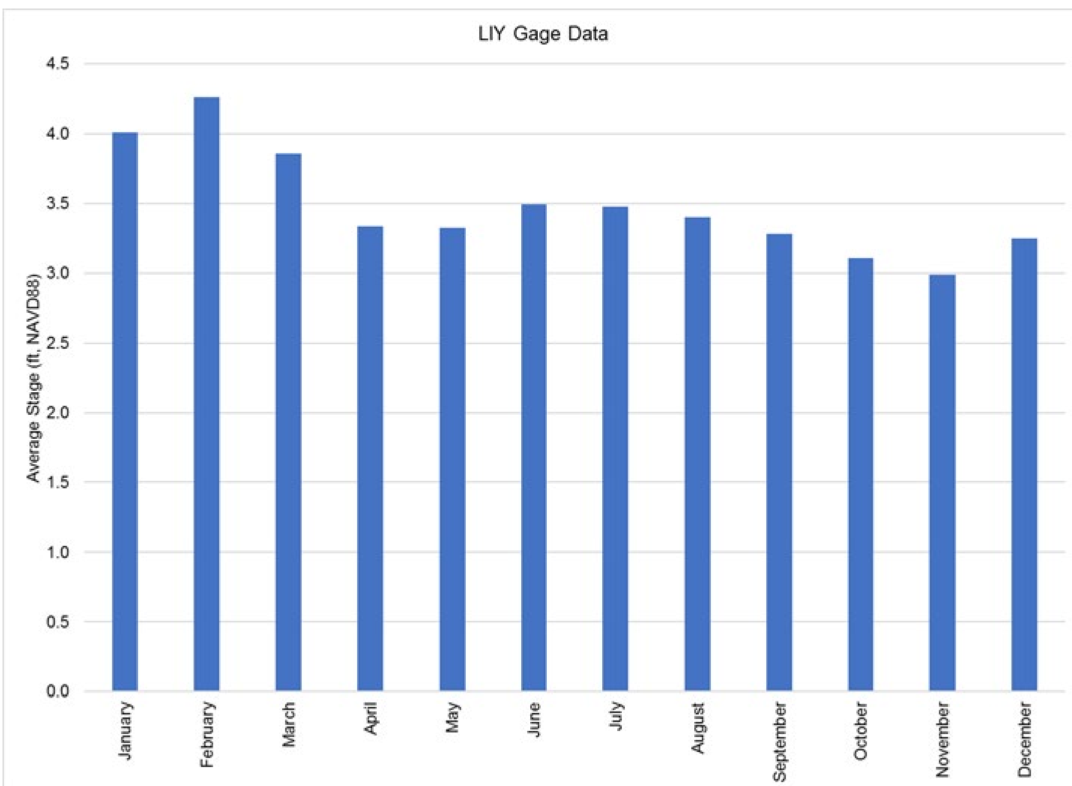
4.1 Design Water Surface Elevations for Steady-State Analysis and Water Surface Elevations for End-of-Construction Analysis

ESA prepared the April 2019 Draft H&H Analysis for the Lookout Slough THRFIP. The H&H Analysis presents a discussion on the Design Water Surface Profile and associated Design Water Surface

Elevations (DWSEs). The analysis compares the 1957 authorized design water surface profile (1957 Profile) with the 100-year design water surface profile along the new DSSL alignment. The H&H Analysis recommends the 1957 Profile for the basis of design water surface elevation for the Lookout Slough THRFIP because it is generally higher than the 100-year profile.

Based on the H&H Analysis, the proposed water surface elevations (WSEs) for geotechnical design include:

- Design Water Surface Elevation (DWSE) for steady-state underseepage and steady-state slope stability analyses equal to the 1957 Profile plus one-foot. The 1-foot adjustment accounts for uncertainties associated with climate change and sea-level rise.
- Average of the Winter and Summer WSE for end-of-construction (EOC) stability analyses. Regulatory design documents do not specify what WSE to use for EOC; however, based on our experience, the standard of care in the area typically evaluates EOC based on the average winter and summer WSEs.
- The design-build team provided BCI with average stage WSEs accessed through http://wdl.water.ca.gov/waterdatalibrary/docs/Hydstra/index.cfm?site=B91510&source=map. Stage daily mean values were taken from the website for each year available between 1995 and 2018, and then grouped by month.



Based on the gage data presented above, BCI used an average WSE = 3.5 feet for EOC analysis. In addition, BCI evaluated one model for the EOC slope stability using the DWSE. The SAR panel suggested we also evaluate EOC at the DWSE because new regulations may include this requirement.

4.2 Levee Composition and Geometry

The California Code of Regulations, Regulations of the Central Valley Flood Protection Board, Title 23, Waters, December 2009 (Title 23) recommends the following for levee construction of a bypass levee:

- At least 20% passing the No. 200 sieve
- Liquid Limit less than 50
- Plasticity Index greater than 8
- 3(H):1(V) landside slope
- 4(H):1(V) waterside slope
- 4-foot to 6-foot freeboard

Title 23 further states that "special construction details (e.g., 4:1 slopes) may be substituted where the soil properties are not easily attainable". In addition, Title 23 also states "Where the design of a new levee structure utilizes zones of various materials or soil types, the requirements of this subdivision do not apply."

BCI worked closely with the design-build team to evaluate on-site soil that would be generated from the habitat restoration component of the Lookout Slough THRFIP for DSSL fill. Our evaluation consisted of test pits within the proposed on-site restoration areas located near the proposed DSSL and laboratory tests on representative samples obtained from the test pits. The findings from the test pits and laboratory tests are contained in the 65% Draft Geotechnical Borrow Report prepared by BCI for the Lookout Slough THRFIP and submitted under separate cover.

Based on our Borrow Report findings, the on-site soil meets Title 23 percent passing the #200 sieve and Plasticity Index criteria but does not consistently meet the Liquid Limit criteria. Based on our tests in the borrow pits, the Liquid Limit of the soil from the proposed excavation lateral extents and excavation depths ranges from 31 to 80 with an average of 56. When used for levee fill, cyclical wetting and drying of fat clay (clay with a Liquid Limit of 50 or greater) can result in shrinkage (desiccation) cracks and softening of the clay along the exterior of the levee, which can lead to surficial slumps when the softened soil becomes near-saturated from rainfall. This phenomenon is generally restricted to within about 6 feet (measured perpendicular) of the slope face, and for slopes steeper than about 4(H):1(V).

Considering the potential for softening and slumps, the project design consists of 4(H):1(V) landside slope and 4(H):1(V) waterside slope. The 4(H):1(V) landside and waterside slope is flat enough to account for material with Liquid Limits that exceed 50 and will help mitigate surficial slumping. Desiccation cracks should be expected, but, due to the relative flat 4(H):1(V) slopes, should not result in significant surficial slumps that would impact the performance of the levee.

The design build team set freeboard at 8 feet above the DWSE which includes 6 feet of freeboard above the 1957 Profile, 1-foot for climate change and future adjustments to the DWSE, and 1-foot for anticipated settlement. This design freeboard relates closely to the original design freeboard for the SSL and other similar DSSL projects in the area. The current DSSL crest is set between Elevation 28 feet to Elevation 29.4 feet.

5 GEOTECHNICAL CROSS-SECTION AND DESIGN PARAMETER SELECTION

5.1 Geotechnical Analysis Cross-Section Selection

For 65% design, BCI evaluated DSSL subsurface conditions along the entire alignment to determine cross-sections for steady-state underseepage, steady-state slope stability, rapid drawdown slope stability and end-of-construction slope stability evaluations. To select the cross-sections for analysis, BCI:

- Reviewed the subsurface soil and ground water conditions in explorations completed by BCI near the centerline levee alignment, and both waterside and landside of the planned DSSL alignment.
- Reviewed laboratory test results performed by BCI on soil samples obtained from the exploratory explorations.
- Reviewed geologic and geomorphic mapping of the area.
- Divided the planned levee alignment into sections with similar subsurface conditions based on the information obtained from the above bullet points.
- Developed subsurface stratigraphy models for the different stations.
- Developed and analyzed cross-sections for the different stations.

Based on the above information, BCI developed cross-sections at the following four locations to represent subsurface soil conditions along the entire DSSL alignment:

- Station 6+50
- Station 42+00
- Station 109+50
- Station 148+00

5.2 Unit Weight Selection

For steady-state underseepage evaluation, the average exit gradient criteria is based on the assumption that the saturated unit weights of the "in situ" landside blanket soils are at or above 112 pounds per cubic foot. BCI performed moisture content and density tests on relatively undisturbed samples of the underlying blanket soil obtained from our exploratory borings and test pits. The results indicate that the average dry density ranges from 97 pounds per cubic foot (pcf) to 103.1 pcf (depending on the range of sample depth) and average in-situ moisture content ranges from 23.7% to 28.3% for the CL, CH blanket layer. This results in an average total unit weight range of about 122 pcf to 128 pcf depending on depth below the ground surface. Assuming a specific gravity of 2.65, the saturation of the samples is close to 100% saturation. Therefore, the in-situ blanket layer material exhibits saturated unit weights greater than 112 pcf.

BCI estimated saturated unit weights for each stability analyses cross-section based on laboratory test results presented in the 65% Draft GDR for explorations included in the cross-section stratigraphy.

5.3 Hydraulic Conductivity and Strength Parameter Selection

The steady-state underseepage evaluation requires hydraulic conductivity parameter input, and each individual slope stability evaluation requires strength parameter input. Selection of these parameters considers both the soil properties encountered within the Lookout Slough THRFIP area as well as the specific subsurface soil layering within each cross-section. BCI assigned the soil layer classification for each layer based on the exploration data encountered within a specified cross-section, as well as surrounding explorations within the cross-section area and considered the variable nature of the soil. We took into consideration the varying soil types and non-continuous nature of the soil layering.

BCI presents the rationale used to determine the input parameters for analysis below.

5.3.1 Hydraulic Conductivity Parameter Selection Rationale

To determine the hydraulic conductivity values for steady-state underseepage analyses, BCI performed an evaluation of existing data and laboratory hydraulic conductivity test results obtained by BCI on soil samples obtained at the Lookout Slough THRFIP site. The evaluation included:

- Review of hydraulic conductivity values proposed by BCI and others for nearby projects.
- Laboratory hydraulic conductivity tests on samples of various soil types from the Lookout Slough THRFIP site at in-situ-estimated confining pressures.
- Review of laboratory test results with respect to sample depth and material type.
- Comparison of the laboratory test results with previous and recently reported hydraulic conductivity values proposed by others for nearby projects including the Lower Elkhorn project, which is entering final design.
- Comparison of the proposed parameters with the hydraulic conductivity tests proposed in the April 2015 Guidance Document for Geotechnical Analyses, Urban Levee Evaluations Project, Contract 4600008101, URS.

BCI considered the hydraulic conductivity values determined for the Southport EIP located in West Sacramento, California. The soil types within the Southport EIP Project area are somewhat similar to those that exist within the Lookout Slough THRFIP. BCI determined the Southport EIP values based on an in-depth review of hydraulic conductivity values used by others in the surrounding areas, as well as a detailed evaluation of numerous hydraulic conductivity test results for samples obtained within the Southport project area.

BCI compared the laboratory test values obtained during this evaluation (presented in Table 1) with the values from Southport EIP, the Lower Elkhorn project and the 2015 Guidance Document (shown in Table 2) and made a final determination of the proposed hydraulic conductivity values presented in Table 3 based on soil types encountered within the Lookout Slough THRFIP area.

BCI considered the following in the final determination of the proposed hydraulic conductivity values for 65%-Design:

- Laboratory hydraulic conductivity tests performed by BCI on samples of various soil types from the Lookout Slough THRFIP site at in-situ-estimated confining pressures to confirm parameters used by others in nearby projects.
- The average laboratory test result on the remolded samples for the new DSSL is $K_v = 3.87 \times 10^{-9}$ cm/s. BCI used the more conservative value of $K_v = 2.5 \times 10^{-7}$ cm/s to align with parameters used in similar nearby projects.
- The average laboratory test result for the Lean CLAY, Fat CLAY blanket layer is $K_v = 1.85 \times 10^{-6}$ cm/s. BCI used a more conservative value of $K_v = 2.5 \times 10^{-7}$ cm/s.

5.3.2 Strength Parameter Selection Rationale

To determine strength parameter values for each slope stability analysis, BCI evaluated published data and laboratory strength test results including direct shear and triaxial tests performed by BCI on samples obtained from the Lookout Slough THRFIP site. The evaluation included:

- Review of strength parameter values used by BCI for nearby projects including the Southport EIP. BCI determined the Southport EIP values based on a review of strength parameter values used by others in the surrounding areas, as well as an evaluation of strength test results from samples obtained within the Southport EIP project area.
- Review of strength parameters used by others for nearby projects including the Lower Elkhorn Basin Levee Setback project.
- BCI laboratory strength parameter test results on various soil types at various depths on samples obtained within the Lookout Slough THRFIP area.
- Evaluation of laboratory test results with respect to sample depth and material type.
- Comparison of the proposed parameters with the strength parameters proposed in the April 2015 Guidance Document for Geotechnical Analyses, Urban Levee Evaluations Project, Contract 4600008101, URS.

BCI strength tests performed for the Lookout Slough THRFIP on both in-situ and remolded samples included direct shear tests and triaxial compression tests including Consolidated Undrained with pore-water pressure measurements (CU w/pp). These tests were performed on Shelby tube samples. With a diameter of approximately 3-inches, three, 3-inch by 6-inch samples of the same material type are required for CU w/pp triaxial compression tests. As discussed in Section 3.5, the thick clay layer consists of varying layers of lean-to fat clay to sandy clay, with discontinuous, relatively thin zones of higher permeability clayey sand, silt and silty sand. It was therefore difficult to obtain a continuous 1.5 foot sample of similar material that would produce reasonable CU w/pp triaxial compression test results to obtain both total and effective strengths. BCI performed three CU w/pp triaxial compression tests on specimens of in-situ soil in an attempt to obtain both effective and total strength tests. However, due to sample variability, BCI could not produce reasonable Mohr circles to determine effective strengths from two of the three test results. We therefore considered the total strength parameters from these tests for the Rapid Drawdown slope stability evaluation. For the steady-state slope stability analysis, we considered the effective strength parameters from the one CU w/pp and the direct shear results as well as typical values from previous studies and values obtained and recommended by others.

With regards to CU w/pp triaxial compression tests, BCI evaluated the total and effective friction angle and cohesion at the maximum principal strength ratio, 5% strain, and the maximum deviator stress (if less than 5%). Based on this evaluation, the strength values at the maximum principal strength ratio generally provided the most reasonable results for the remolded specimens and were therefore used for analysis. The strength values at 5% strain provided the most reasonable results on specimens of in-situ clay and were therefore used for analysis.

5.3.2.1 Undrained Shear Strength for Native Clay

To determine the undrained strength of the clay underlying the DSSL for end-of-construction slope stability analysis, BCI reviewed the undrained shear strength data from the BCI CU w/pp triaxial tests at confining pressures similar to the in-situ vertical stress, as well as the Unconsolidated Undrained (UU) triaxial tests. The test results indicate that the undrained shear strength ranges from about 1,039 psf to 4,650 psf with an average undrained strength of about 2,730 psf and are appropriate for design. BCI confirmed these values with the values obtained from the CPT soundings. For analysis, BCI used a conservative value of 1,000 psf in the slope stability models for 65% design. Higher undrained strengths, such as the average values presented in Table 4, would also be appropriate and may be used for final design.

5.3.2.2 Drained/Effective Strength Parameters for Native Clay

BCI's effective strength test results (direct shear) on samples of the clay underlying the DSSL alignment indicate friction angles from about 17 to 34 degrees with an outlier test exhibiting about 41 degrees, and cohesion values from 382 psf to 690 psf with one outlier test result indicating a cohesion of 94.6 psf. The average effective strength parameters from the direct shear tests are a friction angle of about 27 degrees and 463 psf cohesion. One CU w/pp test indicated a drained friction angle of about 31 degrees and cohesion of 391 psf. Based on these results a friction angle of about 29 degrees and cohesion of about 400 psf are appropriate for design. However, based on initial comments provided by DWR, BCI modeled the clay layer using effective and total cohesion values from URS presumptive values document of a friction angle of 30 to 32 degrees and 150 psf cohesion. The cohesion value is significantly conservative and higher effective and total cohesion values may be used for final design.

5.3.2.3 Remolded Strength Parameters for Compacted Levee Fill

BCI's CU w/pp tests on remolded soil samples obtained from the borrow areas indicated total/undrained strength parameters ranging from a friction angle of about 13 to 21 degrees and 165 to 600 psf cohesion with average values of about 16 degrees and 375 psf. These tests also indicated effective/drained strength parameters ranging from a friction angle of about 19 to 27 degrees and 400 to 550 psf cohesion with an average of about 24 degrees and 475 psf. Based on these results total strength parameters of about 16 degree and 375 psf and effective strength parameter of about 27 degrees and 475 psf are reasonable values for design. Based on our review of the test results, we used total strength parameters of 13 degrees and 450 psf and effective strength parameters of 22 degrees and 400 psf in our analysis. DWR indicated a concern using the results of the remolded CU w/pp triaxial compression tests for the analysis; specifically, the use of a cohesion value greater than 200 psf. BCI therefore performed a slope stability sensitivity analysis with a reduced/conservative cohesion value significantly lower than those obtained from the remolded test values. The sensitivity analysis is discussed in Section 7 and presented in Appendix E.

5.3.2.4 Remolded Fully Softened Strength Parameters

BCI performed two remolded Fully Softened Direct Shear tests on material obtained from the borrow area to determine the drained, fully softened friction angle for evaluation of long-term stability of the surficial clay levee soil, which can lose significant strength over cyclical periods of wetting and drying. BCI followed the procedures outlined in the February 20, 2014, *Use and Measurement of Fully Softened Shear Strength*, Bernardo A. Castellanos. The tests indicate a fully softened friction angle of about 19 degrees and no cohesion, which we used in our preliminary analysis for slopes steeper than 4(H):1(V).

6 GEOTECHNICAL ANALYSIS GUIDANCE DOCUMENTS, CRITERIA AND MODEL DEVELOPMENT

6.1 Seepage and Slope Stability Criteria Guidance Documents

BCI developed geotechnical design criteria for steady-state underseepage, steady-state slope stability, rapid drawdown slope stability and end-of-construction slope stability for this Draft GBODR from the following guideline documents:

- California Code of Regulations, Regulations of the Central Valley Flood Protection Board, Title 23, Waters, December 2009.
- USACE, Engineer Manual, EM 1110-2-1913, Design and Construction of Levees, 30 April 2000.
- USACE, Recommendations for Seepage Design Criteria, Evaluation and Design Practices, prepared by the 2003 CESPK Levee Task Force, 15 July 2003.
- USACE, Engineer Manual, EM 1110-2-1902, Engineering and Design, Slope Stability, 31 October 2003.
- USACE, Engineer Technical Letter ETL 1110-2-569, Design Guidance for Levee Underseepage, May 1, 2005.
- USACE, Geotechnical Levee Practice Standard Operating Procedure, Revision 2, 11 April 2008.

6.2 Steady-State Underseepage Criteria

BCI evaluated the average exit gradients for each cross-section under steady-state conditions at DWSE water levels. The average exit gradient is defined as the average head loss per foot traveling upward through the blanket. Elevated average exit gradients may result in sand boils and piping and may potentially lead to levee failure.

For water levels at the DWSE, the average hydraulic exit gradient criteria for steady-state underseepage design include:

Location	Average Exit Gradient
Landside levee toe:	≤ 0.5
Bottom of empty ditch or depression at landside levee toe:	≤ 0.5
Bottom of empty ditch or depression 150 feet to 300 feet from landside levee toe:	≤ 0.8

For ditches between the landside levee toe and 150 feet from the landside levee toe, the acceptable average exit gradient is determined through linear interpolation of the maximum allowable average exit gradient between 0.5 and 0.8.

The average exit gradient criteria summarized above are based on the assumption that the saturated unit weights of the in- situ landside blanket soils and seepage berm (if present) must be at or above 112 pounds per cubic foot, which is applicable to the Lookout Slough THRFIP analyses (see Section 5.5 of this report).

6.3 Slope Stability Criteria

BCI evaluated steady-state slope stability, rapid drawdown slope stability and end-of-construction slope stability analyses at each cross-section. Based on the guidance documents listed above, the required minimum acceptable slope stability factors of safety are:

Condition	Minimum Factor of Safety
Steady-State DWSE:	1.4
Rapid Drawdown:	1.0 to 1.2
End of Construction:	1.3

In some cases where it can be conclusively shown that the levee embankment is composed of impervious soils, or a cutoff wall/impervious core is used, a lower phreatic line through the levee may be justified and used in the steady state analyses and designs per USACE allowances. For this Draft GBODR, BCI used the unadjusted phreatic line determined by the steady-state underseepage analysis for the steady-state slope stability analysis.

6.4 Geotechnical Analysis Model Development

BCI used the following information provided by the design-build team to create each cross-section model:

- Surface topography and bathymetry provided by the design-build team. BCI prepared models for each cross-section to extend landward a minimum of 2,000 feet, and waterside a minimum of 1,000 feet from the levee.
- Cross-section geometry provided by the design-build team including final grading waterside of the DSSL within the habitat area. BCI did not include an inspection trench in the developed models. Currently, for 65% design, BCI recommends a conventional cutoff wall along the levee alignment. The cutoff wall provides the same engineering benefits as an inspection trench and therefore eliminates the need for an inspection trench, which is required by Title 23.
- Historical Yolo Bypass WSEs provided by the design-build team to determine the end-of-construction slope stability WSE considering both the average winter WSE and average summer WSE.
- DWSE provided by the design-build team based on the evaluation presented in the H&H Analysis. The following table presents a summary of the DWSEs provided by the design-build team and used in BCI's analyses.

Design Water Surface Elevations (NAVD D88 ft)		
Station	**1957 WSE (feet)**	**DWSE (1957 WSE + 1 foot) (feet)**
6+50	19.6	20.6
42+00	19.8	20.8
109+50	20.6	21.6
148+00	20.6	21.6

6.4.1 Through-Seepage and Steady-State Underseepage

6.4.1.1 Through-Seepage

If completed, the new DSSL would be constructed of on-site clay with a relatively low permeability that will restrict through-seepage during high water events.

6.4.1.2 Steady-State Underseepage

For 65% design, BCI evaluated steady-state underseepage at the DWSE for each cross-section with and without the recommended cutoff walls.

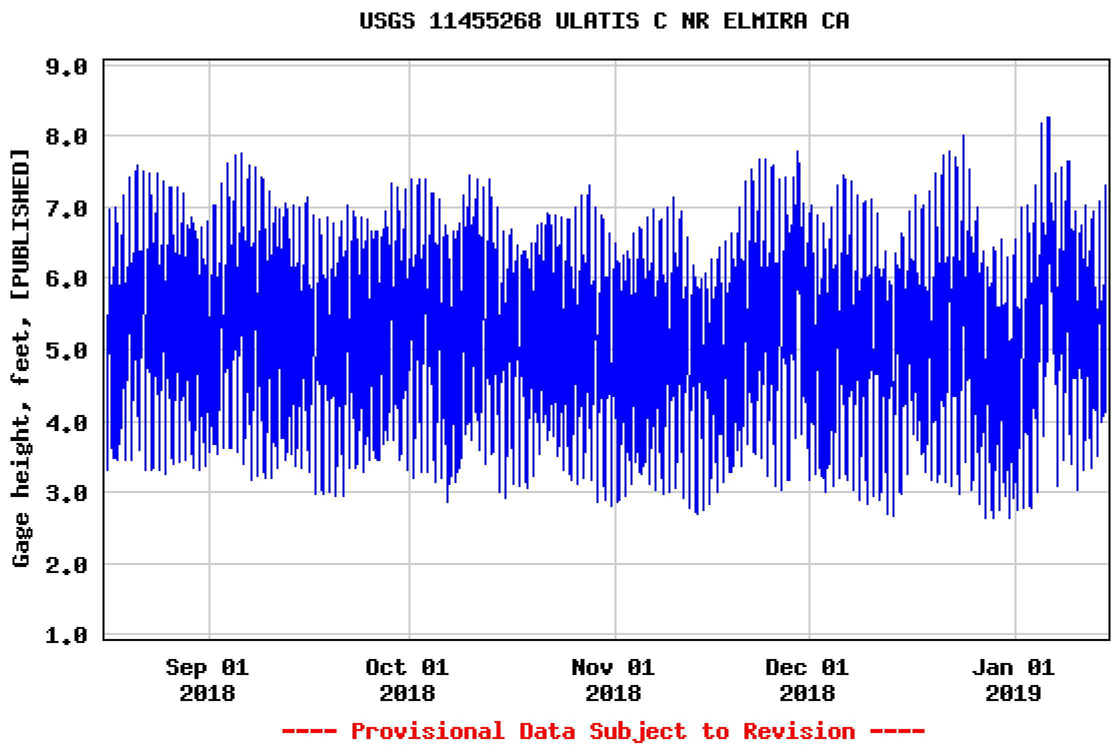
To perform the analysis, BCI used the program SEEP/W, Version 2019, 10.1.0.18696, with the proposed hydraulic conductivity values presented in Table 3 as input parameters. BCI then applied the following boundary conditions to each model:

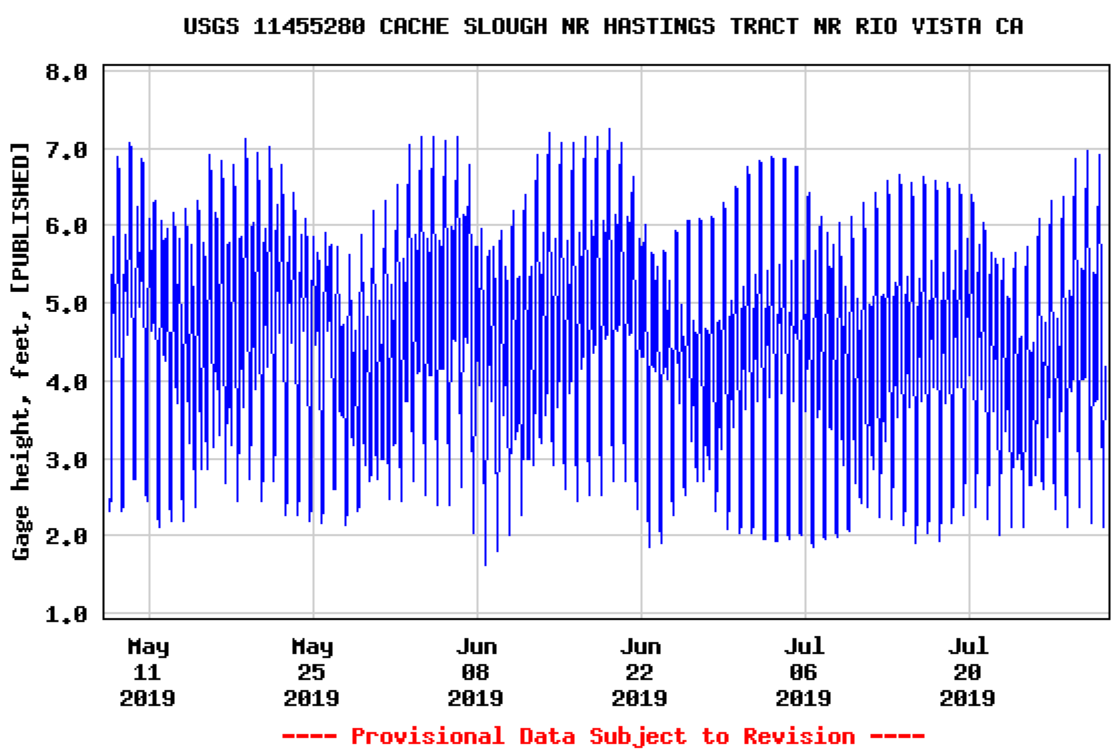
- Fixed-head set to the river stage along the boundary nodes of the waterside levee slope and river bottom.
- Potential seepage surface for nodes on the landside levee slope and landside ground surface.
- No-flow condition along the bottom of the model, and along the waterside vertical edge of the model.
- Total head boundary along the landside vertical edge set to the lower elevation of the landside ground surface elevation at the landside edge, the bottom of the slough landside of the new DSSL or the landside levee toe elevation.

The above boundary conditions are similar to those applied in previous nearby projects by both BCI and the USACE and are recommended in the April 2015 URS Guidance Document.

BCI evaluated Duck Slough, parallel to Lookout Slough along Malcolm Lane, with and without water and the Liberty Island irrigation ditch north of Liberty Island Road without water. BCI spoke with the current lessee of the project area who also leases the property to the north of the project site that includes Duck Slough and will continue to use this property after construction of the Lookout Slough THRFIP. The lessee explained that he uses water within Duck Slough for pasture irrigation and that the Slough always has water, with elevations close to the elevations within Hass Slough as they are hydraulically connected via a gate. In the summer, the gate opens to allow Hass Slough water to enter into Duck Slough and in the winter the gate opens to discharge water from Duck Slough into Hass Slough to reduce flooding potential of the pastures.

To evaluate a reasonable and relatively conservative water surface elevation within Duck Slough, BCI evaluated available gage data in the area. The USGS Water Data for the Nation website, https://waterdata.usgs.gov/nwis, provides gage data at Cache Slough along Hastings Tract and at Ulatis Creek. The data presented for the Cache Slough gage would be more representative of water surface elevations anticipated for Duck Slough. The following graphs were provided by the USGS website:


USGS 11455268 ULATIS C NR ELMIRA CA
Gage height, feet, [PUBLISHED]
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Sep 01 2018
Oct 01 2018
Nov 01 2018
Dec 01 2018
Jan 01 2019
---- Provisional Data Subject to Revision ----


USGS 11455280 CACHE SLOUGH NR HASTINGS TRACT NR RIO VISTA CA
Gage height, feet, [PUBLISHED]
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
May 11 2019
May 25 2019
Jun 08 2019
Jun 22 2019
Jul 06 2019
Jul 20 2019
---- Provisional Data Subject to Revision ----

Based on the above, a conservative WSE of 4 feet is a reasonable WSE to use within Duck Slough during the year. For steady-state underseepage analysis, at flood levels, this WSE is most likely higher than 4 feet.

6.4.2 Steady-State Slope Stability and End-of-Construction Slope Stability

BCI performed steady-state slope stability and end-of-construction slope stability analyses at each cross-section with and without the recommended cutoff walls.

BCI used the program SLOPE/W, Version 2019, 10.1.0.18696, and the proposed strength parameter values presented in Table 5. BCI's slope stability analyses used the following:

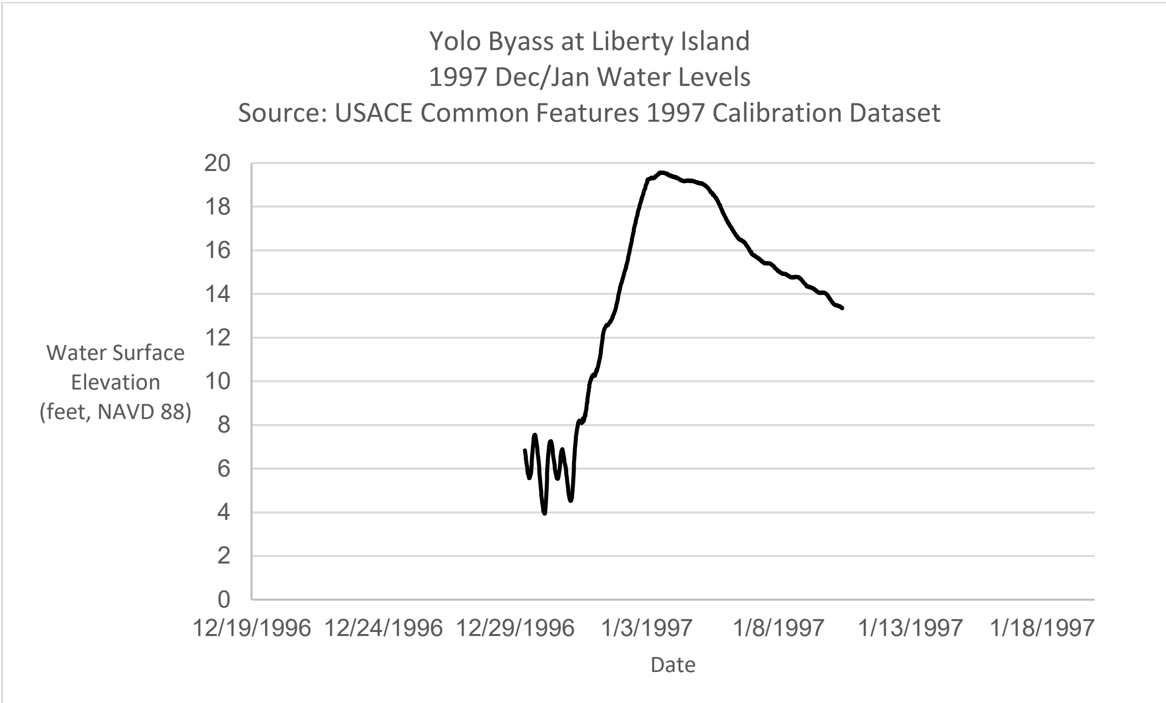
- Spencer's Method, a limit-equilibrium method of analysis.
- A tension crack zone along the levee crest assumed to be 6-feet deep for the steady-state slope stability analyses.
- Effective shear strengths shown in Table 5 and pore water pressures imported from the SEEP/W model for the steady-state slope stability models at the DWSE.
- End-of-construction (EOC) slope stability using the WSE as 3.5 feet (NAVD88) considering average winter and summer WSEs and one model at the DWSE. BCI input undrained shear strengths from Table 5 for slow-draining, fine-grained soil types CL, CH and interbedded layers containing CL and CH. For free-draining material, BCI used the effective strengths presented in Table 5.

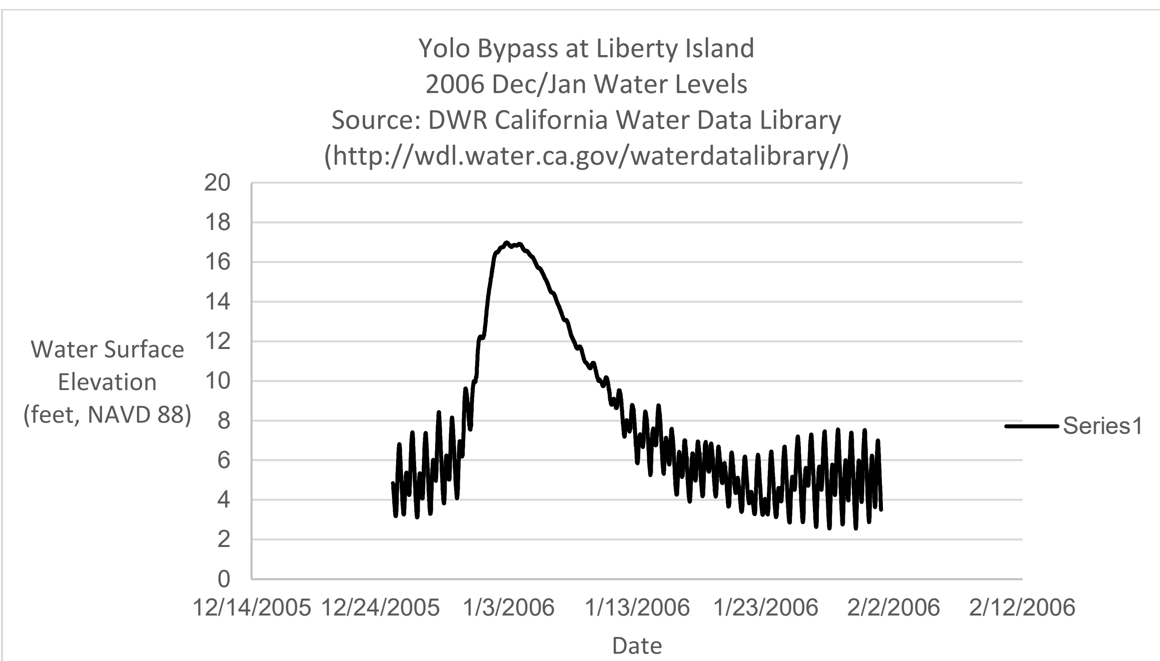
6.4.3 Rapid Drawdown Slope Stability

BCI evaluated the potential for rapid drawdown slope stability to occur along the new DSSL waterside slope. BCI based the analysis on available stage hydrographs provided by the design-build team, drainage properties of native soil underlying the new DSSL alignment, compacted levee fill, past waterside slope performance on existing levees in the area, and duration of pre-drawdown water levels.

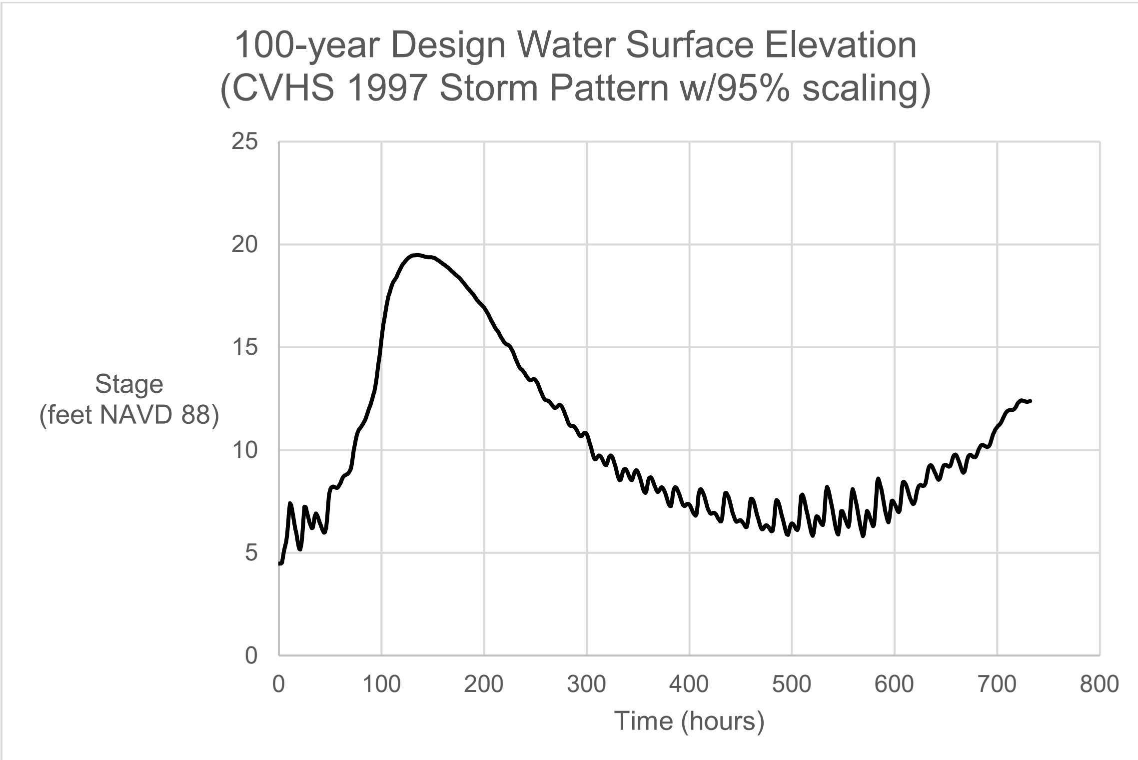
As discussed in Section 2.1, historical erosion sites were identified along the SSL waterside slopes after storm events. This instability may occur when water recedes after storm events, which in turn, may produce a rapid drawdown condition. If completed, the new DSSL would be constructed of clay, which is susceptible to rapid drawdown failures. BCI therefore recommends a rapid drawdown slope stability evaluation of the new DSSL.

Stage Hydrographs
The design-build team provided data from the 1997 flood and 2006 flood events, two of the larger flood events in the past 20 years. This data was collected for Liberty Island at the Yolo Bypass stream gage. The design-build team extracted the 1997 flood data from the USACE's Common Features calibration datasets, and obtained the 2006 flood data from DWR's California Water Data Library to generate the following hydrographs:





BCI then evaluated the simulated 1-in-100-year stage hydrograph provided by the design-build team. To generate the hydrograph, the design-build team scaled the 1997 storm pattern with 95% scaling to prepare the following hydrograph based on the 1957 "design flow", which is a steady-state number.



