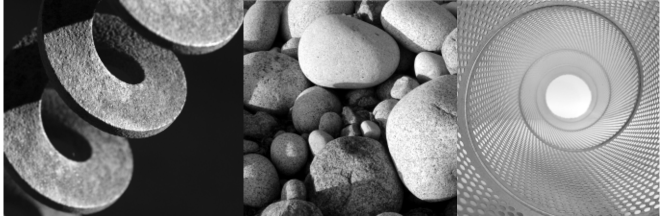

Geotechnical Assessment Report

Delta Small Communities Flood Risk Reduction Program – Community of Isleton
Sacramento County, California

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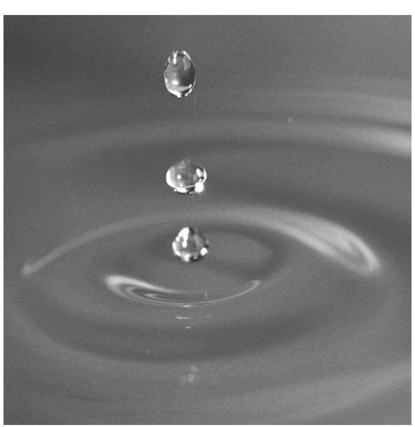

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Abbreviations and Acronyms

AWSE	Assessment Water Surface Elevation
BALMD	Brannan Andrus Levee Maintenance District
CPT	Cone Penetrometer Test
CVFED	Central Valley Floodplain Evaluation and Delineation
CVFPB	Central Valley Flood Protection Board
CVFPP	Central Valley Flood Protection Plan
DWR	Department of Water Resources
FSRP	Flood System Repair Project
GIS	Geographic information system
GPS	Global Positioning System
HASP	Health and Safety Plan
LiDAR	Light detection and ranging
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NULE	Non-Urban Levee Evaluation
RD	Reclamation District
Report	Geotechnical Assessment Report
SCFRRP	Small Communities Flood Risk Reduction Program
SPFC	State Plan of Flood Control
ULDC	Urban Levee Design Criteria
ULE	Urban Levee Evaluation
USA	Underground Service Alert
USACE	United States Army Corps of Engineers

1 Introduction

1.1 Purpose and Scope

The California Department of Water Resources (DWR) Small Communities Flood Risk Reduction Program (SCFRRP) was created following adoption of the 2012 Central Valley Flood Protection Plan (CVFPP) by the Central Valley Flood Protection Board (CVFPB). Under the SCFRRP, Sacramento County, as the local land-use planning entity, was awarded a DWR grant in 2017 on behalf of the community of Isleton, to prepare a Feasibility Study to identify and prioritize flood risk reduction management actions. This Geotechnical Assessment Report (Report) will be an appendix to and has been prepared to support the Feasibility Study.

The purpose of this Report is to summarize the available geotechnical information and geotechnical assessment completed for the levees protecting the community of Isleton as shown on Figures 1 and 2. The focused geotechnical assessment completed for this Report included additional field exploration for the existing levees adjacent to the town of Isleton, levees along Georgiana Slough near the Ox-Bow Marina, and the Reclamation District (RD) 556 South cross levee as shown on Figure 3. This Report will be used to support the Feasibility Study's evaluation of the structural alternatives for the community of Isleton. The identification of conceptual remedial alternatives is essential to facilitate comparative costs assessment for the array of structural alternatives considered in the Feasibility Study.

1.2 Project Description

The Brannan-Andrus Levee Maintenance District (BALMD) levees protect the City of Isleton protect the community that is constructed along the left bank of the Sacramento River (California Department of Water Resources [DWR] Non-Urban Levee Evaluation [NULE] Segment 378), the right bank of Georgiana Slough (NULE Segment 40), the right bank the North Mokelumne River (NULE Segment 1050), the right bank of the San Joaquin River (NULE Segment 1049), and the left bank of Seven Mile Slough (NULE Segment 1048), as shown on Figure 1 and discussed in more detailed below. The ring levee system (Brannan-Andrus Island) protecting the City of Isleton is completed by a cross-levee common with Reclamation District (RD) 556 at the northeastern end and high ground at the southwestern extent between Sacramento River and Three Mile Slough.

1.2.1 Sacramento River (NULE Segment 378)

The Sacramento River left bank levee near Isleton (NULE Segment 378) extends approximately 11.6 miles along the northwest side of Brannan-Andrus Island from the confluence of the Sacramento River and Three Mile Slough, northeast to the cross-levee common between BALMD and RD 556. NULE Segment 378 is a State Plan of Flood Control (SPFC) levee that is a part of the BALMD levee system. Along this Sacramento River extent, flow is from the northeast to the southwest.

1.2.2 Georgiana Slough (NULE Segment 40)

The Georgiana Slough right bank levee (NULE Segment 40) is a SPFC levee that is a part of the BALMD levee system. It is approximately 6 miles long, extending from the RD 556 south cross-levee downstream to the confluence of Georgiana Slough and the North Mokelumne River.

1.2.3 North Mokelumne River (NULE Segment 1050)

The North Mokelumne River right bank levee (NULE Segment 1050) is a Non-SPFC levee that is a part of the BALMD levee system. It is about 2.9 miles long and extends from to the confluence of Georgiana Slough and the Mokelumne River southward to the confluence of the Mokelumne River and the San Joaquin River. The Mokelumne River is affected by backwater conditions.

1.2.4 San Joaquin River (NULE Segment 1049)

The San Joaquin River right bank levee (NULE Segment 1049) is a Non-SPFC levee that is a part of the BALMD levee system. It is about 2.6 miles long and extends from the confluence of the Mokelumne River and the San Joaquin River westward to the confluence of the Seven Mile Slough and the San Joaquin River. The San Joaquin River in this area is affected by backwater conditions.

1.2.5 Seven Mile Slough (Segment 1048)

The Seven Mile Slough left bank levee (NULE Segment 1048) is a Non-SPFC levee that is a part of the BALMD levee system. It is about 4.6 miles long and extends from the confluence of the Three Mile Slough and Seven Mile Slough eastward to the confluence of Seven Mile Slough and the San Joaquin River. Along the western approximately 1.3 miles of the slough water is controlled by a gated dam with two 48-inch diameter pipes with gate valves.

1.2.6 RD 556 South Cross Levee

The cross levee between Upper Andrus (RD 556) and Brannan-Andrus (BALMD) was built by RD 556. The cross levee is approximately 0.5-miles long. No additional information was available at the time this Report was prepared.

1.3 Background Information and Existing Data

The Brannan-Andrus Island levees surrounding the City of Isleton were constructed by various efforts. The Sacramento River levees (NULE Segment 378) were initially constructed between 1860 and 1880. Levees were later built up with clamshell dredging to increase the levee height. The material used to build the levees was taken from the channel, and was likely not compacted. Between 1946 and 1947, USACE constructed a setback levee with material from the existing levees.

Information was not found on the initial construction of the Georgiana Slough levees protecting the City of Isleton (NULE Segment 40). They may have also been initially constructed between 1860 and 1880. Between 1950 and 1952, the Georgian Slough levee was reconstructed by the USACE. Borrow sites were located within the Georgiana slough channel. In most locations the reconstructed levee was setback from the originally constructed levee.

The non-SPFC BALMD levees along the Mokelumne River, San Joaquin River, and Seven Mile Slough (NULE Segments 1050, 1049, and 1048) were originally built by the Tide Land Reclamation Company between 1871 and 1872. In general, the initial levee was about 4 feet high, was 15 feet wide at the base and was 8 feet wide at the crest. After flooding of Brannan-Andrus Island in 1877-78, the levee was rebuilt in 1878 by the newly organized Reclamation District (RD 317). For the most part, material used for reconstruction was imported from outside the island. Details about these imported materials were not reported in reviewed documents. Based on the NULE field reconnaissance interview with the levee district engineer, the control structures controlling the flow on Seven Mile Slough (NULE Segment 1048) were built around 1950.

Past performance is based primarily on the DWR NULE project information which was gathered through review of available documents and interviews with levee maintenance personal. In general, the Sacramento River levee near the City of Isleton has experienced widespread erosion including bank and slope caving and wavewash erosion. Limited occurrences of cracking and landslide sloughing have also been reported. For the remainder of the BALMD basin (NULE Segments 40, 1050, 1049, and 1048) boils and seepage have been reported during past high-water events. Particularly several reports of seepage, boils, or boils moving sand are document along the levee to the southeast of Isleton, near Oxbow Marina (NULE Segment 40) in the 1996-97 and 1997-98 high water events. Occurrences of slope instability, subsidence, cracks, and settlement are also noted at locations throughout the basin.

Based on past performance and field reconnaissance, DWR's Flood System Repair Project (FSRP) identified two *critical* sites along the levees of the BALMD basin, one for through seepage along the NULE Segment 1050 and one for stability along NULE Segment 1049. Thirteen serious sites were also identified in the BALMD basin, nine erosion sites along the Sacramento River lever (NULE Segment 378), two stability sites along Georgiana Slough levee (NULE Segments 40), and two seepage sites along the Mokelumne River levee (NULE Segment 1050). Four of the FSRP serious erosion sites are along the levees directly adjacent to the City of Isleton. A map and table of the critical and serious sites from the FSRP Report are included in the Existing Geotechnical Data Technical Memorandum (Appendix A).

The Existing Geotechnical Data Technical Memorandum (Appendix A) was prepared for Isleton as an earlier task preceding the geotechnical assessment. The Existing Geotechnical Data Technical Memorandum covers more details on the levee construction history, past levee performance, and the existing geotechnical information available prior to this study. Past performance records and existing exploration locations are included in Figure 2.

1.4 Project Stationing and Topography

The levee stationing used in this assessment has been adopted from the stationing developed by DWR for the NULE project. Stationing is shown in Figure 2. Topographic mapping used for levee geometry for the Report assessment was developed using a light detection and ranging (LiDAR) data from DWR's Central Valley Floodplain Evaluation and Delineation (CVFED) LiDAR collected between October 2008 and February 2009. Metadata available with the CVFED LiDAR indicates the data meets the 3.5 feet horizontal accuracy standard at the 95 percent confidence level and post processed LiDAR elevations have been tested to 4-inch vertical accuracy at 95 percent confidence level.

The vertical datum used for elevations in this Report is the 1988 North American Vertical Datum (NAVD88). The horizontal datum is the North American Datum of 1983 (NAD83).

2 Field Exploration and Laboratory Testing

2.1 Purpose

The purpose of the subsurface exploration completed for this study was to gather information where there is currently no data and/or confirm the subsurface stratigraphy on the landside of the levee where data is limited. This additional information was intended to help fill data gaps for the geotechnical assessment.

2.2 Exploration Program Description

The selection of subsurface exploration locations and exploration depths was developed based on a review of available existing exploration data, reports, maps, geomorphologic data, topographic data, and other historical information available (summarized in Appendix A). Based on this review, subsurface exploration locations were chosen to:

- Assess embankment and foundation blanket conditions in areas where data gaps were identified based on existing explorations
- Collect samples of a range of embankment and foundation soils for testing and evaluation

The exploration program was developed to gather data for both the foundation materials and the levee embankment materials where possible. For SPFC levees, permits from USACE are required for drilling through the levee embankment and typically takes 6 months or longer to obtain. Therefore, only toe explorations were completed on the SPFC levees within the scope of this study. The field exploration program included advancing Cone Penetration Test (CPT) soundings and sampling at selected depths at each CPT location. CPT is a direct-push technology where an instrumented cone is pushed into the ground at a constant rate. Sensors in the cone provide essentially continuous measurements of tip resistance, sleeve friction, and dynamic pore pressure. This data can aid in the interpretation of materials encountered and can be used in future studies to help estimate engineering parameters using correlations, including friction angle, undrained shear strength, equivalent blow counts, and soil behavior type (a proxy to textural identification) for analyses.

Prior to the start of field explorations, the goals and challenges of the exploration program were identified through discussion and site reconnaissance with staff and the exploration subcontractor, ConeTec. Other significant considerations of the exploration program included:

- Project goals and objectives;
- Project Health and Safety Plan (HASP)
- The scope of field explorations;
- Sampling procedures and sample requirements;
- Specific sampling targets and strategies to optimize sampling methods;
- Exploration depth targets;
- Site access and contact information;
- Utility clearance and permits;
- Site security and noise;
- Backfill requirements;
- Site restoration requirements

CPTs were advanced by ConeTec using a truck mounted CPT rig and a cone penetrometer with a cross-sectional area of 15 cm^2 and a resulting hole diameter of approximately 2 inches. The CPTs were performed in accordance with ASTM D5778, "Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils."