The hydrographs indicate slightly more than one-foot-per-day drop can be expected after a flood event, with a typical 10-foot drawdown for the 100-year DWSE.

Soil Drainage Properties
In general, clay soil requires a slow drawdown rate to create drained conditions, in the order of less than one-foot-per-day. As information extracted from the hydrographs discussed above indicates drawdowns of up to one-foot-per-day, the clay layers underlying the new DSSL should be modeled as undrained. In addition, the new compacted clay levee fill should also be modeled as undrained after drawdown.

Analysis
BCI used the program SLOPE/W, Version 2019, 10.1.0.18696, and the proposed effective and total strength parameter values presented in Table 5. BCI's rapid drawdown slope stability analyses used the following:

- Spencer's Method, a limit-equilibrium method of analysis, for each stability analysis.
- A 6-foot-deep tension crack zone along the levee crest.
- The rapid drawdown slope stability analysis method in SLOPE/W, which uses the three-stage method developed by Duncan, Wright, and Wong[1]. BCI input the pre-drawdown WSE equal to the DWSE and a drawdown of 10 feet. The analysis used both effective and total shear strengths shown in Table 5 as input into the program. For free-draining material, the analyses use only effective strengths. BCI evaluated waterside stability analysis for each cross-section.

[1] Duncan, J.M., Wright, S.G, and Wong, K.S. (1990), "Slope Stability during Rapid Drawdown". H. Bolton Seed Memorial Symposium, Vol. 2, University of California at Berkeley.

6.4.4 Long-Term Fully Softened Stability of Surficial Clay Levee

BCI performed preliminary stability analysis of the surficial clay levee using fully softened strength parameters. This evaluation indicated unacceptable factors of safety for 3(H):1(V) slopes. We therefore recommend waterside and landside slopes no steeper than 4(H):1(V).

7 GEOTECHNICAL EVALUATIONS AND RECOMMENDATIONS FOR 65% DESIGN

7.1 Through-Seepage, Steady-State Underseepage, Steady-State Slope Stability, Rapid Drawdown Slope Stability, and End-of-Construction Slope Stability

BCI completed steady-state underseepage, steady-state slope stability, rapid drawdown slope stability and end-of-construction slope stability evaluations for each of the cross-sections determined through the process outlined in Section 5.1 of this report. BCI's evaluations considered the DSSL with and without the recommended cutoff wall discussed below. As discussed in Section 6.4.1, the proposed levee fill consisting of lean-to fat clay will mitigate through-seepage.

Between Station 3+50 and Station 32+00 and from Station 53+00 to Station 152+00, the steady-state underseepage and steady-state slope stability, rapid drawdown slope stability and end-of-construction slope stability all met criteria. As discussed above, BCI encountered intermittent, discontinuous layers of material (predominantly sandy clay) in some of the exploratory borings that have a higher permeability than the overlying and underlying soil (generally fat to lean clay). BCI also encountered relatively shallow ground water within some of these explorations near these higher permeable layers. To reduce the potential for nuisance seepage to adjacent properties, BCI recommends a relatively impervious, relatively shallow cutoff wall along the center of the planned levee alignment from Station 3+50 to Station 32+00 and from Station 53+00 to Station 152+00, extending from the ground surface to Elevation -15 feet MSL. The cutoff wall will intersect the intermittent, discontinuous higher permeable soil layers in the upper 20 feet.

Between Station 32+00 to Station 53+00, BCI recommends a relatively impervious, relatively shallow cutoff wall extending from the ground surface to Elevation -40 feet, through the permeable sand and gravel layers and into the underlying clay. The cutoff wall will mitigate uncontrolled underseepage through the near-surface permeable layers from the waterside to the landside of the planned DSSL.

The cutoff wall along the levee alignment will also cut off flow through unidentified old ditches and channel deposits that might pass below the planned levee alignment and mitigate associated constructability issues such as backfilling over wet, unstable soil conditions.
Between Station 3+50 to Station 152+00, the cutoff wall will also eliminate the need for an inspection trench. An inspection trench will be necessary from Station 0+00 to Station 3+50 where there is no cutoff wall.

BCI presents a discussion of the geotechnical analyses for each analyzed cross-section below.

7.1.1 Evaluation Cross-Section at Station 6+50

BCI evaluated the DSSL at Station 6+50 to account for potential hydraulic influences from Hass Slough. The cross-section angles from the existing Hass Slough levee alignment to the DSSL alignment to maintain the shortest path perpendicular to both the existing levee and the DSSL. BCI's evaluation included a waterside pond feature for the Tidal Habitat Restoration and filling in the drainage ditch located landside of the new DSSL based on the direction of the design-build team. The drainage ditch is located between Duck Slough and the new DSSL.

In general, this cross-section represents similar subsurface soil conditions from Station 0+00 to Station 32+00. Our explorations encountered a relatively thick blanket layer of lean-to fat clay to sandy clay from the ground surface to approximate Elevation -32 feet near the new DSSL alignment. An aquifer layer underlies the blanket and generally consists of interbedded relatively permeable soil layers, including poorly-graded sand with clay, clayey gravel, well-graded gravel and well-graded sand with silt.

BCI's steady-state underseepage and steady-state slope stability analyses both with and without the shallow wall indicate that the average exit gradients and slope stability factors of safety meet criteria under the DWSE.

Station 6+50 reflects the model where the new DSSL ties into the Hass Slough East Levee, which may potentially result in an exit gradient higher than that determined with the 2-dimensional model. BCI evaluated the 3-dimensional effects using the recommendations in the 2015 ULE Guidance Document. The 2015 ULE Guidance Document recommends increasing the required average exit gradient calculated by the 2-dimensional model by a range of percentages based on the levee angle created. The tie-in at the Hass Slough East Levee creates an approximate 90-degree angle. The recommended range of increase for a 90-degree angle is from 15 to 25 percent. Considering the high end of this range, 25 percent, the average exit gradients meet criteria with and without the soil-bentonite cutoff wall to Elevation -15 feet (NAVD88). Table 6 presents the results of the 3-dimensional consideration.

Appendix B presents the steady-state underseepage and individual slope stability analysis result exhibits. Tables 6 and 7 present a summary of the results. BCI's analyses at Station 6+50 indicate that the cutoff wall to Elevation -15 feet (NAVD88) satisfy the average exit gradient criteria and slope stability factors of safety criteria.

7.1.2 Evaluation Cross-Section at Station 42+00

BCI analyzed the DSSL at Station 42+00 to evaluate the subsurface soil conditions within the area marked "Water" on the geomorphology map presented in the 2011 Geomorphology TM. The explorations in this area encountered subsurface soil conditions different than elsewhere along the proposed levee alignment. BCI's evaluation included filling in the drainage ditch located landside of the new DSSL based on the direction of the design-build team, similar to the cross-section at Station 6+50 analyses. BCI also included a waterside pond in this analysis, based on the location of the proposed pond near Station 40+00 as shown in Figure 2.

In general, this cross-section represents similar subsurface soil conditions from Station 32+00 to Station 53+00. Our explorations encountered a relatively thin layer of lean-to fat clay overlying an aquifer layer, with the top of the aquifer as shallow as Elevation -2 feet. The aquifer generally consists of interbedded relatively permeable soil layers, including poorly-graded sand, poorly-graded sand with silt, well-graded sand with clay, and well-graded gravel with sand and with clay and extends to Elevation -30 feet to -35 feet under the levee alignment. Lean clay underlies the aquifer.

BCI's steady-state underseepage analysis and steady-state slope stability analysis without the cutoff wall meet criteria at the landside levee toe. The steady-state underseepage analysis exceeds criteria at the Duck Slough toe with and without a soil-bentonite slurry wall when Duck Slough is conservatively modeled empty as discussed above. With the soil-bentonite slurry wall, each slope stability analysis and the steady-state underseepage analysis with a WSE of 4 feet in Duck Slough meet criteria. BCI recommends a relatively impervious shallow soil-bentonite cutoff wall to Elevation -40 feet MSL, through the permeable layers and into the underlying clay.

Appendix B presents the steady-state underseepage and individual slope stability analysis result exhibits. Tables 6 and 7 present a summary of the results. BCI's analyses for Station 42+00 indicate that the cutoff wall to Elevation -40 feet (NAVD88) satisfy the average exit gradient criteria and slope stability factors of safety criteria.

7.1.3 Evaluation Cross-Section at Station 109+50

BCI analyzed the DSSL at Station 109+50 to evaluate the general subsurface conditions along the levee alignment and the close proximity of the landside levee toe with the irrigation ditch north of Liberty Island Road. The subsurface soil conditions past Station 53+00 are similar to those encountered and modeled at Station 6+50. The 65% design indicates the new DSSL with be constructed partially on the existing Liberty Island Road embankment along the northern edge of the property.

At cross-section Station 109+50, the subsurface conditions generally consist of lean clay, with one possible 10-foot thick clayey sand water bearing zone at Elevation -24 feet MSL (NAVD88), interbedded within lean clay. The dashed lines on the subsurface profile indicate this layer is discontinuous.

BCI's steady-state underseepage analysis and steady-state slope stability analysis without the cutoff wall indicate that the average exit gradients and slope stability factors of safety meet criteria under the DWSE water levels.

Appendix B presents the steady-state underseepage and individual slope stability analysis result exhibits. Tables 6 and 7 present a summary of the results. For this cross-section, BCI evaluated the EOC at the DWSE. BCI's analyses at Station 109+50 indicate that the cutoff wall to Elevation -15 feet (NAVD88) satisfy the average exit gradient criteria and slope stability factors of safety criteria.

7.1.4 Evaluation Cross-Section at Station 148+00

BCI evaluated the DSSL at Station 148+00 to account for potential hydraulic influences from the Yolo Bypass. The cross-section angles from the existing SSL alignment to the DSSL alignment to maintain the shortest path perpendicular to both the existing levee and the DSSL.

In general, this cross-section represents similar subsurface soil conditions as those presented on the cross-sections at Stations 6+50 and 109+50. Our explorations near Station 148+00 encountered the top of the aquifer at approximately Elevation -20 feet. The aquifer generally consists of discontinuous layers of poorly-graded sand with silt and with clay, interbedded with the clay. Some explorations did not encounter this aquifer layer. The subsurface soil layer overlying the aquifer consists of a relatively thick blanket layer of lean-to fat clay to sandy clay.

BCI's steady-state underseepage analysis and steady-state slope stability analysis without the cutoff wall indicate that the average exit gradient and slope stability factor of safety meet criteria under the DWSE.

Appendix B presents the steady-state underseepage and individual slope stability analysis result exhibits. Tables 6 and 7 present a summary of the results. BCI's analyses at Station 148+00 indicate that the cutoff wall to Elevation -15 feet (NAVD88) satisfy the average exit gradient criteria and slope stability factors of safety criteria.

Station 148+00 reflects the model where the new DSSL ties into the SSL, which may potentially result in an exit gradient higher than that determined with the 2-dimensional model. BCI evaluated the 3-dimensional effects using the recommendations in the 2015 ULE Guidance Document. As discussed above, the 2015 ULE Guidance Document recommend increasing the average exit gradient calculated by the 2-dimensional model by a range of percentages based on the levee angle created. The tie-in at the SSL creates an approximate 90-degree angle. The recommended range of increase for a 90-degree angle is from 15 to 25 percent. Considering the high end of this range, the exit gradients meet criteria with the soil-bentonite cutoff wall to Elevation -15 feet (NAVD88). Table 6 presents the results of the 3-dimensional consideration.

7.2 Settlement Analysis

BCI performed immediate (elastic) and long-term (consolidation) settlement analyses for the Lookout Slough THRFIP cross-sections. BCI used FoSSA 2.0 Foundation Stress & Settlement Analysis software to determine the magnitude of settlement. BCI used consolidation parameters obtained from consolidation tests conducted for the Lookout Slough THRFIP on samples obtained from the site using Shelby tube sampling methods to minimize disturbance.

BCI used over-consolidation ratios (OCRs) from the consolidation test results and compared the values with CPT data obtained in nearby explorations. BCI's evaluation indicates the clay layers underlying the levee alignment are generally over-consolidated with OCR's ranging from 3 to 10. The CPT data confirms these OCRs. BCI encountered relatively soft clay layers between 14 to 20 feet bgs and from 30 to 33 feet bgs. Although these layers are interbedded with stiffer clay lenses, BCI modeled a continuous clay subsurface profile to evaluate consolidation settlement using the consolidation test results from various samples as presented in the September 2019 GDR.

Our analysis results indicate 1 to 5 inches of elastic settlement could occur during construction, and up to 6 inches of primary consolidation settlement could occur after construction. As discussed, the clay underlying the new DSSL is over-consolidated. Secondary consolidation settlement occurs in sensitive clays, normally consolidated clays, and organic clays. Several sources including Das and Sobhan (2012), and Lambe and Whitman (1969), state that the Rate of Secondary Compression index is negligible for overly-consolidated clays. BCI estimates 5 to 6 inches of settlement could occur after construction at some locations. For 65% design, the design-build team assumed 1-foot of total long-term settlement. Future designs may reduce this value based on BCI's analysis.

Table 8 presents the consolidation parameters used in BCI's analysis. Appendix C contains the settlement results.

7.3 Underseepage Effects at the DSSL Tie-In Locations to the Hass Slough East Levee and the Yolo Bypass West Levee

The new DSSL will tie into the Hass Slough East Levee and the Yolo Bypass West Levee, which will create a condition where water will be introduced against the new levee and immediate adjacent existing levee. This can lead to increased underseepage potential landside of the tie-in caused by the dual seepage sources. To help evaluate this condition, BCI drilled one exploration in August 2019, BCI-19-39, north of the tie-in on the Hass Slough East Levee and one exploration, BCI -19-41, north of the tie-in on the SSL.

Visual classification of the subsurface conditions within BCI-19-39 indicate a 36-foot-thick blanket consisting of 31 feet of lean to fat clay underlain by 5 feet of sandy silt below the Hass Slough East Levee. The blanket is underlain by a poorly-graded sand with silt and poorly-graded sand with silt and gravel aquifer. These subsurface conditions are similar to the subsurface conditions encountered in the cross-section at Station 6+50, and indicate that increased underseepage or elevated seepage gradients should not occur landside of the tie-in and property north of Duck Slough because:

- As discussed in Section 7.1.1, considering a 25 percent increase in exit gradient due to dual direction underseepage at the cross-section at Station 6+50, the average exit gradients at the landside levee toe and at the Duck Slough ditch toe continued to meet criteria without a soil-bentonite cutoff wall.
- A relatively thick clay blanket underlies the Hass Slough East Levee near the tie-in location. We encountered a minimum 36-feet-thick blanket based on visual classification and preliminary laboratory results. BCI-19-38, located just south of BCI-19-39 indicated a 48-thick clay blanket.
- The new DSSL crest is approximately 300-feet minimum from the nearest Hass Slough East Levee toe at the property to the north.

Visual classification of the subsurface conditions within BCI-19-41 indicate lean to fat clay below the SSL. BCI did not encounter an aquifer to the 76.5-foot depth explored. These subsurface conditions reflect the subsurface conditions encountered in the explorations near the cross-section at Station 148+00; and indicate that increased underseepage or elevated seepage gradients should not occur landside of the tie-in because:

- We did not encounter an aquifer in either BCI-19-41 or in BCI-19-57, located just south of BCI-19-41, to the maximum depth of over 75 feet below the existing levee. Therefore, no measurable exit gradient exists in this area.
- The new DSSL crest is greater than 300-feet from the Yolo Bypass West Levee toe at the property to the north.

7.4 Settlement Evaluation at the DSSL Tie-In Locations to the Hass Slough East Levee and the Yolo Bypass West Levee

The new DSSL will tie into the Hass Slough East Levee and the Yolo Bypass West Levee, which may induce settlement of the existing levees. BCI performed a preliminary immediate (elastic) and long-term (consolidation) settlement analyses on cross-sections provided by Wood Rodgers at the two tie-in locations to estimate the magnitude of the settlement and if it could have detrimental impacts on the existing levee at the tie-in locations. BCI will update these evaluations once laboratory tests are complete.

To perform the preliminary analysis, BCI considered the following:

- The subsurface soil condition encountered within BCI-19-39 and BCI-19-40 for the tie-in at the Hass Slough East Levee.
- The subsurface soil conditions encountered within BCI-19-41 and BCI-19-42 for the tie-in at the Yolo Bypass West Levee.
- Comparison of the pocket pen data and pressure required for the Shelby samples within the new explorations with data from the explorations used in the analysis for the DSSL
- The previous consolidation test results performed for the DSSL design by BCI.

Based on the above, BCI created two preliminary models to evaluate immediate and primary consolidation settlement using FoSSA 2.0 Foundation Stress & Settlement Analysis software. The results indicate minimal immediate and primary consolidation settlement at the tie-in locations, which indicates special construction considerations due to settlement may not be required. Final findings and recommendations will be developed following BCI's on-going laboratory testing program and will be included in the 90% GBODR.

7.5 Slope Stability Evaluation at the DSSL Tie-In Locations to the Hass Slough East Levee and the Yolo Bypass West Levee

BCI performed preliminary rapid drawdown and EOC slope stability analyses on cross-sections provided by Wood Rodgers to check stability at the Hass Slough East Levee and Yolo Bypass West Levee (YBEL) tie-ins. We used the strength values used in this GBODR in the analysis. The preliminary Hass Slough East Levee tie-in analysis indicated an EOC FS of 2.04 and a rapid drawdown FS of 1.53. Both of these safety factors meet criteria. The preliminary YBEL tie-in analysis indicated an EOC FS of 1.53 and a rapid drawdown FS of 1.37. Both of these safety factors also meet criteria.

BCI is performing strength tests on relatively undisturbed soil samples obtained in the explorations in both the Hass Slough East Levee and the SSL at the tie-in locations to check these preliminary analyses. BCI will update these evaluations once laboratory tests are complete and provide final findings in the in the 90% GBODR.

7.6 Seismic Analysis

BCI completed a seismic analysis to evaluate the seismic vulnerability of the proposed new DSSL. BCI generally followed the methodology presented in ETL 1110-2-580, *Guidelines for Seismic Evaluation of Levees,* Expires 1 March 2018, USACE. BCI verified with the USACE that these Guidelines are still valid and have not been updated.

To evaluate levee seismic vulnerability, BCI:

- Used an approximate return period of 100 years, defined as 50% probability of exceedance in 75 years.
- Determined site specific Peak Ground Acceleration (PGA) and earthquake Magnitude (M) for an earthquake with a 100-year return period. BCI obtained the PGA from the United States Geological Survey (USGS) website https://earthquake.usgs.gov/hazards/interactive/. BCI determined an average PGA for the levee segment and used an average value where the evaluated PGA is within ±10% of the average value. BCI used a weighted average of major

source contributions as determined from the USGS deaggregation (i.e. all individual seismic sources contributing greater than 2% of the mean hazard).

- Completed liquefaction triggering and seismically induced settlement analysis at select subsurface data locations. BCI used Youd et al., 2001, *Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils*, Journal of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 127, No. 10., pp 817-833. BCI based fine-grained soil susceptibility on Seed et al, 2003, and used a water level, as defined in the USACE Draft publication *Guidelines for Seismic Stability Evaluation of USACE Levees*, equal to the average water level for the wettest month of the year, typically in February.

7.6.1 Site Specific Ground Motion

An estimate of ground motion parameters such as peak horizontal ground acceleration (PGA) and earthquake moment magnitude (M) are necessary for liquefaction analysis. BCI used the USGS Unified Hazards Tool website (https://earthquake.usgs.gov/hazards/interactive/) to complete a probabilistic analysis and develop the peak horizontal ground acceleration (PGA) for an earthquake with a 100-year return period. The USGS 2008 Interactive Deaggregations program is based on source and attenuation models as presented in Petersen, M. and others, 2008, "*Documentation for the 2008 Update of the National Seismic Hazard Maps, USGS OFR 08–1128*," available on the web at http://pubs.usgs.gov/of/2008/1128/.

To estimate the ground motion parameters for the Lookout Slough THRFIP, BCI checked the PGA near the center of the Lookout Slough THRFIP. BCI used Vs_{30} equal to 259 meters per second (mps, approximately 850 feet per second). This velocity is based on the general soil conditions logged in geotechnical borings completed for the Lookout Slough THRFIP by BCI. The 259 mps velocity is the value for Site Class D (Stiff Soil site).

To determine the PGA for an earthquake with a 100-year return period, BCI used the USGS Unified Hazards Tool which determined the PGA for several return periods and plotted the results as a hazard curve. From the hazard curve, the tool calculated a PGA equal to 0.17 for a 108-year return period. A "most likely" earthquake moment magnitude (M) for the event that will cause the PGA of interest is necessary for liquefaction analysis. Deaggregation within the USGS Unified Hazards Tool website allows for determination of the magnitude with the most significant contribution to the ground motion.

For the 100-year return period, the mean M is 6.6; modal M is approximately 6.7. Listed below are the faults that contribute most significantly to the PGA hazard with percent contribution and magnitude shown (from deaggregation at the 108-year return period level).

Fault Name	Contribution (%)	Magnitude
Green Valley	5.11%	6.83
Great Valley 5 Pittsburg – Kirby Hills alt1	4.05%	6.34
Great Valley 4b, Gordon Valley	2.83%	6.65
Rodgers Creek – Healdsburg	2.53%	7.34

A weighted average of the four largest percent contributing faults results in M equal to 6.75. We select an applicable M equal to 6.7 for use in Lookout Slough THRFIP analysis.

The Regional Fault map (Appendix D) shows the locations of these faults and others in the region is attached. The locations of faults shown on the Exhibit are based on the U.S. Geological Survey and California Geological Survey, 2006, Quaternary fault and fold database for the United States (USGS web site: http//earthquake.usgs.gov/hazards/qfaults/).

7.6.2 Liquefaction

Liquefaction is a phenomenon in which granular material can transform from a solid to a liquefied state as a result of increased pore-water pressure and reduced effective stress. Ground shaking can induce an increase in pore-water pressure and granular materials can compact when subjected to the cyclic shear deformations. Liquefaction is most likely to occur in lower relative density granular soils, but some non-to- low plasticity fine-grained soils are also susceptible to liquefaction and/or strength loss via cyclical softening.

In loose materials, a loss of shear strength can occur that may lead to ground deformation or lateral movement (lateral spread) under foundation loading or on sloping ground. Loose soils can also compact following liquefaction and reconsolidation, which can result in ground settlement. For a levee, deformation and volume change can result in settlement at the ground surface, lateral migration (lateral spreading) of liquefied and overlying soils, and ground cracking at the surface. Strength loss within soils following a seismic event can result in slope failure.

BCI performed liquefaction analyses to evaluate potential liquefaction of the soils underlying the planned levee locations during a 100-year earthquake event with methods that include: Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshop on Evaluation of Liquefaction Resistance of Soils by T. L. Youd and I. M. Idriss (Youd et al, 2001); Standard Penetration Test-Based Probabilistic and Deterministic Assessment of Seismic Soil Liquefaction Potential by K. Onder Cetin and Raymond B. Seed (Cetin et al, 2004); and Soil Liquefaction During Earthquakes by I. M. Idriss and R. W. Boulanger (Idriss and Boulanger, 2008).

BCI used the liquefaction analyses results to estimate the post-earthquake strengths of the foundation materials. The post-earthquake strengths are used to evaluate seismic stability and potential levee deformation due to slope failure and/or settlement.

Liquefaction Triggering
BCI completed liquefaction analyses in general accordance with Youd et al, (2001); Cetin et al, (2004); and Idriss and Bourlanger, (2008). In determining the soils Factor of Safety against liquefaction, all three methods use a similar approach where they compare the cyclic stress ratio (CSR), which is the seismic demand on a soil layer, versus the cyclic resistance ratio (CRR), which is the capacity of the soil to resist liquefaction. BCI's analysis considered fine grained soils with Plasticity Index (PI)<10 and Liquid Limit (LL) <35 as potentially liquefiable, consistent with USACE guidelines.

For this evaluation, BCI completed liquefaction triggering analysis at BCI borings BCI-17-B05, BCI-17-B06, BCI-17-B11 through B17 and BCI-18-B28. These borings are located along the proposed levee alignment. BCI also considered the information contained in the CPT data for the five CPTs drilled at the site.

BCI used the following parameters for liquefaction triggering analysis:

- Earthquake magnitude of M=6.7
- PGA of 0.17g
- Design ground water elevation equal to an assumed nominal winter water surface elevation (WSE) of Elevation 4 feet (NAVD88) as the most critical condition when compared to the lower nominal summer WSE

Our analysis indicates that only two, isolated, thin soil zones in two separate borings show the potential for strength loss under the design seismic event; specifically, the thin gravel layer beginning at Elevation -9 feet in BCI-17-B06, and the thin clayey sand layer beginning at Elevation -30 feet in BCI-17-B13. Analysis of nearby explorations confirm that these layers are isolated and not continuous.

Based on this information, post-earthquake slope stability analyses and deformation are not required, and levee settlement due to seismic loading (horizontal and vertical displacement due to slope failure) is not anticipated.

Appendix D presents the liquefaction triggering sheets for each exploration.

8 ADDITIONAL GEOTECHNICAL CONSIDERATIONS

This section addresses additional geotechnical considerations with respect to the DSSL construction.

8.1 Irrigation Ditch, Pond and Existing Slough Fill Recommendations

This section addresses fill recommendations associated with irrigation ditches, ponds and sloughs that currently exist within the new DSSL alignment footprint, and a minimum 20-feet beyond the new DSSL footprint.

All water bearing features (irrigation ditches, ponds and sloughs, etc.) underlying the new DSSL footprint or landside of the levee toe within the Lookout Slough THRFIP area that will receive fill shall be dewatered and mucked out until competent material is encountered. At a minimum, remove one-foot of material after dewatering. Scarify the base of the feature to a depth of 8”, moisture condition to within 3% of optimum, and compact to a minimum 90% relative compaction. If the subgrade is too wet/unstable to achieve compaction, follow recommendations in Section 8.3 of this report. Place fill in maximum 8” thick loose lifts and compact to a minimum 97% relative compaction within the levee footprint and within 20 feet of the landside toe. Compact all other fill to a minimum 90% relative compaction. Bench fill into the side of the feature a minimum of 1’ horizontally for every 1’ of vertical fill or as needed to remove loose material along the side of the feature.

8.2 DSSL Tie-Ins

The new DSSL will tie into existing levees and roadway embankments at points along the levee alignment and at DSSL termination points. This includes a tie-in at the intersection with the Hass Slough East Levee, a tie-in into Malcolm Lane, tie-in into Liberty Island Road and tie-in into the SSL. BCI understands that Liberty Island Road will be reconstructed landside of the new DSSL.

8.2.1 Roadway Tie-In Earthwork Recommendations

Where the new levee ties into Malcom Lane, remove the roadway aggregate base, scarify the soil underlying the aggregate base at to a depth of at least 8-inches, and compact to a minimum 97% of maximum density (ASTM D698) at a moisture content within 2% of optimum. Where the new levee ties into Liberty Road along the north side of the project, remove the pavement section including the asphalt concrete, aggregate base, and underlying roadway embankment soil to a depth of 3 feet. Reconstruct the road to design grade using on-site borrow material. The removed material may be used as fill provided it is free from debris and concentrations of vegetation. Key the rebuilt slope and new levee fill a minimum of 1 foot vertically for every 1 foot (measured horizontally) of fill placed.

8.2.2 Hass Slough East Levee and the SSL Tie-In Earthwork Recommendations

Where the new DSSL ties into the Hass Slough East Levee and SSL, remove the upper 3 feet (measured vertical to the ground surface) of soil within the existing levees. Reconstruct the levees with over-excavated material free of debris and concentrations of vegetation or from on-site borrow. Key the reconstructed and new fill a minimum of 1 foot vertically for every 1 foot (measured horizontally) of fill placed.

8.3 Unstable Subgrade Mitigation

Significant wet weather conditions, high, localized ground water conditions, and conditions encountered at the bottom of dewatered depressions including ditches and ponds may result in challenges to obtain compaction per the project plans and specifications. BCI therefore prepared this section to address these conditions if encountered.

The Contractor should clear, grub and strip per the Lookout Slough THRFIP specifications. If elevated soil moisture and ground pumping prevent the contractor from achieving the specified original ground compaction after stripping and scarification, the Contractor should perform additional scarification to a depth of 12-inches and recompact the upper 6-inches in accordance with the Lookout Slough THRFIP specifications. If compaction still cannot be achieved, or the subgrade pumps significantly, BCI proposes the following mitigation with geogrid. Stabilization with geogrid has been evaluated and used successfully on other levee projects for similar applications within the regional area.

For minimally unstable areas where minor flexing with no pumping is observed, place geogrid (BX 1200 biaxial or equivalent) at the surface of the unstable soil, leaving a 6-foot-wide (± 6 inches) gap centered along the levee alignment for cutoff wall construction, as necessary, prior to placing the first lift of levee fill. If large areas of minimally unstable areas are observed, a test section should be performed to verify mitigation measures will address the instability prior to placement of geogrid over the entire area to be stabilized.

For significantly unstable areas where significant pumping and rutting is observed, mitigate these areas as follows:

- Over-excavate the unstable soil to a depth of up to 18-inches (actual depth will depend on the severity of instability as determined by BCI).
- Place geogrid (BX 1200 or equivalent) on the surface of the excavated area, leaving a gap for cutoff wall construction, as necessary.

- Place and compact (at 90% relative compaction of ASTM D698) on-site borrow material, or the previously excavated, dried out material, in a 12-inch-thick lift to within 6-inches of the original ground surface.
- Place and compact (per Lookout Slough THRFIP specifications) on-site borrow material, or the previously excavated, dried out material, in the upper 6-inches of subgrade.
- If excessively unstable conditions exist, a second layer of geogrid may be warranted prior to replacement and compaction of the upper 6-inches. If instability persists that prevents the ability to achieve the specified compaction, additional layers of geogrid may be required to continue into the levee embankment. In this case, BCI will perform additional analyses to evaluate the effect on Lookout Slough THRFIP design.

If large areas of significantly unstable areas are observed, a test section shall be performed to verify mitigation measures will address the instability prior to excavation and placement of geogrid over the entire area.

The Contractor shall comply with the Lookout Slough THRFIP specifications regarding geogrid. In addition, the Contractor shall perform the following:

- Minimize subgrade disturbance prior to geotextile placement.
- Consideration to unrolling geogrid transversely or perpendicular to the embankment alignment to reduce lateral spreading or overlap separation.
- Overlap adjacent rolls along their sides and ends with a 3-feet overlap.
- Consider the use of nylon cable ties or zip ties to help maintain overlap dimensions.
- At the beginning of a roll, consider anchoring the beginning and the corners to the underlying surface using a washer and pin, or heavy-gauge staples.
- Use a lightweight, low ground pressure dozer to evenly push out the fill over the exposed geogrid.

9 FUTURE GEOTECHNICAL CONSIDERATIONS

Future geotechnical evaluations include the following:

- An updated evaluation, as necessary, at the two tie-in locations based on completed laboratory test results.
- Updated analyses as required based on refined design of the DSSL model and alignment, borrow sites and channels designed for the restoration habitat.

10 LIMITATIONS

BCI prepared this Draft GBODR for EIP and the design-build team for the Lookout Slough Tidal Habitat Restoration and Flood Improvement Project. This Draft GBODR should not be used by others or for other projects without BCI's written permission.

BCI prepared this report in accordance with the generally accepted geotechnical standard of practice currently being used in this area. BCI based this Draft GBODR on the current site and project conditions.

11 GUIDANCE DOCUMENTS

BCI reviewed the following documents to help determine the findings and conclusions of this Draft GBODR:

- California Code of Regulations, December 2009, Regulations of the Central Valley Flood Protection Board, Title 23, Waters.
- State of California, The Natural Resources Agency, Department of Water Resources, May 2012 Urban Levee Design Criteria.
- URS January 2011, Final Geomorphology Technical Memoranda and Maps, North NULE Area, Geomorphic Assessments, Non-Urban Levee Evaluations Project Contract 46000008101, prepared for the Department of Water Resources, Division of Flood Management.
- URS April 2011, Geotechnical Assessment Report, North NULE Project Study Area, Non-Urban Levee Evaluations Project Contract 46000008101, prepared for the Department of Water Resources, Division of Flood Management.
- URS August 2011, Remedial Alternatives and Cost Estimates Report (RACER), North NULE Study Area, Non-Urban Levee Evaluations Project Contract 46000008101, prepared for the Department of Water Resources, Division of Flood Management.
- URS April 2015, Guidance Document for Geotechnical Analyses, Urban Levee Evaluations Project, Contract 4600008101, (URS Guidance Document), prepared for Department of Water Resources, Division of Flood Management (DWR).
- USACE, EM 1110-2-1913, Design and Construction of Levees, 30 April 2000.
- USACE, EM 1110-2-1902, Engineering and Design, Slope Stability, 31 October 2003.
- USACE, Recommendations for Seepage Design Criteria, Evaluation and Design Practices, prepared by the 2003 CESPK Levee Task Force, 15 July 2003.
- USACE, ETL 1110-2-569, Design Guidance for Levee Underseepage, 1 May 2005.
- USACE, Geotechnical Levee Practice Standard Operating Procedure, Revision 2, 11 April 2008.
- USACE, ETL 1110-2-580, Guidelines for Seismic Evaluation of Levees, Expires 1 March 2018 (no update available).

TABLES

TABLE 1

Lookout Slough THRFIP Hydraulic Conductivity Laboratory Test Results

Segment	Boring	Depth (ft)	USCS Soil Type	Hydraulic Conductivity Laboratory Kv (cm/sec)	Hydraulic Conductivity Kh a=0.25	% Fines	LL	PI	Comments
	BCI-17-B10.4	6.5’-7’	SC	9.92E-06	3.97E-05	28	34	16	
	BCI-17-B20.4	9’-9.5’	SC	2.51E-06	1.00E-05	45	38	20	
		Average:	**SC**	**6.22E-06**	**2.49E-05**				
	BCI-17-B01.6	12’-12.5’	CL	9.94E-06	3.98E-06		41	20	
	BCI-17-B03.4	9’-9.5’	CL	1.45E-05	5.80E-05	79	32	14	Outlier
	BCI-17-B08.6	11’4”-11’8”	CL	4.19E-07	1.68E-06	56	35	22	
	BCI-17-B18.3	5.5-6’	CL	2.86E-07	1.14E-06	59	46	29	
	BCI-17-B08.2	3’8”-4’2”	CH	2.80E-07	1.12E-06	95	68	48	
	BCI-17-B11.1	2.5’-3’	CH	2.72E-08	1.09E-07	90	52	37	
	BCI-17-B15.1	1.5’-2’	CH	4.34E-07	1.74E-06	97	63	46	
	BCI-17-B17.1	2.5’-3.0’	CH	1.59E-06	6.36E-06				
		Average:	**CL, CH**	**1.85-06**	**2.30E-06**				
	TP4	1’-3’	CH	2.78E-09	1.11E-08		50	33	New Levee Fill
	BTP15-B	3’-6’	CH	4.24E-09	1.70E-08		50	33	
	BTP20-A	1’-3’	CL	4.60E-09	1.84E-08		43	29	
		Average:	**CL, CH**	**3.87E-09**	**1.55E-08**				

TABLE 2

Hydraulic Conductivity Values Used By Others for Lookout Slough THRFIP Soil Layers

Material Type	USCS Designation	Soil Description	Southport EIP Kh (ft/day)	Southport EIP Kh (cm/s)	Southport EIP Kv/Kh	Southport EIP Kv (cm/s)	Lower Elkhorn Basin Levee Kh (cm/s)	Lower Elkhorn Basin Levee Kv/Kh	Lower Elkhorn Basin Levee Kv (cm/s)	USACE West Sacramento Kh (cm/s)	USACE West Sacramento Kv/Kh	USACE West Sacramento Kv (cm/s)	URS Presumptive HC Values Kh (cm/s)	URS Presumptive HC Values Kv/Kh	URS Presumptive HC Values Kv (cm/s)
Cutoff Wall	NA	SCB, SB	0.0028	1.0×10^{-6}	1.0	1.0×10^{-6}	--	--	--	1.0×10^{-6}	1.0	1.0×10^{-6}	1.0×10^{-6} to 1.0×10^{-7}	1.0	1.0×10^{-6} to 1.0×10^{-7}
New Levee Soil, Embankment	CL, CH	New Levee Lean CLAY and Fat CLAY	0.0028	1.0×10^{-6}	0.25	2.5×10^{-7}	1.0×10^{-6}	0.25	2.5×10^{-7}	--	--	--	1.0×10^{-6} to 1.0×10^{-8}	.25-1.0	varies
Lean CLAY, Fat CLAY, Lean CLAY	CL, CH	Layers of medium stiff to hard Lean and Fat CLAY	0.0028	1.0×10^{-6}	0. 25	2.5×10^{-7}	4.0×10^{-6}	0.25	1.0×10^{-6}	1×10^{-5}	0.25	2.5×10^{-6}	5.0×10^{-6} to 5.0×10^{-8}	.25-1.0	varies
	CL	Soft to Medium Stiff Lean CLAY	0.016	5.6×10^{-6}	0. 25	1.4×10^{-6}	--	--	--	--	--	--			
Clayey SAND, Sandy Lean CLAY	SC, CL	Interbedded layers of SC and CL	--	--	--	--	1×10^{-4}	0.25	2.5×10^{-5}	1×10^{-4}	0.25	2.5×10^{-5}	1.0×10^{-4} to 1.0×10^{-5}	.25-1.0	varies
Interbedded Poorly-graded SAND/Sand with Silt/SAND with Clay	SP, SP-SM	Interbedded layers of SP and SP-SM	22.68	8.0×10^{-3}	0. 25	2.0×10^{-3}	(SP-SM) 1×10^{-2}	0.50	(SP-SM) 5.0×10^{-3}	--	--	--	--	--	--
	SP-SM, SP-SC	Interbedded layers of SP-SM and SP-SC predominantly	(SP-SM) 14.74	(SP-SM) 5.2×10^{-3}	0.25	(SP-SM) 1.3×10^{-3}	1.0×10^{-2} to 4.0×10^{-4}	0.50	5.0×10^{-3} to 2.0×10^{-4}	5×10^{-3}	0.25	1.3×10^{-3}	--	--	--
Interbedded Clayey GRAVEL and Poorly-graded SAND with Clay	GC, SP-SC	Interbedded layers of GC and SP-SC	--	--	--	--	(GM 26-49%) 2.0×10^{-3}	0. 25	(GM 26-49%) 5.0×10^{-4}	--	--	--	--	--	--
Well-graded SAND with Silt, Poorly-graded GRAVEL with SILT	GP-GC, SW-SM	Interbedded layers of SW-SM and GP-GC	(SP-SM) 14.74	(SP-SM) 5.2×10^{-3}	0.25	(SP-SM) 1.3×10^{-3}	(GM 13-25%) 4.0×10^{-3}	0.25	(GM 13-25%) 1.0×10^{-3}	--	--	--	--	--	--

TABLE 3						
Lookout Slough THRFIP Hydraulic Conductivity Values For 65%-Design						
Material Type	**USCS Designation**	**Soil Description**	**Kh (ft/day)**	**Kh (cm/s)**	**Kv/Kh**	**Kv (cm/s)**
Cutoff Wall	NA	SCB, SB	0.0028	1.0×10^{-6}	1.0	1.0×10^{-6}
New Levee Soil, Embankment	CL, CH	New Levee Lean CLAY and Fat CLAY	0.0028	1.0×10^{-6}	0.25	2.5×10^{-7}
Lean CLAY, Fat CLAY, Interbedded SILT/CLAY	CL, CH	Layers of medium stiff to hard Lean and Fat CLAY	0.0028	1.0×10^{-6}	0. 25	2.5×10^{-7}
	CL	Soft to Medium Stiff Lean CLAY	0.0057	2.0×10^{-6}	0. 25	5.0×10^{-7}
Clayey SAND, Sandy Lean CLAY	SC, CL	Interbedded layers of SC and CL	0.057	2.0×10^{-5}	0.25	5.0×10^{-6}
Interbedded Poorly-graded SAND/Sand with Silt/SAND with Clay	SP, SP-SM	Interbedded layers of SP and SP-SM	22.68	8.0×10^{-3}	0. 25	2.0×10^{-3}
	SP-SM, SP-SC	Interbedded layers of SP-SM and SP-SC predominantly	14.74	5.2×10^{-3}	0. 25	1.3×10^{-3}
Interbedded Clayey GRAVEL and Poorly-graded SAND with Clay	GC, SP-SC	Interbedded layers of GC and SP-SC	5.67	2.0×10^{-3}	0. 25	5.0×10^{-4}
Well-graded SAND with Silt, Poorly-graded GRAVEL with SILT	GP-GC, SW-SM	Interbedded layers of SW-SM and GP-GC	14.74	5.2×10^{-3}	0.25	1.3×10^{-3}

TABLE 4									
Lookout Slough THRFIP Strength Parameter Laboratory Test Results									
USCS	**BCI Boring/Test Pit**	**Effective Strength**		**Total Strength**		**Undrained Shear Strength (Su)**		**Remarks**	**Averages**
		ϕ' (deg)	**c' (psf)**	**ϕ^{total} (deg)**	**c^{total} (psf)**	Su (psf)	Cell Pressure (psf)		
CL	BCI-17-B1 (4.5'-4.9')	40.9[2]	382.3[2]					Lean CLAY with Sand (LL = 38, PI = 21)	Average Values: **ϕ' = 27 deg** **c' = 463 psf** Average values did not include BCI-17-B1 ϕ' = 40.9 deg **Average Undrained Shear Strength Su = 2730 psf**
CH	BCI-17-B2 (4.0'-5.0')	34.2[2]	94.6[2]					Fat CLAY (LL = 54, PI = 42)	
CL	BCI-17-B2 (11.5'-12.0'					3923.6	1008	Lean CLAY with Sand	
CL	BCI-17-B2 (20' – 20.5')					2570.3	1728	Sandy Lean CLAY (LL = 38, PI = 22)	
CH	BCI-17-B3 (12.3' – 12.8')					4664.4	1008	Fat CLAY	
CL	BCI-17-B4 (8.7' – 9.3')	33.8[2]	419.6[2]					Lean CLAY, Brown	
CL	BCI-17-B7 (3.8' – 4.2')	17.1[2]	690.4[2]					Lean CLAY with Sand (LL = 48, PI = 32)	
CL	BCI-17-B4 (13.0' – 13.5')					2411.3	1152.0	Lean CLAY (LL = 46, PI = 25)	
CH	BCI-17-B6 (4.3' – 4.8')					2684.2	432	Fat CLAY (LL = 68, PI = 50)	
CH	BCI-17-B8 (3.8' – 4.2')	24.5[2]	648.1[2]					Fat CLAY (LL = 68, PI = 48)	
CL	BCI-17-B9 (9.8' – 10.3')					1817.1	1008	Lean CLAY with Sand	
CH	BCI-19-57 (5.0'-5.5')					1039	576	Fat CLAY with Sand (LL = 51, PI = 32)	
CL	BCI-17-14 (4.5' – 6.0')	31[3]	390.9[3]	21[3]	287.6[3]			Lean CLAY	Average Total Strength Values for Upper CL/CH Layer **ϕ^{total} = 24 deg, c^{total} = 318.6 psf**
CH	BCI-17-17-1 (2.0'- 3.5')			25.8[4]	336.2[4]			Fat CLAY	
CL	BCI-17-19-1 (1.0' – 2.5')			24.2[4]	331.9[4]			Lean CLAY	
CH	TP4 Bulk[1] (1.0' - 3.0')	24.4[3]	462.0[3]	20.9[3]	165.3[3]	1996.5	750.2	Fat CLAY with Sand (LL = 59, PI = 44)	Average for New DSSL Fill **ϕ' = 23.6 deg, c' = 475 psf** **ϕ^{total} = 16 deg, c^{total} = 375.6 psf**
CH	TP6 Bulk[1] (1.0' – 3.0')	27.4[3]	538.1[3]	13.2[3]	579.6[3]	1758.3	748.8	Fat CLAY with Sand (LL = 51, PI = 13)	
CH	BTP24 Bulk[1] (4.0' – 7.0')	19.0[3]	424.1[3]	13.8[3]	381.8[3]			Fat CLAY (LL = 56, PI = 38)	
CH	BTP4 Bulk[5] (1.0' – 3.0')	18.3[5]	0[5]						
CH	BTP12 Bulk[5] (1.0' – 3.0')	19.8[5]	0[5]						
CH	BTP3 Bulk[1] (1.0' – 3.0')					1298.5	720		Average for New DSSL Fill **Su = 1676 psf**
CH	BTP15[1] (3.0' – 6.0')					1566.9	720		
CH	BTP26[1] (4.0' – 7.0')					1583.6	720		
CH	BTP29[1] (1.0' – 4.0')					1930.9	720		
CH	BTP31[1] (1.0' – 3.0')					1598.6	720		

[1] Specimens remolded to 97% relative compaction (ASTM D698)
[2] Direct Shear Test (ASTM D3080)
[3] Consolidated Undrained with pore-water pressure measurements Triaxial Compression Tests (ASTM D4767)
[4] Consolidated Undrained with pore-water pressure measurements Triaxial Compression Tests (ASTM D4767). However, due to sample variability, BCI could not produce reasonable Mohr circles to determine effective strengths.
[5] Fully-Softened Direct Shear Test following the procedures outlined in the February 20, 2014, *Use and Measurement of Fully Softened Shear Strength*, Bernardo A. Castellanos

TABLE 5																
Lookout Slough THRFIP Soil Strength Parameters for 65%-Design																
Type (USCS)	**BCI Recommended Strength Values**					**Southport EIP**					**Lower Elkhorn Basin Levee**				**URS Presumptive Values**	
	ϕ' (deg)	**c' (psf)**	**ϕ^{total} (deg)**	**c^{total} (psf)**	**Su (psf)**	**ϕ' (deg)**	**c' (psf)**	**ϕ^{total} (deg)**	**c^{total} (psf)**	**Su (psf)**	**ϕ' (deg)**	**c' (psf)**	**ϕ^{total} (deg)**	**c^{total} (psf)**	**ϕ' (deg)**	**c' (psf)**
Slurry Wall (SB)	0	50			20	0	50	0	20	20	-	-	-	-	-	-
New Levee (CL, CH)	22	400	13	450	1500	22[1]	240[1]	13[1]	250[1]	1500[1]	23	160	11	230	≤32	≤150
Lean CLAY/Fat CLAY (CL, CH)	30	150	15	175	1000	28-30	75-200	15	150-400	600-1000	30/23	100/150	17/10	180/250	-	-
Lean CLAY (CL)	32	150	16	175	1000						30	100	17	180	≤35	≤200
Clayey SAND, Sandy Lean CLAY (SC, CL)	32	100	16	115	-	-	-	-	-	-	-	-	-	-	≥32 to ≤35	0
Poorly-graded SAND, Poorly-graded SAND with SILT (SP, SP-SM)	32	0	-	-	-	34	0	-	-	-	-	-	-	-		
Poorly-graded SAND with SILT, Poorly-graded SAND with CLAY (SP-SM/SP-SC)	30	0	-	-	-	30	0	-	-	-	-	-	-	-		
Clayey GRAVEL/Poorly-graded SAND with CLAY (GC, SP-SC)	34	0	-	-	-	-	-	-	-	-	-	-	-	-		
Poorly-graded GRAVEL with CLAY, Well-graded SAND with SILT (GP-GC, SW-SM)	34	0	-	-	-	-	-	-	-	-	-	-	-	-		

[1] Based on New Levee Deep Core (CL, CH)

TABLE 6

Lookout Slough THRFIP 65%-Design Steady-State Underseepage Analysis Results

BCI Cross-Section	Levee Improvement Measure	Underseepage Mitigation Measure	Steady-State Underseepage Analysis Results, $i_{exit\ avg}$ at Landside Levee Toe			Steady-State Underseepage Analysis Results, $i_{exit\ avg}$ at Landside Ditch (Duck Slough or Irrigation Canal)		
		Cutoff Wall Toe Elev. (ft) NAVD88	DWSE $i_{exit\ avg}$	DWSE $i_{exit\ avg}$* 1.25 3-D effect	Meets Criteria ($i_{exit\ avg} \leq 0.5$)	DWSE $i_{exit\ avg}$	DWSE $i_{exit\ avg}$* 1.25 3-D effect	Meets Criteria ($i_{exit\ avg}$ varies)
Station 6+50	DSSL	---	<0.05	<0.1	Yes	0.22	0.28	Yes ($i_{exit\ avg}$ 0.8)
	DSSL w/wall	-15	<0.05	<0.1	Yes	0.22	0.28	Yes
Station 42+00	DSSL	---	<0.05		Yes	3.85		No ($i_{exit\ avg}$ 0.77)
	DSSL w/wall	-40	<0.05		Yes	2.31		No ($i_{exit\ avg}$ 0.77)
	DSSL w/wall[1]	-40	<0.05		Yes	0.59		Yes
Station 109+50	DSSL	---	<0.05		Yes	0.24		Yes ($i_{exit\ avg}$ 0.61)
	DSSL w/wall	-15	<0.05		Yes	0.24		Yes
Station 148+00	DSSL	---	<0.05	<0.1	Yes	0.29	0.36	Yes
	DSSL w/wall	-15	<0.05	<0.1	Yes	0.29	0.36	Yes

[1] With water surface elevation set at 4 feet in Duck Slough

TABLE 7

Lookout Slough THRFIP 65%-Design Steady-State Slope Stability Analysis Results

BCI Cross-Section	Levee Improvement Measure	Mitigation Measure	Steady-State Slope Stability Analysis Results, Minimum Factor of Safety					
		Cutoff Wall Toe Elev. (ft) NAVD88	SS DWSE	Meets Criteria (FS≥1.4)	Rapid DD	Meets Criteria (FS≥1.2)	EOC WSE	Meets Criteria (FS≥1.3)
Station 6+50	DSSL	---	2.89	Yes	---	---	---	---
	DSSL w/wall	-15	2.89	Yes	1.88	Yes	2.40	Yes
Station 42+00	DSSL	---	3.11	Yes	---	---	---	---
	DSSL w/wall	-40	3.16	Yes	2.88	Yes	3.46	Yes
Station 109+50	DSSL	---	2.49	Yes	---	---	---	---
	DSSL w/wall	-15	2.49	Yes	1.84	Yes	2.38/2.42[1]	Yes
Station 148+00	DSSL	---	2.75	Yes	---	---	---	---
	DSSL w/wall	-15	2.87	Yes	1.87	Yes	2.35	Yes

[1] With water at the Design Water Surface Elevations

TABLE 8

Lookout Slough THRFIP Settlement Analysis Parameters

Consolidation Settlement at Levee Centerline

Layer No.	Soil Description	Depth Below Levee Base (ft)	Unit Weight (pcf)	Elastic Soil Modulus, Es (ksf)	Poisson's Ratio (U)	C_c	C_r	OCR	C_v (ft^2/day)	e_o	Results
1	New Levee Fill	--	125	--	--	--	--	--	--	--	
2	Med. Stiff to Hard Fat CLAY (CH)	0-5	120	500	0.30	--	--	--	--	--	
3	Hard Lean CLAY (CL)	5-14	120	500	0.40	0.27	0.075	10.00	0.123	0.810	
4	Soft to Med. Stiff Lean CLAY (CL)	14-20	118	310	0.40	0.24	0.020	3.00	0.554	0.780	Elastic Settlement: 0.21 feet (2.5 inches)
5	Hard Lean CLAY (CL)	20-30	125	1000	0.40	--	--	--	--	--	Consolidation Settlement: 0.50 feet (6.0 inches)
6	Med. Stiff Lean CLAY (CL)	30-33	117	250	0.40	0.29	0.060	3.00	0.218	0.895	
7	Stiff Lean CLAY (CL)	33-40	120	1000	0.40	0.30	0.060	10.00	0.218	0.895	
8	Stiff Lean Clay (SC)	40-55	120	625	0.40	0.30	0.060	4.00	0.231	0.895	
9	Hard Fat to Lean CLAY (CH, CL)	55-80	120	1000	0.40	--		--	--	--	

BCI-17-06

Layer No.	Soil Description	Depth Below Levee Base (ft)	Unit Weight (pcf)	Elastic Soil Modulus, Es (ksf)	Poisson's Ratio (U)	C_c	C_r	OCR	C_v (ft^2/day)	e_o	Notes
1	New Levee Fill	--	125	--	--	--	--	--	--	--	
2	Stiff to Hard Fat to Lean CLAY (CH, CL)	0-5	120	1500	0.40	--	--	--	--	--	
3	Stiff Lean CLAY, Clayey SAND (SC, CL)	5-10	120	250	0.30	--	--	--	--	--	
4	Poorly-graded SAND (SP)	10-15	105	450	0.30	--	--	--	--	--	
5	Well-graded GRAVEL (GW)	15-25	115	250	0.30	--	--	--	--	--	Elastic Settlement: 0.43 feet (5.2 inches)
6	Firm Sandy SILT, Lean CLAY (ML, CL)	25-45	115	150	0.30	--	--	--	--	--	
7	Firm Fat CLAY (CH)	45-55	120	500	0.40	--	--	--	--	--	
8	Very Hard Lean CLAY (CL)	55-75	125	2000	0.40	--	--	--	--	--	

BCI-17-02, 03, 04, 05

Layer No.	Soil Description	Depth Below Levee Base (ft)	Unit Weight (pcf)	Elastic Soil Modulus, Es (ksf)	Poisson's Ratio (U)	C_c	C_r	OCR	C_v (ft^2/day)	e_o	Notes
1	New Levee Fill	--	125	--	--	--	--	--	--	--	
2	Stiff Fat to Lean CLAY (CH, CL)	0-5	120	1000	0.40	--	--	--	--	--	Elastic Settlement: 0.07 feet (0.8 inches)
3	Hard to Very Hard Lean CLAY (CL)	5-40	125	2000	0.40	--	--	--	--	--	

GEOTECHNICAL BASIS OF DESIGN REPORT

65% Design

Lookout Slough THRFIP

Solano County, California

FIGURES

Project Vicinity Map
Project Site Limits
Exploration Site Plan
Geologic Map
Plan and Profile Sheets

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FIGURE 1, PROJECT VICINITY MAP
Geotechnical Basis of Design Report - 65% Design
September 2019

N
W E
S

0 10,000
SCALE: 1" = 10,000'

Lookout Slough THRFIP

Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

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Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x Fig1 LSRP 65%.dwg

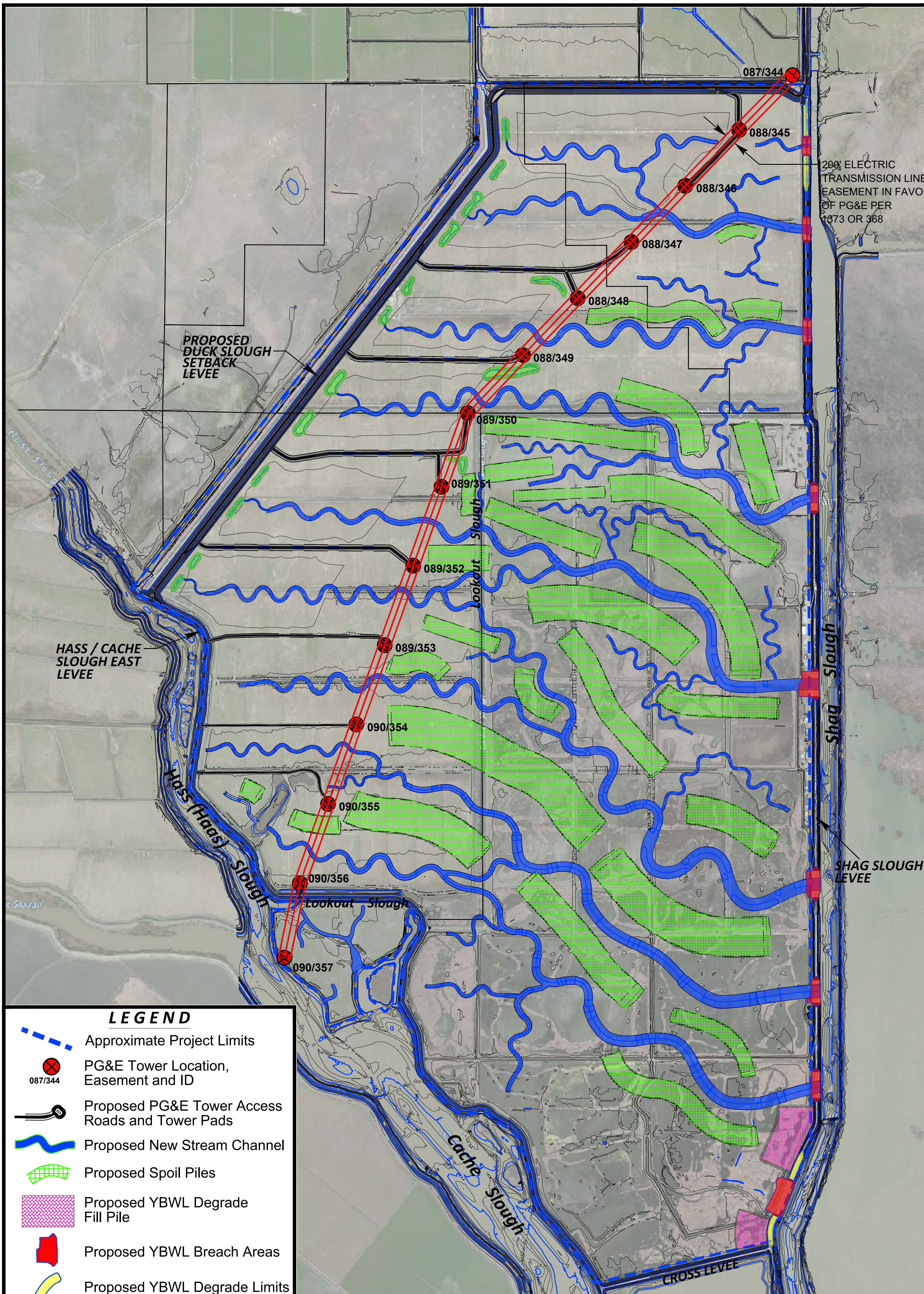

FIGURE 2, PROJECT SITE LIMITS
Geotechnical Basis of Design Report - 65% Design
September 2019

Drawing References: Lookout Slough boundary lines and easements provided by Wood Rodgers, Inc., 12/08/2017. Proposed levee alignment, stream channels, and topography updated 7/30/2019.

0 1500
SCALE: 1 " = 1500'

Lookout Slough THRFIP

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Checked By: N.C.H.
Job No.: 3195.x

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Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x Fig2 LSRP 65%.dwg

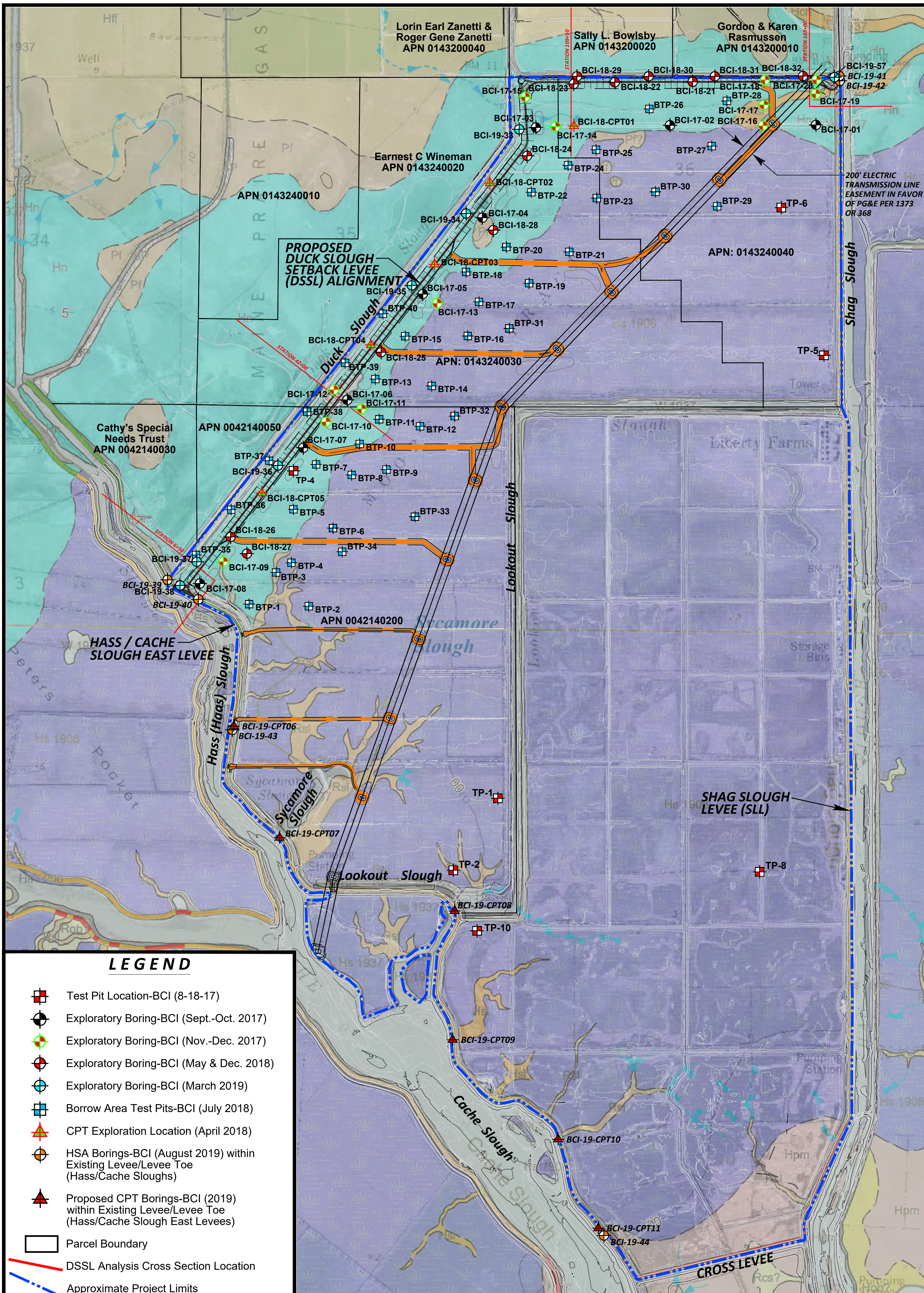

FIGURE 3A, EXPLORATION SITE PLAN

Geotechnical Basis of Design Report - 65% Design

September 2019

Drawing References: Lookout Slough boundary lines and easements provided by Wood Rodgers, Inc., 12/08/2017. Proposed levee alignment updated 2/1/2019 and topography updated11/12/2018.

0 1500

SCALE: 1 " = 1500'

Lookout Slough THRFIP

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Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

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Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x Fig3 LSRP 65%.dwg

This map shows surficial geologic deposits and levees as they existed in 1937. Map units and boundaries are drawn by interpretation of historical aerial photography supplemented by data from historical maps and surveys. For reference, the mapping is superimposed on modern U.S. Geological Survey 7.5' topographic base maps (individual maps referenced below).
Screened back semi-transparent mapping shown on this plate is from Deep Water Ship Channel study area, which is not assessed in this investigation. For clarity, only the surficial geologic map units of this study appear in the explanation.
See accompanying technical memorandum for complete descriptions of map units, process descriptions and methodology.
Adjacent polygons that have identical map unit symbols are employed to delineate sequences of sedimentation and landscape evolution.

Explanation

Underseepage Susceptibility Along Non-Urban Levee Alignment

Very High | High | Moderate | Low

Geologic contact; dashed where approximate, dotted where concealed, queried where uncertain. Solid contacts accurate to within 100' of line shown on map; dashed contacts accurate to within about 250' on either side of the line.

Narrow channel, generally <100 ft in width. Dashed where approximate, dotted where concealed.

Narrow, tidally influenced channel (<100 ft in width), commonly connected to a larger slough channel.

Canal

Levee; artificial fill prism, generally <70 ft in width.

Borrow pit, generally <70 ft in width.

W 1937	Water; date indicates year of historical dataset.
BP	Borrow pit present in 1937.

Geologic Units

HISTORICAL

AF	Artificial fill, circa 1937.
L	Levee (made of artificial fill), circa 1937.
Rob	Overbank deposits; silt, sand, and lesser clay; deposited during high-stage water flow, overtopping channel banks.
Rcs	Crevasse splay deposits; fine sand and silt with clay deposited from breaching of natural or artificial levees.
Rch	Channel deposits; well sorted sand and trace fine gravel.
Rsl	Slough deposits; silt, clay, and sand, fining upward facies, low-energy channel deposits.
Ril 1906	Intermittent lake; seasonal lake shown on historical topographic maps. Date indicates source data set.

HOLOCENE

Hob	Overbank deposits; silt, sand, and clay; deposited during high-stage water flow, overtopping channel banks.
Hcs	Crevasse splay deposits; fine sand and silt with clay deposited from breaching of natural levees.
Hff	Fine-grained alluvial fan deposits; silt and clay with sand.
Hch	Channel deposits; well sorted sand and trace fine gravel.
Hsl	Slough deposits; silt, clay, and sand, fining upward facies, low-energy channel deposits.
Ha	Alluvial deposits, undifferentiated; sand, silt, clay and minor lenses of gravel.
Hpm	Peat and muck; interbedded peat and organic-rich silt and clay, former tidal marsh deposits, mostly now leveed, drained, and farmed.
Hn	Basin deposits; fine sand, silt and clay.
Hs 1937	Marsh deposits; silt and clay, possibly with organic-rich beds; perennially or seasonally submerged. Date indicates year of historical dataset used to map the marsh.

PLEISTOCENE

Pf	Alluvial fan deposits; semi-consolidated silt, sand, sandy clay and fine to coarse subrounded gravel.
Pf (m)	Alluvial fan deposits of the Montezuma Hills; semi-consolidated sandy silt, sandy clayey silt, clay, sand and minor pebble gravel eroded from the early Pleistocene Montezuma Formation

Stratigraphic Correlation Chart

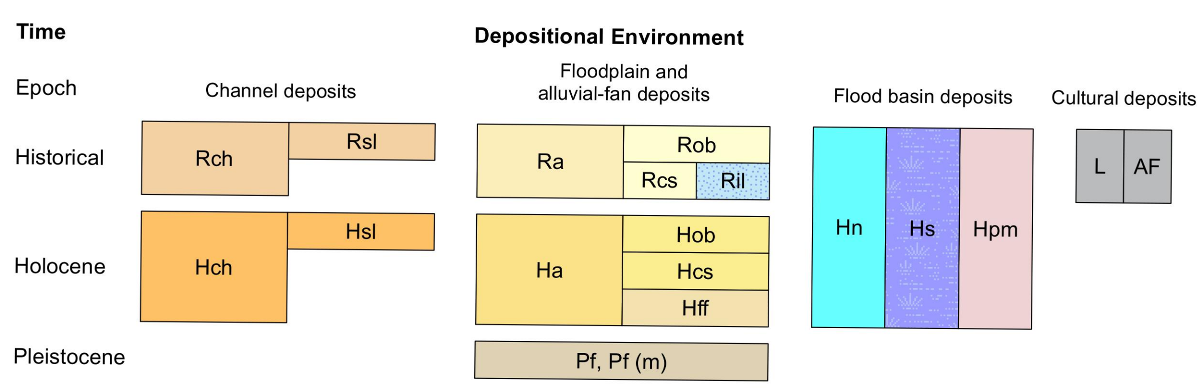

FIGURE 3B, LEGEND, EXPLORATION SITE PLAN
Geotechnical Basis of Design Report - 65% Design
September 2019

Source: Surficial Geologic Map of the West Delta Study Area, Plate 1 for the North Non-Urban Levee Evaluations. Produced by Department of Water Resources, Division of Flood Management, Levee Evaluations Branch in association with URS and Fugro, Scale is 1"=2000'.

Lookout Slough THRFIP

Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
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Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x Fig3 LSRP 65%.dwg

FIGURE 4, GEOLOGIC MAP
Geotechnical Basis of Design Report - 65% Design
September 2019

Lookout Slough boundary lines and easements provided by Wood Rodgers, Inc., 12/08/2017. Proposed levee alignment and topography updated 02/01/2019. Liberty Island, Geologic Map of the Sacramento-San Joaquin Delta, California, by Brian F. Atwater, 1982.

0 1500
SCALE: 1 " = 1500'

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Map Prepared Date: 09/01/19
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Job No.: 3195.x

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Lookout Slough THRFIP

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x Fig4 LSRP 65%.dwg

GROUP SYMBOLS AND NAMES

Graphic/Symbol	Group Names	Graphic/Symbol	Group Names
GW	Well-graded GRAVEL Well-graded GRAVEL with SAND	CL	Lean CLAY Lean CLAY with SAND Lean CLAY with GRAVEL SANDY lean CLAY SANDY lean CLAY with GRAVEL GRAVELLY lean CLAY GRAVELLY lean CLAY with SAND
GP	Poorly-graded GRAVEL Poorly-graded GRAVEL with SAND		
GW-GM	Well-graded GRAVEL with SILT Well-graded GRAVEL with SILT and SAND	CL-ML	SILTY CLAY SILTY CLAY with SAND SILTY CLAY with GRAVEL SANDY SILTY CLAY SANDY SILTY CLAY with GRAVEL GRAVELLY SILTY CLAY GRAVELLY SILTY CLAY with SAND
GW-GC	Well-graded GRAVEL with CLAY (or SILTY CLAY) Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)		
GP-GM	Poorly-graded GRAVEL with SILT Poorly-graded GRAVEL with SILT and SAND	ML	SILT SILT with SAND SILT with GRAVEL SANDY SILT SANDY SILT with GRAVEL GRAVELLY SILT GRAVELLY SILT with SAND
GP-GC	Poorly-graded GRAVEL with CLAY (or SILTY CLAY) Poorly-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)		
GM	SILTY GRAVEL SILTY GRAVEL with SAND	OL	ORGANIC lean CLAY ORGANIC lean CLAY with SAND ORGANIC lean CLAY with GRAVEL SANDY ORGANIC lean CLAY SANDY ORGANIC lean CLAY with GRAVEL GRAVELLY ORGANIC lean CLAY GRAVELLY ORGANIC lean CLAY with SAND
GC	CLAYEY GRAVEL CLAYEY GRAVEL with SAND		
GC-GM	SILTY, CLAYEY GRAVEL SILTY, CLAYEY GRAVEL with SAND	0L	ORGANIC SILT ORGANIC SILT with SAND ORGANIC SILT with GRAVEL SANDY ORGANIC SILT SANDY ORGANIC SILT with GRAVEL GRAVELLY ORGANIC SILT GRAVELLY ORGANIC SILT with SAND
SW	Well-graded SAND Well-graded SAND with GRAVEL		
SP	Poorly-graded SAND Poorly-graded SAND with GRAVEL	CH	Fat CLAY Fat CLAY with SAND Fat CLAY with GRAVEL SANDY fat CLAY SANDY fat CLAY with GRAVEL GRAVELLY fat CLAY GRAVELLY fat CLAY with SAND
SW-SM	Well-graded SAND with SILT Well-graded SAND with SILT and GRAVEL		
SW-SC	Well-graded SAND with CLAY (or SILTY CLAY) Well-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)	MH	Elastic SILT Elastic SILT with SAND Elastic SILT with GRAVEL SANDY elastic SILT SANDY elastic SILT with GRAVEL GRAVELLY elastic SILT GRAVELLY elastic SILT with SAND
SP-SM	Poorly-graded SAND with SILT Poorly-graded SAND with SILT and GRAVEL		
SP-SC	Poorly-graded SAND with CLAY (or SILTY CLAY) Poorly-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)	OH	ORGANIC fat CLAY ORGANIC fat CLAY with SAND ORGANIC fat CLAY with GRAVEL SANDY ORGANIC fat CLAY SANDY ORGANIC fat CLAY with GRAVEL GRAVELLY ORGANIC fat CLAY GRAVELLY ORGANIC fat CLAY with SAND
SM	SILTY SAND SILTY SAND with GRAVEL		
SC	CLAYEY SAND CLAYEY SAND with GRAVEL	OH	ORGANIC elastic SILT ORGANIC elastic SILT with SAND ORGANIC elastic SILT with GRAVEL SANDY ORGANIC elastic SILT SANDY ORGANIC elastic SILT with GRAVEL GRAVELLY ORGANIC elastic SILT GRAVELLY ORGANIC elastic SILT with SAND
SC-SM	SILTY, CLAYEY SAND SILTY, CLAYEY SAND with GRAVEL		
PT	PEAT	OL/OH	ORGANIC SOIL ORGANIC SOIL with SAND ORGANIC SOIL with GRAVEL SANDY ORGANIC SOIL SANDY ORGANIC SOIL with GRAVEL GRAVELLY ORGANIC SOIL GRAVELLY ORGANIC SOIL with SAND
	COBBLES COBBLES and BOULDERS BOULDERS		

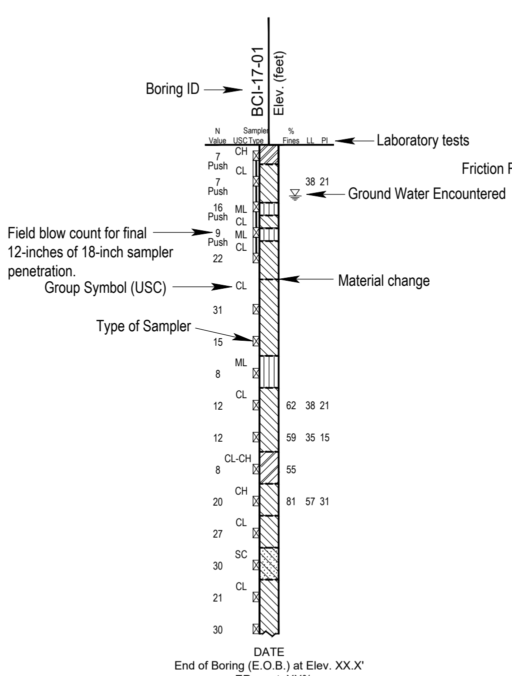
SAMPLER GRAPHIC SYMBOLS

- Standard Penetration Test (1.4 in ID)
- Modified California (2.5 in ID)
- Standard California (2.0 in ID)
- Shelby Tube (2.38 or 2.87 in ID)
- Punch Core
- Dry Core
- Sonic Core or Grab Sample
- Bag Sample

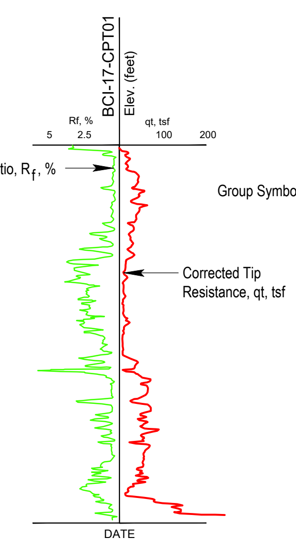
BLACKBURN BORINGS AND TEST PITS

- BCI-YEAR-ID — Exploratory Boring (September-October 2017)
- BCI-YEAR-ID — Exploratory Boring (May and December 2018)
- BCI-YEAR-ID — Exploratory Boring (November-December 2017)
- BCI-YEAR-ID — Exploratory Boring (March 2019)
- TP-ID — Approximate Test Pit Location (8-18-17)
- BTP-ID — Borrow Area Test Pits (July 2018)
- BTP-ID — Duck Slough Embankment Test Pits (July 2018) (Not in Profile View)
- BCI-YEAR-ID — CPT Exploration Location (April 2018)
- HSA Boring (August 2019) Existing Levee/Levee Toe (Hass/Cache & Skag Sloughs)
- 5 — Proposed Duck Slough Setback Levee Centerline
- Parcel Boundary
- STA 42+00 — Geotechnical Analysis
- Approximate Project Limits

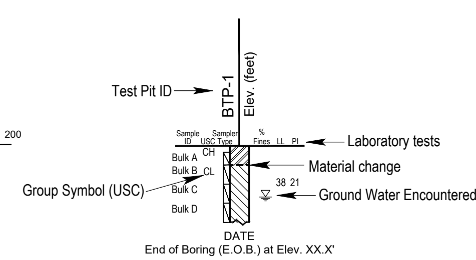
Boring Information



CPT Information



Test Pit Information



NOTES:

1. Boring locations and elevations shown are approximate and based on various levels of certainty according to available data.
2. Boring logs represent soil conditions at the point of exploration on the date indicated.
3. Lines separating strata on boring logs represent approximate boundaries.
4. No warranty is provided as to the continuity of soil conditions between individual boring locations.
5. Geomorphology overlay source: Surficial Geologic Map of the West Delta Study Area, Plate 1 for the North Non-Urban Levee Evaluations. Produced by Department of Water Resources, Division of Flood Management, Levee Evaluations Branch in association with URS and Fugro, Scale is 1"=2000'. This is a color figure. black and white reproductions should not be relied upon as data will be lost.
6. Base drawings for the levee profiles are based on topography terrain model data provided by Wood Rodgers, Inc. 4-10-2019.
7. Boring locations on plan and profile sheets are referenced to 60% design levee alignment received 4-29-2019.
8. Base drawings for the levee plan and profiles are based on topography terrain model data and drawings provided by Wood Rodgers, Inc. September 2019.

This map shows surficial geologic deposits and levees as they existed in 1937. Map units and boundaries are drawn by interpretation of historical aerial photography supplemented by data from historical maps and surveys. For reference, the mapping is superimposed on modern U.S. Geological Survey 7.5' topographic base maps (individual maps referenced below).
Screened back semi-transparent mapping shown on this plate is from Deep Water Ship Channel study area, which is not assessed in this investigation. For clarity, only the surficial geologic map units of this study appear in the explanation.
See accompanying technical memorandum for complete descriptions of map units, process descriptions and methodology.
Adjacent polygons that have identical map unit symbols are employed to delineate sequences of sedimentation and landscape evolution.

Explanation

- Geologic contact; dashed where approximate, dotted where concealed, queried where uncertain. Solid contacts accurate to within 100' of line shown on map; dashed contacts accurate to within about 250' on either side of the line.
- Narrow channel, generally <100 ft in width. Dashed where approximate, dotted where concealed.
- Narrow, tidally influenced channel (<100 ft in width), commonly connected to a larger slough channel.
- Canal
- Levee; artificial fill prism, generally <70 ft in width.
- Borrow pit, generally <70 ft in width.
- W 1937 — Water; date indicates year of historical dataset.
- BP — Borrow pit present in 1937.

Geologic Units

HISTORICAL

- AF — Artificial fill, circa 1937.
- L — Levee (made of artificial fill), circa 1937.
- Rob — Overbank deposits; silt, sand, and lesser clay; deposited during high-stage water flow, overtopping channel banks.
- Rcs — Crevasse splay deposits; fine sand and silt with clay deposited from breaching of natural or artificial levees.
- Rch — Channel deposits; well sorted sand and trace fine gravel.
- Rsl — Slough deposits; silt, clay, and sand, fining upward facies, low-energy channel deposits.
- Ril 1906 — Intermittent lake; seasonal lake shown on historical topographic maps. Date indicates source data set.

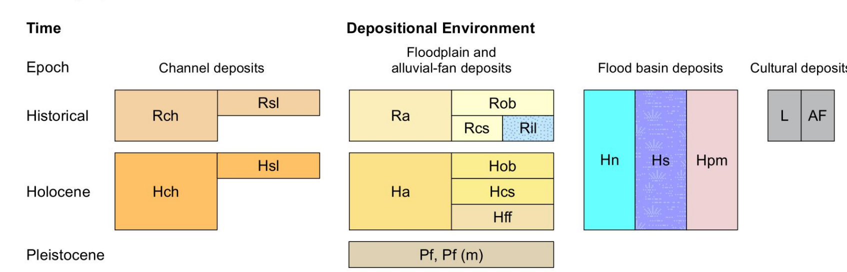
HOLOCENE

- Hob — Overbank deposits; silt, sand, and clay; deposited during high-stage water flow, overtopping channel banks.
- Hcs — Crevasse splay deposits; fine sand and silt with clay deposited from breaching of natural levees.
- Hff — Fine-grained alluvial fan deposits; silt and clay with sand.
- Hch — Channel deposits; well sorted sand and trace fine gravel.
- Hsl — Slough deposits; silt, clay, and sand, fining upward facies, low-energy channel deposits.
- Ha — Alluvial deposits, undifferentiated; sand, silt, clay and minor lenses of gravel.
- Hpm — Peat and muck; interbedded peat and organic-rich silt and clay, former tidal marsh deposits, mostly now leveed, drained, and farmed.
- Hn — Basin deposits; fine sand, silt and clay.
- Hs 1937 — Marsh deposits; silt and clay, possibly with organic-rich beds; perennially or seasonally submerged. Date indicates year of historical dataset used to map the marsh.