For this study, eight (8) CPTs were completed by GEI in September 2020. The completed CPTs are summarized in Table 1 and shown in Figure 2. The CPTs located near the landside toe were approximately 15 feet or more from the landside toe, which is outside of the USACE levee easement. The depth of the CPTs ranged between 60 and 95 feet, approximately four times the levee height. A complete report on the CPT soundings, which includes plots of the CPT data is included as Appendix B.

Soil sampling consisted of advancing a second CPT probe adjacent to the first CPT and sampling at depths selected by the field engineer. Samples were collected in tubes and were bagged, labeled, and retained for visual inspection and potential laboratory testing. Upon completion the CPT probe holes were backfilled with a cement-bentonite grout mix in accordance with Sacramento County permit requirements and consistent with the standard of practice for levee evaluations in the area. The grout mix used for backfill contained approximately 5 percent bentonite to provide the grout some elasticity to help with shrinkage and cracking. The grout was placed in the hole by the tremie method, with the tremie pipe extending to the bottom of the hole. The tremie was removed as grout was being pumped; the bottom of the tremie was submerged in grout at all times. At the end of each day/next day, the holes were revisited and topped off with additional grout mix if needed.

In addition to soil sampling, pore pressure dissipation tests were conducted during each CPT sounding, typically within granular materials below the water table. The test results were used to estimate the depth to groundwater. In a dissipation test, the CPT sounding is advanced to the estimated test depth, or as directed by the field representative, and then paused. The changes in the "dynamic" pressure is then monitored. Pore pressure data during the test are digitally recorded for subsequent analyses. After the dissipation test data are recorded, cone advancement is resumed. Dissipation test results are included in the CPT report (Appendix B). The interpreted depth to groundwater from the pore pressure dissipation tests are included in Table 1. Detailed methods and equipment used to advance the CPT soundings, is also included in Appendix B.

2.2.1 Health and Safety

A project-specific HASP was developed for the subsurface field exploration. Field personnel were given a health and safety briefing by the Field Exploration Manager and also held daily health and safety tailgate meetings with subcontractors during the field exploration. Field personnel were also provided with specific guidelines and information about emergency action protocols, including the location of the closest emergency medical facility. Field personnel had no reportable incidents during field explorations.

2.2.2 Drilling Permit

GEI obtained a county well permit from the Sacramento County Environmental Management Department before starting the field exploration. A copy of the well permit is located in the Work Plan (Appendix C).

2.2.3 Utility Clearance

Each exploration location was visually observed for the presence of overhead and underground utilities and then outlined in white paint as required by Underground Service Alert (USA). USA was then contacted a minimum of two business days before subsurface exploration of the site. A USA ticket number as well as the clearance date, expiration date and extension date were obtained for the work area and documented in the project file.

2.2.4 Documentation of Exploration Locations

Field personnel and ConeTec used a handheld Global Positioning System (GPS) unit to record CPT locations in the field. GPS coordinates and spatial references in the field were used to position the exploration locations in a geographic information system (GIS). The CVFED LiDAR topographic survey data was then used to estimate the ground surface elevations of each boring. Coordinates and estimated ground surface elevations are provided in Table 1. The locations are reported in feet, with reference to the NAVD88 vertical datum and NAD83 horizontal datum.

2.3 Geotechnical Laboratory Testing

Geotechnical laboratory tests were performed on selected samples obtained from the CPT sampling to assist with characterization of the embankment and foundation materials. The geotechnical laboratory testing for the explorations covered by this Report was performed by Blackburn Consulting, in West Sacramento, CA. Soil sample laboratory testing included:

- Fines content (percent passing #200), ASTM D1140
- Atterberg Limits, ASTM D4318

Laboratory test results are presented in Appendix D.

2.4 Quality Assurance and Quality Control

2.4.1 Cone Penetration Test and Data Quality Control

To confirm consistency and repeatability of collected CPT data, the measuring and test equipment used for ConeTec's cone penetration testing was calibrated, adjusted, and maintained at intervals prescribed in the most current ASTM D5778 standard. The additional non-measuring parts of the cone (wear ring and cone body) were changed out whenever excessive wear was observed.

Checks of field equipment were performed before, during and after the execution of related field activities to ensure compliance with technical and quality requirements and specifications. A log of zero load baseline readings for every CPT sounding is maintained in a field log book. These recordings are maintained and reviewed by the field operator prior to performing a CPT sounding.

Field records (i.e. equipment serial numbers, load cell capacities, baselines and calibrations) having direct bearing on the quality of the work were maintained as the work progressed and were checked and verified for consistency and completeness by ConeTec. Any unusual or nonconforming equipment conditions were recorded and reported as required by ASTM and ConeTec's standard operating procedures.

The documents resulting from the CPT work were controlled in the field and subsequently in a completed final report (Appendix B). The final report submitted to the client was prepared by either the ConeTec project manager, field manager, or regional manager, and reviewed by ConeTec's technical oversight (technical manager, regional manager, and/or field manager, who was not responsible for the original data processing).

2.4.2 Laboratory Testing and Test Results

While the tests were in progress, project team engineers/geologists reviewed test results as they became available, maintained regular coordination with the laboratory representatives, addressed questions posed by laboratory representatives and provided additional instructions as necessary.

Laboratory index test results were reviewed by project team engineers/geologists to gauge conformance with CPT interpretations. If laboratory results were in conflict with the field data, the matter was typically resolved through a visual check and classification of a sample of the soil in question.

3 Site Conditions

3.1 Regional Geology

The study area is located in the Sacramento San Joaquin River Delta. The Delta is formed at the western edge of the Central Valley by the confluence of the Sacramento and San Joaquin Rivers and lies just east of where the rivers enter the Suisun Bay.

The Delta was formed by the raising of sea level, leading to the accumulation of Sacramento and San Joaquin River sediments. The Delta was a large freshwater marsh consisting of many shallow channels and sloughs surrounding low islands of peat and Tule.

3.2 Geomorphology

Geomorphic classification maps prepared for the DWR NULE project were reviewed to aid in the assessment of foundation conditions that could affect the vulnerability of the levees. The purposes of the review were to identify depositional conditions that could be linked to past performance issues and provide context for the limited existing subsurface exploration data.

NULE Level 2-II studies yielded detailed geologic and geomorphic information and involved the integration and analysis of aerial photography, topographic maps, geologic maps, soil maps, and historical documents. Synthesis of these data helped construct a detailed surficial geologic map, develop an assessment of the primary geomorphic processes responsible for distributing or modifying surficial deposits in the study area, and develop levee underseepage susceptibility hazard maps. The Level 2-II Geomorphic Assessment and Surficial Mapping was completed in December 2010 (DWR, 2010) and included the Sacramento River left bank levee, RD 556 South Cross Levee, and the right bank of Georgiana Slough within the community of Isleton. DWR's report (DWR, 2010) covering the community of Isleton, geologic, and underseepage susceptibility maps are included in Appendix C of the Existing Geotechnical Data Technical Memorandum which is Appendix A to this report.

For the Sacramento River left bank levee, NULE Level 2-II mapping indicates NULE Segment 378 levee within the study area overlay recent overbank deposits (interbedded silt, sand and clay) with narrow channels north of the town of Isleton (DWR, 2010).

For the RD 556 South Cross levee, NULE Level 2-II mapping indicates the southwestern side of the levee within the study area overlays recent overbank deposits while the northeastern portion overlays Holocene peat and muck deposits (interbedded peat and organic-rich silt and clay, former tidal marsh deposits, now drained and farmed) (DWR, 2010).

For the Georgiana Slough left bank levee, NULE Level 2-II mapping indicates the portion of the NULE Segment 40 levee within the study area overlays recent overbank deposits and recent crevasse splay deposits (fine sand and silt with clay deposited from breaching of natural or artificial levees) (DWR, 2010).

The available DWR NULE geomorphology mapping for the BALMD levees along the right bank the North Mokelumne River, the right bank of the San Joaquin River, and the left bank of Seven Mile Slough is less detailed but indicates that these portions of the BALMD levee system overlie Holocene peat and muck (Hpm).

3.3 Sacramento River (NULE Segment 378)

The geotechnical assessment for the Sacramento River portion of the Isleton study area have been narrowed down to focus on the frontage levee near the town of Isleton. The details below are for the Sacramento River from approximately Station 1975+00 to 2060+00 as shown in Figure 3.

In addition to geomorphology, two CPTs performed for this area were used to assess the embankment and subsurface conditions along the Sacramento River left bank levee protecting the community of Isleton (NULE Segment 378). No historical explorations were available for NULE Segment 378.

3.3.1 Embankment Conditions

No CPTs performed for this study area were collected through the levee prism of the Sacramento River due to permitting requirements for performing explorations through federal “project” levees, as described in Section 2.2 above. As such, embankment composition was not available.

3.3.2 Foundation Conditions

Available explorations for the interpretation of foundation conditions were limited to the two CPTs performed for this project. No historical explorations were found at the time the report was written. The two CPTs performed for this project were located at the landside toe and indicated there is no blanket present. The coarse-grained layer beneath the embankment is approximately 4 to 6 feet thick underlain by 25 to 50 feet thick fine-grained layer with interbedded sand layers. The CPT plots are in included in Appendix B.

3.4 RD 556 South Cross Levee

No historical explorations were available for RD 556 South Cross Levee (RD556 SCL). One CPT was completed along this levee for the community of Isleton and was used to estimate the levee segment's subsurface conditions along with geomorphology.

3.4.1 Embankment Conditions

The one CPT completed for the RD 556 South Cross Levee was performed from the levee crest and used to assess the embankment conditions. The CPT indicates the embankment consists of silt and sand mixtures. The CPT plot is in Appendix B.

3.4.2 Foundation Conditions

The one CPT completed for the RD 556 Cross Levee indicated a fine-grained blanket layer of approximately 55 feet thick. The CPT plot is in Appendix B.

3.5 Georgiana Slough (NULE Segment 40)

Five historical explorations were available for NULE Segment 40 along the Georgiana Slough right bank levee. One CPT was completed along this focused levee segment for the community of Isleton and was used to estimate the levee segment's subsurface conditions along with geomorphology.

3.5.1 Embankment Conditions

Two historic explorations were drilled through the levee along NULE Segment 40. The explorations indicated the embankment material consists of silt and sand. The exploration subsurface information are in Appendix A.

3.5.2 Foundation Conditions

Five historic explorations and one CPT performed for this project were available for the focused assessment area of NULE Segment 40. The explorations indicated the foundation material ranged from sand to clay beneath the embankment. When clay was present, it was approximately 3 to 5 feet thick. The historic explorations are in Appendix A and the CPT plots are in Appendix B.

4 Assessment Approach and Criteria

The assessment of existing condition and conceptual remediation requirements of various segments of the levees within the study area was based on available existing information (Appendix A) and data collected during the field exploration summarized in Section 2. The assessment performed for this study area consisted of a paper study and modeled analysis was not performed. The levee was evaluated at the assessment water surface elevation (AWSE) based on the hydraulic profile from hydraulic analysis performed by GEI (GEI, 2020). The AWSE incorporates proposed future projects, sea level rise, and climate change, and breach analysis. Additional detail on the AWSE profile can be found in the hydrology and hydraulics technical memorandum prepared for this Project (GEI, 2020). The purpose of this screening level assessment was to identify stretches of levee that are potentially vulnerable to underseepage, through seepage, slope instability, erosion, and freeboard and develop dimensions for conceptual level levee remediations. The identification of conceptual remedial alternatives will support the comparative costs assessment for the array of structural alternatives considered in the Feasibility Study.

Each levee segment was divided into reaches of similar conditions by evaluating cross-sections at 500-foot spacing along the levee alignment and comparing factors including levee geometry, head pressure, blanket thickness/presence, embankment materials, foundation materials, and reported past performance. As a result of this assessment the levees surrounding the community of Isleton were subdivided into three reaches as summarized in Table 2 and shown on Figure 4.