PLEISTOCENE

- Pf — Alluvial fan deposits; semi-consolidated silt, sand, sandy clay and fine to coarse subrounded gravel.
- Pf (m) — Alluvial fan deposits of the Montezuma Hills; semi-consolidated sandy silt, sandy clayey silt, clay, sand and minor pebble gravel eroded from the early Pleistocene Montezuma Formation

Stratigraphic Correlation Chart



REV.	DATE	BY	CHK.	APPR.	DESCRIPTION

DESIGNED BY: ROBERT B. LOKTEFF, P.E.,G.E.
DRAWN BY: MIKE ROBERTSON
CHECKED BY: NICOLE C. HART, P.E.
IN CHARGE: JONATHAN KORS, P.E.
DATE: 09/02/2019

PRELIMINARY
REGISTERED PROFESSIONAL ENGINEER — ROBERT B. LOKTEFF — GEOTECHNICAL — STATE OF CALIFORNIA

Prepared by:
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JOB NO.: 3195.x

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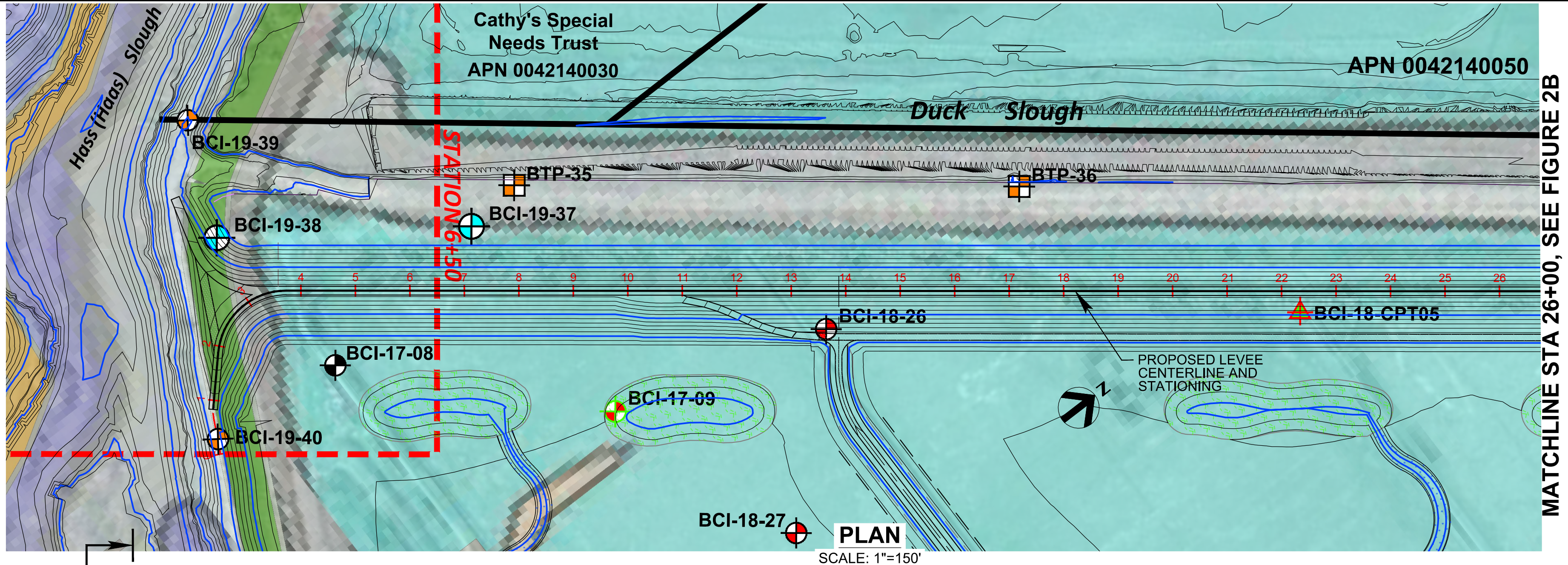
ECOSYSTEM INVESTMENT PARTNERS

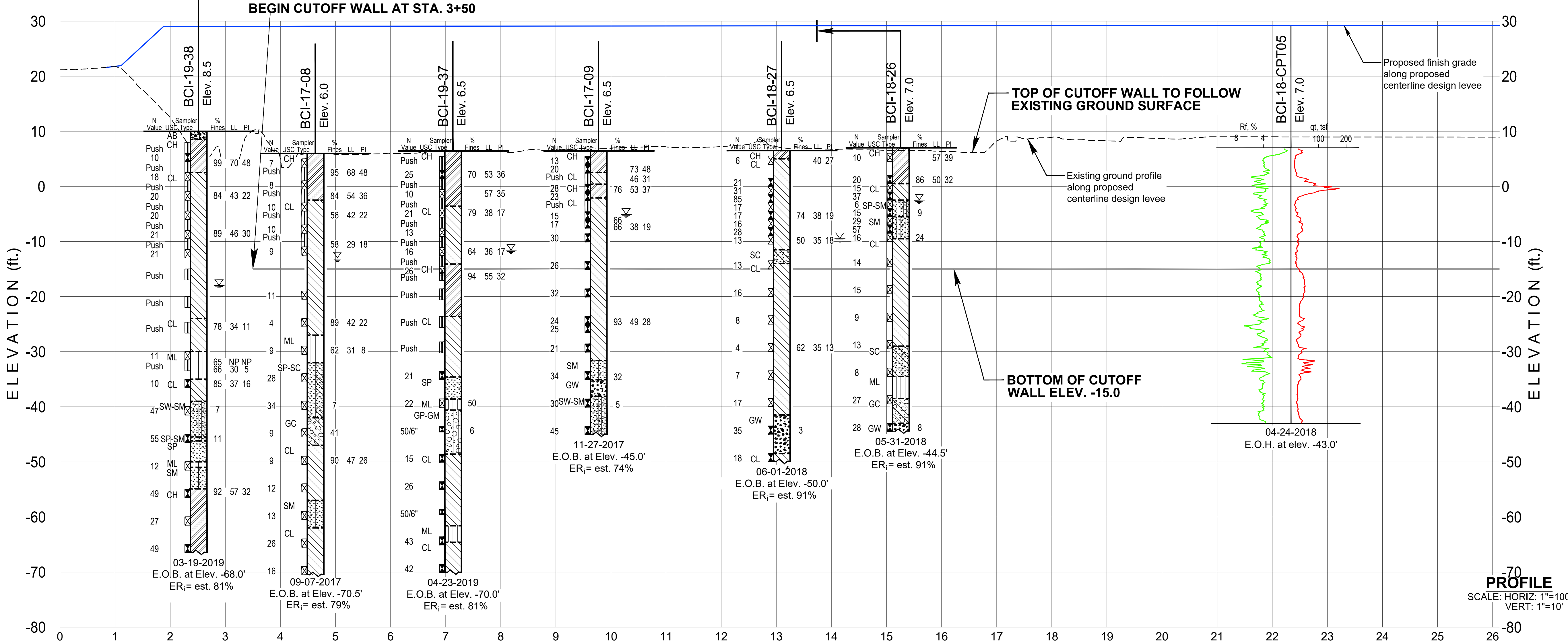
LOOKOUT SLOUGH THRFIP
Geotechnical Basis of Design Report - 65% Design
PLAN AND PROFILE LEGEND

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING, ADJUST SCALES FOR REDUCED PLOTS
0 1"

FIGURE NO. 5
SHEET A

\\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x Fig5 LSRP 65%.dwg 9/26/2019 12:08 PM Mike Robertson





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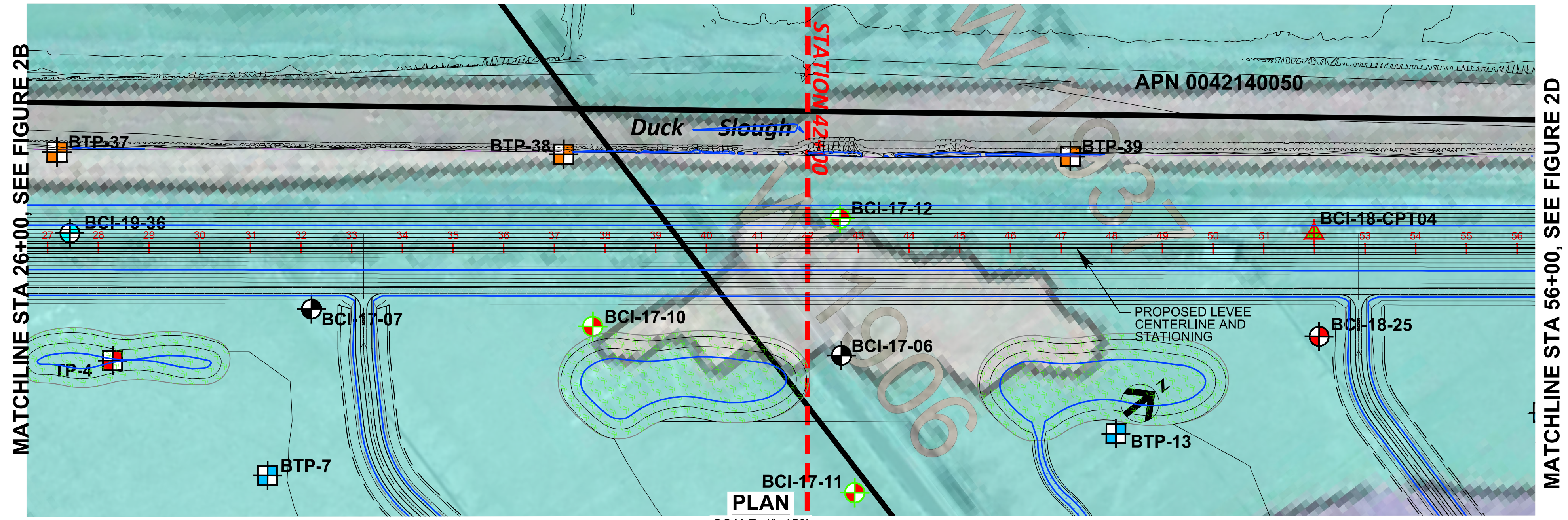
PLAN AND PROFILE STA. 0+00 to 26+00

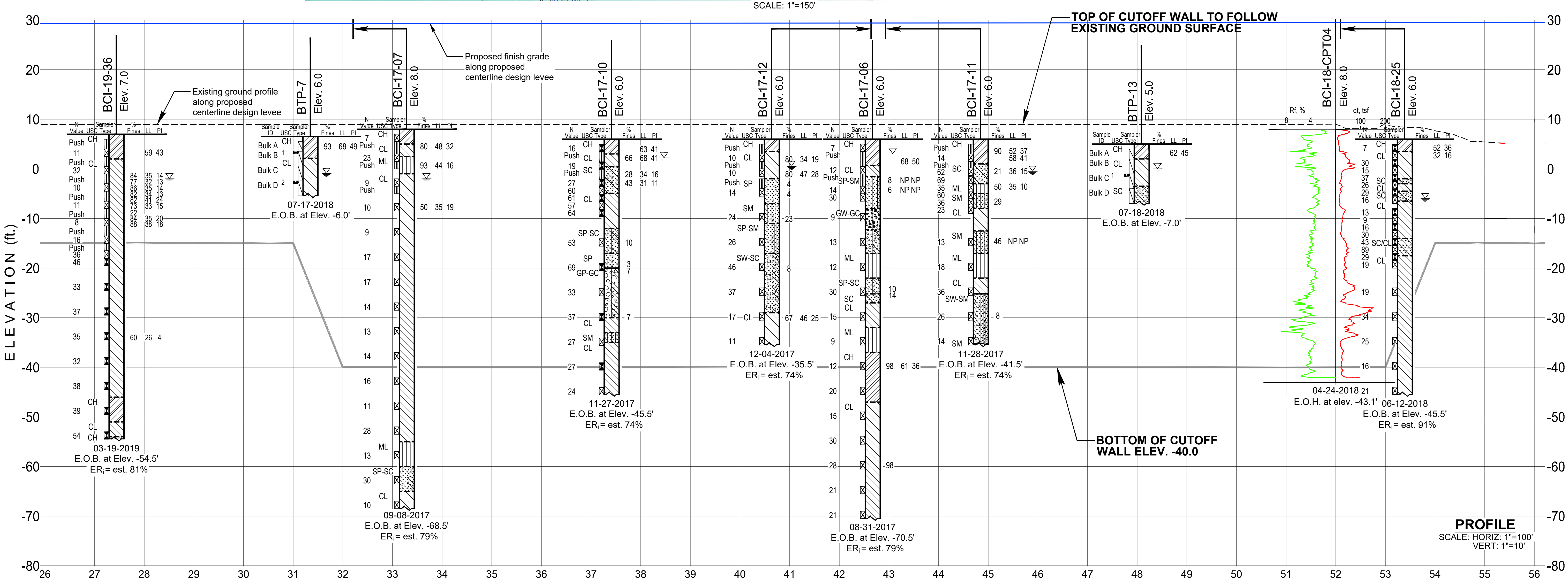
VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING, ADJUST SCALES FOR REDUCED PLOTS

FIGURE NO. 5
SHEET B



PLAN

SCALE: 1"=150'



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DRAWN BY: MIKE ROBERTSON
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IN CHARGE: JONATHAN KORS, P.E.
DATE: 09/02/2019

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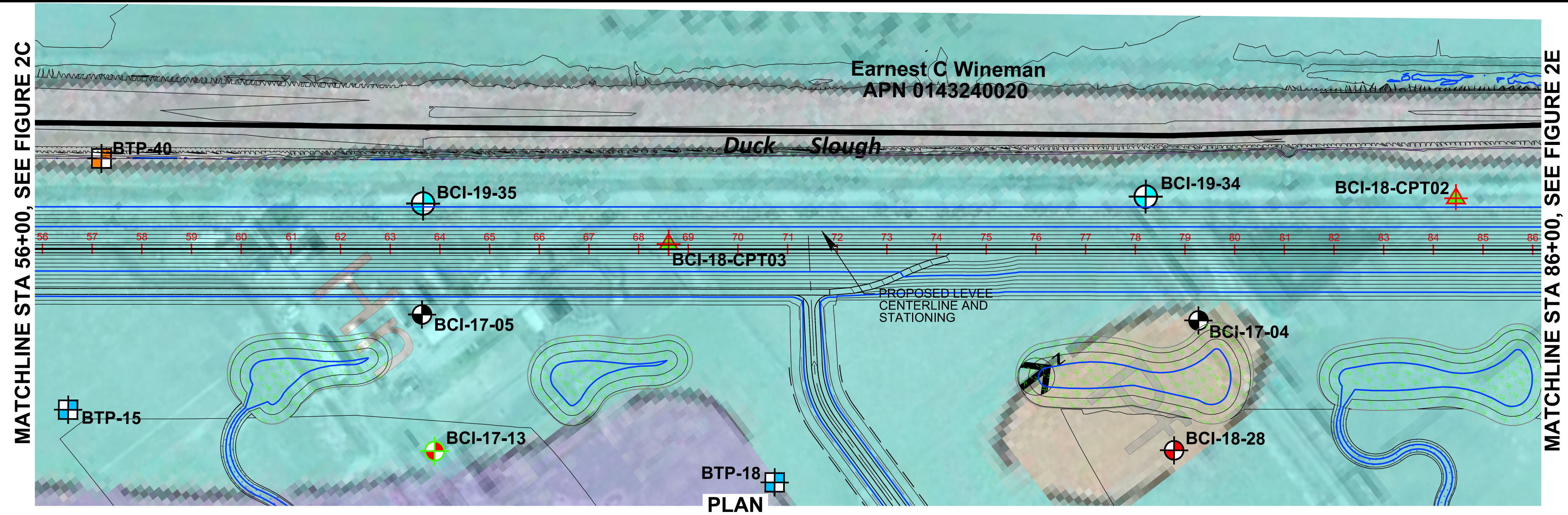
PLAN AND PROFILE STA. 26+00 to 56+00

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING, ADJUST SCALES FOR REDUCED PLOTS

FIGURE NO. 5
SHEET C



PLAN

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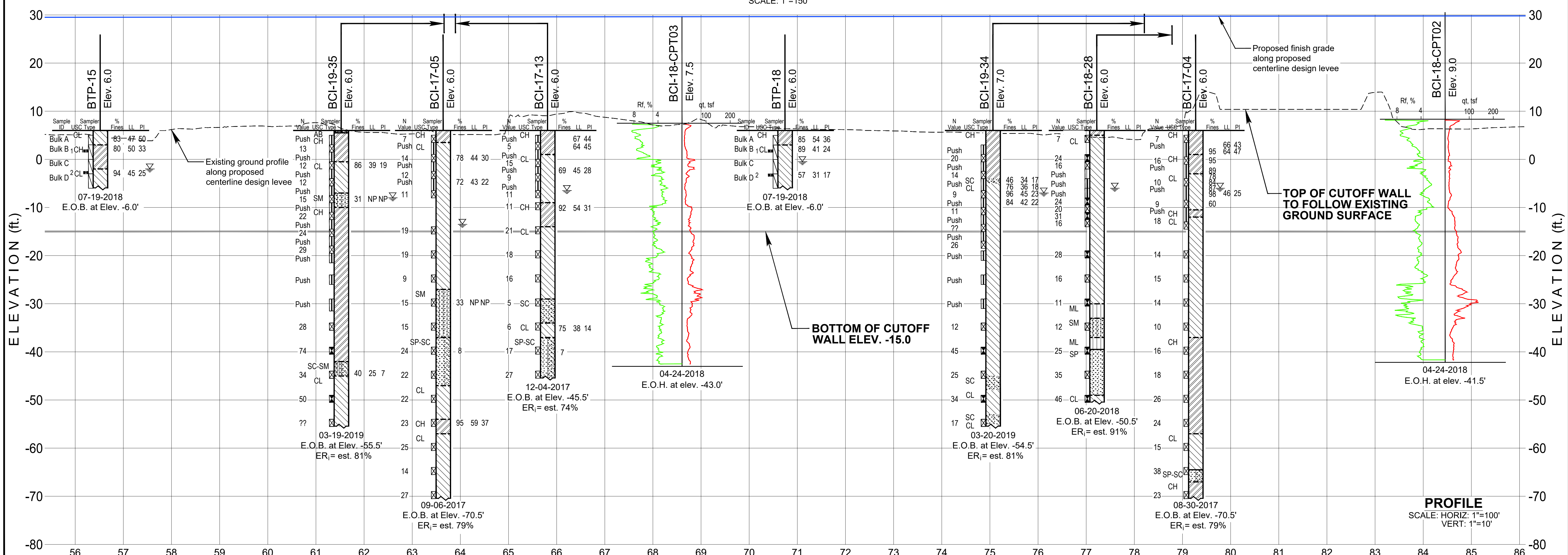

PROFILE

SCALE: HORIZ: 1"=100'
VERT: 1"=10'

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DRAWN BY: MIKE ROBERTSON
CHECKED BY: NICOLE C. HART, P.E.
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DATE: 09/02/2019

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PLAN AND PROFILE STA. 56+00 to 86+00

VERIFY SCALES
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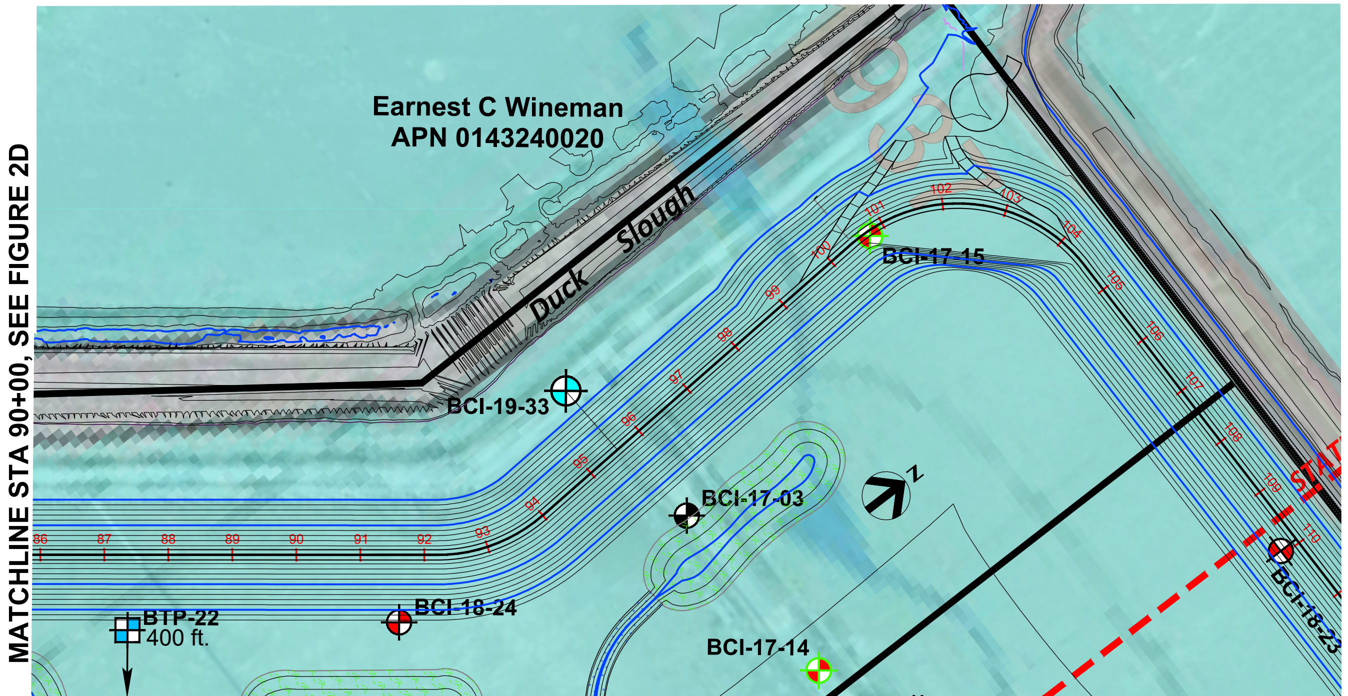
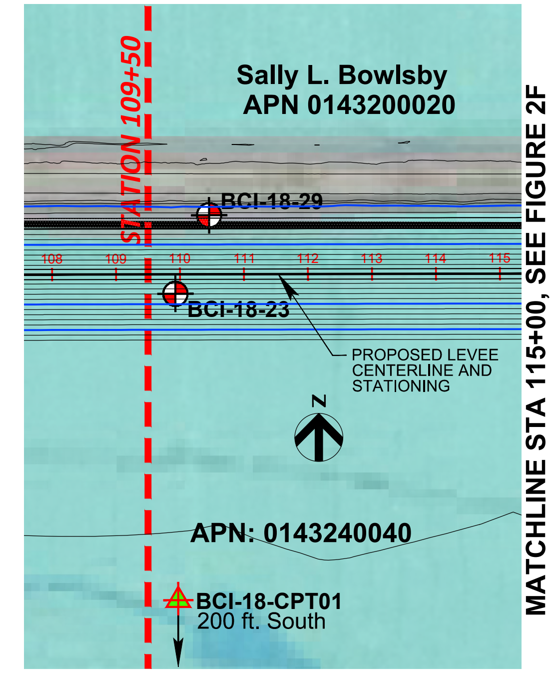
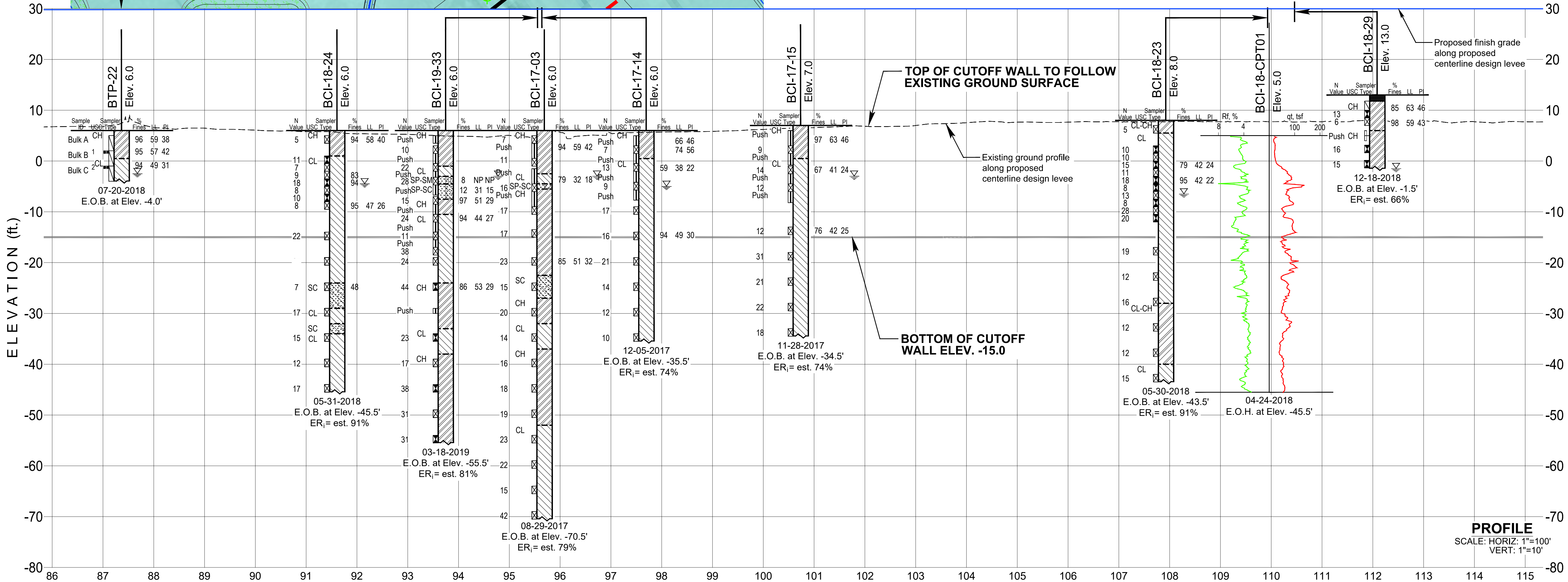
FIGURE NO. 5
SHEET D





PLAN

SCALE: 1"=150'



PROFILE

SCALE: HORIZ: 1"=100'
VERT: 1"=10'

REV.	DATE	BY	CHK.	APPR.	DESCRIPTION

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DRAWN BY: MIKE ROBERTSON
CHECKED BY: NICOLE C. HART, P.E.
IN CHARGE: JONATHAN KORS, P.E.
DATE: 09/02/2019

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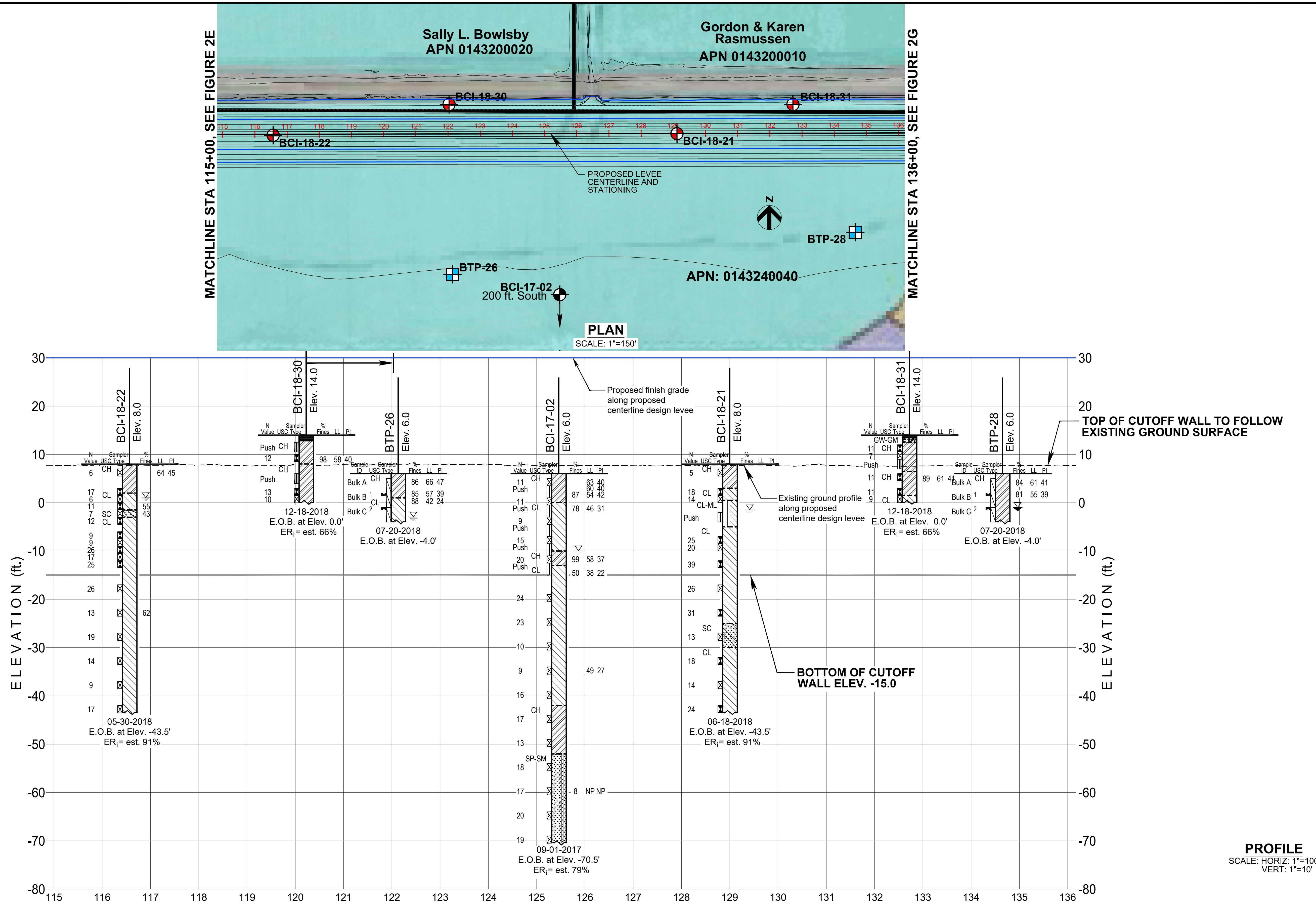
PLAN AND PROFILE STA. 86+00 to 115+00

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING, ADJUST SCALES FOR REDUCED PLOTS

FIGURE NO. 5
SHEET E



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DRAWN BY: MIKE ROBERTSON
CHECKED BY: NICOLE C. HART, P.E.
IN CHARGE: JONATHAN KORS, P.E.
DATE: 09/02/2019

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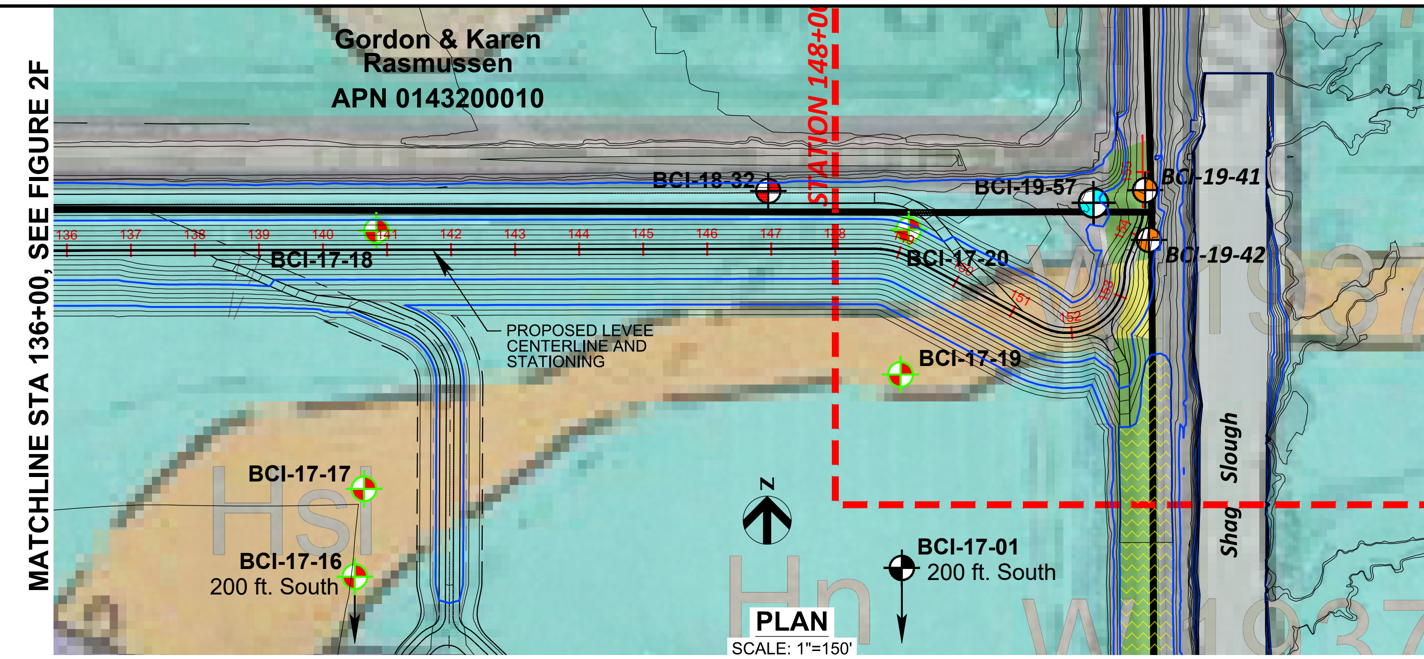
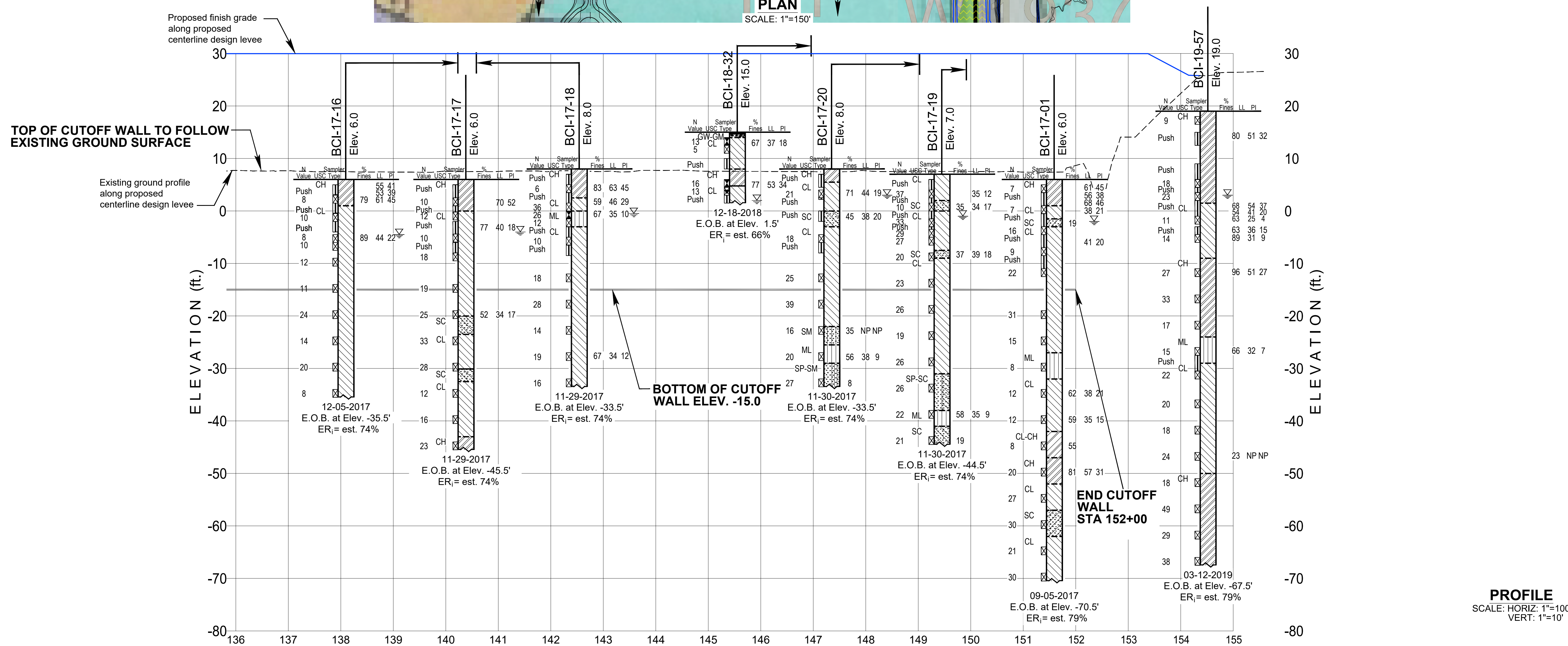
Geotechnical Basis of Design Report - 65% Design
PLAN AND PROFILE STA. 115+00 to 136+00

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING, ADJUST SCALES FOR REDUCED PLOTS

FIGURE NO. 5
SHEET F





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IN CHARGE: JONATHAN KORS, P.E.
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VERIFY SCALES
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FIGURE NO. 5
SHEET G

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GEOTECHNICAL BASIS OF DESIGN REPORT

65% Design

Lookout Slough THRFIP

Solano County, California

APPENDIX A

Historical Documents

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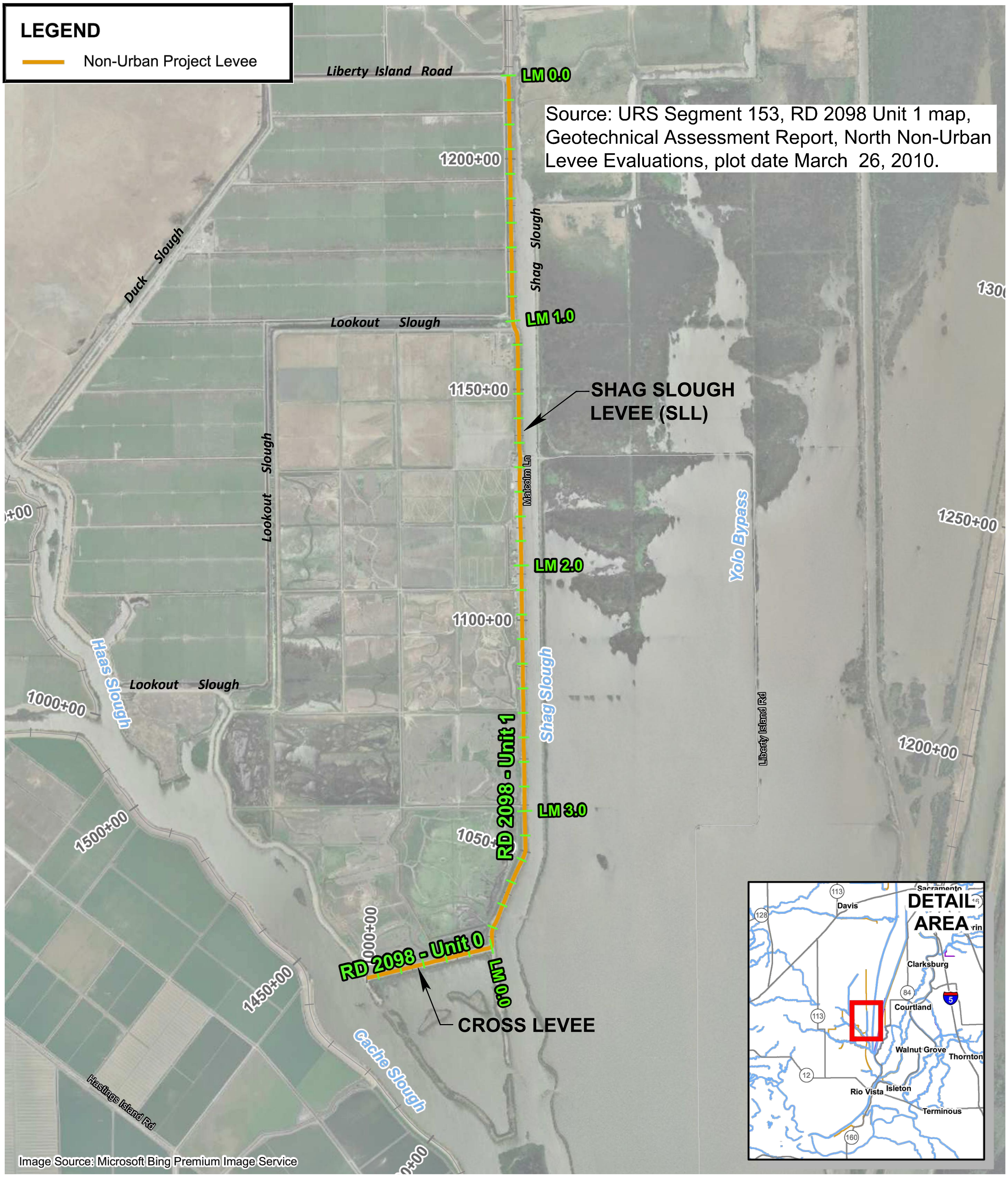


APPENDIX A-1, SEGMENT 153, RD 2098 Unit 1
Geotechnical Basis of Design Report - 65% Design
September 2019

N
W E
S

0 3000
SCALE: 1" = 3000'

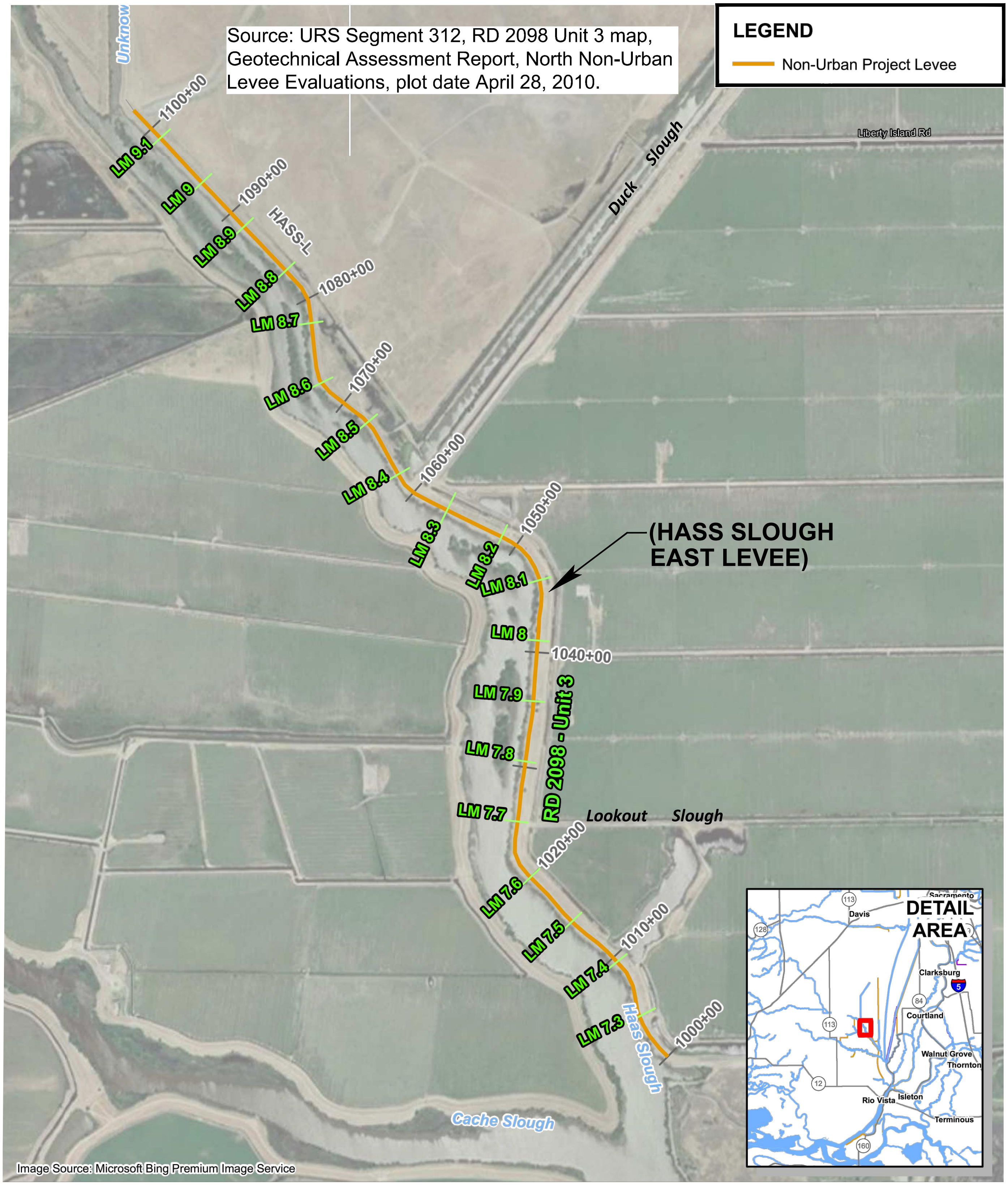
Ecosystem Investment Partners

Prepared by:
Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Lookout Slough THRFIP

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x LSRP GBOD 65% AppA-1.dwg



APPENDIX A-2, SEGMENT 312, RD 2098 Unit 3
Geotechnical Basis of Design Report - 65% Design
September 2019

N
W E
S

0 1200
SCALE: 1" = 1200'

Lookout Slough THRFIP

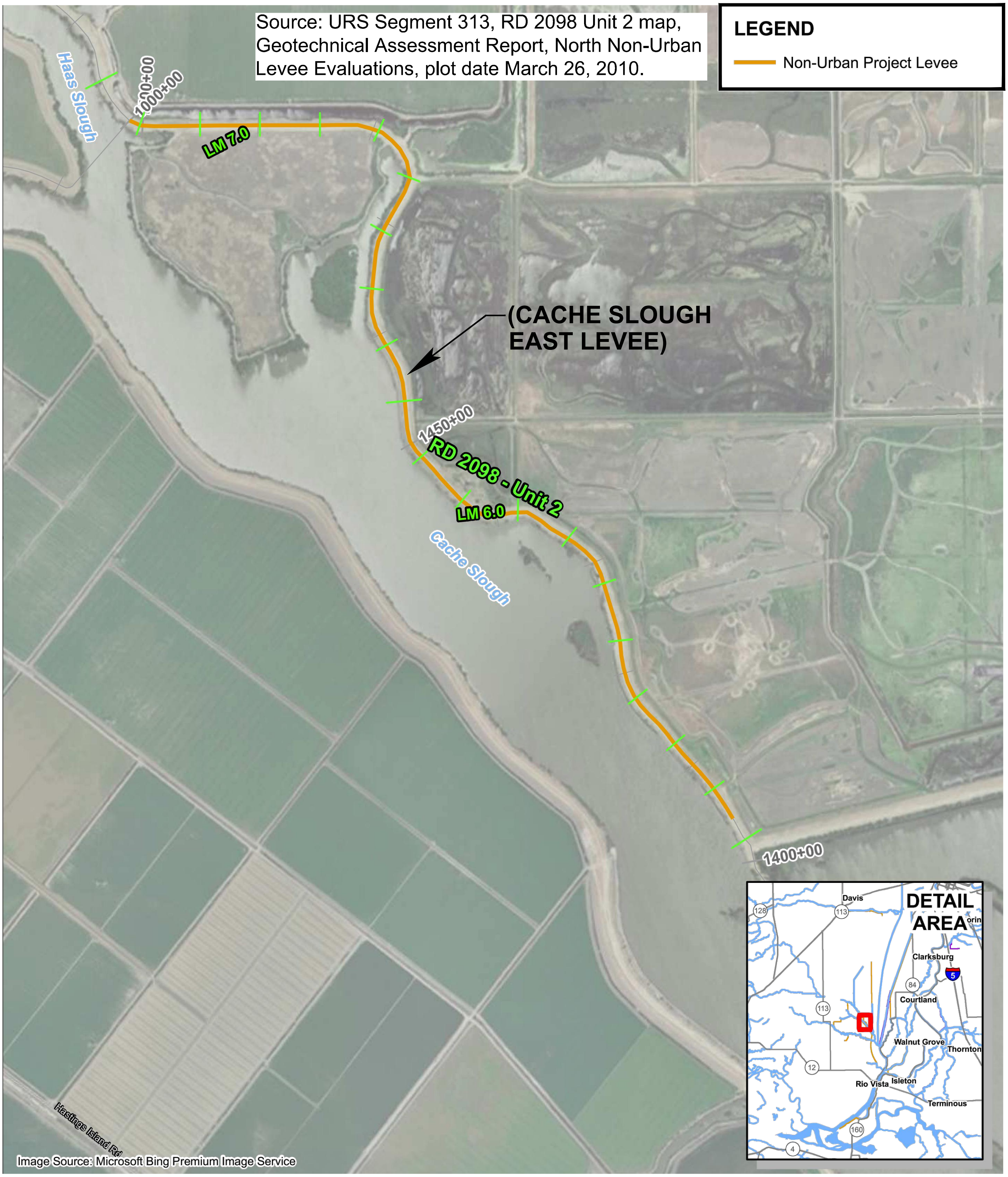
Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x LSRP GBOD 65% AppA-2.dwg



APPENDIX A-3, SEGMENT 313, RD 2098 Unit 2
Geotechnical Basis of Design Report - 65% Design
September 2019

N W E S

0 1200
SCALE: 1" = 1200'

Lookout Slough THRFIP

Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x LSRP GBOD 65% AppA-3.dwg

APPENDIX A-4, TOPOGRAPHIC MAP 1908
Geotechnical Basis of Design Report - 65% Design
September 2019

N
W E
S

0 3000
SCALE: 1" = 3000'

Lookout Slough THRFIP

Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x LSRP GBOD 65% AppA-4.dwg

APPENDIX A-5, TOPOGRAPHIC MAP 1916
Geotechnical Basis of Design Report - 65% Design
September 2019

N
W E
S

0 3000
SCALE: 1" = 3000'

Lookout Slough THRFIP

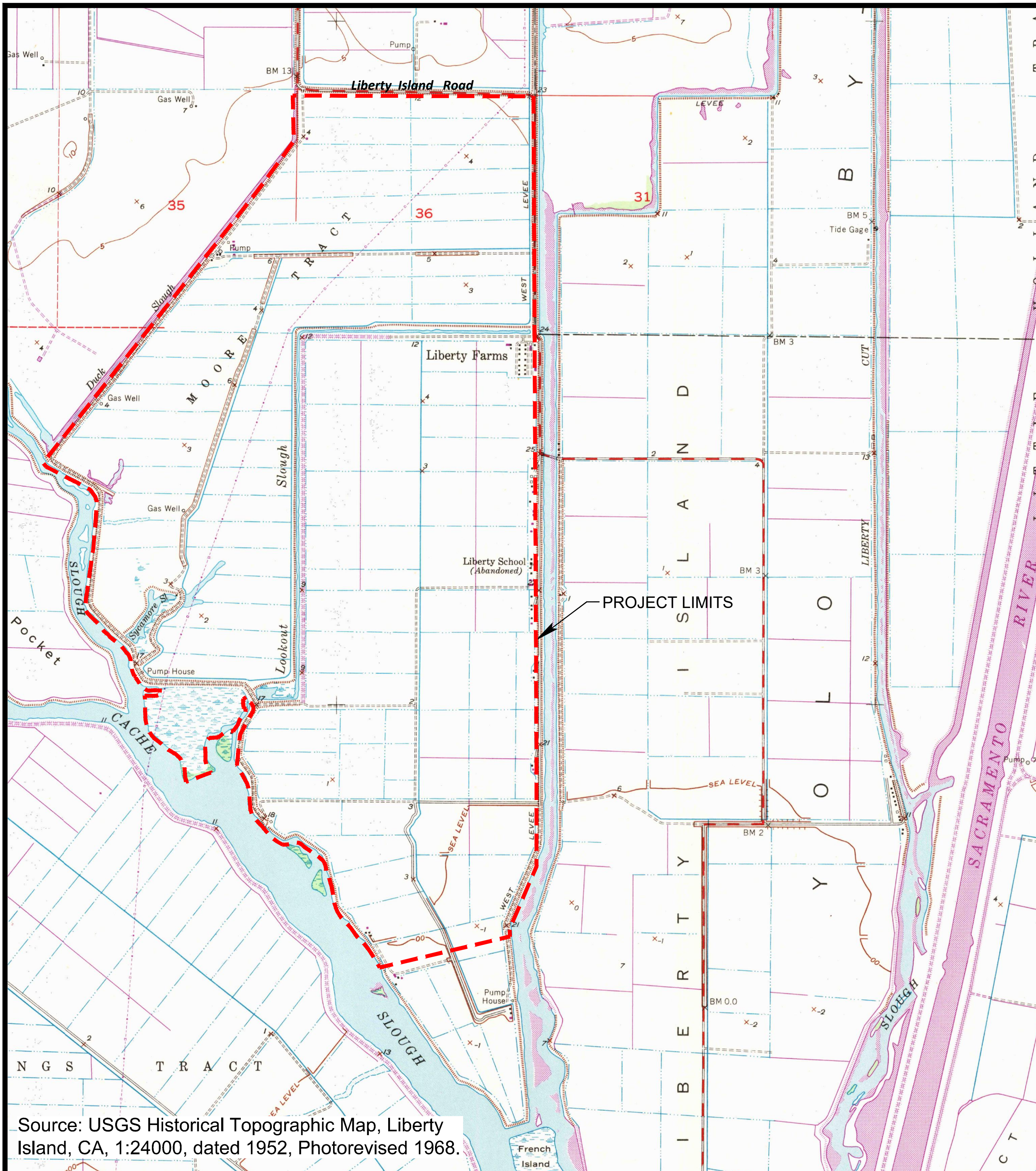
Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x LSRP GBOD 65% AppA-5.dwg



APPENDIX A-6, TOPOGRAPHIC MAP 1952
Geotechnical Basis of Design Report - 65% Design
September 2019

N W E S

0 3000
SCALE: 1" = 3000'

Lookout Slough THRFIP

Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x LSRP GBOD 65% AppA-6.dwg

GEOTECHNICAL BASIS OF DESIGN REPORT

65% Design

Lookout Slough THRFIP

Solano County, California

APPENDIX B

SEEP/W and SLOPE/W Analytical Results

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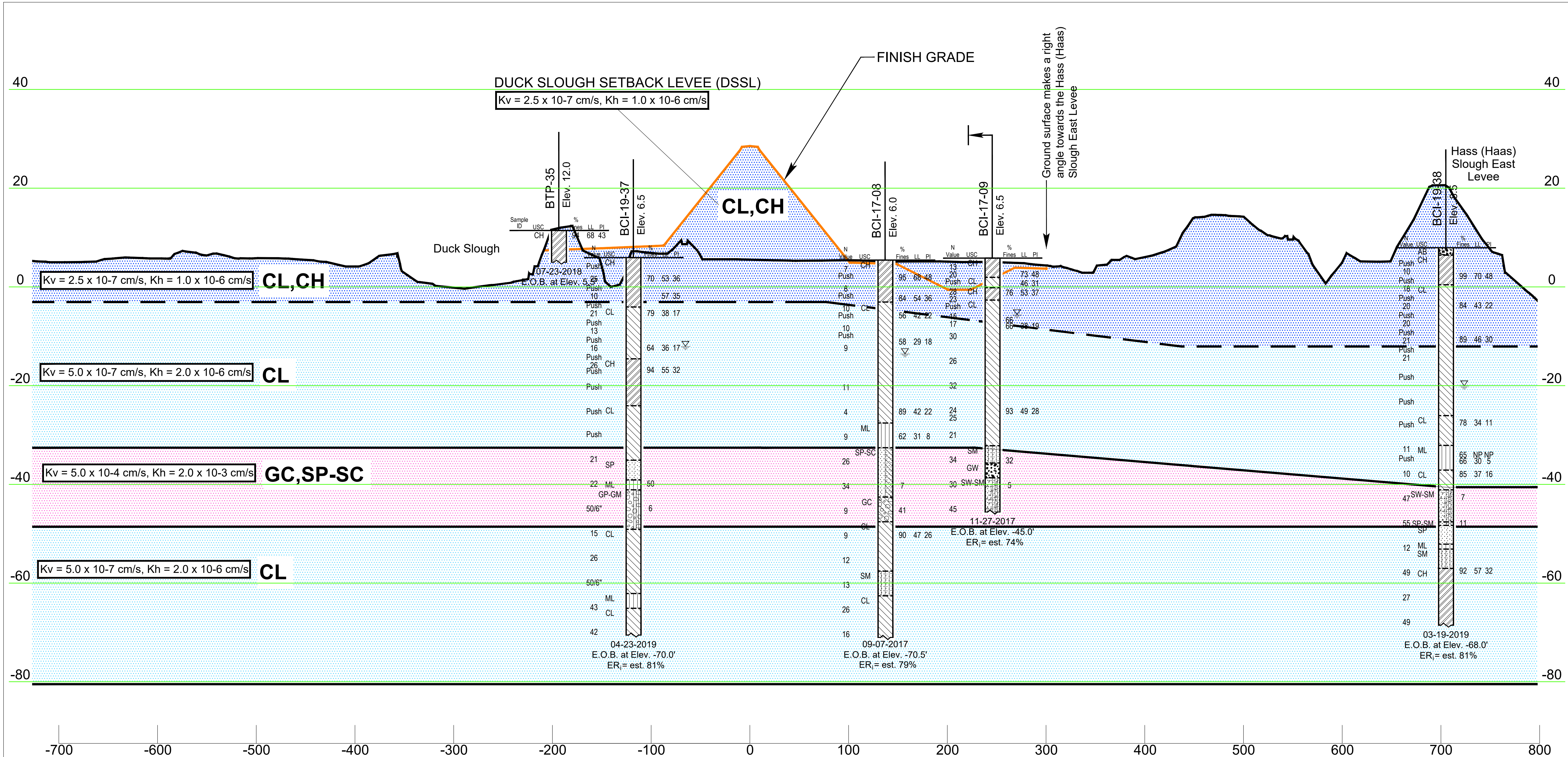


APPENDIX B-1, STA 6+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
SUBSURFACE PROFILE USED IN ANALYSIS
September 2019

LEGEND

Kv, Kh = - Hydraulic Conductivity Values for Soil Layers

NOTES:
Cross section updated 05-14-19. Levee shifted to centerline of new alignment. Boring logs updated 5-8-19.

SCALE: 1 inch = 100 ft Hor.
1 inch = 20 ft Vert.

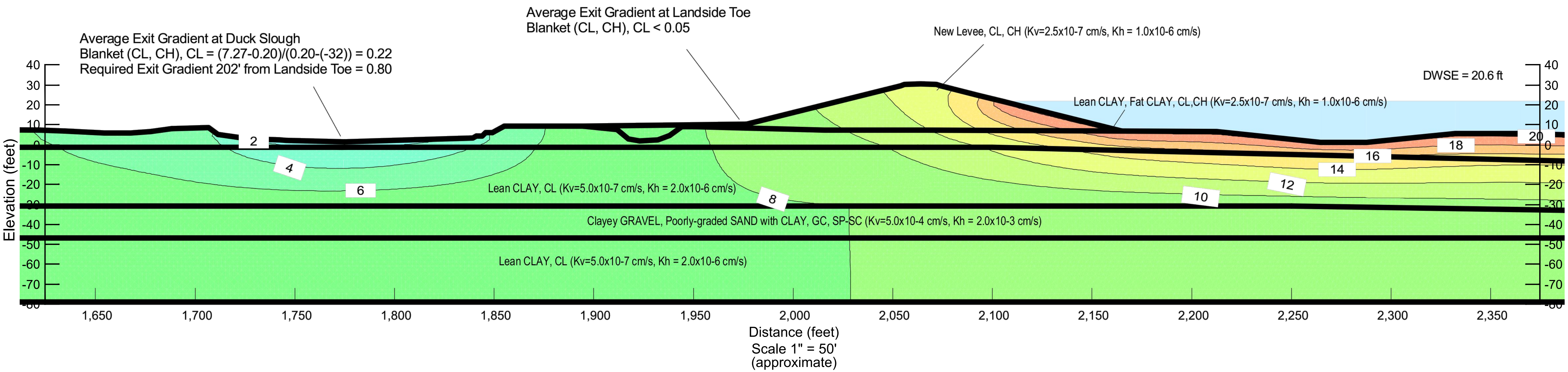
Ecosystem Investment Partners

Lookout Slough THRFIP

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\CROSS SECTIONS NEW 06_20_2019\3195.x LSRP BDR 65% 06+50 AppB.dwg



Material ID and Type, Hydraulic Conductivity (Kh), Anisotropic Ratio (Kv/Kh)

Clayey GRAVEL, Poorly-Graded SAND with CLAY, GC, SP-SC	Kh=5.67 ft/day	(=2.0x10-3 cm/s)	0.25
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	0.25
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25

APPENDIX B-2, STA 6+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Seepage Analysis
Setback Levee with No Cutoff Wall
September 2019

Lookout Slough THRFIP

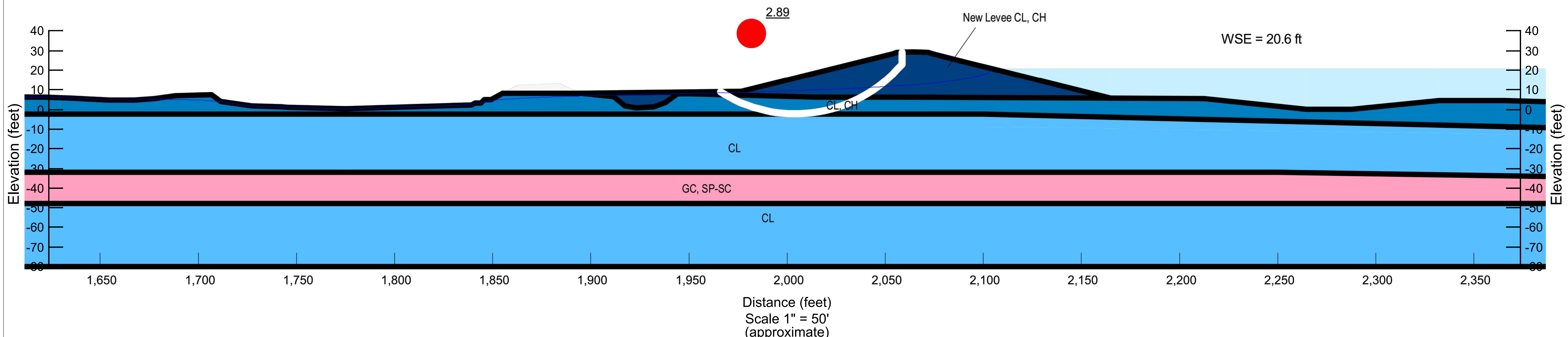
Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 6+50.dwg



Material ID and Type, Unit Weight, Effective Cohesion, Effective Friction Angle

Material	Kh		(pcf)	(psf)	(°)
Clayey GRAVEL, Poorly-Graded SAND with CLAY, GC, SP-SC	Kh=5.67 ft/day	(=2.0x10-3 cm/s)	125	0	34
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	150	32
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	150	30
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	400	22

APPENDIX B-3, STA 6+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Slope Stability Analysis
Setback Levee with No Cutoff Wall
September 2019

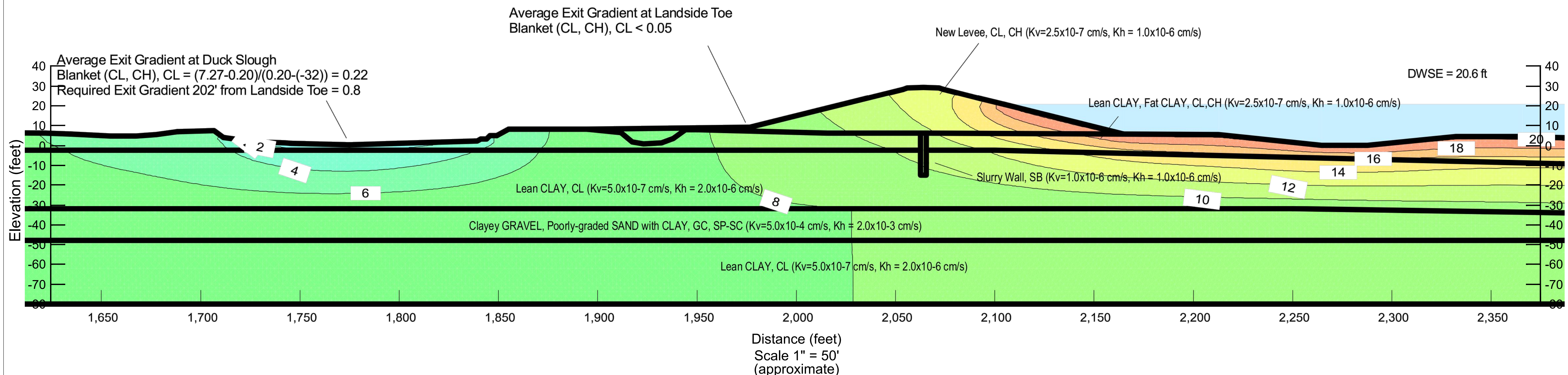
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 6+50.dwg



Material ID and Type, Hydraulic Conductivity (Kh), Anisotropic Ratio (Kv/Kh)

Clayey GRAVEL, Poorly-Graded SAND with CLAY, GC, SP-SC	Kh=5.67 ft/day	(=2.0x10-3 cm/s)	0.25
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	0.25
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	1

APPENDIX B-4, STA 6+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Seepage Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

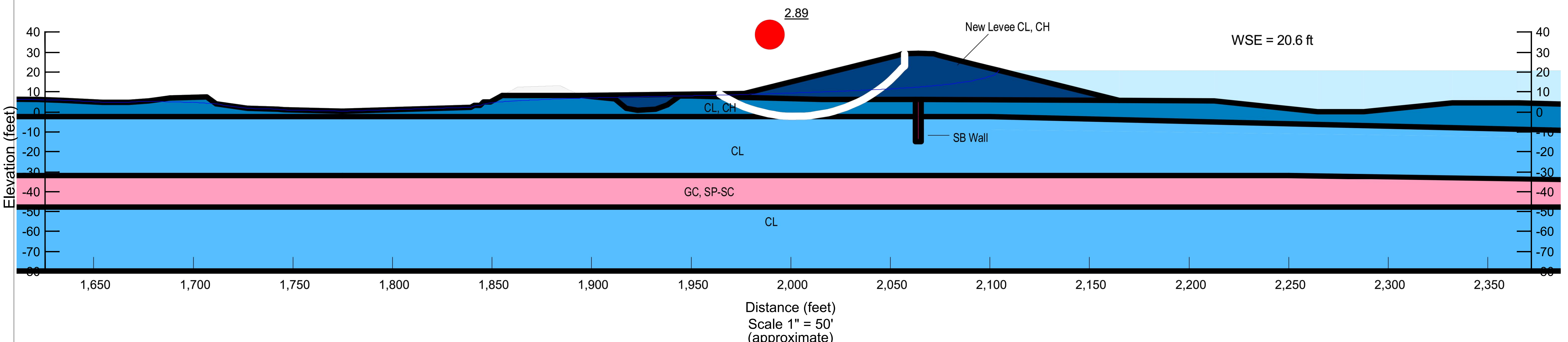
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 6+50.dwg



Material ID and Type, Unit Weight, Effective Cohesion, Effective Friction Angle

			(pcf)	(psf)	(°)
Clayey GRAVEL, Poorly-Graded SAND with CLAY, GC, SP-SC	Kh=5.67 ft/day	(=2.0x10-3 cm/s)	125	0	34
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	150	32
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	150	30
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	400	22
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	50	0

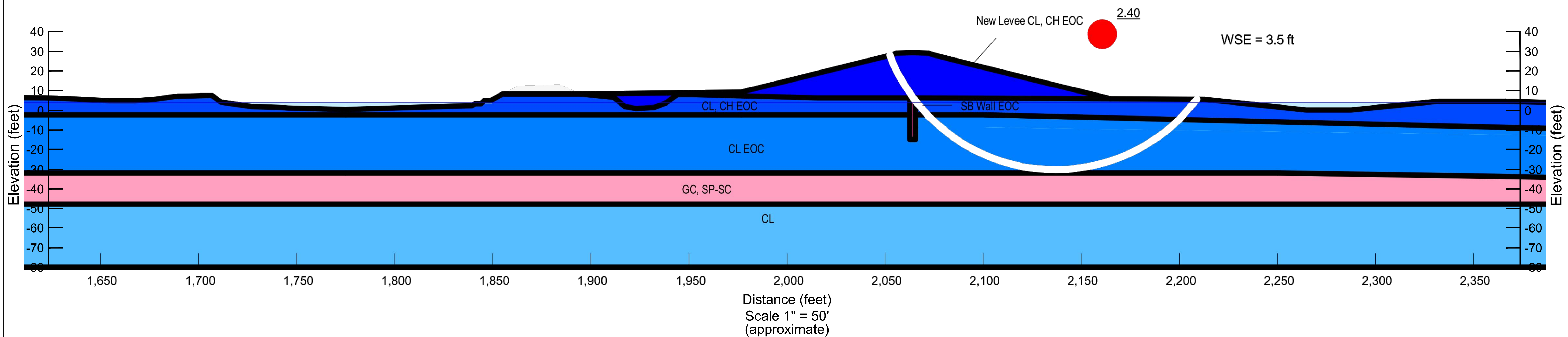
APPENDIX B-5, STA 6+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Slope Stability Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

Lookout Slough THRFIP

Ecosystem Investment Partners

Prepared by:
Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 6+50.dwg



Material ID and Type, Unit Weight, Undrained Shear Strength, Effective Cohesion, Effective Friction Angle

Material ID and Type	Kh		(pcf)	(psf)	(psf)	(°)
Clayey GRAVEL, Poorly-Graded SAND with CLAY, GC, SP-SC	Kh=5.67 ft/day	(=2.0x10-3 cm/s)	125		0	34
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115		150	32
Lean CLAY, CL EOC	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	1,000		
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115		150	30
Lean CLAY, Fat CLAY, CL, CH EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	1,000		
New Levee, CL, CH EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	1,500		
Slurry Wall, SB, EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	20		

APPENDIX B-6, STA 6+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
End-of-Construction Slope Stability Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

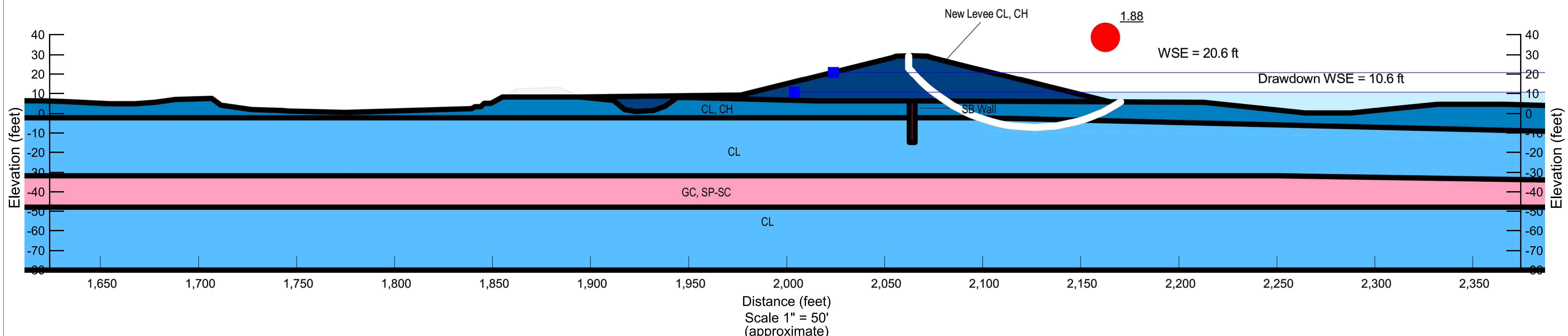
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65%
GBOD REPORT\3195.x LSRP GBOD 65% AppB 6+50.dwg



Material ID and Type, Unit Weight, Effective Cohesion, Effective Friction Angle, Total Cohesion, Total Friction Angle

Material ID and Type	Kh		(pcf)	(psf)	(°)	(psf)	(°)
Clayey GRAVEL, Poorly-Graded SAND with CLAY, GC, SP-SC	Kh=5.67 ft/day	(=2.0x10-3 cm/s)	125	0	34	0	0
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	150	32	175	16
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	150	30	175	15
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	400	22	450	13
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	50	0	0	0

APPENDIX B-7, STA 6+50

GEOTECHNICAL BASIS OF DESIGN REPORT - 60% DESIGN

Rapid Drawdown Slope Stability Analysis, 10 ft. Drawdown
Setback Levee with Shallow Cutoff Wall
September 2019

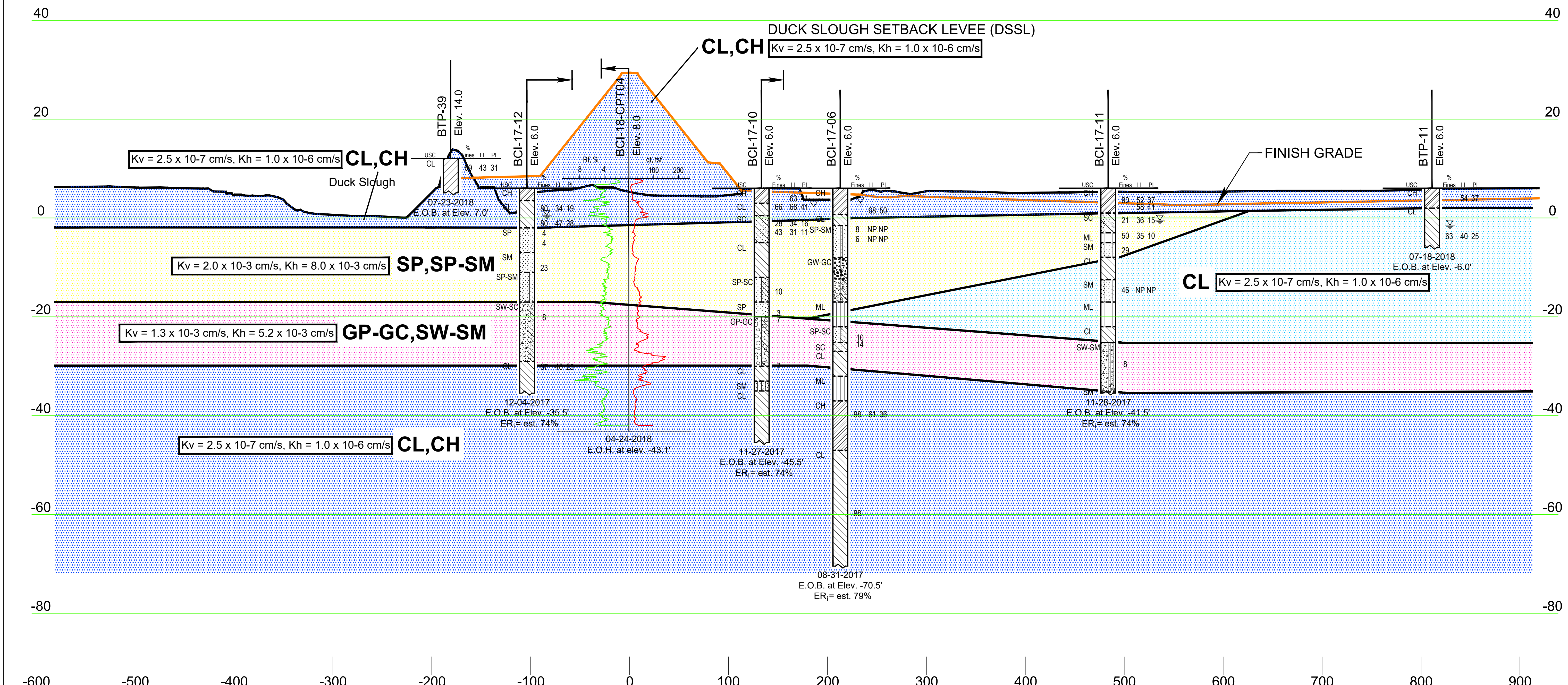
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 6+50.dwg



APPENDIX B-8, STA 42+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
SUBSURFACE PROFILE USED IN ANALYSIS
September 2019

Lookout Slough THRFIP

LEGEND

Kv, Kh = - Hydraulic Conductivity Values for Soil Layers

NOTES:
Cross section updated 05-14-19. Levee shifted to centerline of new alignment. Boring logs updated 5-8-19.

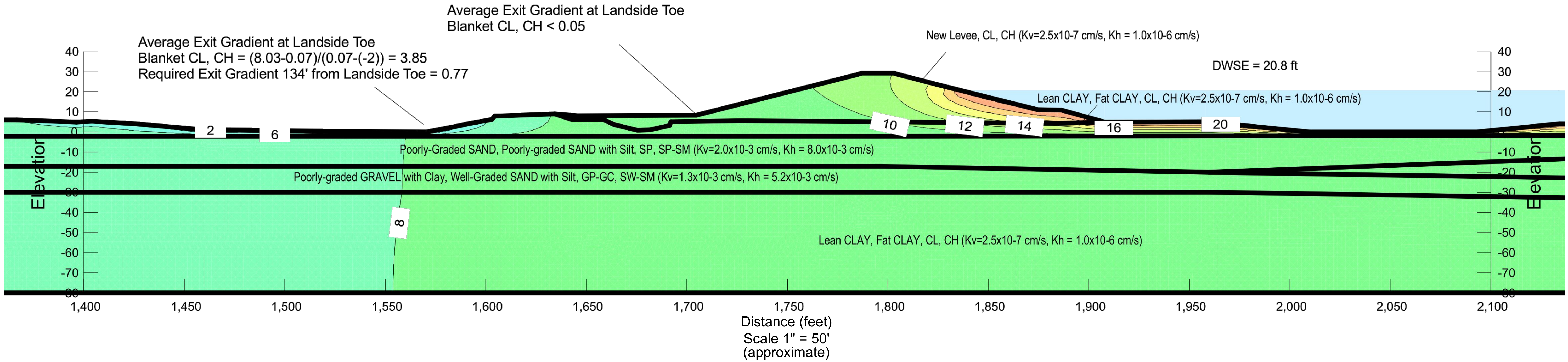
SCALE: 1 inch = 100 ft Hor.
1 inch = 20 ft Vert.