The assessment also considered the understanding of geotechnical conditions from two prior studies, the NULE Phase 1 Geotechnical Assessment and DWR's Flood System Repair Project (FSRP). The NULE Phase 1 geotechnical assessments were utilized on non-intrusive studies and readily available data to evaluate hazard indicators and levee performance history as the basis for categorizing each levee segment for four potential failure mechanisms: underseepage, slope stability, through seepage, and erosion. The FSRP program evaluated past performance records project for non-urban SPFC levees through existing documentation and field reconnaissance and identified critical and serious sites for repair. Further description and results identified by these studies are included in Existing Geotechnical Data Technical Memorandum prepared for Isleton (Appendix A). For the community of Isleton, the FSRP identified five serious erosion sites.

4.1 Geotechnical Evaluation of Underseepage

Underseepage issues along levees generally occur when there is a pervious foundation layer, or aquifer, that is overlain by a relatively continuous top stratum of semi-pervious or impervious soil, or where the levee is built directly on a pervious stratum. The impervious or semi-pervious top stratum, or blanket, tends to confine seepage from the river through the aquifer to the landside area beyond the levee, thus allowing seepage pressures to build up in the aquifer beneath the blanket. If the pressures are high enough and the blanket is thin enough, the pressures may crack and uplift the blanket (often referred to as “heave”) allowing concentrated flows to occur and the formation of sand boils. If an erosion pipe forms (which would require overlying materials that are able to support the development of a “roof”) that extends continuously under the levee to the river, seepage flows could increase causing further erosion, eventually leading to collapse of the pipe, settlement/deformation of the levee and subsequent breaching of the levee. For blanket layers consisting of semi-pervious, low plasticity soils (i.e. plasticity index less than 7) subjected to excessive hydraulic gradients, the hydraulic conductivity may be high enough to allow flow through the top stratum at sufficient velocity to initiate internal erosion and piping without heaving or cracking the blanket layer.

The assessment for underseepage vulnerability was completed by comparing the head at the base of the fine-grained blanket layer to the fine-grained blanket thickness (where present) using a unitless parameter known as an exit gradient and evaluating it against an average vertical exit gradient criterion of 0.5 (United States Army Corps of Engineers [USACE] EM 1110-1-1913). Where ditches/depressions occurred at a distance from the landside toe, the exit gradient criterion was increased to 0.8 at 150 feet or greater beyond the toe with linear interpolation between the landside toe and 150 feet from the toe.

The exit gradient is calculated as the head at the base of the blanket (net head minus an assumed 2 feet of head loss) divided by the blanket thickness. For this study, the head at the base of the blanket was estimated from the AWSE, subtracting 2 feet for head loss in the aquifer and then subtracting the landside toe elevation. An average vertical exit gradient of 0.5 (criterion per USACE EM 1110-1-1913) corresponds to a factor of safety of 1.6 for an assumed saturated unit weight of soil equal to 112.5 pounds per cubic foot. Based on this relationship and an exit gradient criterion of 0.5 the estimated required blanket thickness is computed as shown below:

Estimated required blanket thickness = (Net Head – 2 ft) / 0.5

If available information indicates that the blanket thickness is less than the estimated required blanket thickness, it assumed for this study that the levee is vulnerable to underseepage.

Additionally, if no fine-grained blanket material was present beneath the levee, referred to in this report as a “leaker” condition, a Creep Ratio calculation was performed where sandy soil layers exist in the upper foundation. Creep Ratio is a metric for evaluating the risk of backward erosion of a sandy layer below a hypothetical impermeable roof, which is considered not erodible. Creep Ratios were originally based on observations of piping occurring from foundations supporting masonry dams, but the use of Creep Ratios for evaluation of levees provides an indication of conditions that may lead to piping and backward erosion of the foundation. Backward erosion is a mechanical process that initiates and continues if the hydraulic shear forces are of a sufficient magnitude to detach soil particles and no compatible filter is in place to arrest the erosion process. Use of creep ratio for evaluation of this potential condition in levees in consistent with the *Guidance Document for Geotechnical Analysis* (ULE Guidance Document) prepared for the DWR Urban Levee Evaluation (ULE) project (DWR, 2015) and the International Levee Handbook (CIRIA, 2013). The calculation compares the seepage flow distance, or the levee base width (W), to the Net Head (h_{cr}).

Specific critical Creep Ratios, or creep factors, have been identified for different soil types, with more erodible soils (i.e. fine sands or silt) requiring a greater base width for a given hydraulic head. For purposes of this screening level study, where a "leaker" condition was indicated, a conservative assumption was made to treat the material as very fine sand for purposes of creep ratio evaluation. Bligh (1927) provides a creep factor of 18 for very fine sand, indicating that if a site's base width/net head ratio is less than the 18, it would be susceptible to backward erosion and piping (assuming no flow through the overlying structure) (CIRIA, 2013). The use of Creep Ratios for this evaluation provides a relative indication of conditions that may be more vulnerable to "leaker" seepage and/piping.

Where available geotechnical data indicated the presence of silt in the shallow foundation, engineering judgement was used to determine the characteristics of the underlying material would act as a blanket condition or a leaker condition. For example, if a high fines content silt was present underlain by a sand, the silt would likely act as confining layer creating a blanket condition. Alternatively, a sandy silt underlain by a clay layer would create a leaker condition.

4.2 Geotechnical Evaluation of Through Seepage

Through levee seepage is a concern principally in cohesionless soils within the levee embankment where a high phreatic line can develop during the relatively short duration of a flood event, and when the phreatic surface intersects and exits on the landside slope. In such a case, there is a concern for both slope stability and for removal of soil particles by the exit flows, commonly known as backward erosion. As described above, backward erosion is a mechanical process that initiates and continues if the hydraulic shear forces are of a sufficient magnitude to detach soil particles and no compatible filter is in place to arrest the erosion process. Therefore, the composition and potential erodibility of the levee embankment must be assessed. It is commonly accepted that if the embankment materials are cohesive and not susceptible to backward erosion (i.e. plasticity index greater than 7), remedial measures are not generally required (FEMA, 2011). Further, such soils may not develop a high phreatic line during the short duration of a flood event due to their low hydraulic conductivity. If the embankment materials are susceptible to backward erosion (i.e. fine-grained soils with a plasticity index less than 7 or uniformly graded granular soils), remedial measures may be required.

Through seepage was assessed using phreatic surface breakout (i.e. at least 1 foot above the landside levee toe) and composition and erodibility of the embankment (i.e. sand or silt). This approach is generally consistent with past levee feasibility assessments such as DWR’s Urban Levee Evaluation (ULE) and NULE projects.

Based on review of available embankment data, it appears a majority of the study area levees are constructed of erodible material. Therefore, for this assessment, screening for through seepage vulnerability relied on the estimated phreatic breakout height, which was related to the AWSE height above the waterside toe through a series of sensitivity seepage analyses performed varying the embankment geometry and soil type of the shallow foundation material (Figure 5 and Figure 6). The sensitivity analyses involved a theoretical homogeneous levee modeled in Geostudio SEEP/W software to estimate the amount of head on the waterside of the levee above the landside toe elevation, also referred to as “head differential”, that would result in a phreatic breakout of 1 foot. The head values were then used as the screening criteria for through seepage vulnerability based on geometry and shallow subsurface conditions.

The embankment was assumed to be an erodible silty sand material during the sensitivity analyses which was conservative, resulting in a more limited head drop across the levee prism (i.e. higher breakout for a given AWSE). The ranges of embankment geometry and shallow foundation soil types were based on data collected throughout the study area. The shallow foundation conditions varied from a blanket condition/confining layer condition (i.e. lower hydraulic conductivity lean clay) to a no-blanket condition/non-confining layer condition (i.e. higher hydraulic conductivity silty sand). The hydraulic conductivity parameters were selected based on the recommended values published in the ULE Guidance Document (DWR, 2015). Based on the data summarized in Section 4 of the ULE Guidance Document (DWR, 2015) the following parameters were used in the seepage models:

- Erodible Embankment (silty sand) with a vertical hydraulic conductivity of $6x10^{-4}$ cm/sec
- Blanket/Confining Foundation (lean clay) with a vertical hydraulic conductivity of $5x10^{-6}$ cm/sec
- No-blanket/Non-confining Foundation (silty sand) with a vertical hydraulic conductivity of $6x10^{-4}$ cm/sec

For these models, an anisotropy ratio (k_v/k_h) of 0.25 was assumed for each material. For evaluating the effect of levee geometry on through seepage vulnerability, a crest width of 20 feet was assumed and the landside and waterside slopes were varied to create a range of embankment base widths. Analyses were performed with 95-, 120-, 145-, 170-, 195-, 220-, and 245-foot base widths. The 95-foot base width case is presented as an example (Figure 4) and the results for all base widths are summarized and plotted in Figure 5. For screening, the results established the criteria for levees up to the next analysis base width (i.e. the 95-foot base width case was used for levees with base widths ranging from 95 to 119 feet). This was considered a reasonable, but still conservative approach for this screening level study. Where no data on the embankment composition was available the material was conservatively assumed to be erodible.

4.3 Geotechnical Evaluation of Slope Stability

To assess the stability of the levees for this study, the slopes were compared to typical design slopes as described in the DWR Urban Levee Design Criteria (ULDC) guidance (DWR, 2012) and EM 1110-1-1913. The geometry guidance for existing levee slopes are generally 2 horizontal(H) : 1 vertical(V) for the landslide slope and 3H:1V for the waterside slope. At locations where the slopes were steeper than these typical slopes, the overall levee geometry was assessed to establish if the levee section in those locations appear to be overbuilt (i.e. wide crest width/base width). If the levee appears to be overbuilt, the levee was not identified as vulnerable to slope instability, since slope instability would be less likely to encroach on the central portion of the levee associated with the typical design prism for the project. If the levee was not overbuilt, and the slopes were steeper than those discussed above, then the levee was identified as vulnerable to slope instability.

4.4 Evaluation of Erosion

Within the focus area of the Community of Isleton, there are five serious erosion sites identified by FSRP. BALMD is currently repairing the erosion sites identified in the FSRP report (Appendix A). Therefore, erosion was not assessed as part of this report.

4.5 Evaluation of Freeboard

To limit overtopping risk, FEMA requires riverine levees must provide a minimum freeboard of three feet above the 100-year water-surface level. For this study, freeboard was assessed at each 500-foot cross-section by comparing the existing levees crest elevations (taken from LiDAR data at the stationing alignment location on the crest) to a threshold set three feet above the AWSE.

5 Discussion of Site Specific Assessment

5.1 Sacramento River (NULE Segment 378)

The Sacramento River left bank levee segment in the Isleton focused study area was analyzed as a single reach based on the assessment approach described in Section 4. The reach and locations of available explorations are shown in Figure 2. Segment 378 is located within the northern portion of the focused study area. The assessments performed for Segment 378 are described below. Appendix E provides the Isleton Assessment Table that includes the assessment details for cross-sections every 500-feet along the levee.

5.1.1 Reach 378-A

Reach 378-A is 8,500 feet long and is located between Station 1975+00 and Station 2060+00 of Segment 378. Two explorations are located along the levee toe within or near the extents of the reach. This reach was identified as vulnerable to underseepage since both explorations indicate a leaker condition with creep ratios of 10.1 and 13.8 that does not meet criteria as described in Section 4.1. This is consistent with reports of past performance including seepage during past highwater events along the reach. This reach was identified as potentially vulnerable to through seepage because, assuming an erodible embankment material, the AWSE is higher than the criteria described in Section 4.2. The embankment material was assumed to be erodible since there are no available crest explorations for this reach.

Landside slopes average 2.8H:1V along Reach 378-A. The reach was not identified as vulnerable to landside slope instability due to an average landside slope flatter than 2H:1V and a crest width that generally indicates the levee is overbuilt at the locations were slopes are steeper than 2H:1V. The only documented history of landside slope instability for this reach is near Station 2060+00, however, the crest width at this station is approximately 26 feet wide indicating an overbuilt levee.

The assessment also found that approximately 5 percent of the reach has insufficient freeboard at the AWSE. The available freeboard along the reach dropped below 3 feet at Station 1990+00 where State Route 160 enters/exits the southerly end of the Isleton. The available freeboard at Station 1990+00 is 2.9 feet. The available freeboard along the rest of the reach ranges from 3.1 to 7.5 feet above the AWSE.

5.2 RD 556 South Cross Levee

The RD 556 South Cross levee in the Isleton focused study area was analyzed as a single reach based on the assessment approach described in Section 4. The reach and locations of available explorations are shown in Figure 3. The RD 556 south cross levee is located within the northeastern portion of the focused study area between NULE Segments 40 and 378. The assessments performed for RD 556 south cross levee are described below. Appendix E provides the Isleton Assessment Table that includes the assessment details for cross-sections every 500-feet along the levee.