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\CROSS SECTIONS NEW 06_20_2019\3195.x LSRP BDR 65% 42+00 AppB.dwg



Material ID and Type, Hydraulic Conductivity (Kh), Anisotropic Ratio (Kv/Kh)

Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	0.25
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
Poorly-Graded GRAVEL with Clay, Well-Graded SAND with Silt, GP-GC, SW-SM	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	0.25
Poorly-graded SAND, Poorly-graded SAND with Silt, SP, SP-SM	Kh=22.68 ft/day	(=8.0x10-3 cm/s)	0.25

APPENDIX B-9, STA 42+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Seepage Analysis
Setback Levee with No Cutoff Wall
September 2019

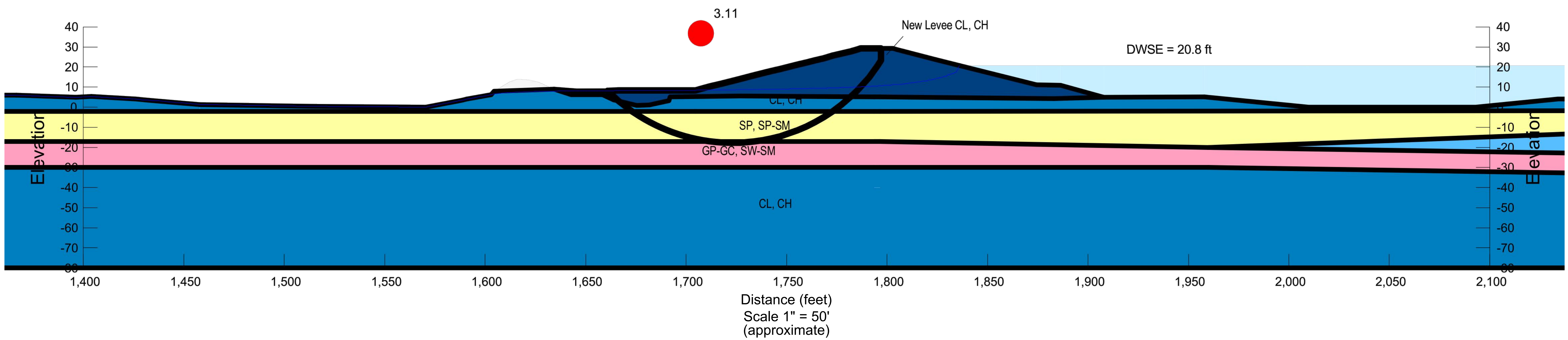
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 42+00.dwg



Material ID and Type, Hydraulic Conductivity (Kh), Unit Weight, Effective Cohesion, Effective Friction Angle

Material	Kh		Model	(pcf)	(psf)	(°)
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	Mohr-Coulomb	115	150	32
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	Mohr-Coulomb	115	150	30
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	Mohr-Coulomb	125	400	22
Poorly-Graded GRAVEL with Clay, Well-Graded SAND with Silt, GP-GC, SW-SM	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	Mohr-Coulomb	125	0	34
Poorly-graded SAND, Poorly-graded SAND with Silt, SP, SP-SM	Kh=22.68 ft/day	(=8.0x10-3 cm/s)	Mohr-Coulomb	120	0	32

APPENDIX B-10, STA 42+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Slope Stability Analysis
Setback Levee with No Cutoff Wall
September 2019

Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

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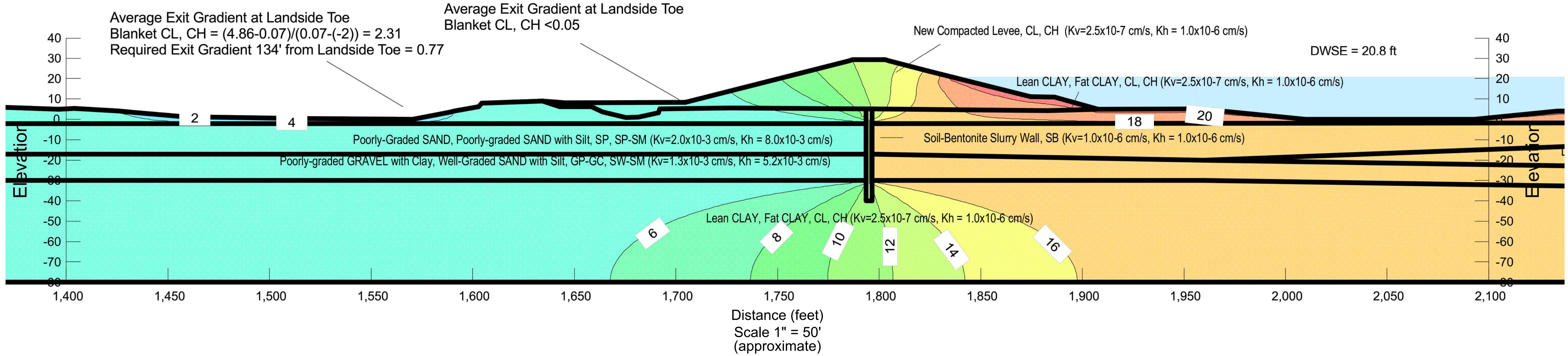


Material ID and Type, Hydraulic Conductivity (Kh), Anisotropic Ratio (Kv/Kh)

Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	0.25
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
Poorly-Graded GRAVEL with Clay, Well-Graded SAND with Silt, GP-GC, SW-SM	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	0.25
Poorly-graded SAND, Poorly-graded SAND with Silt, SP, SP-SM	Kh=22.68 ft/day	(=8.0x10-3 cm/s)	0.25
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	1

APPENDIX B-11, STA 42+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Seepage Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

Lookout Slough THRFIP

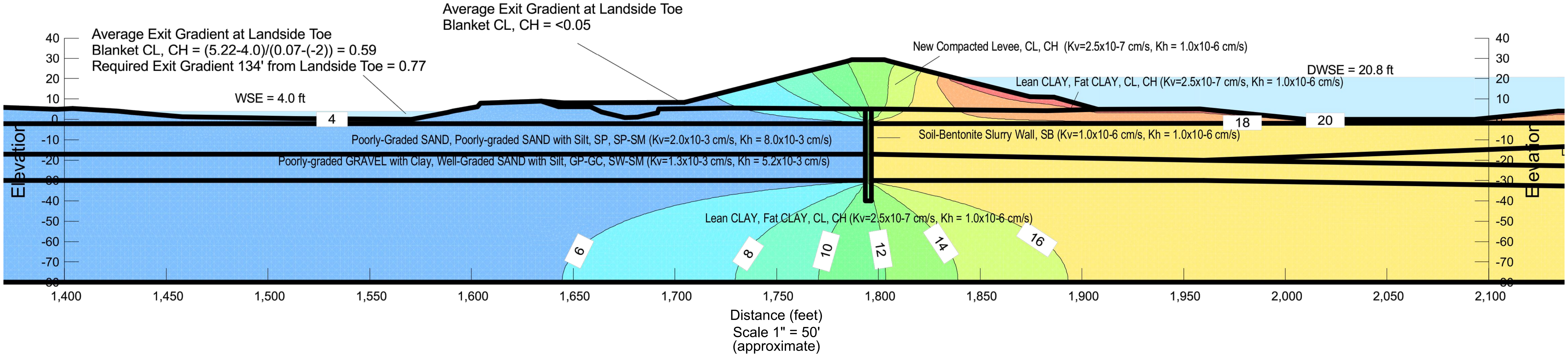
Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 42+00.dwg



Material ID and Type, Hydraulic Conductivity (Kh), Anisotropic Ratio (Kv/Kh)

Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	0.25
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
Poorly-Graded GRAVEL with Clay, Well-Graded SAND with Silt, GP-GC, SW-SM	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	0.25
Poorly-graded SAND, Poorly-graded SAND with Silt, SP, SP-SM	Kh=22.68 ft/day	(=8.0x10-3 cm/s)	0.25
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	1

APPENDIX B-12, STA 42+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Seepage Analysis with Water in Duck Slough
September 2019

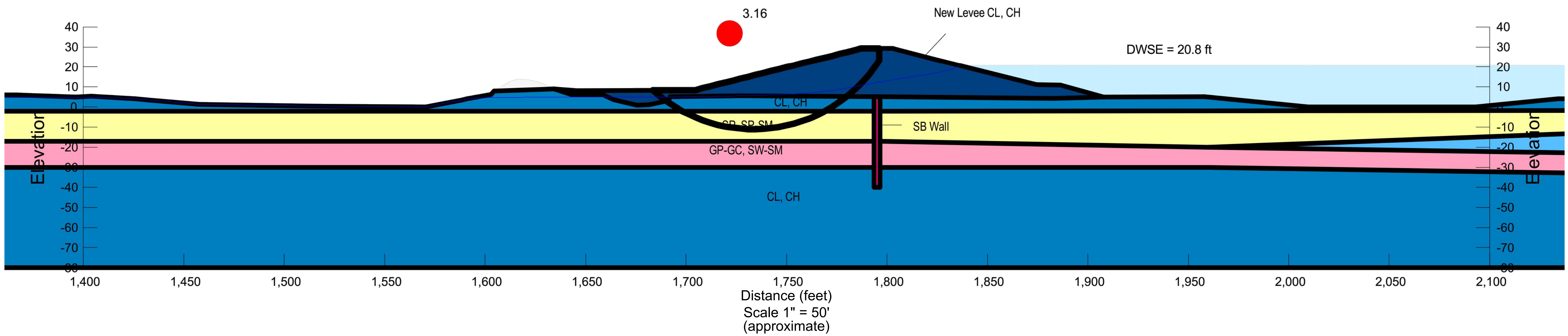
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 42+00.dwg



Material ID and Type, Hydraulic Conductivity (Kh), Unit Weight, Effective Cohesion, Effective Friction Angle

Material	Kh		Model	(pcf)	(psf)	(°)
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	Mohr-Coulomb	115	150	32
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	Mohr-Coulomb	115	150	30
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	Mohr-Coulomb	125	400	22
Poorly-Graded GRAVEL with Clay, Well-Graded SAND with Silt, GP-GC, SW-SM	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	Mohr-Coulomb	125	0	34
Poorly-graded SAND, Poorly-graded SAND with Silt, SP, SP-SM	Kh=22.68 ft/day	(=8.0x10-3 cm/s)	Mohr-Coulomb	120	0	32
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	Mohr-Coulomb	100	50	0

APPENDIX B-13, STA 42+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Slope Stability Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

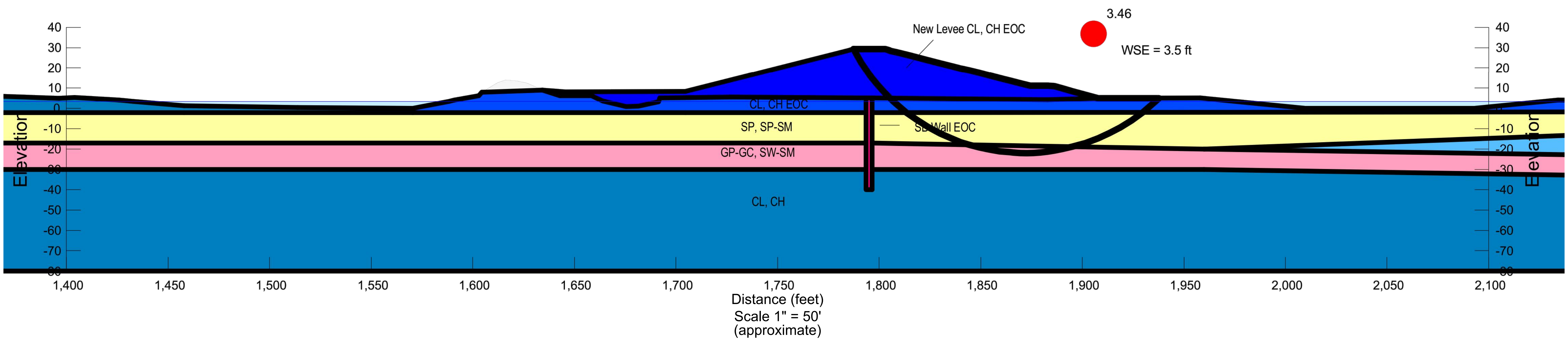
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 42+00.dwg



Material ID and Type, Hydraulic Conductivity (Kh), Unit Weight, Undrained Shear Strength, Effective Cohesion, Effective Friction Angle

Material	Kh		(pcf)	(psf)	(psf)	(°)
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115		150	32
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115		150	30
Lean CLAY, Fat CLAY, CL, CH EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	1,000		
New Levee, CL, CH EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	1,500		
Poorly-Graded GRAVEL with Clay, Well-Graded SAND with Silt, GP-GC, SW-SM	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	125		0	34
Poorly-graded SAND, Poorly-graded SAND with Silt, SP, SP-SM	Kh=22.68 ft/day	(=8.0x10-3 cm/s)	120		0	32
Slurry Wall, SB, EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	20		

APPENDIX B-14, STA 42+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
End-of-Construction Slope Stability Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

Lookout Slough THRFIP

Ecosystem Investment Partners

Prepared by:
BLACKBURN CONSULTING

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

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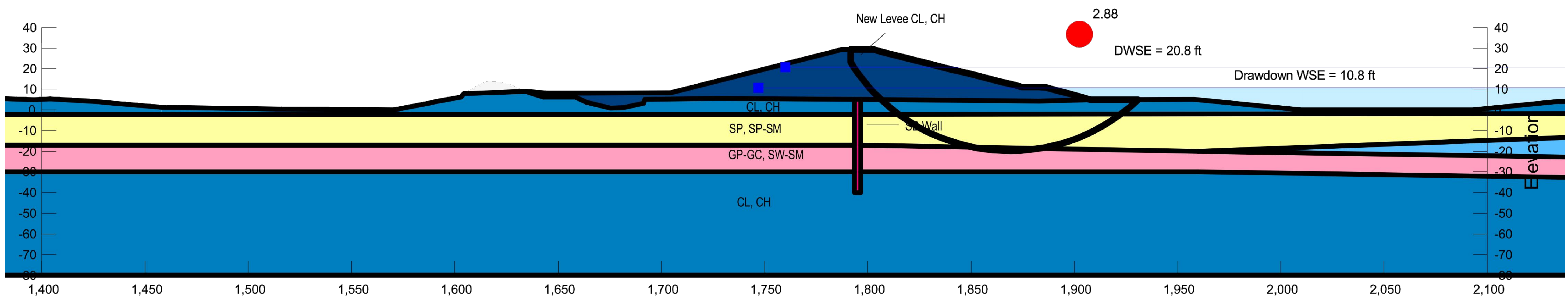


Material ID and Type, Hydraulic Conductivity (Kh), Unit Weight, Effective Cohesion, Effective Friction Angle, Total Cohesion, Total Friction Angle

Material	Kh	Kh (cm/s)	(pcf)	(psf)	(°)	(psf)	(°)
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	150	32	175	16
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	150	30	175	15
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	400	22	450	13
Poorly-Graded GRAVEL with Clay, Well-Graded SAND with Silt, GP-GC, SW-SM	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	125	0	34	0	0
Poorly-graded SAND, Poorly-graded SAND with Silt, SP, SP-SM	Kh=22.68 ft/day	(=8.0x10-3 cm/s)	120	0	32	0	0
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	50	0	0	0

APPENDIX B-15, STA 42+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
Rapid Drawdown Slope Stability Analysis, 10 ft. Drawdown
Setback Levee with Shallow Cutoff Wall
September 2019

Lookout Slough THRFIP

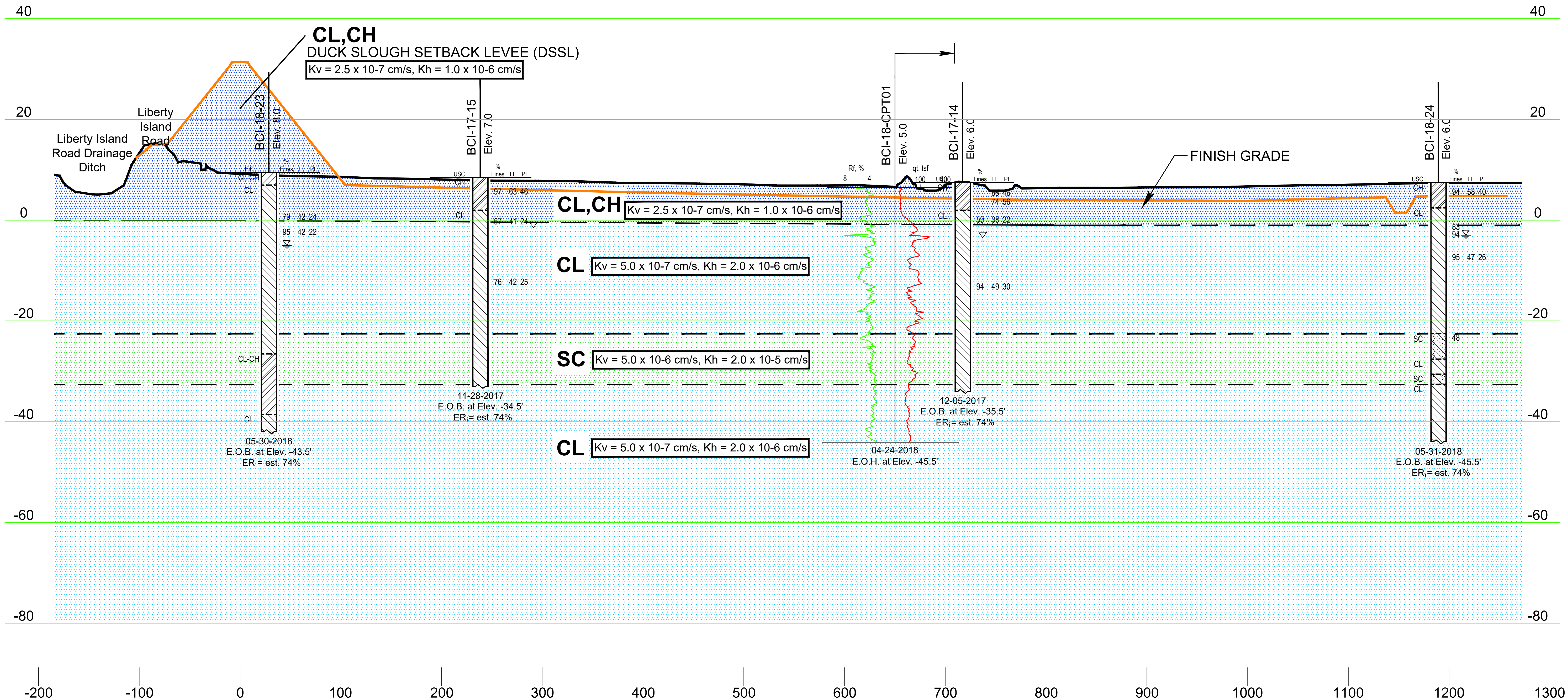
Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 42+00.dwg



APPENDIX B-16, STA 109+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
SUBSURFACE PROFILE USED IN ANALYSIS
September 2019

LEGEND

Kv, Kh = - Hydraulic Conductivity Values for Soil Layers

NOTES:
Cross section updated 05-14-19. Levee shifted to centerline of new alignment. Boring logs updated 5-8-19.

SCALE: 1 inch = 100 ft Hor.
1 inch = 20 ft Vert.

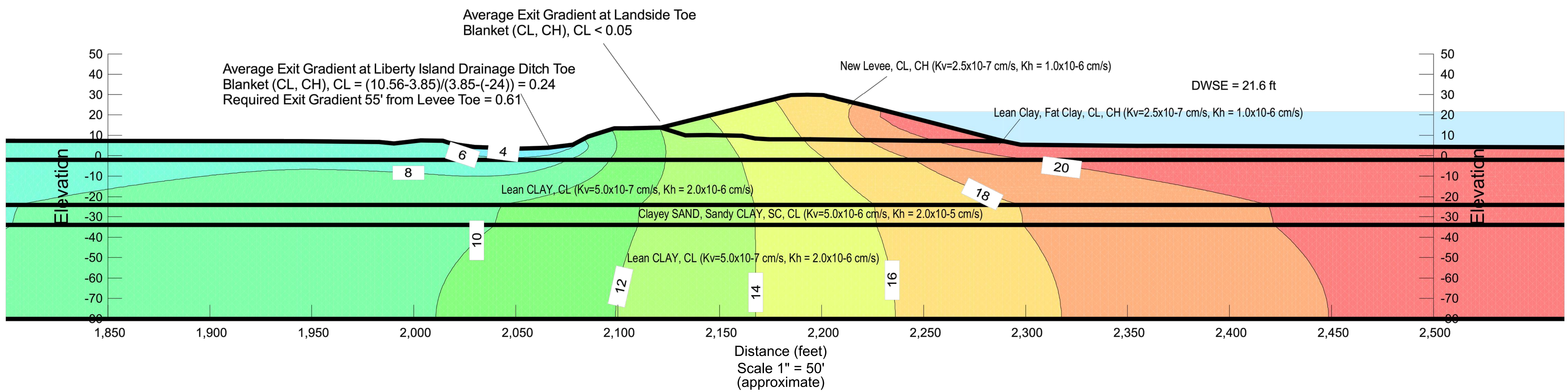
Ecosystem Investment Partners

Prepared by:
BLACKBURN CONSULTING

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Lookout Slough THRFIP

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\CROSS SECTIONS NEW 06_20_2019\3195.x LSRP BDR 65% 109+50 AppB.dwg



Material ID and Type, Hydraulic Conductivity (Kh), Anisotropic Ratio (Kv/Kh)

Clayey SAND, Sandy Lean CLAY, SC, CL	Kh=0.057 ft/d	(=2.0x10-5 cm/s)	0.25
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	0.25
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25

APPENDIX B-17, STA 109+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Seepage Analysis
Setback Levee with No Cutoff Wall
September 2019

Lookout Slough THRFIP

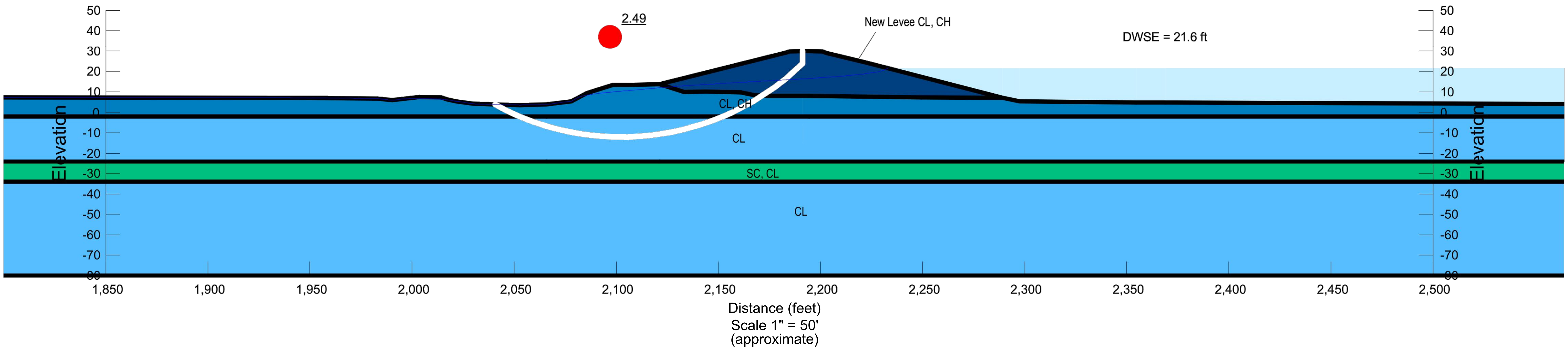
Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 109+50.dwg



Material ID and Type,Unit Weight, Effective Cohesion, Effective Friction Angle

			(pcf)	(psf)	(°)
Clayey SAND, Sandy Lean CLAY, SC, CL	Kh=0.057 ft/d	(=2.0x10-5 cm/s)	115	100	32
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	150	32
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	150	30
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	400	22

APPENDIX B-18, STA 109+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Slope Stability Analysis
Setback Levee with No Cutoff Wall
September 2019

Lookout Slough THRFIP

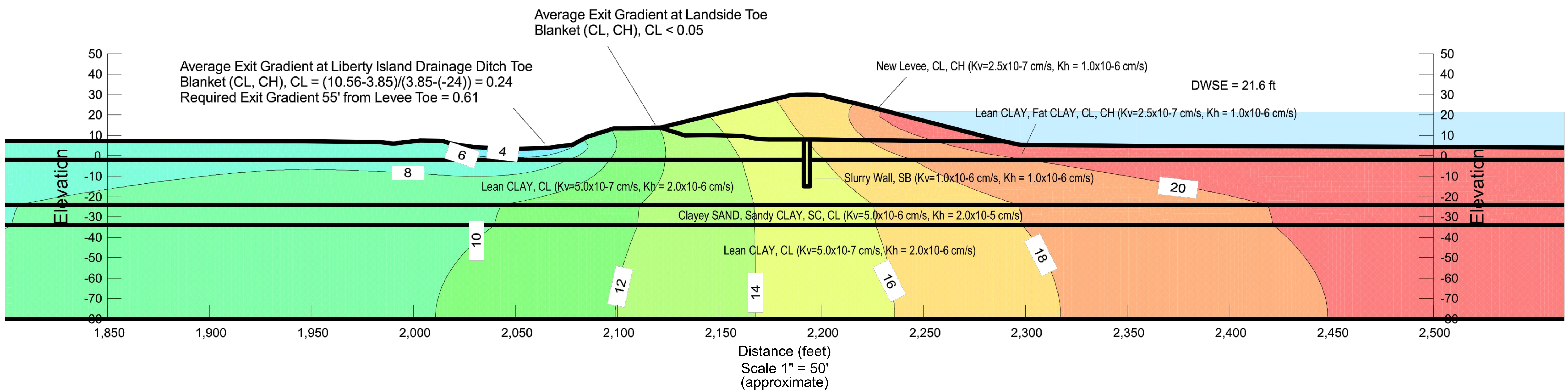
Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 109+50.dwg



Material ID and Type, Hydraulic Conductivity (Kh), Anisotropic Ratio (Kv/Kh)

Clayey SAND, Sandy Lean CLAY, SC, CL	Kh=0.057 ft/d	(=2.0x10-5 cm/s)	0.25
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	0.25
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	1

APPENDIX B-19, STA 109+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Seepage Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

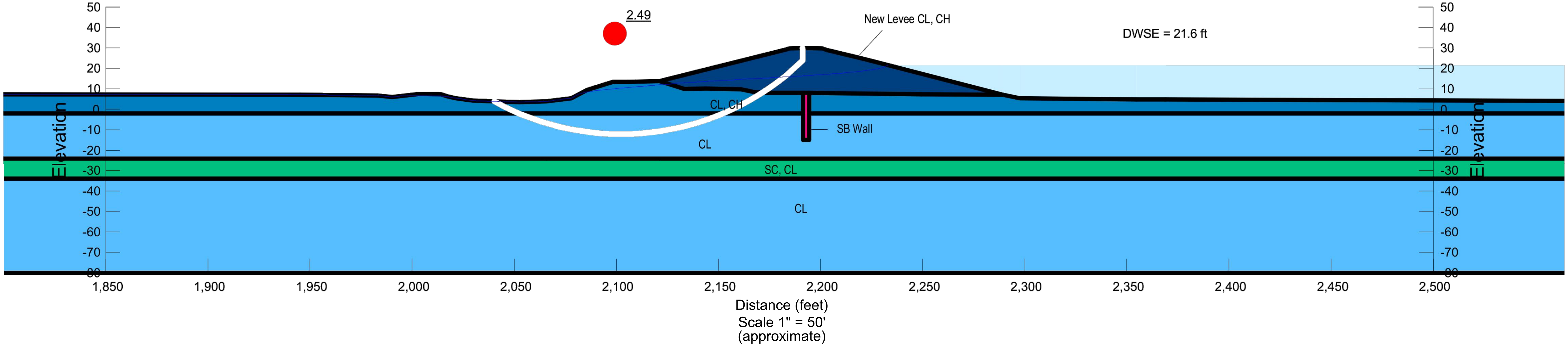
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65%
GBOD REPORT\3195.x LSRP GBOD 65% AppB 109+50.dwg



Material ID and Type, Unit Weight, Effective Cohesion, Effective Friction Angle

			(pcf)	(psf)	(°)
Clayey SAND, Sandy Lean CLAY, SC, CL	Kh=0.057 ft/d	(=2.0x10-5 cm/s)	115	100	32
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	150	32
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	150	30
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	400	22
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	50	0

APPENDIX B-20, STA 109+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Slope Stability Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

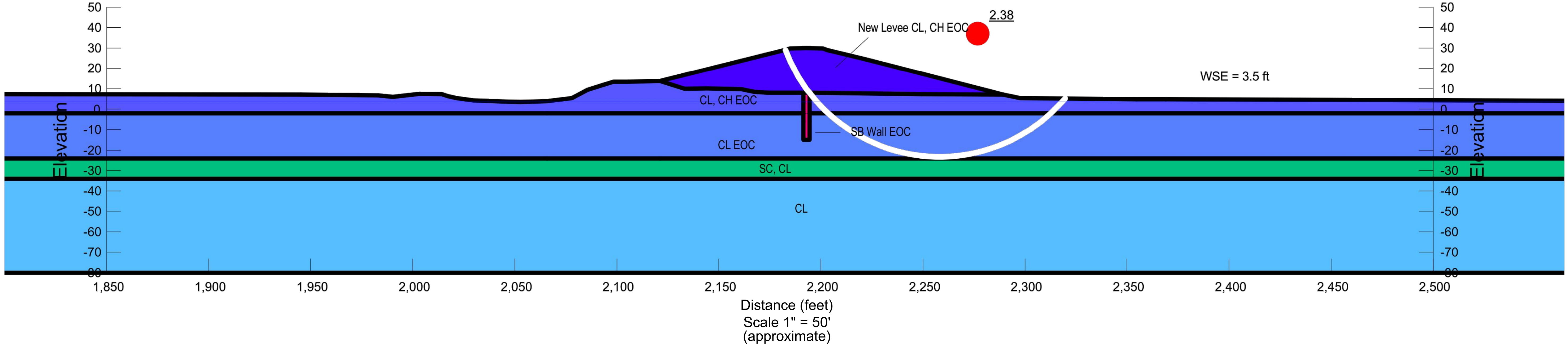
Lookout Slough THRFIP

Ecosystem Investment Partners

Prepared by:
BLACKBURN CONSULTING

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 109+50.dwg



Material ID and Type, Unit Weight, Undrained Shear Strength, Effective Cohesion, Effective Friction Angle

			(pcf)	(psf)	(psf)	(°)
Clayey SAND, Sandy Lean CLAY, SC, CL	Kh=0.057 ft/d	(=2.0x10-5 cm/s)	115		100	32
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115		150	32
Lean CLAY, CL EOC	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	1,000		
Lean CLAY, Fat CLAY, CL, CH EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	1,000		
New Levee, CL, CH EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	1,500		
Slurry Wall, SB, EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	20		

APPENDIX B-21, STA 109+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
End-of-Construction Slope Stability Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

Lookout Slough THRFIP

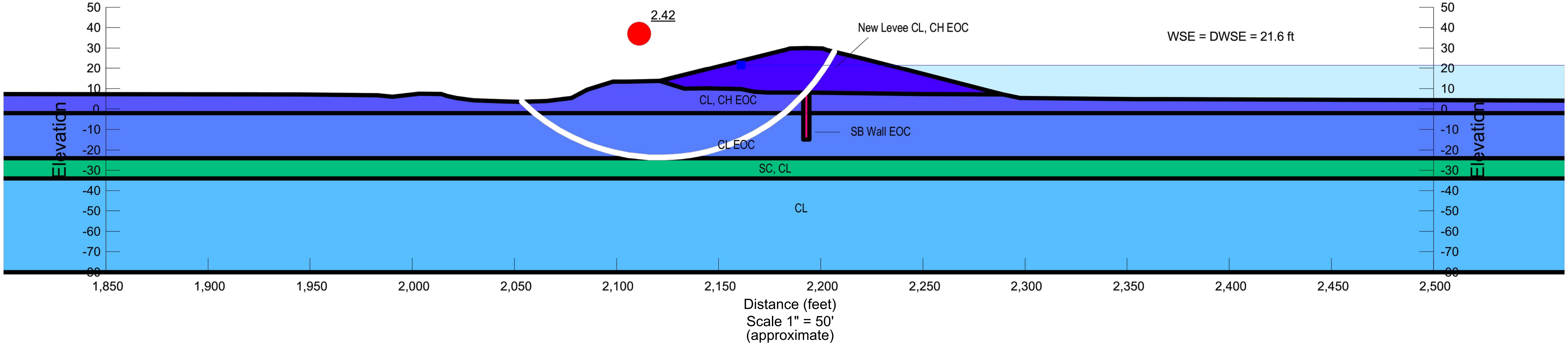
Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 109+50.dwg



Material ID and Type, Unit Weight, Undrained Shear Strength, Effective Cohesion, Effective Friction Angle

Material	Kh		(pcf)	(psf)	(psf)	(°)
Clayey SAND, Sandy Lean CLAY, SC, CL	Kh=0.057 ft/d	(=2.0x10-5 cm/s)	115		100	32
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115		150	32
Lean CLAY, CL EOC	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	1,000		
Lean CLAY, Fat CLAY, CL, CH EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	1,000		
New Levee, CL, CH EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	1,500		
Slurry Wall, SB, EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	20		

APPENDIX B-22, STA 109+50

GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN

End-of-Construction Slope Stability Analysis at DWSE
Setback Levee with Shallow Cutoff Wall
September 2019

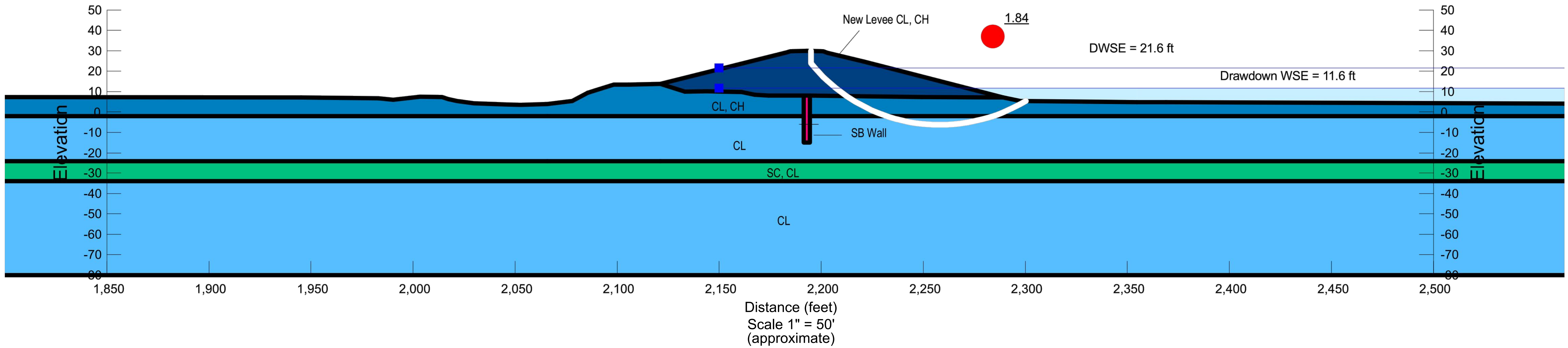
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 109+50.dwg



Material ID and Type, Unit Weight, Effective Cohesion, Effective Friction Angle, Total Cohesion, Total Friction Angle

			(pcf)	(psf)	(°)	(psf)	(°)
Clayey SAND, Sandy Lean CLAY, SC, CL	Kh=0.057 ft/d	(=2.0x10-5 cm/s)	115	100	32	115	16
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	150	32	175	16
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	150	30	175	15
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	400	22	450	13
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	50	0	0	0

APPENDIX B-23, STA 109+50
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
Rapid Drawdown Slope Stability Analysis, 5 ft. Drawdown
Setback Levee with Shallow Cutoff Wall
September 2019

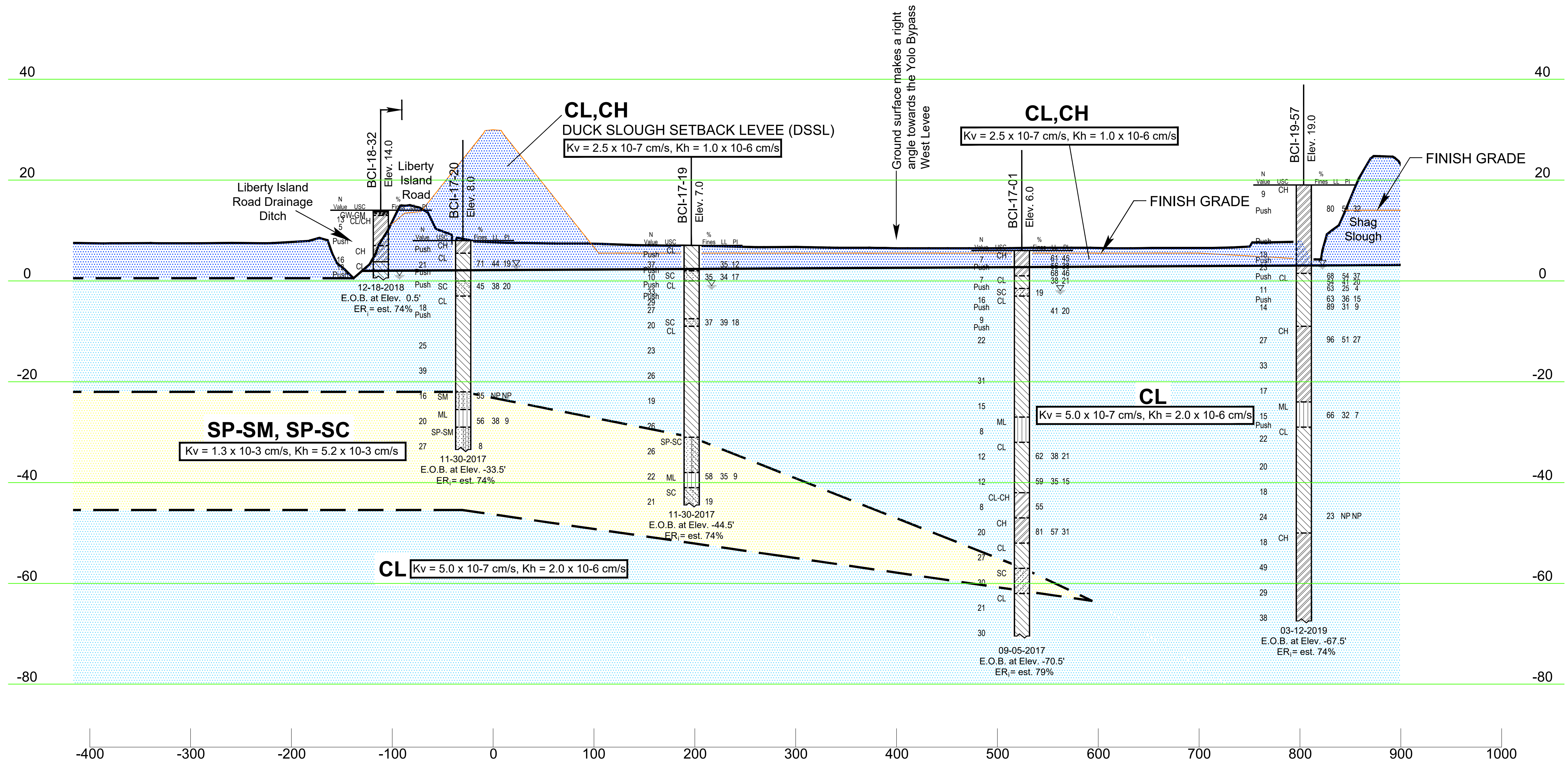
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 109+50.dwg



APPENDIX B-24, STA 148+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
SUBSURFACE PROFILE USED IN ANALYSIS
September 2019

LEGEND

Kv, Kh = - Hydraulic Conductivity Values for Soil Layers

NOTES:
Cross section updated 05-14-19. Levee shifted to centerline of new alignment. Boring logs updated 5-8-19.

SCALE: 1 inch = 100 ft Hor.
1 inch = 20 ft Vert.

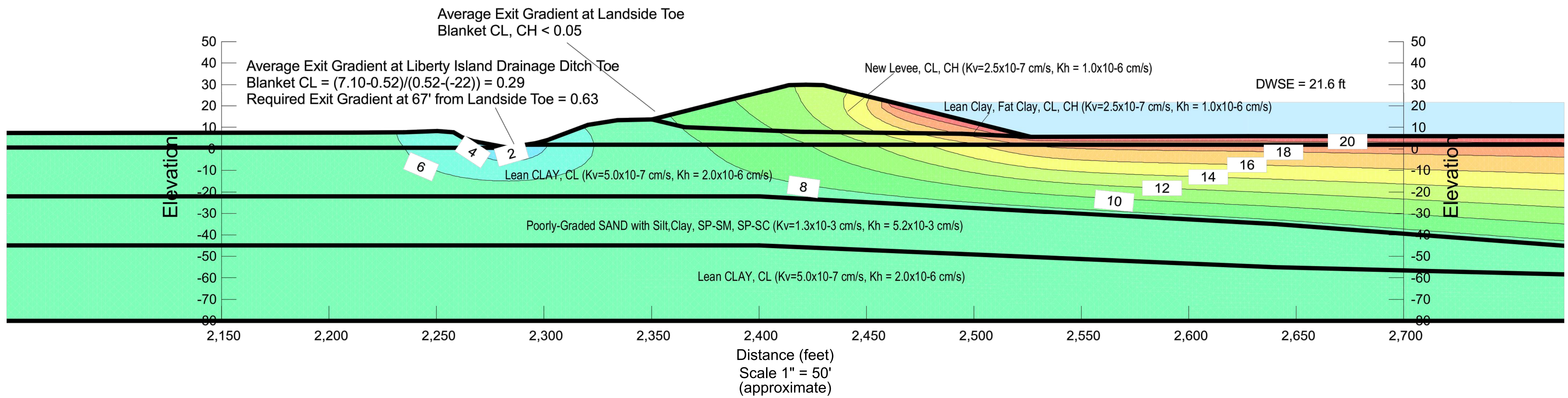
Ecosystem Investment Partners

Lookout Slough THRFIP

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\CROSS SECTIONS NEW 06_20_2019\3195.x LSRP BDR 65% 148+00 AppB.dwg



Material ID and Type, Hydraulic Conductivity (Kh), Anisotropic Ratio (Kv/Kh)

Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	0.25
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
Poorly-graded SAND with Silt, Clay SP-SM, SP-SC	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	0.25

APPENDIX B-25, STA 148+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Seepage Analysis
Setback Levee with No Cutoff Wall
September 2019

Lookout Slough THRFIP

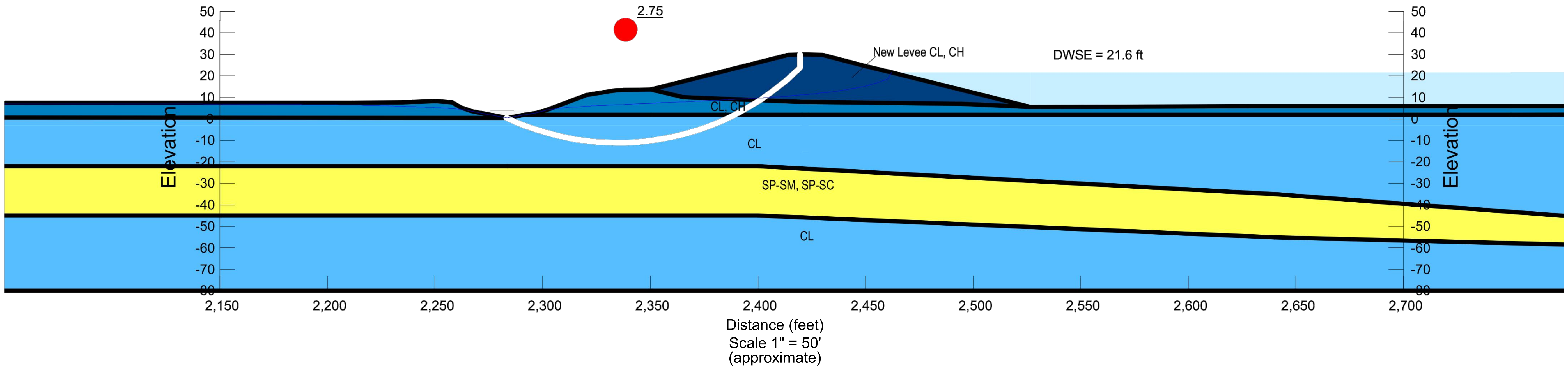
Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65% GBOD REPORT\3195.x LSRP GBOD 65% AppB 148+00.dwg



Material ID and Type, Unit Weight, Effective Cohesion, Effective Friction Angle

			(pcf)	(psf)	(°)
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	150	32
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	150	30
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	400	22
Poorly-graded SAND with Silt, Clay SP-SM, SP-SC	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	120	0	30

APPENDIX B-26, STA 148+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Slope Stability Analysis
Setback Levee with No Cutoff Wall
September 2019

Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65%
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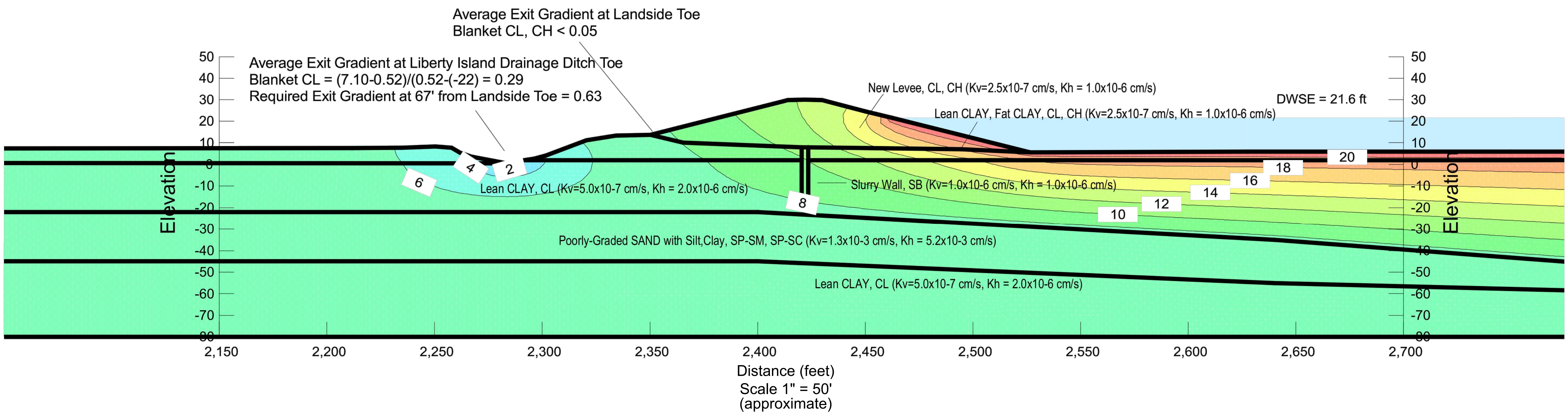

Material ID and Type, Hydraulic Conductivity (Kh), Anisotropic Ratio (Kv/Kh)

	Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	0.25
	Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
	New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	0.25
	Poorly-graded SAND with Silt, Clay SP-SM, SP-SC	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	0.25
	Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	1

APPENDIX B-27, STA 148+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Seepage Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

Lookout Slough THRFIP

Ecosystem Investment Partners

Prepared by:

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65%
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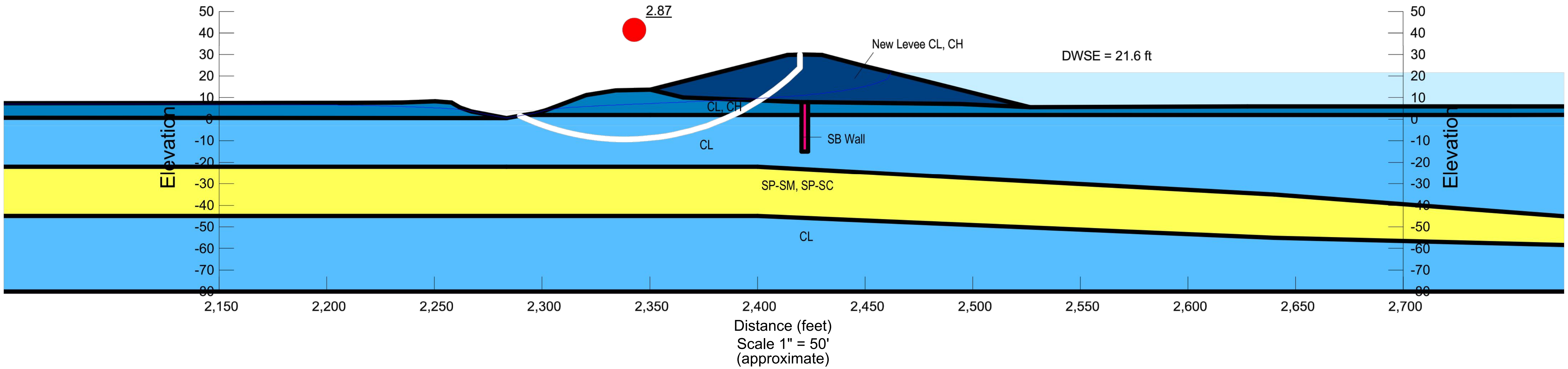


Material ID and Type, Unit Weight, Effective Cohesion, Effective Friction Angle

			(pcf)	(psf)	(°)
Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	150	32
Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	150	30
New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	400	22
Poorly-graded SAND with Silt, Clay SP-SM, SP-SC	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	120	0	30
Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	50	0

APPENDIX B-28, STA 148+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
DWSE Steady-State Slope Stability Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

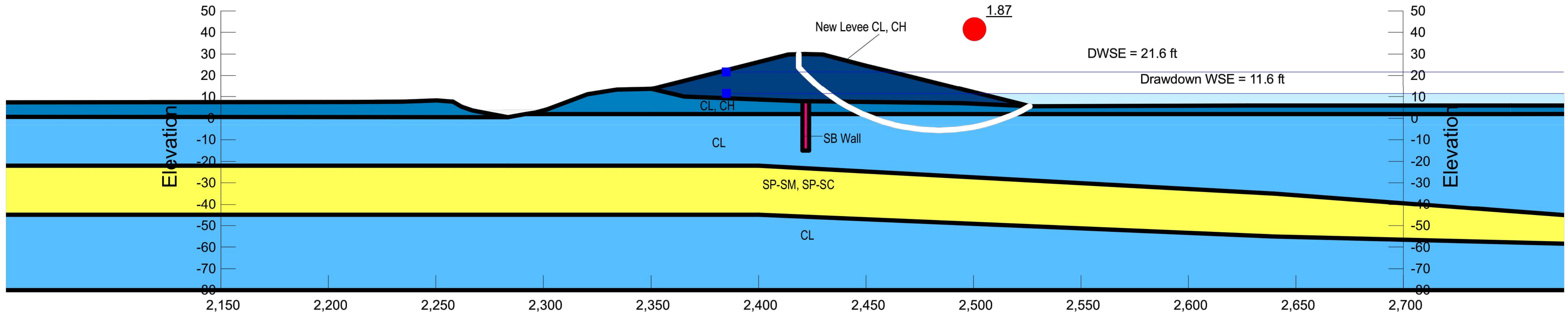
Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65%
GBOD REPORT\3195.x LSRP GBOD 65% AppB 148+00.dwg



Material ID and Type, Unit Weight, Effective Cohesion, Effective Friction Angle, Total Cohesion, Total Friction Angle

Color	Name			Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion R (psf)	Phi R (°)
	Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	150	32	175	16
	Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	150	30	175	15
	New Levee, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	400	22	450	13
	Poorly-graded SAND with Silt, Clay SP-SM, SP-SC	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	120	0	30	0	0
	Slurry Wall, SB	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	50	0	0	0

APPENDIX B-29, STA 148+00
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
Rapid Drawdown Slope Stability Analysis, 10 ft. Drawdown
Setback Levee with Shallow Cutoff Wall
September 2019

Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

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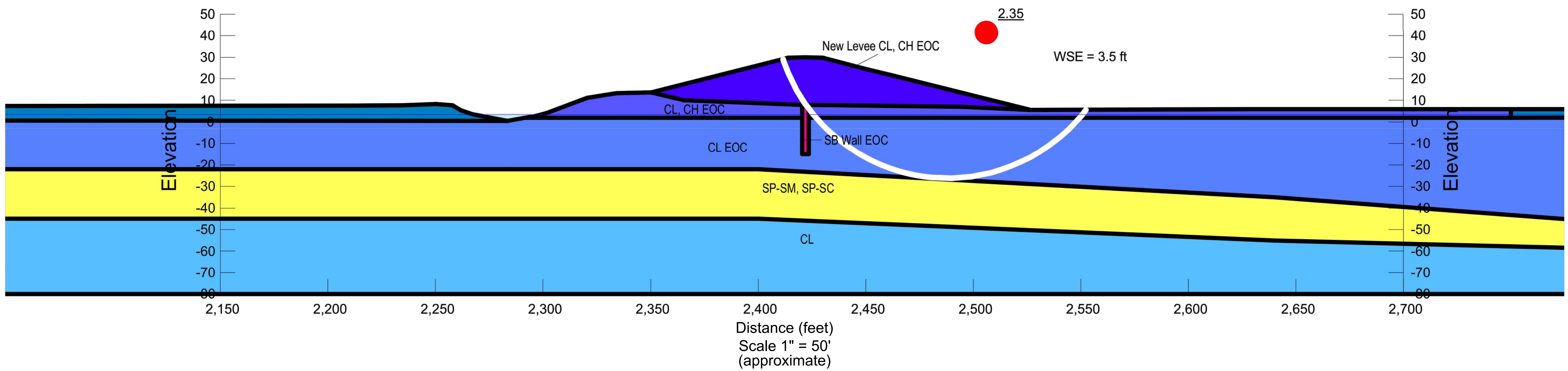

Material ID and Type, Unit Weight, Undrained Shear Strength, Effective Cohesion, Effective Friction Angle

Color	Name			Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)
	Lean CLAY, CL	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115		150	32
	Lean CLAY, CL EOC	Kh=0.0057 ft/day	(=2.0x10-6 cm/s)	115	1,000		
	Lean CLAY, Fat CLAY, CL, CH	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115		150	30
	Lean CLAY, Fat CLAY, CL, CH EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	115	1,000		
	New Levee, CL, CH EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	125	1,500		
	Poorly-graded SAND with Silt, Clay SP-SM, SP-SC	Kh=14.74 ft/day	(=5.2x10-3 cm/s)	120		0	30
	Slurry Wall, SB, EOC	Kh=0.0028 ft/day	(=1.0x10-6 cm/s)	100	20		

APPENDIX B-30, STA 148+00

GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN

End-of-Construction Slope Stability Analysis
Setback Levee with Shallow Cutoff Wall
September 2019

Lookout Slough THRFIP

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\65%
GBOD REPORT\3195.x LSRP GBOD 65% AppB 148+00.dwg

GEOTECHNICAL BASIS OF DESIGN REPORT

65% Design

Lookout Slough THRFIP

Solano County, California

APPENDIX C

Settlement Evaluations

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Lookout Slough THRFIP

PROJECT IDENTIFICATION

Title: Lookout Slough THRFIP
Project Number: 3195.x -
Client: Ecosystem Investment Partners
Designer: David J. Morrell
Station Number:

Description:
Borings BCI-17-02, BCI-17-03, BCI-17-04, BCI-17-05 Soil Profile

Company's information:

Name: Blackburn Consulting
Street: 2491 Boatman Avenue
West Sacramento, CA 95691
Telephone #:
Fax #:
E-Mail:

Original file path and name: Z:\Active ..... Settlement Analysis\(B2-B3-B4-B5) Soil Profile.2ST
Original date and time of creating this file: Fri Nov 03 15:12:26 2017

GEOMETRY: Analysis of a 2D geometry

INPUT DATA – FOUNDATION LAYERS – 2 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	120.00	0.40	
2	125.00	0.40	

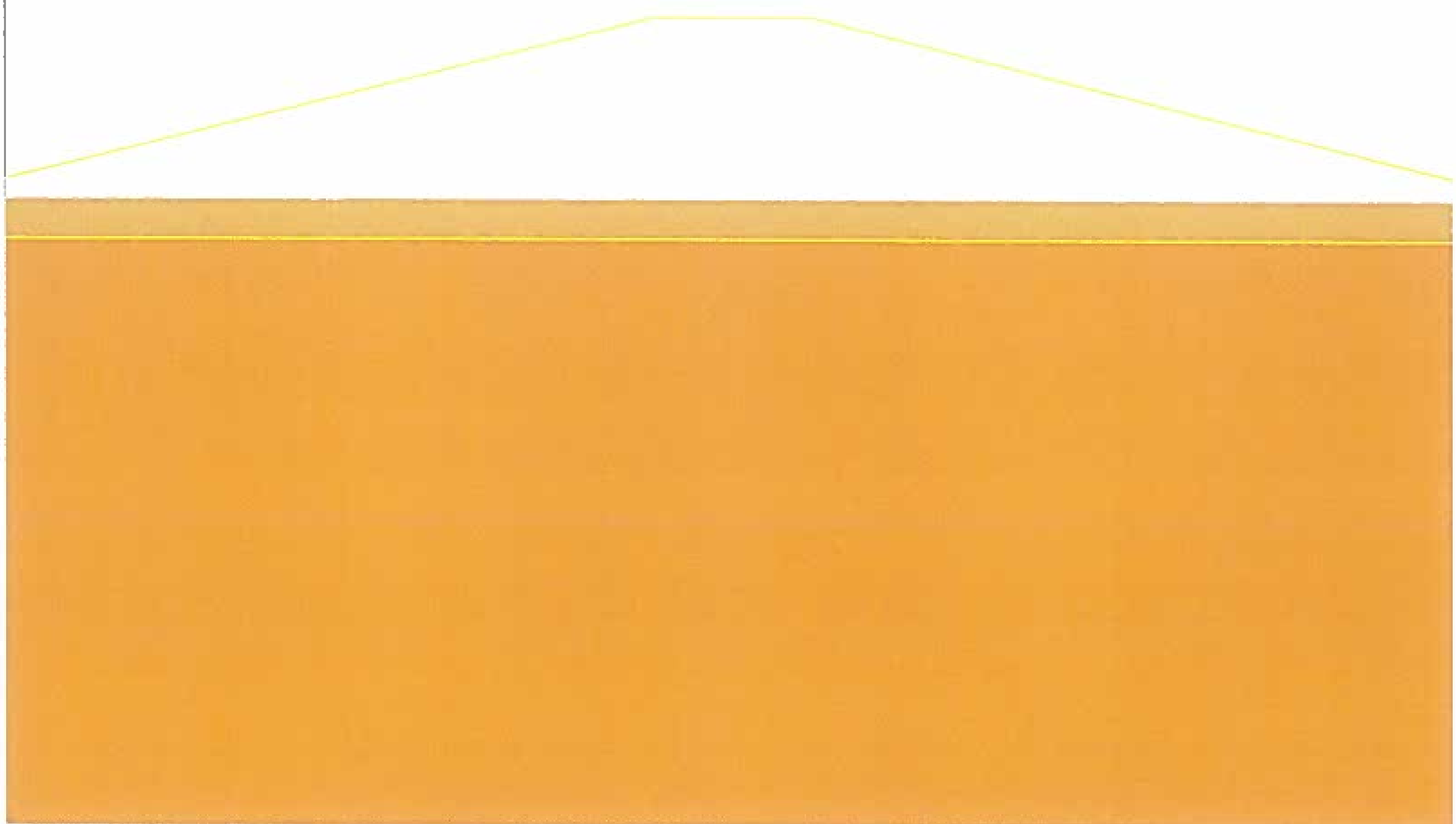
INPUT DATA – EMBANKMENT LAYERS – 1 layers

	Wet Unit Weight, γ [lb/ft³]	Description of Soil
1	125.00	

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	-500.00	95.00
2	-250.00	95.00
3	0.00	95.00
4	250.00	95.00
5	500.00	95.00

DRAWING OF SPECIFIED GEOMETRY



IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	0.00	0.00	1	1000000	0.4000	0.0054	100.00	99.93	0.07
			2	2000000	0.4000	0.0676			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	100.00	
2	1	0.00	95.00	

TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

Embankment footprint width = 204.00 [ft]. Side slope of embakment: 14.04 degrees.

Embank. Soil #	Coordinates (X, Z) of center line : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	0.00	123.00	

Lookout Slough THRFIP

PROJECT IDENTIFICATION

Title:	Lookout Slough THRFIP
Project Number:	3195.x -
Client:	Ecosystem Investment Partners
Designer:	David J. Morrell
Station Number:	

Description:

Borings BCI-17--06 Soil Profile

Company's information:

Name:	Blackburn Consulting
Street:	2491 Boatman Avenue West Sacramento, CA 95691
Telephone #:	
Fax #:	
E-Mail:	

Original file path and name: Z:\Active ..... Analysis\Settlement Analysis\(B6) Soil Profile.2ST
Original date and time of creating this file: Fri Nov 03 15:12:26 2017

GEOMETRY: Analysis of a 2D geometry

INPUT DATA -- FOUNDATION LAYERS -- 7 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	120.00	0.40	
2	120.00	0.30	
3	105.00	0.30	
4	115.00	0.30	
5	115.00	0.30	
6	120.00	0.40	
7	125.00	0.40	

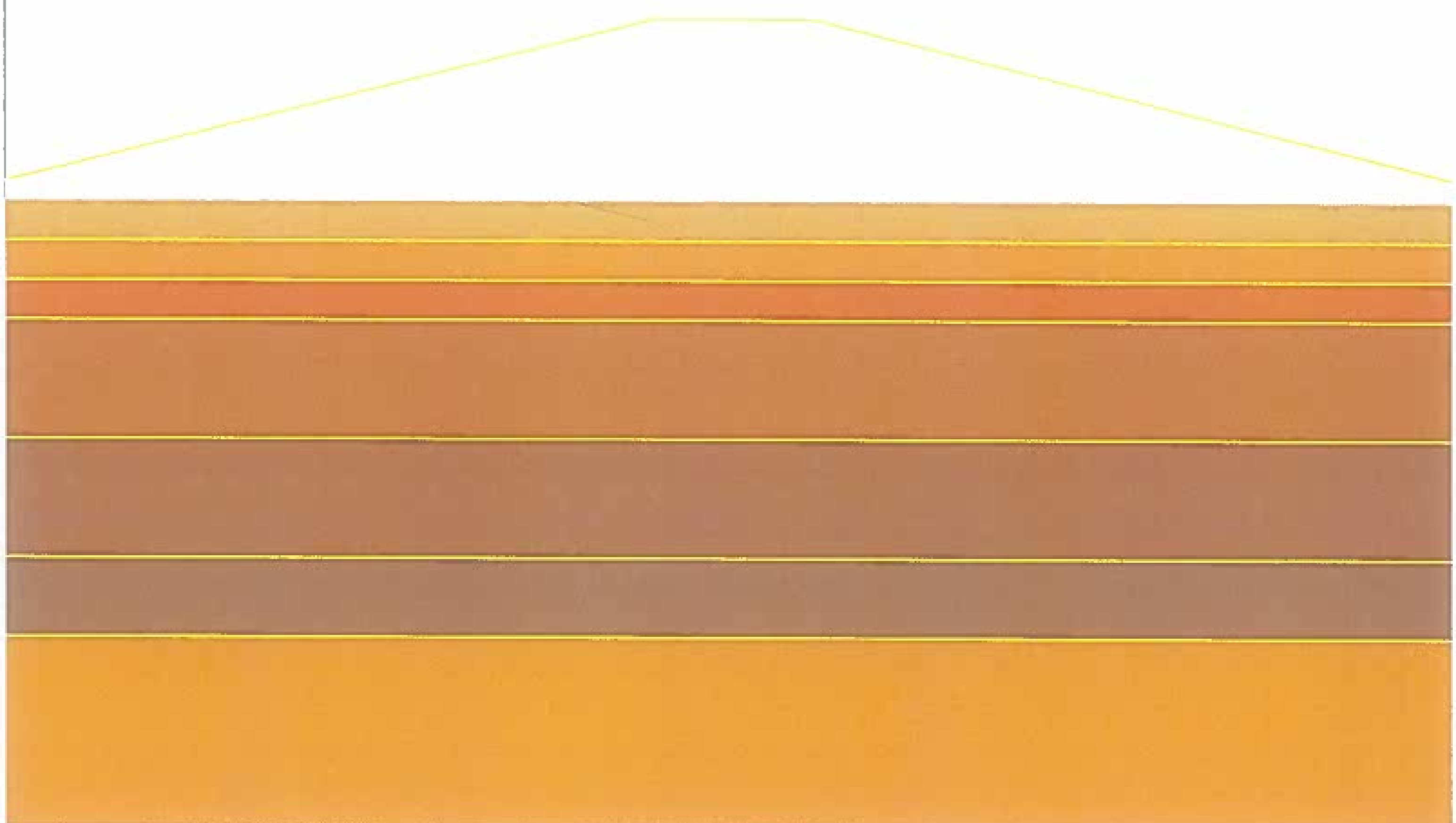
INPUT DATA -- EMBANKMENT LAYERS -- 1 layers

	Wet Unit Weight, γ [lb/ft³]	Description of Soil
1	125.00	

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	-500.00	95.00
2	-250.00	95.00
3	0.00	95.00
4	250.00	95.00
5	500.00	95.00

DRAWING OF SPECIFIED GEOMETRY



IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	0.00	0.00	1	1500000	0.4000	0.0036	100.00	99.57	0.43
			2	250000	0.3000	0.0367			
			3	450000	0.3000	0.0214			
			4	250000	0.3000	0.1144			
			5	150000	0.3000	0.1876			
			6	500000	0.4000	0.0311			
			7	2000000	0.4000	0.0311			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	100.00	
2	1	0.00	95.00	
3	1	0.00	90.00	
4	1	0.00	85.00	
5	1	0.00	70.00	
6	1	0.00	55.00	
7	1	0.00	45.00	

TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

Embankment footprint width = 204.00 [ft]. Side slope of embakment: 14.04 degrees.

Embank. Soil #	Coordinates (X, Z) of center line : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	0.00	123.00	

Lookout Slough THRFIP

PROJECT IDENTIFICATION

Title:	Lookout Slough THRFIP
Project Number:	3195.x -
Client:	Ecosystem Investment Partners
Designer:	David J. Morrell
Station Number:	

Description:

SETTLEMENT AT LEVEE CENTERLINE; 4:1 Levee Side Slopes with Updated Soil Profile

Company's information:

Name:	Blackburn Consulting
Street:	2491 Boatman Avenue West Sacramento, CA 95691
Telephone #:	
Fax #:	
E-Mail:	

Original file path and name: Z:\Active ..... alysis\4 to 1 Side Slopes Updated Soil Profile.2ST
Original date and time of creating this file: Fri Nov 03 15:12:26 2017

GEOMETRY: Analysis of a 2D geometry

INPUT DATA – FOUNDATION LAYERS – 8 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	120.00	0.30	
2	120.00	0.40	
3	118.00	0.40	
4	125.00	0.40	
5	117.00	0.40	
6	120.00	0.40	
7	120.00	0.40	
8	120.00	0.40	

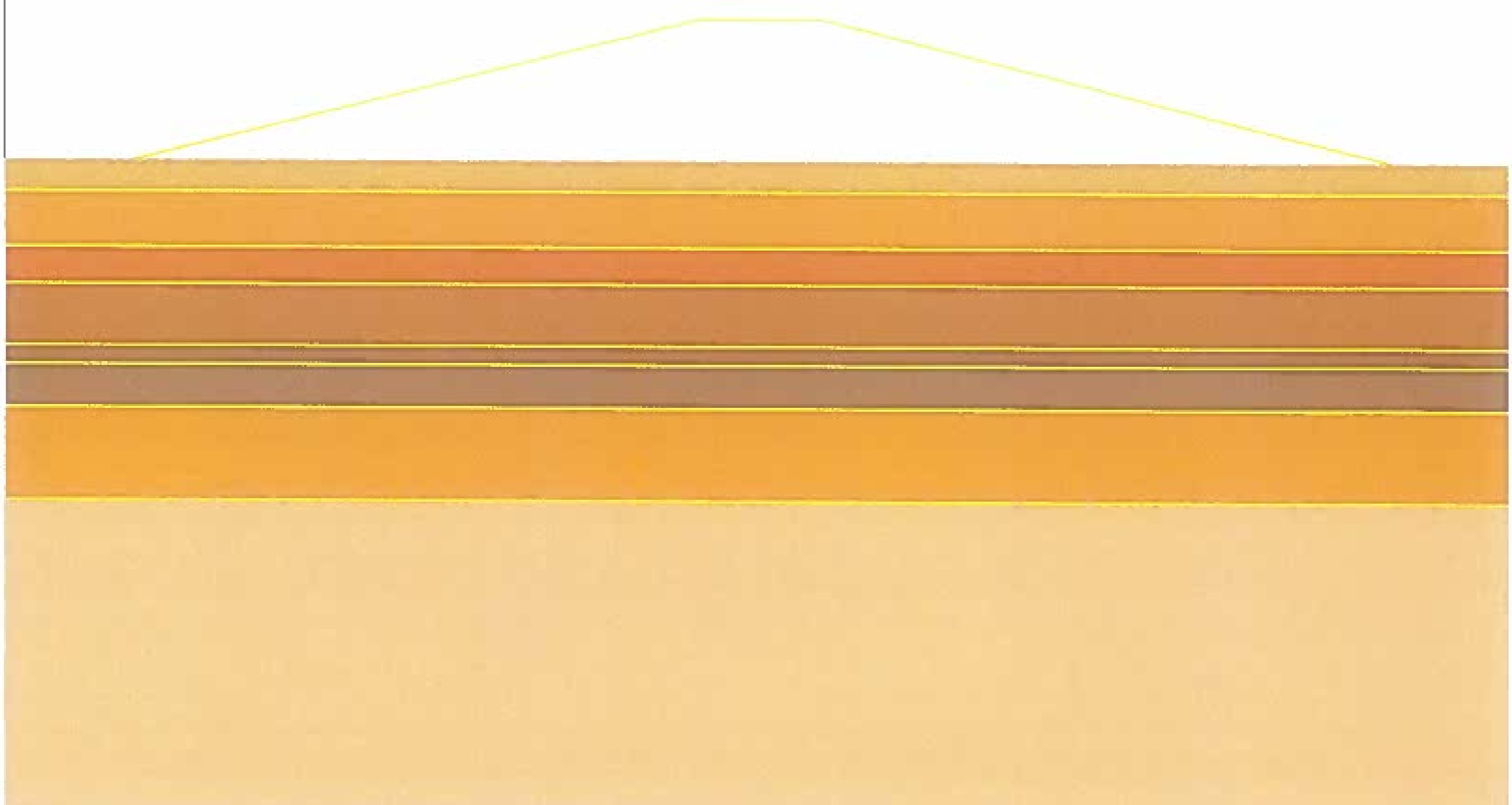
INPUT DATA – EMBANKMENT LAYERS – 1 layers

	Wet Unit Weight, γ [lb/ft³]	Description of Soil
1	125.00	

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	-500.00	95.00
2	-250.00	95.00
3	0.00	95.00
4	250.00	95.00
5	500.00	95.00

DRAWING OF SPECIFIED GEOMETRY



INPUT DATA FOR CONSOLIDATION — $\alpha = 1/2$

Layer #	Underging Consolidation [Yes/No]	OCR = Pc / Po	Cc	Cr	e0	Cv [ft ²/day]	Drains at :
1	No	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	10.00	0.270	0.075	0.810	0.1230	Top
3	Yes	3.00	0.240	0.020	0.780	0.5540	Top
4	No	N/A	N/A	N/A	N/A	N/A	N/A
5	Yes	3.00	0.290	0.060	0.895	0.2180	Bottom
6	Yes	10.00	0.300	0.060	0.895	0.2180	Bottom
7	Yes	4.00	0.300	0.060	0.895	0.2310	Bottom
8	No	N/A	N/A	N/A	N/A	N/A	N/A

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	0.00	0.00	1	500000	0.3000	0.0174	100.00	99.79	0.21
			2	500000	0.4000	0.0231			
			3	310000	0.4000	0.0285			
			4	1000000	0.4000	0.0153			
			5	250000	0.4000	0.0202			
			6	1000000	0.4000	0.0112			
			7	625000	0.4000	0.0370			
			8	1000000	0.4000	0.0622			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	0.00	0.00	100.00	0.50	99.50

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	100.00	
2	1	0.00	95.00	
3	1	0.00	86.00	
4	1	0.00	80.00	
5	1	0.00	70.00	
6	1	0.00	67.00	
7	1	0.00	60.00	
8	1	0.00	45.00	

TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

Embankment footprint width = 204.00 [ft]. Side slope of embakment: 14.04 degrees.

Embank. Soil #	Coordinates (X, Z) of center line : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	0.00	123.00	

GEOTECHNICAL BASIS OF DESIGN REPORT

65% Design

Lookout Slough THRFIP

Solano County, California

APPENDIX D

Seismic Information

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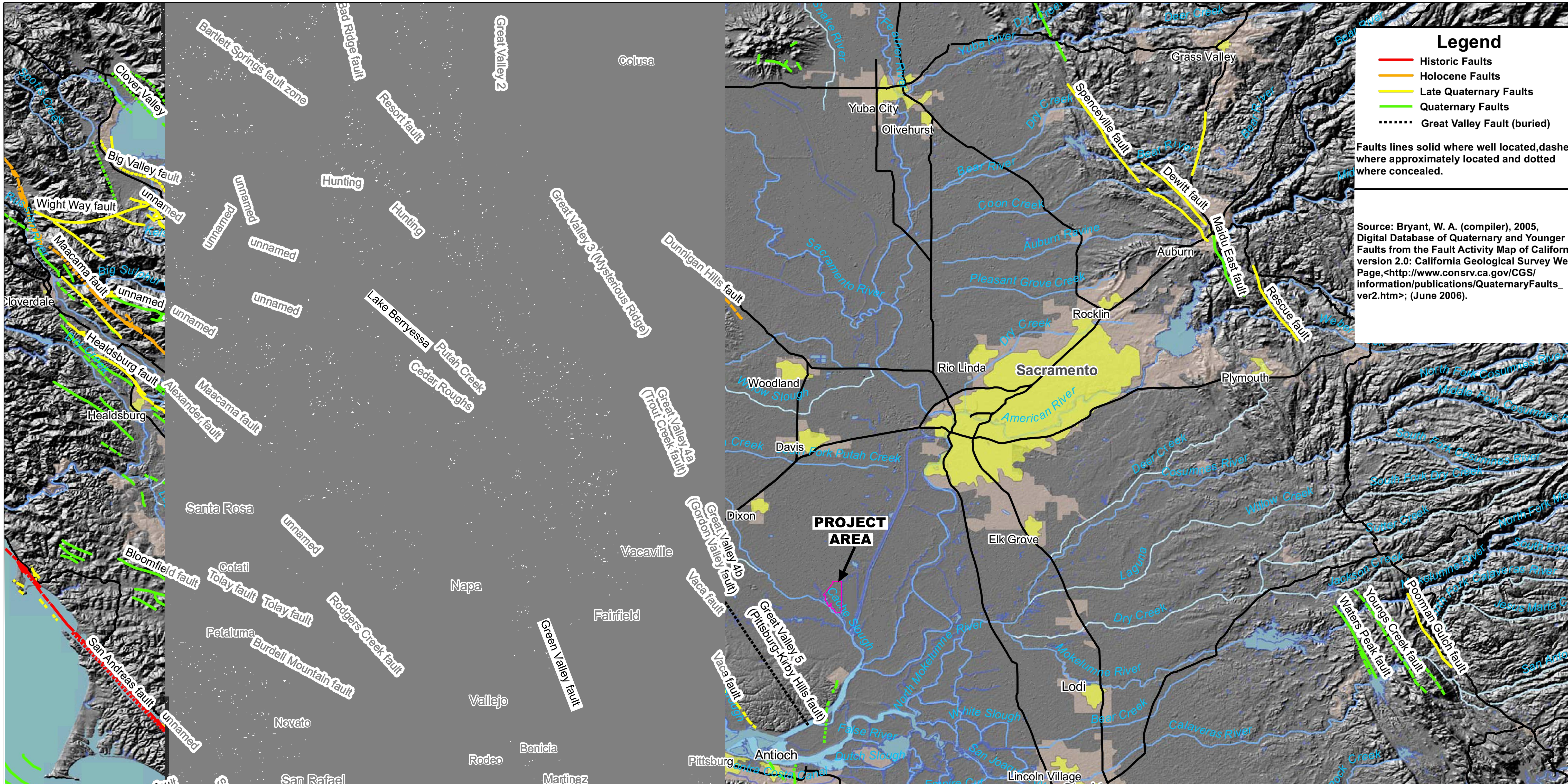

APPENDIX D, REGIONAL FAULT MAP
GEOTECHNICAL BASIS OF DESIGN REPORT - 65% DESIGN
September 2019

Lookout Slough THRFIP

N
W E
S

0 60,000
SCALE: 1" = 60,000'

Ecosystem Investment Partners

Map Prepared Date: 09/01/19
Map Prepared By: M.D.R.
Checked By: N.C.H.
Job No.: 3195.x

Prepared by:
BLACKBURN CONSULTING

Path: \\FS-01\Common\Active Projects\3195.P DWR Lookout Slough Restoration Project\CAD\3195.x LSRP GBOD 65% AppD.dwg

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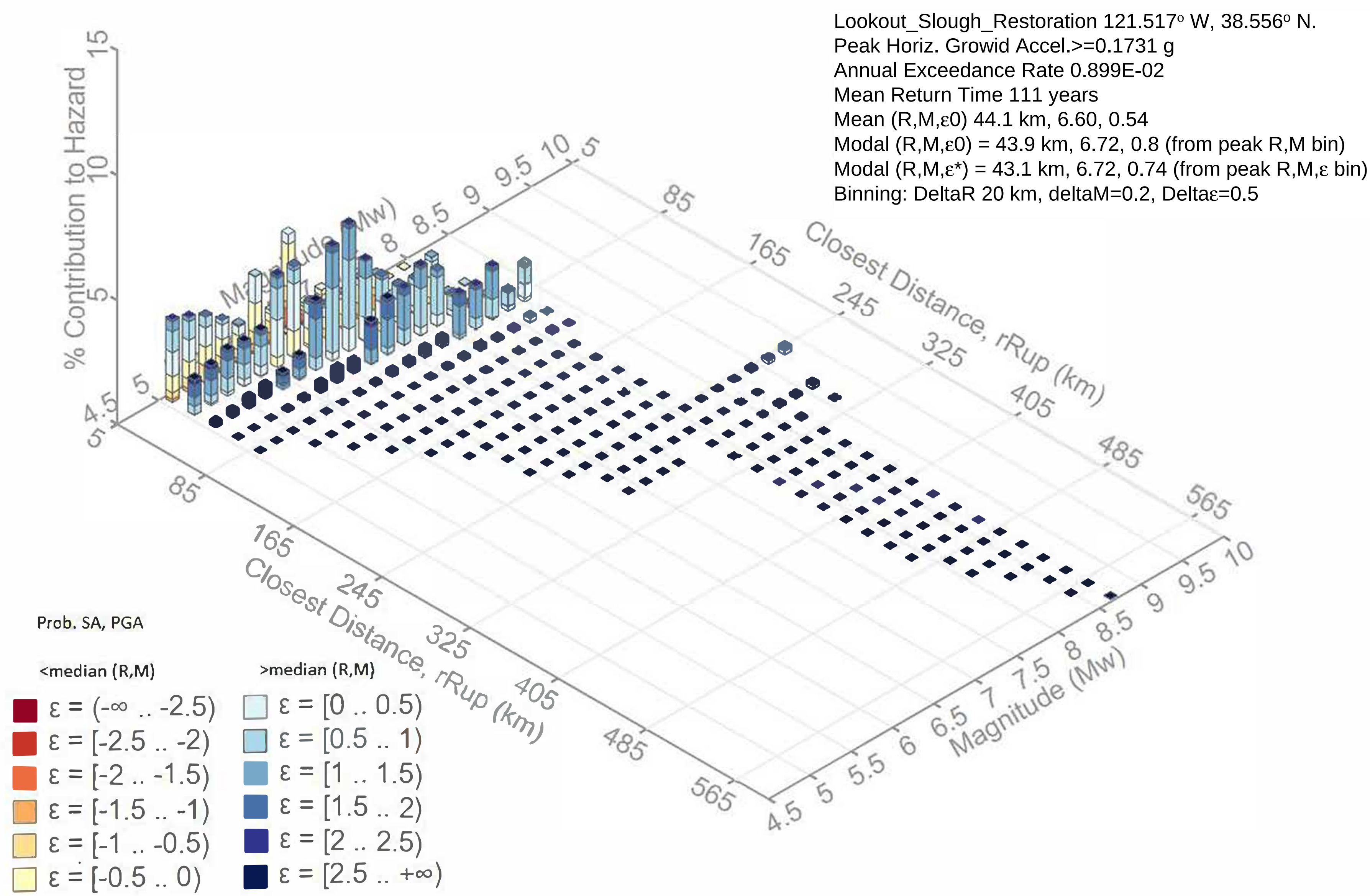
Lookout_Slough_Restoration 121.517º W, 38.556º N.
Peak Horiz. Growid Accel.>=0.1731 g
Annual Exceedance Rate 0.899E-02
Mean Return Time 111 years
Mean (R,M,ε0) 44.1 km, 6.60, 0.54
Modal (R,M,ε0) = 43.9 km, 6.72, 0.8 (from peak R,M bin)
Modal (R,M,ε*) = 43.1 km, 6.72, 0.74 (from peak R,M,ε bin)
Binning: DeltaR 20 km, deltaM=0.2, Deltaε=0.5
% Contribution to Hazard
Closest Distance, rRup (km)
Magnitude (Mw)
Prob. SA, PGA
<median (R,M)
ε = (-∞ .. -2.5)
ε = [-2.5 .. -2)
ε = [-2 .. -1.5)
ε = [-1.5 .. -1)
ε = [-1 .. -0.5)
ε = [-0.5 .. 0)
>median (R,M)
ε = [0 .. 0.5)
ε = [0.5 .. 1)
ε = [1 .. 1.5)
ε = [1.5 .. 2)
ε = [2 .. 2.5)
ε = [2.5 .. +∞)

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Summary -- Liquefaction Analysis

Lookout Slough

BCI-17-05 (Near Station 63+00)