5.2.1 Reach RD556-A

Reach RD556-A is 2,447 feet long and spans between Station 0+00 and Station 24+47. Only one exploration is located along the levee crest within the extents of the reach. This reach was not identified as vulnerable to underseepage. The exploration showed a blanket thickness greater than 50 feet. Additionally, there are no documented past performance seepage issues for this reach. This reach was identified as vulnerable to through seepage because of the existing erodible embankment material indicated by the exploration and the AWSE is higher than the criteria described in Section 4.2.

Landside slopes average 2.7H:1V along Reach RD556-A. The reach was not identified as vulnerable to landside slope instability since landside slopes throughout the entire reach are flatter than 2H:1V. Additionally, there are no documented past performance landside slope instability issues for this reach.

The assessment also found that approximately 90 percent of the reach has insufficient freeboard for the AWSE. There is insufficient freeboard along approximate Station 2+50 to 24+47. The levee is deficient in freeboard by an average of 8 feet along this stationing.

5.3 Georgiana Slough (NULE Segment 40)

The Georgiana Slough right bank levee segment in the Isleton focused study area was analyzed as a single reach based on the assessment approach described in Section 4. The reach and locations of available explorations are shown in Figure 3. Segment 40 is located within the southern portion of the focused study area. The assessments performed for Segment 40 are described below. Appendix E provides the Isleton Assessment Table that includes the assessment details for cross-sections every 500-feet along the levee.

5.3.1 Reach 40-A

Reach 40-A is 12,000 feet long and is located between Station 1100+00 and Station 1220+00 of Segment 40. Three explorations are located along the levee crest and three explorations are located along the levee toe within the extents of the reach. This reach was identified as vulnerable to underseepage since three explorations indicated a blanket condition that is thinner at the landside toe than the estimated required blanket thickness in the reach, calculated as described in Section 4.1. Additionally, two other explorations indicate a leaker condition with creep ratios of 7.4 and 11.4 that does not meet criteria as described in Section 4.1. This is consistent with reports of past performance including seepage and boils during past highwater events along the reach. This reach was identified as vulnerable to through seepage because of the existing erodible embankment material indicated by the three crest explorations and the AWSE is higher than the criteria described in Section 4.2.

Landside slopes average 2.7H:1V along Reach 40-A. The reach was not identified as vulnerable to landside slope instability since landside slopes throughout the entire reach are flatter than 2H:1V. There are documented past performance landside slope instability issues (including slides and cracking) for this reach. However, based on the current assessment of the levee, the reach was not identified as vulnerable to this failure mechanism.

The assessment also found that the entire reach has insufficient freeboard for the AWSE. The levee is deficient in freeboard by an average of 1.5 feet along this reach.

6 Existing Geotechnical Condition Summary

The Isleton levees were assessed using existing information as well as data gathered for this project and assessed based on the approaches described in Section 4. A total of approximately 3.4 miles were assessed along a total of 3 segments. Each segment was analyzed as a single reach and assessed for underseepage, through seepage, slope stability, and freeboard as described in Section 4.

The geotechnical vulnerabilities for the existing conditions were assessed considering available geotechnical data, levee geometry, and documented past performance observations. This screening level assessment was appropriate for the support of the Feasibility Study, facilitating evaluation of conceptual structural alternatives and comparative costs assessment. If levee mitigation needs for this study area progress to subsequent study or design, additional subsurface exploration and analysis will be necessary to refine the understanding of the levee and foundation conditions and repair requirements.

6.1 Sacramento River (NULE Segment 378)

The geotechnical evaluation along the Sacramento River left bank levee in the Isleton focused study area indicates that Reach 378-A was identified as vulnerable to underseepage and potentially vulnerable to through seepage. Additionally, approximately 5 percent of the reach has insufficient freeboard at the AWSE. See the Evaluation table included in Appendix E for more details.

6.2 RD 556 South Cross Levee

The geotechnical evaluation along the RD 556 south cross levee in the Isleton focused study area indicates that RD556-A was identified as vulnerable to through seepage. Additionally, approximately 90 percent of the reach has insufficient freeboard at the AWSE. See the Evaluation table included in Appendix E for more details.

6.3 Georgiana Slough (NULE Segment 40)

The geotechnical evaluation along the Georgiana Slough right bank levee in the Isleton focused study area indicates that Reach 40-A was identified as vulnerable to underseepage and through seepage. Additionally, the entire reach has insufficient freeboard at the AWSE. See the Evaluation table included in Appendix E for more details.

7 Fix-in-Place Levee Improvement Alternatives

Standardized conceptual remedial alternatives were considered for this screen level assessment. They were identified to be generally consistent with the DWR ULE and NULE project's limited and standardized conceptual remedial alternatives considered.

For the purpose of the Feasibility Study's comparative costs assessment, where feasible, two remedial alternatives were considered for each reach to address underseepage, through seepage, and/or landside levee stability. Restrictions on the landside of the levee, such as developed property and/or land use activity, may limit practical solutions to a single alternative in some locations.

The following standardized conceptual remedial alternatives were considered for the vulnerability indicated:

Remedial Alternative	Existing Condition Levee Vulnerabilities Addressed				
	Underseepage	Through Seepage	Landside Levee Stability	Freeboard	Erosion
Cutoff Wall	X	X	X		
Seepage Berm	X				
Drained Stability Berm		X	X		
Combination Seepage-Stability Berm	X	X	X		
Freeboard Repair				X	

The standardized conceptual remedial alternatives considered in this study, included standardized dimensions or approaches to dimensions. This was in line with the goal of the assessment, facilitation of cost estimating, and necessary based on limited information available for the levees. Assumptions for remedial alternative dimensions included:

- Cutoff Walls:
    - Cutoff walls were considered to address underseepage, through seepage, and stability as follows:
        - A shallow wall was considered for scenarios where through seepage vulnerabilities were identified or where a leaker condition was present beneath the levee and a shallow wall would serve to cutoff the leaker and extending into a shallow aquitard layer.

        - A full-depth wall was considered for scenarios where an aquifer is present underlying a thin blanket condition, or a leaker condition with a thick pervious layer beneath the embankment and the deep wall would cutoff the aquifer by extending through the pervious aquifer and ending in a deep aquitard layer.
        - Where slope instability is driven by the seepage conditions a cutoff wall to mitigate the seepage was considered to indirectly improve the stability of the slope.
    - For full-depth cutoff walls:
        - When subsurface exploration data is available to depths deep enough to identify a fine-grained layer (aquitard), the cutoff wall depth is identified to provide a tip elevation embedment 5 feet into the fine-grained layer (aquitard).
        - When exploration data is not available or a fine-grained layer (aquitard) layer depth is not identified within the depth of available data, an 80-foot deep wall was assumed (deepest wall achievable with a conventional long-reach excavator).
    - Depths assume construction from a half-levee height degrade working surface.
    - The cutoff wall thickness of 36 inches is identified for the standardized conceptual remedial wall alternative.
- Seepage berm dimensions assume a berm thickness of 5 feet at the levee toe sloping to 3 feet thick at the berm toe.

This information is intended for feasibility study level cost estimates to compare repair alternatives. Cost estimates will be prepared separately and are not a part of this Geotechnical Assessment Report.

Remediation Alternatives for seepage and stability improvements, including lengths and Reach specific dimensions, are included in Table 3, and are shown in Figures 7 through 9.

8 Geotechnical Considerations for Additional Structural Alternatives

The Feasibility study this Report is supporting will be considering other structural alternatives such as new cross-levees, ring levees, etc. Geotechnical considerations for new levees are generally the same as existing levees; freeboard, stability, through seepage, and underseepage need to meet FEMA and other relevant design criteria. Freeboard, stability, and through seepage considerations will be addressed by the design requirements for the new levee embankment. Underseepage vulnerability is largely based on existing foundation conditions at the cross-levee location. Very limited data is available for the foundation materials in the Isleton study area, therefore underseepage mitigation requirements for new cross-levees could not be fully evaluated. Structural alternatives that include cross-levees will need to conservatively assume underseepage mitigation is necessary. Further site exploration and subsequent evaluation and/or design might be able to eliminate the need for the underseepage mitigation.

Any new levee construction will also need to consider settlement. The levees within the community of Isleton are located in the Sacramento Delta. Settlement in the Delta is common based on the presence of Marsh and peat deposits (compressible soils), which have been mapped within the study area. Additional explorations will need to be performed along the proposed levee alignment to determine the subsurface conditions and thickness of peat and other compressible soils. The thickness of the compressible soils can have a major effect on the design and construction of the new levee.

Other possible structural alternatives that were not included in this report could include half to full levee rebuild to address through seepage and stability vulnerability and relief wells to address underseepage vulnerability. Rebuilding a levee is extremely costly compared to other remedial alternatives to mitigate for through seepage and/or stability concerns. Relief wells can be used to mitigate underseepage issues but were not considered as one of the remedial alternatives due to the high potential for maintenance issues. If relief wells are not maintained properly, the screens could plug and render the relief well ineffective.

9 Limitations

This assessment report, associated data, and preparation have been performed in accordance with the standard of care commonly used as the state-of-practice in the engineering profession for levee evaluation projects. Standard of care is defined as the ordinary diligence exercised by fellow practitioners in this area performing the same services under similar circumstances during the same period.

Discussions of subsurface conditions summarized in this report are based on subsurface soil and groundwater conditions at limited exploration locations. Variations in subsurface conditions may exist between exploration locations, and the Project team may not be able identify all adverse conditions in the levee and/or its foundation.

No warranty, either expressed or implied, is made in the furnishing of this report. The Project team makes no warranty that actual encountered site and subsurface conditions will exactly conform to the conditions described herein, nor that this report's interpretations and recommendations will be sufficient for all construction planning aspects of the work. The design engineer and/or contractor should perform a sufficient number of independent explorations and tests as they believe necessary to verify subsurface conditions rather than relying solely on the information presented in this report.

The Project team does not attest to the accuracy, completeness, or reliability of geotechnical borings and other subsurface data collected by other consultants or agencies as part of prior studies that are included in this report. The Project team has not performed independent validation or verification of data by others.

Data presented in this report are time-sensitive in that they apply only to locations and conditions existing at the time of the exploration and preparation of this report. Data should not be applied to any other projects in or near the area of this study nor should they be applied at a future time without appropriate verification.

This report is for the use and benefit of the County of Sacramento. Use by any other party is at their own discretion and risk.

This report is one of multiple documents describing work completed. It supplements other reports presenting the geotechnical data collected for this study.

10 References

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Tables

Table 1: Summary of Subsurface Explorations
Small Communities Flood Risk Reduction Plan
Community of Isleton

Exploration ID	Exploration Area	Segment Number	Exploration Location	Approximate NULE Levee Station (ft)	Approximate Coordinates[1]		Approx. Levee Crown Elev[2] (ft)	Approx. LS Toe Elev[2] (ft)	Approx. Levee Height	Approximate Depth to Groundwater[3] (ft)	Exploration Depth (ft)
					Latitude	Longitude					
GEI_BALMD_001C	Sevenmile Slough	1048	Landside Toe	1215+96	38.117647	-121.622037	11.2	-12.9	24.1	8.5	95.2
GEI_BALMD_002C	Sacramento River	378	Landside Toe	1779+12	38.168413	-121.669267	19.8	2.0	17.8	1.2	90.6
GEI_BALMD_003C	Sacramento River	378	Landside Toe	1865+96	38.172553	-121.653052	23.3	8.3	15.0	3.0	71.2
GEI_BALMD_004C	Sacramento River	378	Landside Toe	1967+52	38.162941	-121.619353	22.5	7.9	14.6	7.0	61.0
GEI_BALMD_005C	Sacramento River	378	Landside Toe	2030+47	38.172273	-121.591868	21.8	6.6	15.2	3.1	75.2
GEI_BALMD_006C	RD 556 South Cross Levee	N/A	Crest	11+91	38.189207	-121.56518	11.3	-5.9	17.2	16.1	72.6
GEI_BALMD_007C	Georgiana Slough	40	Landside Toe	1127+31	38.155117	-121.59216	14.4	-4.5	18.9	2.0	75.2
GEI_BALMD_008C	Georgiana Slough	40	Landside Toe	1053+95	38.134794	-121.59408	12.5	-2.0	14.5	9.5	60.2

(1) Locations are approximate - based on field GPS and GIS tools. Horizontal datum is NAD 83.
(2) Elevations are approximate - based on GIS tools and GPS. Vertical datum is NAVD 88
(3) Depth to groundwater was based on the results of the shallowest pore pressure dissipation tests performed within the sounding.

Table 2. Summary of Isleton Levee Vulnerability

NULE Alignment ID	NULE Segment	Reach	Start Station	End Station	Vulnerability			Freeboard (% Deficient)	Notes
					Underseepage	Through Seepage	Slope Stability		
SACR-L	378	378-A	1975+00	2060+00	X	X	-	5%	Reach Characteristics: - Predominantly underlain by Historical overbank deposits and Historical crevasse splay deposits. - Average 8 feet of head above landside toe. - History of waterside erosion and seepage all throughout reach. Additionally, history of landside slope stability issues at north end of reach. - Two explorations along the reach - both indicated a leaker condition with creep ratios of approximately 10.1 and 13.8. Levee Geometry: - Average Height: 13 feet - Average LS Slope: 2.8H:1V - Average WS Slope: 2.7H:1V - Average Crest Width: 66 feet Conclusions: - Underseepage: Identified as vulnerable due to a leaker condition that does not meets creep ratio criteria. - Through Seepage: Identified as potentially vulnerable due to an assumed erodible embankment material and head that does not meet criteria. - Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along the reach and a crest width that generally indicates the levee is overbuilt at the locations were slopes are steeper than 2H:1V. - Freeboard: More than 3 feet of freeboard present along 95% of the reach.
ILNCL	RD556 SCL	RD556-A	0+00	24+47	-	X	-	90%	Reach Characteristics: - Predominantly underlain by Historical overbank deposits and Holocene peat and muck. - Average 6.5 feet of head above landside toe. - No documented past performance. -One exploration along the reach - indicated a blanket condition approximately 56 feet thick. Levee Geometry: - Average Height: 18 feet - Average LS Slope: 2.7H:1V - Average WS Slope: 2.8H:1V - Average Crest Width: 21 feet Conclusions: - Underseepage: Not identified as vulnerable due to a blanket condition that meets criteria. - Through Seepage: Identified as vulnerable due to an erodible embankment material and head that does not meet criteria. - Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along the reach. - Freeboard: Less than 3 feet of freeboard present along 90% of the reach.

Table 2. Summary of Isleton Levee Vulnerability

NULE Alignment ID	NULE Segment	Reach	Start Station	End Station	Vulnerability			Freeboard (% Deficient)	Notes
					Underseepage	Through Seepage	Slope Stability		
GGAS-R	40	40-A	1100+00	1220+00	X	X	-	100%	Reach Characteristics: - Predominantly underlain by Historical overbank deposits, Historical crevasse splay deposits, Historical distributary channel deposits, and Holocene peat and muck. - Average 13 feet of head above landside toe. - History of waterside erosion along northern half of reach, landside slope stability issues (including slides and cracking) throughout majority of reach, seepage along approximate Sta. 1115+00 to 1175+00, and boils along approximate Sta. 1100+00 to 1110+00, Sta. 1150+00, and Sta. 1175+00 to 1180+00. - Six explorations along the reach - three indicated a blanket condition approximately 3-4 feet thick, two indicated a leaker condition with creep ratio of approximately 7.4 and 11.4, and the last exploration only drilled through levee material. Levee Geometry: - Average Height: 14 feet - Average LS Slope: 2.7H:1V - Average WS Slope: 3.4H:1V - Average Crest Width: 23 feet Conclusions: - Underseepage: Identified as vulnerable due to the high head condition with a landside blanket that does not meet criteria and a leaker condition that does not meets creep ratio criteria. - Through Seepage: Identified as vulnerable due to an erodible embankment material and head that does not meet criteria. - Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along the reach. - Freeboard: Less than 3 feet of freeboard present along the reach.

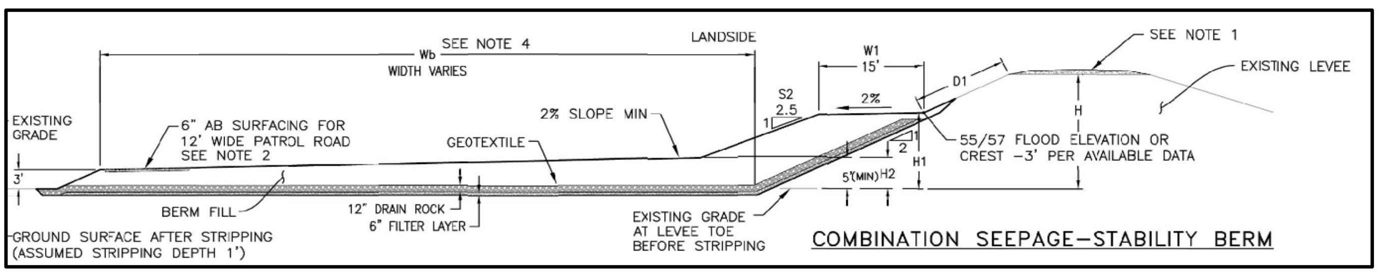
Table 3. Summary of Isleton Remedial Alternatives

NULE Alignment ID	Segment Name	NULE Segment	Reach	Start Station	End Station	Reach Lengths (feet)	Remediation Alternative 1 Dimensions	Remediation Alternative 2 Dimensions[1]	Vulnerability			Freeboard (% Deficient)
									Underseepage	Through Seepage	Slope Stability	
SACR-L	Sacramento River Left Bank	378	378-A	1975+00	2060+00	8,500	30-foot deep Cutoff Wall 0.5 foot Freeboard Repair (500 feet)	65-foot wide 9-foot tall Combo Berm 0.5 foot Freeboard Repair (500 feet)	X	X	-	5%
-	RD 556 South Cross Levee	RD556 SCL	RD556-A	0+00	24+47	2,447	20-foot deep Cutoff Wall 8 foot Freeboard Repair (2,200 feet)	23-foot tall Drained Stability Berm 8 foot Freeboard Repair (2,200 feet)	-	X	-	90%
GGAS-R	Georgiana Slough Right Bank	40	40-A	1100+00	1220+00	12,000	75-foot deep Cutoff Wall 1.5 foot Freeboard Repair	70-foot wide 13-foot tall Combo Berm 1.5 foot Freeboard Repair	X	X	-	100%

*Only affects a portion of the reach

Note: Wall depths and berm widths rounded up to the nearest 5-foot dimension and stability berm heights rounded to the nearest 1-foot dimension.

[1] Combo berm standard dimensions include: 1) W1 = 15-foot wide stability berm and 2) H2 = 5-foot tall seepage berm



Figures

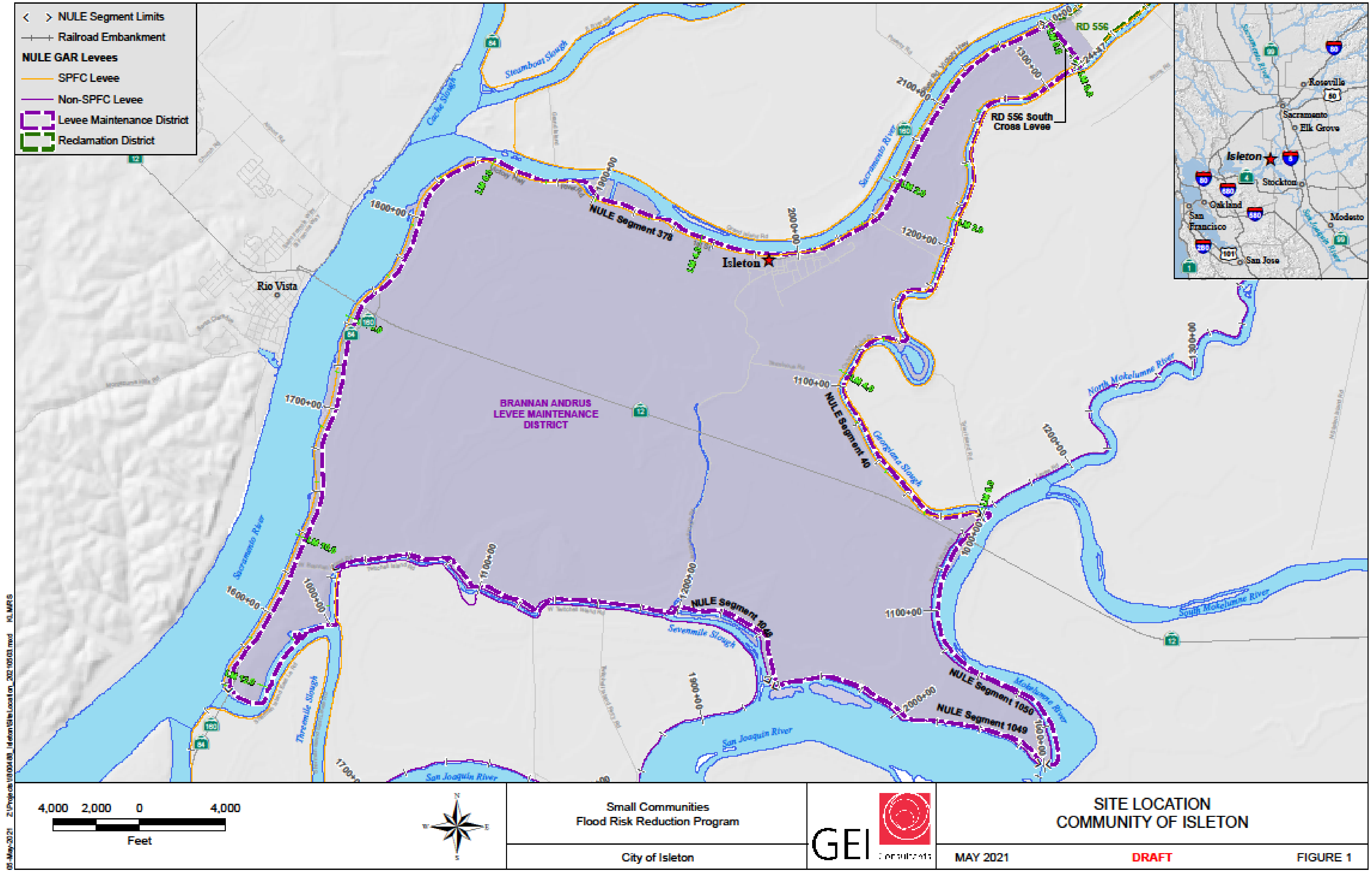
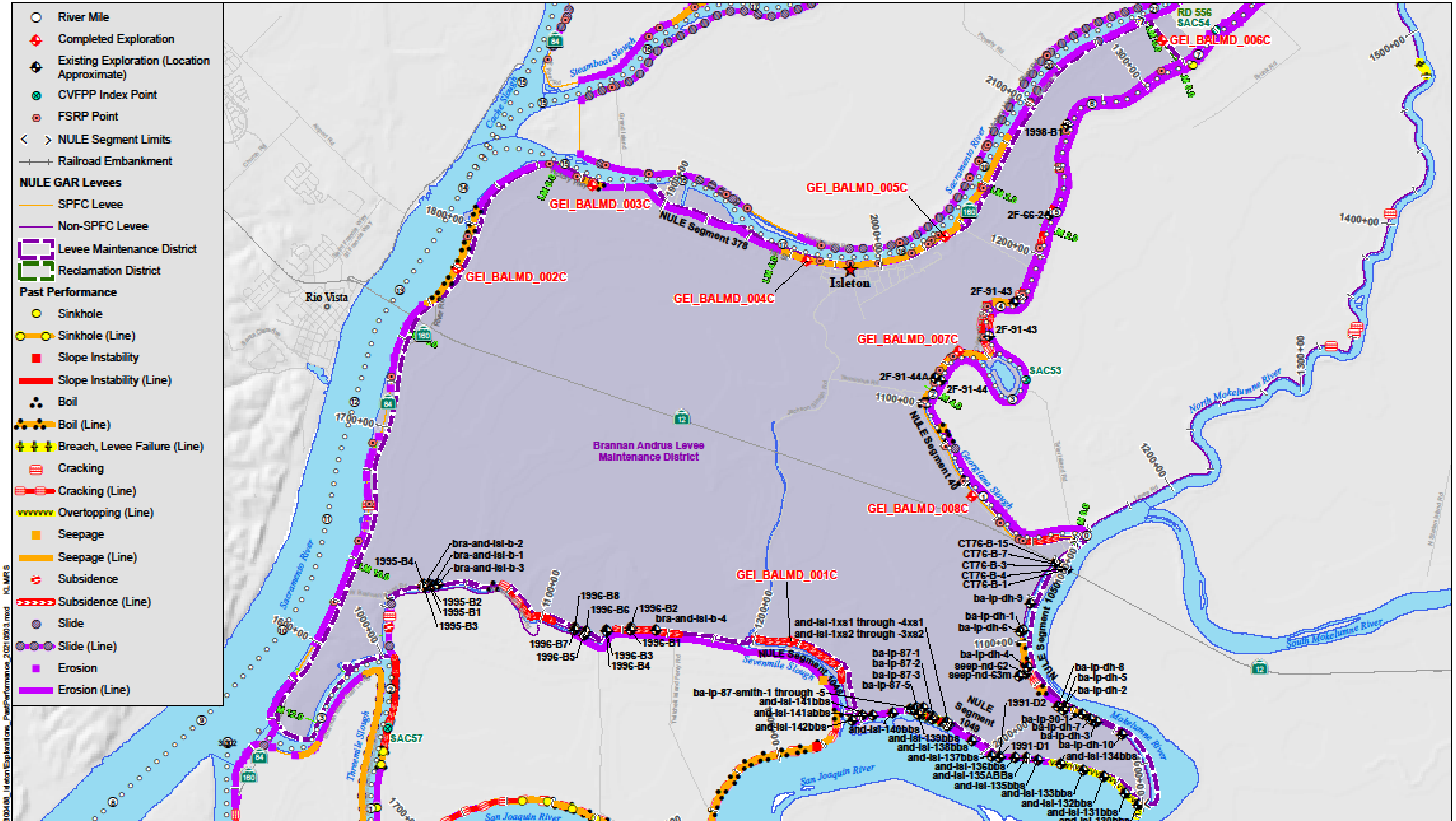