Project: Lookout Slough
BCI No.: 3195.X
Date: 8/13/2018
Location: BCI-17-05 (Near Station 63+00)
By: DWC

Boring Elevation:	6	feet
Ground Water Elevation:	4.3	feet (For Liquefaction Analysis)
Hammer Energy (ER):	79	%
Ground Water Depth:	19.0	feet (At Time of Drilling)
Ground Water Depth:	1.8	feet (For Liquefaction Analysis)
Distance to Fault (R) =	27.6	miles
Moment Magnitude, M_w =	6.7	
PGA =	0.17	g
Liquefaction Factor of Safety (FS):	1.2	

Soil Layer

Granular	
Cohesive	

Input Data										Overburden Stress			Liquefaction Analysis							Strength Parameters	
Sample Number	Sample Depth (feet)	Depth to Bottom of Layer (feet)	Layer Thickness (feet)	Soil Type (USCS)	Total Unit Weight (pcf)	Field N (bpf)	Fines %	PI %	Average Mean Grain Size D50 (mm)	Total Stress (psf)	Effective Stress at Time of Drilling (psf)	Effective Stress for Liquefaction Analysis (psf)	N_{SPT} (bpf)	$(N_1)_{60}$ NCEER $(N_1)_{60}$ Boulanger (bpf)	$(N_1)_{60}$ Cetin (bpf)	$(N_1)_{60CS}$ NCEER (bpf)	$(N_1)_{60CS}$ Boulanger (bpf)	$(N_1)_{60CS}$ Cetin (bpf)	$(N_1)_{60}$ (bpf)	Effective Friction Angle (φ') (degrees)	
1	1.0	5.0	5.0	CH	126	7	90	--	--	126	126	126	7	12	12	12	12	12	18	32	
3	5.0	7.5	2.5	CL	125	14	78	30	--	631	631	428	14	25	23	25	25	23	26	34	
5	8.5	11.5	4.0	CL	125	12	80	--	--	1068	1068	647	12	19	18	19	19	18	19	32	
7	12.5	17.0	5.5	CL	132	11	72	22	--	1575	1575	904	11	14	14	14	14	14	16	31	
8	20.0	23.0	6.0	CL	125	19	75	--	--	2543	2480	1404	19	22	22	22	22	22	23	33	
9	25.0	28.0	5.0	CL	131	19	90	--	--	3179	2805	1728	19	21	21	21	21	21	22	33	
10	30.0	33.0	5.0	CL	130	9	90	--	--	3831	3145	2068	9	9	9	9	9	9	10	30	
11	35.0	38.0	5.0	SM	125	16	33	0	--	4471	3473	2396	16	16	16	24	22	20	17	32	
12	40.0	43.0	5.0	SM	125	15	33	--	--	5096	3786	2709	15	15	14	22	20	18	16	31	
13	45.0	48.0	5.0	SP-SC	125	24	10	--	--	5721	4099	3022	24	23	22	24	24	24	24	34	
14	50.0	53.0	5.0	SP-SC	125	22	10	--	--	6346	4412	3335	22	20	20	21	21	21	21	33	
15	55.0	60.0	7.0	CL	125	22	90	--	--	6971	4725	3648	22	19	19	19	19	19	21	32	
16	60.0	63.0	3.0	CH	125	23	95	37	--	7596	5038	3961	23	20	20	20	20	20	21	32	
17	65.0	68.5	5.5	CL	125	25	90	--	--	8221	5351	4274	25	21	21	21	21	21	22	33	
18	70.0	73.0	4.5	CL	125	14	90	--	--	8846	5664	4587	14	11	11	11	11	11	12	31	
19	75.0	76.5	3.5	CL	125	27	90	--	--	9471	5977	4900	27	21	21	21	21	21	23	33	

	Liquefaction Factor of Safety: Factor of Safety (FS)						Residual Shear Strength (Sr)										
Sample Number	NCEES (FS)	FS ≤ 1.2	Cetin (FS)	FS ≤ 1.2	Boulanger (FS)	FS ≤ 1.2	$(N_1)_{60CS\text{-}Sr}$ (bpf)	Idriss and Boulanger 2008 [1] Case 1 (psf)	Idriss and Boulanger 2008 [1] Case 2 (psf)	Idriss and Boulanger 2007 [2] (psf)	Seed & Harder 1990 w/ NCEER FS [3] Lower Bound (psf)	Seed & Harder 1990 w/ NCEER FS [3] Upper Bound (psf)	Seed & Harder 1990 w/ NCEER FS [3] Average (psf)	Seed & Harder 1990 w/ NCEER FS [3] Bound plus 1/3 (psf)	Idriss 1998 (psf)	Olson & Stark 2002 [4] (psf)	Sr. Kramer and Wang 2007 (psf)
1	unsaturated	--	unsaturated	--	unsaturated	--	12	--	--	--	--	--	--	--	--	--	--
3	NL	--	NL	--	NL	--	25	--	--	--	--	--	--	--	--	--	--
5	12.12	--	11.39	--	11.31	--	19	404	148	977	1310	1870	1590	1496	992	NA	415
7	NL	--	NL	--	NL	--	14	--	--	--	--	--	--	--	--	--	--
8	8.29	--	7.30	--	8.06	--	22	912	432	1723	--	--	--	--	1674	NA	870
9	6.71	--	5.77	--	6.69	--	21	1122	470	1364	--	--	--	--	1358	NA	841
10	2.67	--	2.25	--	2.73	--	9	379	251	225	360	810	585	509	219	205	267
11	1.90	--	1.17	x	1.66	--	24	1497	378	2682	750	1270	1010	923	2429	NA	634
12	1.68	--	1.01	x	1.52	--	22	950	385	1837	560	1050	805	723	1770	NA	565
13	1.87	--	1.37	--	1.96	--	24	2039	695	2571	1310	1870	1590	1496	2348	NA	1426
14	1.62	--	1.17	x	1.69	--	21	2166	628	1550	1090	1630	1360	1269	1524	NA	1129
15	4.59	--	3.26	--	4.55	--	19	2280	887	1099	--	--	--	--	1110	NA	1104
16	NL	--	NL	--	NL	--	20	--	--	--	--	--	--	--	--	--	--
17	4.99	--	2.78	--	4.75	--	21	2776	1167	1378	--	--	--	--	1370	NA	1395
18	2.77	--	1.46	--	2.56	--	11	1385	631	307	560	1050	805	723	303	525	520
19	5.35	--	2.64	--	4.77	--	21	3182	1396	1493	--	--	--	--	1473	NA	1586

[1] Idriss, I. M. and Boulanger, R. W., "Soil Liquefaction During Earthquakes," Earthquake Engineering Research Institute, pages 140-142 and 152-158, 2008.

[2] Idriss, I. M. and Boulanger, R. W., "Residual Shear Strength of Liquified Soils," Proceedings, 27th USSD Annual Meeting and Conference, Modernization and Optimization of Existing Dams and Reservoirs, Philadelphia, Pennsylvania, March 5-9, 2007, where, Sr = exp[((N1)60CS-Sr/5.1 - ((N1)60CS-Sr/16.5)2 + ((N1)60CS-Sr/21.4)3 + 0.8]/0.0479 (psf)

[3] Seed, R.B. and Harder, L.F., "SPT-based Analysis of Cyclic Pore Pressure Generation and Undrained Residual Strength", Proceedings of the H.B. Seed Memorial Symposium, BiTech Publishers Ltd., Vancouver,

[4] Olson and Stark (2002), where, $S_u(LIQ) = \sigma'_{v0}[0.03+(0.0075(N_1)_{60})]$; valid for $(N_1)_{60} \le 12$

Summary -- Liquefaction Analysis

Lookout Slough

BCI-17-06 (Near Station 42+00)

Project: Lookout Slough
BCI No.: 3195.X
Date: 8/13/2018
Location: BCI-17-06 (Near Station 42+00)
By: DWC

Boring Elevation:	6	feet
Ground Water Elevation:	4.3	feet (For Liquefaction Analysis)
Hammer Energy (ER):	79	%
Ground Water Depth:	3.0	feet (At Time of Drilling)
Ground Water Depth:	1.8	feet (For Liquefaction Analysis)
Distance to Fault (R) =	27.6	miles
Moment Magnitude, M_w =	6.7	
PGA =	0.17	g
Liquefaction Factor of Safety (FS):	1.2	

Soil Layer	
Granular	(yellow)
Cohesive	(green)

Input Data										Overburden Stress		
Sample Number	Sample Depth (feet)	Depth to Bottom of Layer (feet)	Layer Thickness (feet)	Soil Type (USCS)	Total Unit Weight (pcf)	Field N (bpf)	Fines %	PI %	Average Mean Grain Size D50 (mm)	Total Stress (psf)	Effective Stress at Time of Drilling (psf)	Effective Stress for Liquefaction Analysis (psf)
1	1.0	5.0	5.0	CH	124	7	80	50	--	124	124	124
3	5.5	7.5	2.5	CL	125	12	65	--	--	681	525	447
5	9.5	11.0	3.5	SP-SM	128	14	6	0	--	1187	781	703
6	11.0	14.0	3.0	SP-SM	128	30	6	--	--	1378	879	801
7	15.0	19.0	5.0	GW-GC	146	9	10	--	--	1908	1160	1082
8	20.0	23.0	4.0	GW-GC	150	13	10	--	--	2644	1583	1505
9	25.0	28.0	5.0	ML	125	12	60	--	--	3344	1971	1893
10	30.0	33.0	5.0	SP-SC	138	30	12	--	--	3994	2309	2231
11	35.0	38.0	5.0	CL	125	15	80	--	--	4658	2661	2583
12	40.0	43.0	5.0	ML	125	9	80	--	--	5283	2974	2896
13	45.0	47.5	4.5	CH	125	12	98	36	--	5908	3287	3209
14	50.0	53.0	5.5	CH	125	20	98	35	--	6533	3600	3522
15	55.0	59.0	6.0	CL	127	15	60	--	--	7161	3916	3838
16	60.0	62.5	3.5	CL	125	30	98	--	--	7793	4236	4158
17	65.0	67.5	5.0	CL	125	28	98	--	--	8418	4549	4471
18	70.0	72.5	5.0	CL	125	21	98	--	--	9043	4862	4784
19	75.0	76.5	4.0	CL	125	21	98	--	--	9668	5175	5097

	Liquefaction Analysis						Strength Parameter		Liquefaction Factor of Safety					
Sample Number	N_{SPT} (bpf)	$(N_1)_{60}$ NCEER $(N_1)_{60}$ Boulanger (bpf)	$(N_1)_{60}$ Cetin (bpf)	$(N_1)_{60CS}$ NCEER (bpf)	$(N_1)_{60CS}$ Boulanger (bpf)	$(N_1)_{60CS}$ Cetin (bpf)	$(N_1)_{60}$ (bpf)	Effective Friction Angle (φ') (degrees)	NCEES (FS)	FS ≤ 1.2	Cetin (FS)	FS ≤ 1.2	Boulanger (FS)	FS ≤ 1.2
1	7	12	12	12	12	12	18	32	unsaturated	--	unsaturated	--	unsaturated	--
3	12	21	20	21	21	20	23	33	18.86	--	18.09	--	17.48	--
5	14	25	23	26	26	24	24	34	NL	--	NL	--	NL	--
6	30	52	48	52	52	49	50	43	NL	--	NL	--	14.63	--
7	9	14	14	15	15	15	14	31	1.10	x	1.03	x	1.10	x
8	13	19	18	20	20	20	18	32	1.53	--	1.32	--	1.48	--
9	12	16	16	16	16	16	16	31	4.03	--	3.47	--	4.02	--
10	30	36	37	39	38	39	38	36	NL	--	NL	--	14.35	--
11	15	18	17	18	18	17	18	32	3.83	--	3.09	--	3.91	--
12	9	10	10	10	10	10	10	30	2.12	--	1.64	--	2.16	--
13	12	13	12	13	13	12	13	31	NL	--	NL	--	NL	--
14	20	20	20	20	20	20	21	33	NL	--	NL	--	NL	--
15	15	15	14	15	15	14	15	31	3.05	--	2.18	--	3.02	--
16	30	28	28	28	28	28	30	35	5.94	--	4.10	--	5.78	--
17	28	25	25	25	25	25	27	34	5.45	--	3.05	--	5.19	--
18	21	18	18	18	18	18	19	32	4.06	--	2.14	--	3.76	--
19	21	18	18	18	18	18	19	32	4.08	--	2.01	--	3.64	--

	Residual Shear Strength (Sr)										
Sample Number	$(N_1)_{60CS-Sr}$ (bpf)	Idriss and Boulanger 2008 [1] Case 1 (psf)	Idriss and Boulanger 2008 [1] Case 2 (psf)	Idriss and Boulanger 2007 [2] (psf)	Seed & Harder 1990 w/ NCEER FS [3] Lower Bound (psf)	Seed & Harder 1990 w/ NCEER FS [3] Upper Bound (psf)	Seed & Harder 1990 w/ NCEER FS [3] Average (psf)	Seed & Harder 1990 w/ NCEER FS [3] Bound plus 1/3 (psf)	Idriss 1998 (psf)	Olson & Stark 2002 [4] (psf)	Sr. Kramer and Wang 2007 (psf)
1	12	--	--	--	--	--	--	--	--	--	--
3	21	291	116	1493	--	--	--	--	1473	NA	457
5	26	--	--	--	--	--	--	--	--	--	--
6	52	--	--	--	--	--	--	--	--	--	--
7	15	214	134	524	360	810	585	509	531	NA	307
8	20	941	260	1236	850	1390	1120	1029	1240	NA	640
9	16	1137	321	592	850	1390	1120	1029	601	NA	507
10	39	--	--	--	--	--	--	--	--	--	--
11	18	1614	545	821	1190	1740	1465	1373	836	NA	750
12	10	627	368	253	360	810	585	509	247	304	348
13	13	--	--	--	--	--	--	--	--	--	--
14	20	--	--	--	--	--	--	--	--	--	--
15	15	2306	609	504	750	1270	1010	923	510	NA	668
16	28	2911	2693	5827	--	--	--	--	4349	NA	3015
17	25	3016	1971	3193	--	--	--	--	2790	NA	2323
18	18	2989	1059	909	1310	1870	1590	1496	925	NA	1139
19	18	3185	1081	830	1190	1740	1465	1373	845	NA	1112

[1] Idriss, I. M. and Boulanger, R. W., "Soil Liquefaction During Earthquakes," Earthquake Engineering Research Institute, pages 140-142 and 152-158, 2008.

[2] Idriss, I. M. and Boulanger, R. W., "Residual Shear Strength of Liquified Soils," Proceedings, 27th USSD Annual Meeting and Conference, Modernization and Optimization of Existing Dams and Reservoirs, Philadelphia, Pennsylvania, March 5-9, 2007, where, Sr = exp[((N1)60CS-Sr/5.1 - ((N1)60CS-Sr/16.5)2 + ((N1)60CS-Sr/21.4)3 + 0.8]/0.0479 (psf)

[3] Residual Strength", Proceedings of the H.B. Seed Memorial Symposium, BiTech Publishers Ltd., Vancouver, B.C., Canada, Vol. 2, pp. 351-376, 1990.

[4] Olson and Stark (2002), where, $S_u(LIQ) = \sigma'_{v0}[0.03+(0.0075(N_1)_{60})]$; valid for $(N_1)_{60} \leq 12$

Project: Lookout Slough
BCI No.: 3195.X
Date: 8/13/2018
Location: BCI-17-11 (Near Station 42+20)
By: DWC

Soil Layer	
Granular	
Cohesive	

Boring Elevation:	6	feet
Ground Water Elevation:	4.3	feet (For Liquefaction Analysis)
Hammer Energy (ER):	74	%
Ground Water Depth:	6.5	feet (At Time of Drilling)
Ground Water Depth:	1.8	feet (For Liquefaction Analysis)
Distance to Fault (R) =	27.6	miles
Moment Magnitude, M_w =	6.7	
PGA =	0.17	g
Liquefaction Factor of Safety (FS):	1.2	

	Input Data										Overburden Stress			Liquefaction Analysis							Strength Parameters
Sample Number	Sample Depth (feet)	Depth to Bottom of Layer (feet)	Layer Thickness (feet)	Soil Type (USCS)	Total Unit Weight (pcf)	Field N (bpf)	Fines %	PI %	Average Mean Grain Size D50 (mm)	Total Stress (psf)	Effective Stress at Time of Drilling (psf)	Effective Stress for Liquefaction Analysis (psf)	N_{SPT} (bpf)	$(N_1)_{60}$ NCEER $(N_1)_{60}$ Boulanger (bpf)	$(N_1)_{60}$ Cetin (bpf)	$(N_1)_{60CS}$ NCEER (bpf)	$(N_1)_{60CS}$ Boulanger (bpf)	$(N_1)_{60CS}$ Cetin (bpf)	$(N_1)_{60}$ (bpf)	Effective Friction Angle (φ') (degrees)
2	3.0	5.0	5.0	CL	125	14	90	--	--	375	375	297	14	23	22	23	23	22	27	34
4	5.5	7.5	2.5	SC	119	62	21	15	--	685	685	451	62	102	96	115	107	105	104	43
5	7.5	9.0	1.5	SC	120	69	21	--	--	923	861	564	69	112	105	126	117	115	109	43
6	9.0	10.5	1.5	SM	124	35	50	10	--	1103	947	651	35	52	48	52	52	48	54	43
7	10.5	12.0	1.5	SM	124	60	40	--	--	1288	1039	742	60	90	80	113	95	93	90	43
8	12.0	13.5	1.5	SM	126	36	29	--	--	1474	1131	835	36	52	49	64	57	56	53	43
9	13.5	18.5	5.0	CL	125	23	80	--	--	1663	1226	930	23	32	32	32	32	32	33	36
10	20.0	23.0	4.5	SM	125	13	46	0	--	2475	1633	1337	13	17	17	26	23	21	17	32
11	25.0	28.0	5.0	ML	125	18	60	--	--	3101	1946	1650	18	22	22	22	22	22	22	33
12	30.0	31.0	3.0	CL	120	36	90	--	--	3716	2249	1953	36	41	42	41	41	42	43	37
13	35.0	40.0	9.0	SW-SM	125	26	8	--	--	4336	2557	2261	26	29	28	30	30	30	29	35
14	40.0	41.5	1.5	SM	125	14	20	--	--	4961	2870	2574	14	15	14	20	19	17	15	31

	Liquefaction Factor of Safety						Residual Shear Strength (Sr)										
	Factor of Safety (FS)							Idriss and Boulanger 2008 [1]		Idriss and Boulanger 2007 [2]	Seed & Harder 1990 w/ NCEER FS [3]				Idriss 1998	Olson & Stark 2002 [4]	Sr. Kramer and Wang 2007 (psf)
Sample Number	NCEES (FS)	FS ≤ 1.2	Cetin (FS)	FS ≤ 1.2	Boulanger (FS)	FS ≤ 1.2	$(N_1)_{60CS-Sr}$ (bpf)	Case 1 (psf)	Case 2 (psf)	(psf)	Lower Bound (psf)	Upper Bound (psf)	Average (psf)	Bound plus 1/3 (psf)	(psf)	(psf)	(psf)
2	37.23	--	36.32	--	34.34	--	23	200	103	2140	--	--	--	--	2017	NA	470
4	NL	--	NL	--	NL	--	115	--	--	--	--	--	--	--	--	--	--
5	NL	--	NL	--	15.11	--	126	--	--	--	--	--	--	--	--	--	--
6	32.10	--	30.07	--	30.00	--	52	607	607	80915248	--	--	--	--	192963	NA	15072
7	NL	--	NL	--	14.46	--	113	--	--	--	--	--	--	--	--	--	--
8	NL	--	NL	--	14.33	--	64	--	--	--	--	--	--	--	--	--	--
9	14.14	--	12.89	--	13.41	--	32	675	675	14874	--	--	--	--	7935	NA	2039
10	2.07	--	1.36	--	1.74	--	26	835	224	3663	850	1390	1120	1029	3102	NA	513
11	6.10	--	5.23	--	6.08	--	22	1072	463	1736	--	--	--	--	1684	NA	950
12	10.32	--	8.66	--	10.56	--	41	1472	1472	327380	--	--	--	--	34762	NA	8172
13	3.09	--	2.41	--	3.20	--	30	1583	886	9218	--	--	--	--	5910	NA	2459
14	1.43	--	0.92	x	1.42	--	20	687	345	1144	460	940	700	619	1152	NA	553

[1] Idriss, I. M. and Boulanger, R. W., "Soil Liquefaction During Earthquakes," Earthquake Engineering Research Institute, pages 140-142 and 152-158, 2008.

[2] Idriss, I. M. and Boulanger, R. W., "Residual Shear Strength of Liquified Soils," Proceedings, 27th USSD Annual Meeting and Conference, Modernization and Optimization of Existing Dams and Reservoirs, Philadelphia, Pennsylvania, March 5-9, 2007, where, Sr = exp[((N1)60CS-Sr/5.1 - ((N1)60CS-Sr/16.5)2 + ((N1)60CS-Sr/21.4)3 + 0.8]/0.0479 (psf)

[3] Residual Strength", Proceedings of the H.B. Seed Memorial Symposium, BiTech Publishers Ltd., Vancouver, B.C., Canada, Vol. 2, pp. 351-376, 1990.

[4] Olson and Stark (2002), where, $S_u(LIQ) = \sigma'_{v0}[0.03+(0.0075(N_1)_{60})]$; valid for $(N_1)_{60} \le 12$

Summary -- Liquefaction Analysis

Lookout Slough

BCI-17-12 (Near Station 42+00)

Project: Lookout Slough
BCI No.: 3195.X
Date: 8/13/2018
Location: BCI-17-12 (Near Station 42+00)
By: DWC

Boring Elevation:	6	feet
Ground Water Elevation:	4.3	feet (For Liquefaction Analysis)
Hammer Energy (ER):	74	%
Ground Water Depth:	5.5	feet (At Time of Drilling)
Ground Water Depth:	1.8	feet (For Liquefaction Analysis)
Distance to Fault (R) =	27.6	miles
Moment Magnitude, M_w =	6.7	
PGA =	0.17	g
Liquefaction Factor of Safety (FS):	1.2	

Soil Layer	
Granular	
Cohesive	

Input Data										Overburden Stress			Liquefaction Analysis						Strength Parameter	
Sample Number	Sample Depth (feet)	Depth to Bottom of Layer (feet)	Layer Thickness (feet)	Soil Type (USCS)	Total Unit Weight (pcf)	Field N (bpf)	Fines %	PI %	Average Mean Grain Size D50 (mm)	Total Stress (psf)	Effective Stress at Time of Drilling (psf)	Effective Stress for Liquefaction Analysis (psf)	N_{SPT} (bpf)	$(N_1)_{60}$ NCEER $(N_1)_{60}$ Boulanger (bpf)	$(N_1)_{60}$ Cetin (bpf)	$(N_1)_{60CS}$ NCEER (bpf)	$(N_1)_{60CS}$ Boulanger (bpf)	$(N_1)_{60CS}$ Cetin (bpf)	$(N_1)_{60}$ (bpf)	Effective Friction Angle (φ') (degrees)
2	3.0	5.5	5.5	CL	126	10	80	19	--	379	379	301	10	17	16	17	17	16	19	32
4	6.0	8.0	2.5	CL	125	10	80	28	--	757	726	492	10	17	16	17	17	16	17	32
6	10.0	13.0	5.0	SP	125	14	4	--	--	1257	977	743	14	21	20	21	21	20	21	33
7	15.0	17.0	4.0	SM	125	24	23	--	--	1883	1290	1056	24	32	34	40	37	38	34	36
8	20.0	23.0	6.0	SP-SM	125	26	10	--	--	2508	1604	1370	26	35	34	37	36	36	34	36
9	25.0	28.0	5.0	SW-SC	132	46	8	--	--	3148	1931	1697	46	56	57	57	57	59	58	43
10	30.0	35.0	7.0	SW-SC	130	37	8	--	--	3804	2276	2042	37	42	43	43	42	44	44	37
11	35.0	38.0	3.0	CL	125	17	67	25	--	4454	2614	2380	17	19	18	19	19	18	19	32
12	40.0	41.5	3.5	CL	120	11	90	--	--	5069	2917	2683	11	12	11	12	12	11	12	30

	Liquefaction Factor of Safety: Factor of Safety (FS)						Residual Shear Strength (Sr)										
								Idriss and Boulanger 2008 [1]		Idriss and Boulanger 2007 [7]	Seed & Harder 1990 w/ NCEER FS [5]				Idriss 1998	Olson & Stark 2002 [6]	Sr. Kramer and Wang 2007 (psf)
Sample Number	NCEES (FS)	FS ≤ 1.2	Cetin (FS)	FS ≤ 1.2	Boulanger (FS)	FS ≤ 1.2	$(N_1)_{60}$ CS-Sr (bpf)	Case 1 (psf)	Case 2 (psf)	(psf)	Lower Bound (psf)	Upper Bound (psf)	Average (psf)	Bound plus 1/3 (psf)	(psf)	(psf)	(psf)
2	NL	--	NL	--	NL	--	17	--	--	--	--	--	--	--	--	--	--
4	NL	--	NL	--	NL	--	17	--	--	--	--	--	--	--	--	--	--
6	1.67	--	1.44	--	1.65	--	21	482	143	1546	1090	1630	1360	1269	1520	NA	593
7	NL	--	NL	--	12.99	--	40	--	--	--	--	--	--	--	--	--	--
8	NL	--	NL	--	10.35	--	37	--	--	--	--	--	--	--	--	--	--
9	NL	--	NL	--	14.41	--	57	--	--	--	--	--	--	--	--	--	--
10	NL	--	NL	--	14.16	--	43	--	--	--	--	--	--	--	--	--	--
11	NL	--	NL	--	NL	--	19	--	--	--	--	--	--	--	--	--	--
12	2.53	--	1.98	--	2.57	--	12	882	376	321	560	1050	805	723	317	313	396

[1] Idriss, I. M. and Boulanger, R. W., "Soil Liquefaction During Earthquakes," Earthquake Engineering Research Institute, pages 140-142 and 152-158, 2008.

[2] Idriss, I. M. and Boulanger, R. W., "Residual Shear Strength of Liquified Soils," Proceedings, 27th USSD Annual Meeting and Conference, Modernization and Optimization of Existing Dams and Reservoirs, Philadelphia, Pennsylvania, March 5-9, 2007, where, Sr = exp[((N1)60CS-Sr/5.1 - ((N1)60CS-Sr/16.5)2 + ((N1)60CS-Sr/21.4)3 + 0.8]/0.0479 (psf)

[3] Strength", Proceedings of the H.B. Seed Memorial Symposium, BiTech Publishers Ltd., Vancouver, B.C., Canada, Vol. 2, pp. 351-376, 1990.

[4] Olson and Stark (2002), where, $S_u(LIQ) = \sigma'_{v0}[0.03+(0.0075(N_1)_{60})]$; valid for $(N_1)_{60} \leq 12$

Summary -- Liquefaction Analysis

Lookout Slough

BCI-17-13 (Near Station 63+20)

Project: **Lookout Slough**
BCI No.: **3195.X**
Date: **8/13/2018**
Location: **BCI-17-13 (Near Station 63+20)**
By: **DWC**

Soil Layer	
Granular	
Cohesive	

Boring Elevation:	6	feet
Ground Water Elevation:	4.3	feet (For Liquefaction Analysis)
Hammer Energy (ER):	74	%
Ground Water Depth:	12.5	feet (At Time of Drilling)
Ground Water Depth:	1.8	feet (For Liquefaction Analysis)
Distance to Fault (R) =	27.6	miles
Moment Magnitude, M_w =	6.7	
PGA =	0.17	g
Liquefaction Factor of Safety (FS):	1.2	

Input Data										Overburden Stress			Liquefaction Analysis						Strength Parameters	
Sample Number	Sample Depth (feet)	Depth to Bottom of Layer (feet)	Layer Thickness (feet)	Soil Type (USCS)	Total Unit Weight (pcf)	Field N (bpf)	Fines %	PI %	Average Mean Grain Size D50 (mm)	Total Stress (psf)	Effective Stress at Time of Drilling (psf)	Effective Stress for Liquefaction Analysis (psf)	N_{SPT} (bpf)	$(N_1)_{60}$ NCEER $(N_1)_{60}$ Boulanger (bpf)	$(N_1)_{60}$ Cetin (bpf)	$(N_1)_{60CS}$ NCEER (bpf)	$(N_1)_{60CS}$ Boulanger (bpf)	$(N_1)_{60CS}$ Cetin (bpf)	$(N_1)_{60}$ (bpf)	Effective Friction Angle (φ') (degrees)
2	3.0	5.0	5.0	CH	115	5	90	--	--	345	345	267	5	8	8	8	8	8	10	29
4	6.0	7.5	2.5	CL	120	15	90	--	--	695	695	430	15	25	23	25	25	23	25	34
6	9.0	11.0	3.5	CL	120	9	69	28	--	1055	1055	603	9	13	12	13	13	12	13	31
8	12.5	15.0	4.0	CL	125	11	90	--	--	1483	1483	812	11	14	13	14	14	13	15	31
9	15.0	20.0	5.0	CH	123	11	92	31	--	1795	1639	968	11	13	14	13	13	14	14	31
10	20.0	23.0	3.0	CL	125	21	90	--	--	2411	1943	1272	21	26	25	26	26	25	26	34
11	25.0	28.0	5.0	CL	125	18	90	--	--	3036	2256	1585	18	20	21	20	20	21	21	33
12	30.0	35.0	7.0	CL	125	16	90	--	--	3661	2569	1898	16	17	17	17	17	17	18	32
13	35.0	40.0	5.0	SC	115	5	40	--	--	4286	2882	2211	5	5	5	11	11	8	5	28
14	40.0	43.0	3.0	CL	120	6	75	14	--	4861	3145	2474	6	6	6	6	6	6	6	28
15	45.0	48.0	5.0	SP-SC	125	17	7	--	--	5471	3443	2772	17	16	16	17	17	17	17	32
16	50.0	51.5	3.5	SP-SC	125	27	7	--	--	6096	3756	3085	27	25	25	25	25	26	26	34

Sample Number	Liquefaction Factor of Safety: Factor of Safety (FS) NCEES (FS)	FS ≤ 1.2	Cetin (FS)	FS ≤ 1.2	Boulanger (FS)	FS ≤ 1.2	Residual Shear Strength (Sr): $(N_1)_{60CS-Sr}$ (bpf)	Idriss and Boulanger 2008 [1] Case 1 (psf)	Idriss and Boulanger 2008 [1] Case 2 (psf)	Idriss and Boulanger 2007 [7] (psf)	Seed & Harder 1990 w/ NCEER FS [5] Lower Bound (psf)	Seed & Harder Upper Bound (psf)	Seed & Harder Average (psf)	Seed & Harder Bound plus 1/3 (psf)	Idriss 1998 (psf)	Olson & Stark 2002 [6] (psf)	Sr. Kramer and Wang 2007 (psf)
2	14.45	--	14.13	--	13.33	--	8	41	30	193	290	740	515	439	187	25	89
4	21.68	--	20.81	--	20.11	--	25	290	181	2957	--	--	--	--	2627	NA	665
6	NL	--	NL	--	NL	--	13	--	--	--	--	--	--	--	--	--	--
8	7.57	--	7.04	--	7.15	--	14	488	131	450	750	1270	1010	923	453	NA	271
9	NL	--	NL	--	NL	--	13	--	--	--	--	--	--	--	--	--	--
10	9.05	--	8.23	--	8.81	--	26	858	600	3567	--	--	--	--	3039	NA	1242
11	6.24	--	5.64	--	6.22	--	20	1029	422	1314	--	--	--	--	1312	NA	785
12	4.65	--	4.23	--	4.76	--	17	1186	383	746	1190	1740	1465	1373	760	NA	595
13	0.85	x	0.56	x	0.87	x	11	166	162	311	20	360	190	133	307	154	180
14	NL	--	NL	--	NL	--	6	--	--	--	--	--	--	--	--	--	--
15	1.22	--	1.08	x	1.24	--	17	880	386	709	560	1050	805	723	722	NA	686
16	2.03	--	1.79	--	2.16	--	25	2081	791	3316	--	--	--	--	2874	NA	1851

[1] Idriss, I. M. and Boulanger, R. W., "Soil Liquefaction During Earthquakes," Earthquake Engineering Research Institute, pages 140-142 and 152-158, 2008.

[2]

Idriss, I. M. and Boulanger, R. W., "Residual Shear Strength of Liquified Soils," Proceedings, 27th USSD Annual Meeting and Conference, Modernization and Optimization of Existing Dams and Reservoirs, Philadelphia, Pennsylvania, March 5-9, 2007, where, Sr = exp[((N1)60CS-Sr/5.1 - ((N1)60CS-Sr/16.5)2 + ((N1)60CS-Sr/21.4)3 + 0.8]/0.0479 (psf)

[3] Seed, R.B. and Harder, L.F., "SPT-based Analysis of Cyclic Pore Pressure Generation and Undrained Residual Strength", Proceedings of the H.B. Seed Memorial Symposium, BiTech Publishers Ltd., Vancouver, B.C., Canada, Vol. 2, pp. 351-

[4] Olson and Stark (2002), where, $S_u(LIQ) = \sigma'_{v0}[0.03+(0.0075(N_1)_{60})]$; valid for $(N_1)_{60} \le 12$

Summary -- Liquefaction Analysis

Lookout Slough

BCI-18-28 (Near Station 78+00)
SEGMENT B

Project: Lookout Slough
BCI No.: 3195.X
Date: 8/13/2018
Location: BCI-18-28 (Near Station 78+00)
By: DWC

Boring Elevation:	6	feet
Ground Water Elevation:	4.3	feet (For Liquefaction Analysis)
Hammer Energy (ER):	74	%
Ground Water Depth:	12.0	feet (At Time of Drilling)
Ground Water Depth:	1.8	feet (For Liquefaction Analysis)
Distance to Fault (R) =	27.6	miles
Moment Magnitude, M_w =	6.7	
PGA =	0.17	g
Liquefaction Factor of Safety (FS):	1.2	

Soil Layer	
Granular	(yellow)
Cohesive	(green)

Input Data										Overburden Stress			Liquefaction Analysis						Strength Parameters	
Sample Number	Sample Depth	Depth to Bottom of Layer	Layer Thickness	Soil Type	Total Unit Weight	Field N	Fines	PI	Average Mean Grain Size D50	Total Stress	Effective Stress at Time of Drilling	Effective Stress for Liquefaction Analysis	N_{SPT}	$(N_1)_{60}$ NCEER $(N_1)_{60}$ Boulanger	$(N_1)_{60}$ Cetin	$(N_1)_{60CS}$ NCEER	$(N_1)_{60CS}$ Boulanger	$(N_1)_{60CS}$ Cetin	$(N_1)_{60}$	Effective Friction Angle (φ')
	(feet)	(feet)	(feet)	(USCS)	(pcf)	(bpf)	%	%	(mm)	(psf)	(psf)	(psf)	(bpf)	(bpf)	(bpf)	(bpf)	(bpf)	(bpf)	(bpf)	(degrees)
1	1.0	4.0	4.0	CL	120	7	90	--	--	120	120	120	7	12	11	12	12	11	17	32
2	5.0	6.5	2.5	CL	125	24	90	--	--	605	605	402	16	26	24	26	26	24	27	34
3	6.5	11.0	4.5	CL	125	16	85	--	--	793	793	496	16	25	25	25	25	25	26	34
7	14.0	15.5	4.5	CL	125	24	80	--	--	1730	1605	966	16	19	19	19	19	19	21	32
8	15.5	17.0	1.5	CL	125	20	90	--	--	1918	1699	1060	20	23	25	23	23	25	26	34
9	17.0	18.5	1.5	CL	125	31	90	--	--	2105	1793	1153	20	23	24	23	23	24	26	34
10	18.5	23.0	4.5	CL	125	16	90	--	--	2293	1887	1247	16	20	19	20	20	19	20	32
11	25.0	30.0	7.0	CL	125	28	90	--	--	3105	2294	1654	18	20	21	20	20	21	21	33
12	30.0	35.0	5.0	CL	125	16	80	--	--	3730	2607	1967	16	17	17	17	17	17	18	32
13	35.0	39.0	4.0	ML	120	11	60	--	--	4355	2920	2280	7	8	7	8	8	7	8	29
14	40.0	45.0	6.0	SM	125	12	40	--	--	4960	3213	2573	12	12	12	19	18	15	12	31
15	45.0	48.0	3.0	SP	125	25	5	--	--	5585	3526	2886	16	16	15	16	16	16	16	32
16	50.0	55.0	7.0	SP	130	35	5	--	--	6220	3849	3209	35	32	32	32	32	32	34	36
17	55.0	56.5	1.5	CL	125	46	90	--	--	6870	4187	3547	30	26	26	26	26	26	28	34

Sample Number	Liquefaction Factor of Safety: Factor of Safety (FS)						Residual Shear Strength (Sr)										
	NCEES (FS)	FS ≤ 1.2	Cetin (FS)	FS ≤ 1.2	Boulanger (FS)	FS ≤ 1.2	$(N_1)_{60}$ CS-Sr	Idriss and Boulanger 2008 [1] Case 1	Idriss and Boulanger 2008 [1] Case 2	Idriss and Boulanger 2007 [7]	Seed & Harder 1990 w/ NCEER FS [5] Lower Bound	Seed & Harder 1990 w/ NCEER FS [5] Upper Bound	Seed & Harder 1990 w/ NCEER FS [5] Average	Seed & Harder 1990 w/ NCEER FS [5] Bound plus 1/3	Idriss 1998	Olson & Stark 2002 [6]	Sr. Kramer and Wang 2007 (psf)
							(bpf)	(psf)	(psf)	(psf)	(psf)	(psf)	(psf)	(psf)	(psf)	(psf)	(psf)
1	unsaturated	--	unsaturated	--	unsaturated	--	12	--	--	--	--	--	--	--	--	--	--
2	25.84	--	24.86	--	23.92	--	26	271	192	3626	--	--	--	--	3078	NA	718
3	20.30	--	19.34	--	18.85	--	25	335	226	3361	--	--	--	--	2903	NA	760
7	9.23	--	8.40	--	8.77	--	19	603	223	993	1310	1870	1590	1496	1007	NA	509
8	10.72	--	9.67	--	10.23	--	23	715	380	2259	--	--	--	--	2110	NA	883
9	9.87	--	8.83	--	9.48	--	23	778	394	2074	--	--	--	--	1963	NA	877
10	7.22	--	6.41	--	6.98	--	20	779	316	1190	--	--	--	--	1196	NA	651
11	6.16	--	5.30	--	6.14	--	20	1074	443	1327	--	--	--	--	1323	NA	807
12	4.57	--	3.85	--	4.68	--	17	1229	393	731	1090	1630	1360	1269	745	NA	598
13	1.83	--	1.47	--	1.86	--	8	269	231	172	150	590	370	296	166	197	233
14	1.42	--	0.85	x	1.29	--	19	451	307	1105	360	810	585	509	1115	NA	407
15	1.15	x	0.88	x	1.19	x	16	712	379	590	460	940	700	619	599	NA	635
16	NL	--	NL	--	4.67	--	32	--	--	--	--	--	--	--	--	--	--
17	5.93	--	4.22	--	5.87	--	26	2393	1798	3996	--	--	--	--	3312	NA	2287

[1] Idriss, I. M. and Boulanger, R. W., "Soil Liquefaction During Earthquakes," Earthquake Engineering Research Institute, pages 140-142 and 152-158, 2008.

[2] Idriss, I. M. and Boulanger, R. W., "Residual Shear Strength of Liquified Soils," Proceedings, 27th USSD Annual Meeting and Conference, Modernization and Optimization of Existing Dams and Reservoirs, Philadelphia, Pennsylvania, March 5-9, 2007, where, Sr = exp[((N1)60CS-Sr/5.1 - ((N1)60CS-Sr/16.5)2 + ((N1)60CS-Sr/21.4)3 + 0.8]/0.0479 (psf)

[3] Undrained Residual Strength", Proceedings of the H.B. Seed Memorial Symposium, BiTech Publishers Ltd., Vancouver, B.C., Canada, Vol. 2, pp. 351-376, 1990.

[4] Olson and Stark (2002), where, $S_u(LIQ) = \sigma'_{v0}[0.03+(0.0075(N_1)_{60})]$; valid for $(N_1)_{60} \leq 12$