Figure 1 **Site Location**



Small Communities Flood Risk Reduction Program	GEI Consultants	EXPLORATIONS AND PAST PERFORMANCE COMMUNITY OF ISLETON	
City of Isleton		MAY 2021 DRAFT	FIGURE 2

Figure 2 **Explorations and Past Performance Community of Isleton**

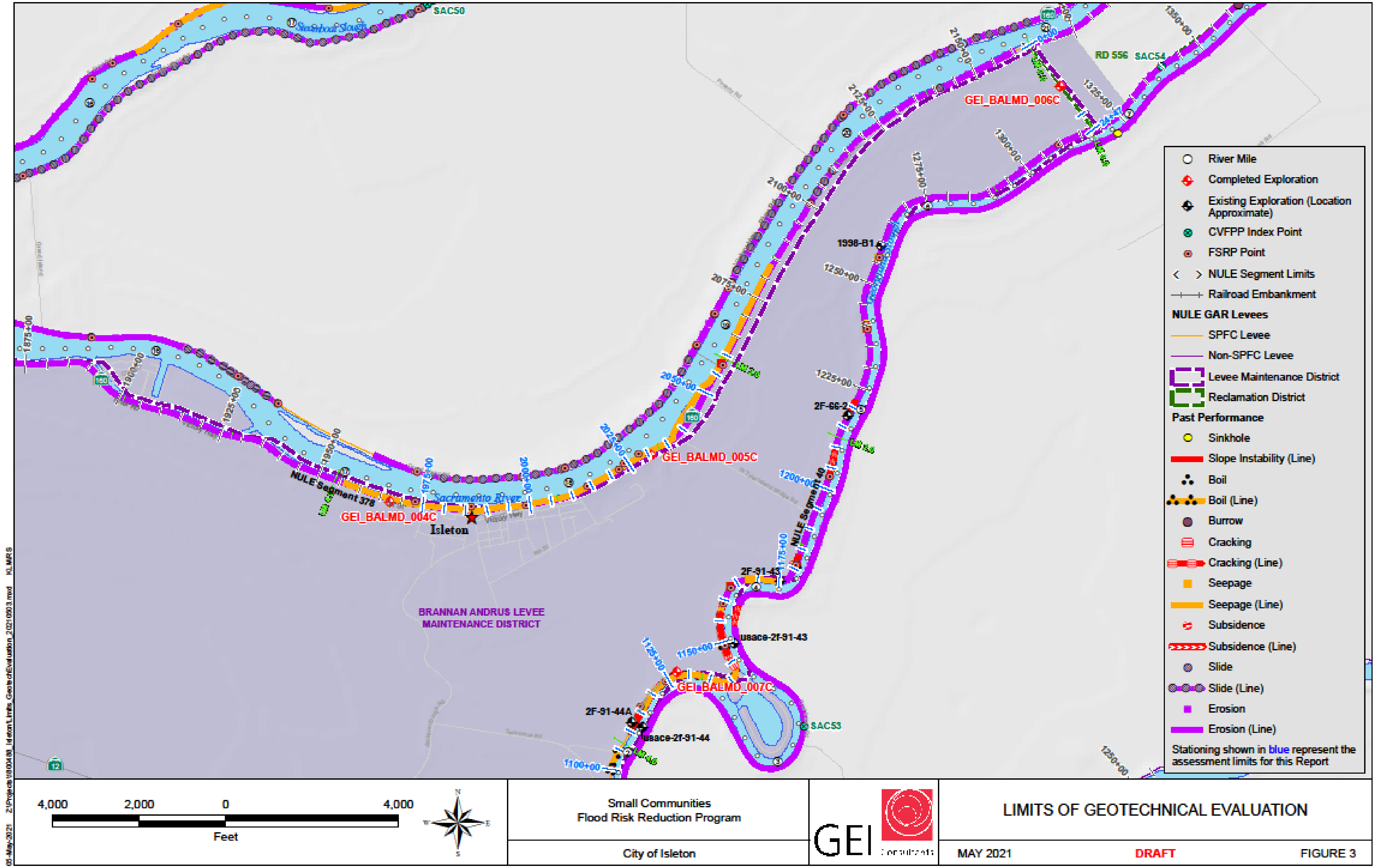


Figure 3 **Limits of Geotechnical Evaluation**

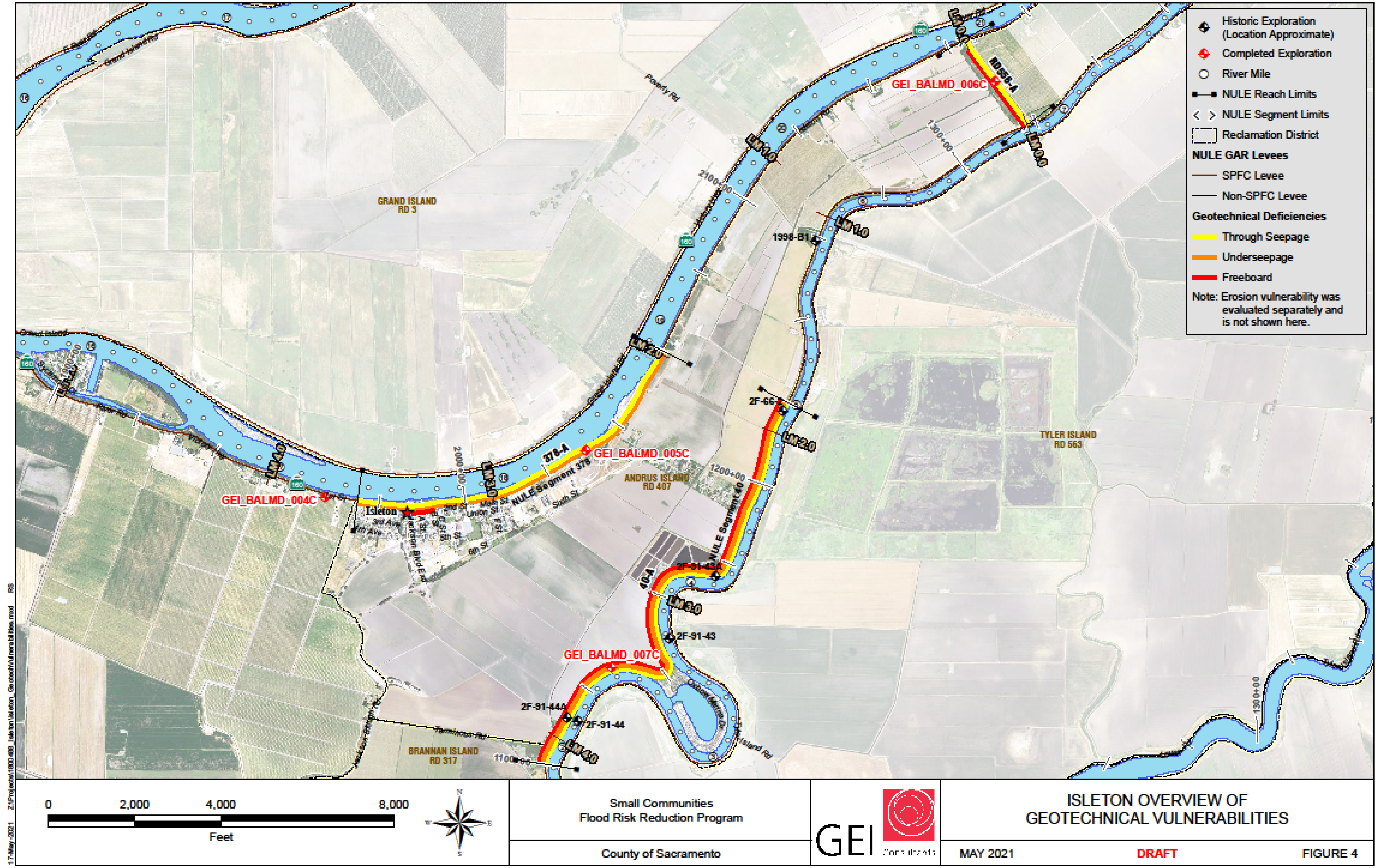


Figure 4 Isleton Overview of Geotechnical Vulnerabilities

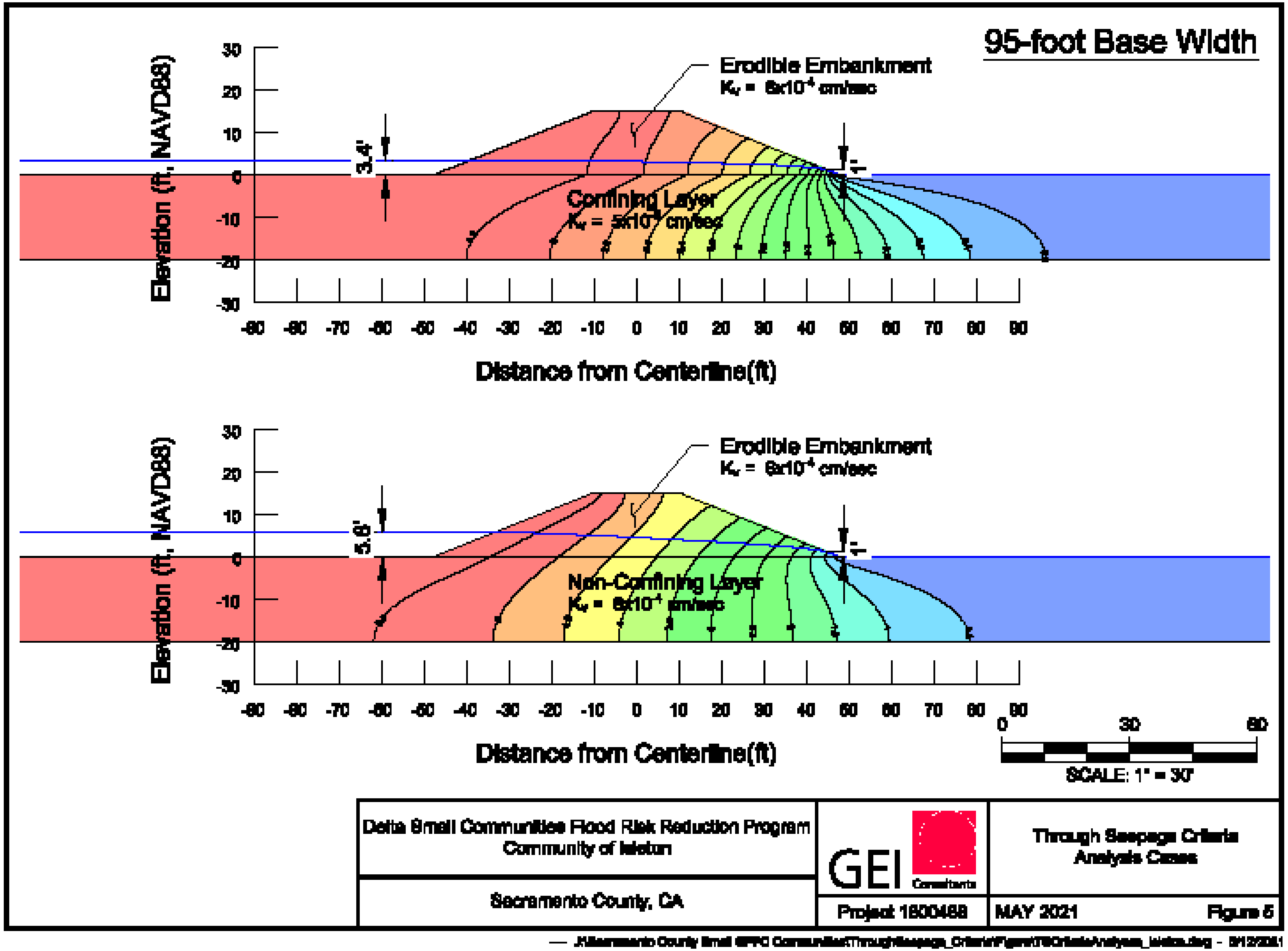
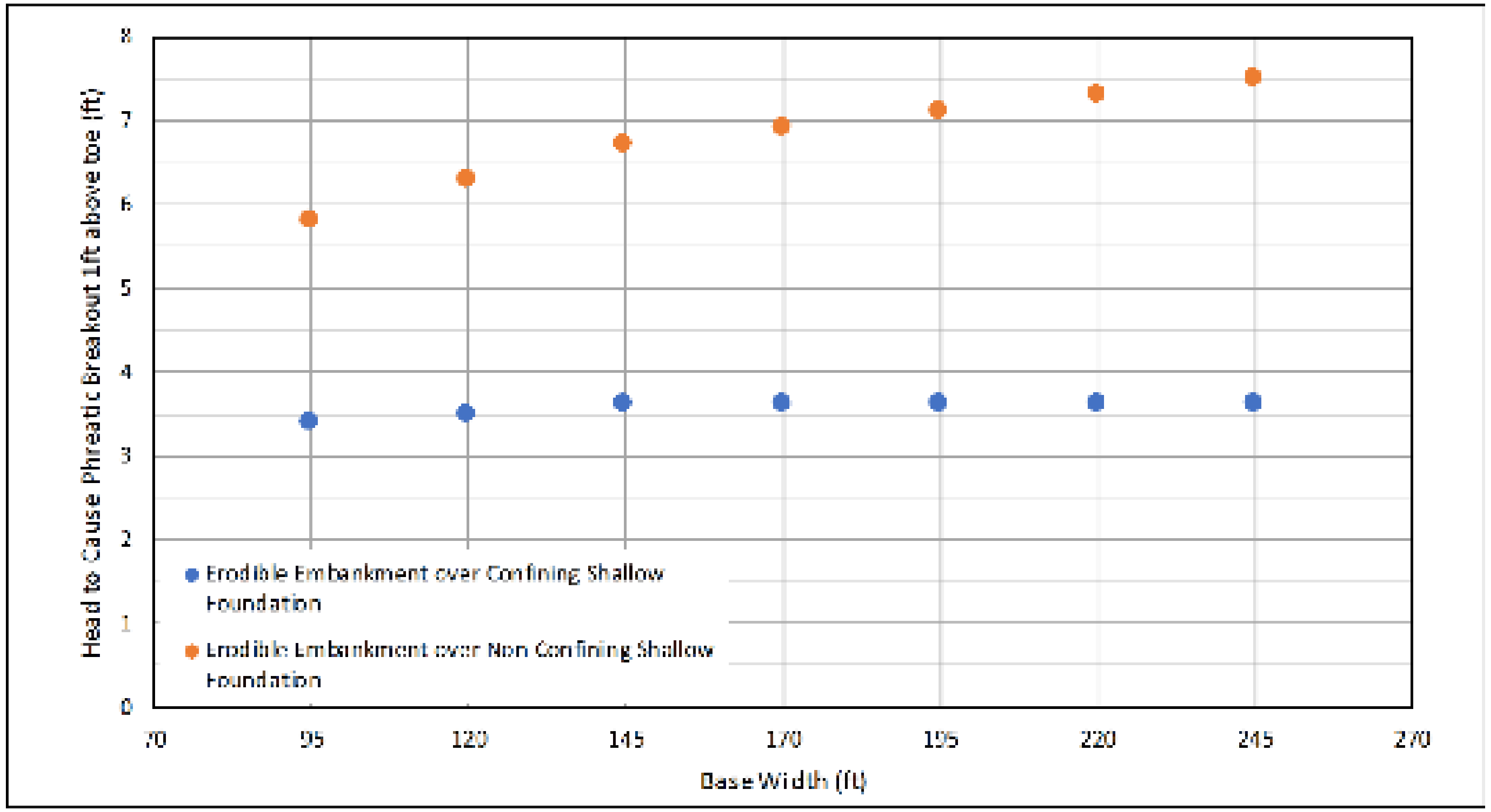


Figure 5 Through Seepage Criteria Analysis Cases



CRITERIA SUMMARY		Levee Base Width (feet)						
Analysis Case	Emb./Found.	95	120	145	170	195	220	245
		Head to Cause Through Seepage						
1	Erodible Embankment over Confining Shallow Foundation	3.4	3.5	3.6	3.6	3.6	3.6	3.6
2	Erodible Embankment over Non-Confining Shallow Foundation	5.8	6.3	6.7	6.9	7.1	7.3	7.5

NOTES:

1. Model assumes 20-foot crest width
2. Erodible Embankment: $k_v = 5x10^{-4}$ cm/sec
3. Confining Foundation: $k_v = 5x10^{-6}$ cm/sec
4. Non-confining Foundation: $k_v = 5x10^{-4}$ cm/sec

Delta Small Communities Flood Risk Reduction Plan - Community of Isleton

Sacramento County, CA

GEI Consultants

Project 1600488

Head to Cause Phreatic Breakout 1ft above toe

MAY 2021 **Figure 6**

Figure 6 Head to Cause Phreatic Breakout 1-Foot Above Toe

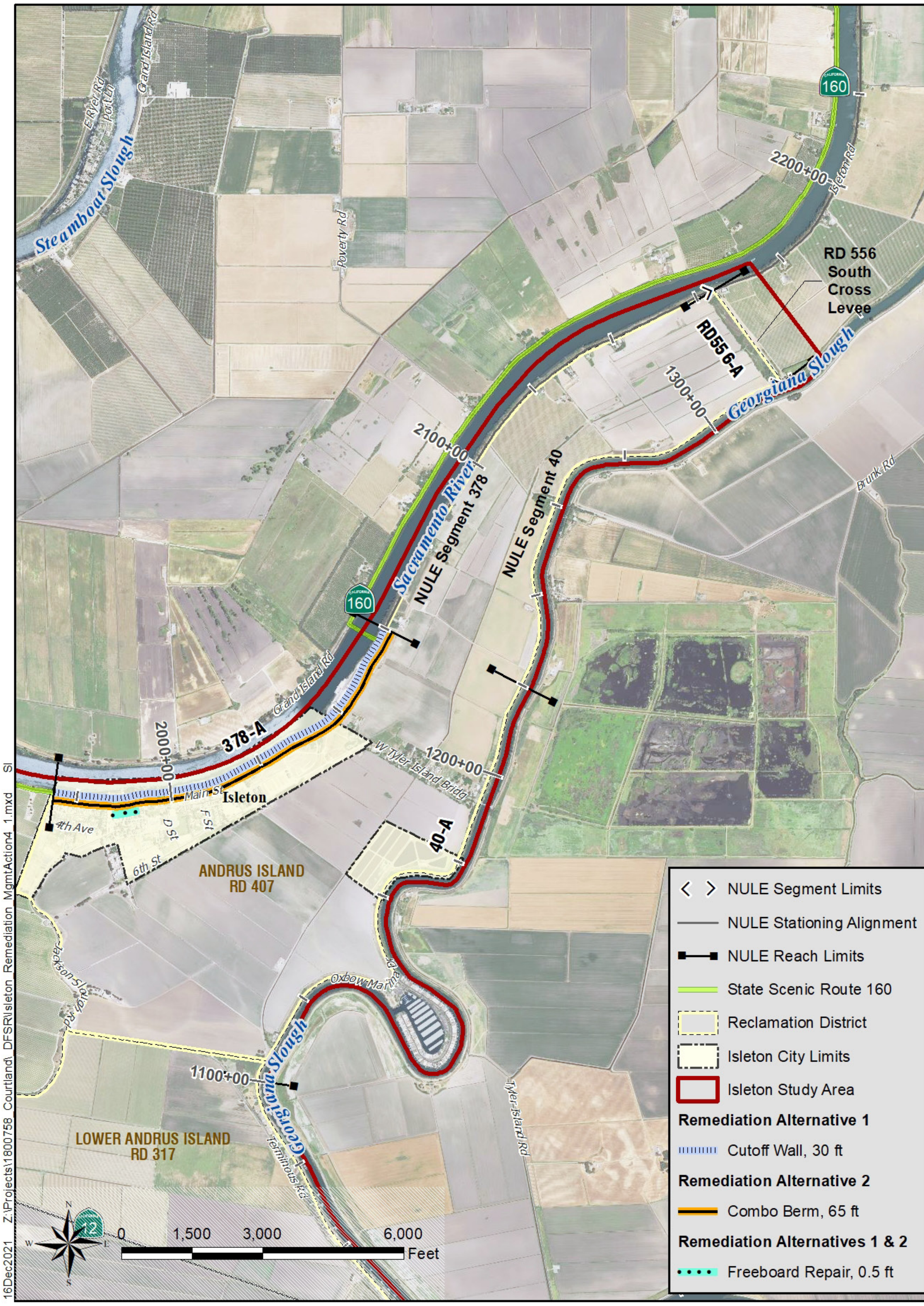


Figure 7 **Repair and Strengthen-in-Place Remedial Alternatives for Sacramento River Left Bank SPFC Levee Adjoining Isleton (Portion of NULE Segment 378)**

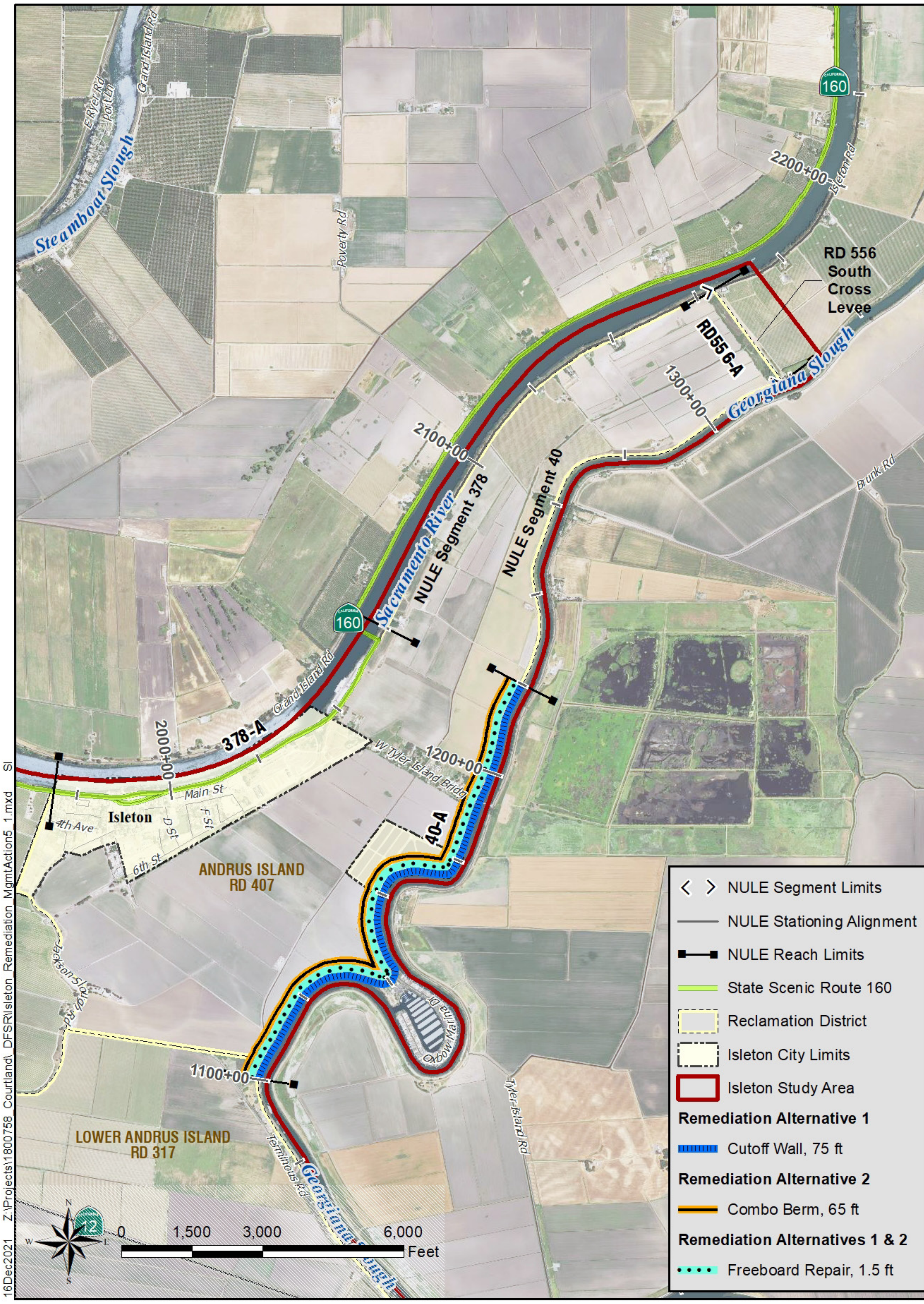


Figure 8 **Repair and Strengthen-in-Place Remedial Alternatives for Georgiana Slough Right Bank SPFC Levee near Isleton (Portion of NULE Segment 40)**

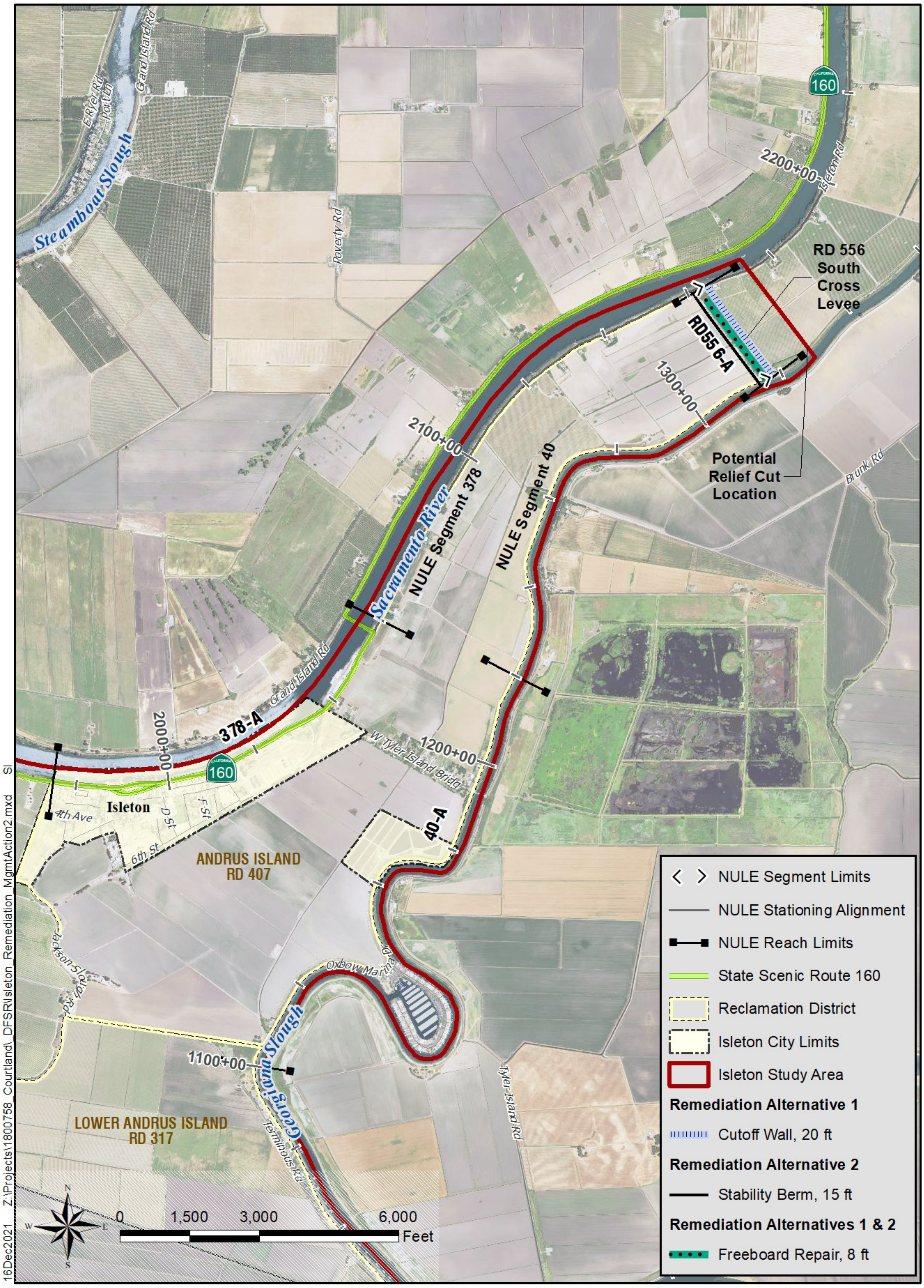


Figure 9 Raise and Repair/Strengthen-in-Place Remedial Alternatives for RD 556 South Cross Levee (RD 556-SCL)

Appendix A Existing Geotechnical Data Technical Memorandum, July 2018

Technical Memorandum

To: Charles Bergson and Romi Balbini, City of Isleton

From: Graham Bradner and Jeff Twitchell, GEI Consultants, Inc.

Date: July 2018

Re: Existing Geotechnical Data Technical Memorandum
SCFRR – City of Isleton, Sacramento County, CA

Introduction

The purpose of this memorandum is to summarize existing geotechnical information and past performance for the levees protecting the City of Isleton in Sacramento County, California and identify recommendations for further subsurface investigation. The Brannan-Andrus Levee Maintenance District (BALMD) levees protect the City of Isleton are constructed along the left bank of the Sacramento River (California Department of Water Resources [DWR] Non-Urban Levee Evaluation [NULE] Segment 378), the right bank of Georgiana Slough (NULE Segment 40), the right bank the North Mokelumne River (NULE Segment 1050), the right bank of the San Joaquin River (NULE Segment 1049), and the left bank of Seven Mile Slough (NULE Segment 1048), as shown on Figure 1 and discussed in more detailed below. The ring levee system (Brannan-Andrus Island) protecting the City of Isleton is completed by a cross-levee common with Reclamation District (RD) 556 at the northeastern end and high ground at the southwestern extent between Sacramento River and Three Mile Slough.

Existing conditions information for these levees is primarily available from the DWR Division of Flood Management's NULE project which addressed State Plan of Flood Control (SPFC) levees protecting populations of fewer than 10,000 people and Non-SPFC levees that were considered appurtenant and may impact the performance of SPFC levees.

Sacramento River Levee

The Sacramento River left bank levee near Isleton (NULE Segment 378) extends approximately 11.6 miles along the northwest side of Brannan-Andrus Island from the confluence of the Sacramento River and Three Mile Slough, northeast to the cross-levee common between BALMD and RD 556. NULE Segment 378 is a SPFC levee that is a part of the BALMD levee system. Along this Sacramento River extent, flow is from the northeast to the southwest. The approximate upstream water surface elevation (WSE) near river mile (RM) 20.7 for the 100-year WSE is 13.8 feet and the downstream 100-year WSE near RM 10.5 is approximately 10.6 feet (GEI, 2016). The United States Army Corps of Engineers (USACE) 1955/57 design profile WSE as provided by DWR (1955/57 design profile) is 14.4 feet at the upstream end of the Sacramento River portion of the levee and 11.5 feet at the downstream end. These WSEs are in reference to the North American Vertical Datum of 1988 (NAVD88).

Georgiana Slough Levee

The Georgiana Slough right bank levee (NULE Segment 40) is a SPFC levee that is a part of the RD BALMD levee system. It is approximately 6 miles long, extending from the cross-levee common between BALMD and RD 556 downstream to the confluence of Georgiana Slough and the North Mokelumne River. The approximate upstream water surface elevation (WSE) near river mile (RM) 6.8 for the 100-year WSE is 14.2 feet NAVD88 and the downstream 100-year WSE near RM 0.2 is approximately 10.3 feet NAVD88 (GEI, 2016). The 1955/57 design profile WSE is 13.7 feet NAVD88 upstream and 9.9 feet NAVD88 downstream.

North Mokelumne River Levee

The North Mokelumne River right bank levee (NULE Segment 1050) is a Non-SPFC levee that is a part of the BALMD levee system. It is about 2.9 miles long and extends from to the confluence of Georgiana Slough and the Mokelumne River southward to the confluence of the Mokelumne River and the San Joaquin River. The Mokelumne River is affected by backwater conditions and a 100-year water surface is not available for the BALMD North Mokelumne River levee. As a Non-SPFC levee, a 1955/57 design profile water surface is also not available.

San Joaquin River Levee

The San Joaquin River right bank levee (NULE Segment 1049) is a Non-SPFC levee that is a part of the BALMD levee system. It is about 2.6 miles long and extends from the confluence of the Mokelumne River and the San Joaquin River westward to the confluence of the Seven Mile Slough and the San Joaquin River. The San Joaquin River in this area is affected by backwater conditions and a 100-year water surface is not available for the BALMD North Mokelumne River levee. As a Non-SPFC levee, a 1955/57 design profile water surface is also not available.

Seven Mile Slough Levee

The Seven Mile Slough left bank levee (NULE Segment 1048) is a Non-SPFC levee that is a part of the BALMD levee system. It is about 4.6 miles long and extends from the confluence of the Three Mile Slough and Seven Mile Slough eastward to the confluence of Seven Mile Slough and the San Joaquin River. 100-year and 1955/57 design profile WSEs are not available for the Seven Mile Slough levee. Along the western approximately 1.3 miles of the slough water is controlled by a gated dam with two 48-inch diameter pipes with gate valves.

RD 556 South Cross Levee

The cross levee between Upper Andrus (RD 556) and Brannan-Andrus (BALMD) was built by RD 556. The cross levee is approximately 0.5-miles long. No additional information was available during the preparation of this technical memorandum.

Levee Construction History and Improvements

The Brannan-Andrus Island levees surrounding the City of Isleton were constructed by various efforts. The Sacramento River levees (NULE Segment 378) were initially constructed between 1860 and 1880 by Chinese laborers using shovels and wheelbarrows. Levees were later built up with clamshell dredging to increase the levee height. The material used to build the levees was taken from the channel, and was likely not compacted. Between 1946 and 1947, USACE constructed a setback levee with material from the existing levees. The setback levee was constructed with a 20-foot crest width and 2H:1V slopes.

Information was not found on the initial construction of the Georgiana Slough levees protecting the City of Isleton (NULE Segment 40). They may have also been initially constructed between 1860 and

1880 by Chinese laborers using shovels and wheelbarrows as other levees in the area were. Between 1950 and 1952, the Georgian Slough levee was reconstructed by the USACE. Borrow sites were located within the Georgiana slough channel. Design drawings generally identify a 20-foot crest with, 2H:1V landside slopes, and 3H:1V slopes. In most locations the reconstructed levee was setback from the originally constructed levee.

The non-SPFC BALMD levees along the Mokelumne River, San Joaquin River, and Seven Mile Slough (NULE Segments 1050, 1049, and 1048) were originally built by the Tide Land Reclamation Company between 1871 and 1872. In general, the initial levee was about 4 feet high, was 15 feet wide at the base and was 8 feet wide at the crown. The levee along the San Joaquin River was reported to have settled persistently, and about 1.5 to 2 feet of additional material was placed on top of the levee every year between 1873 and 1878. After flooding of Brannan-Andrus Island in 1877-78, the levee was rebuilt in 1878 by the newly organized Reclamation District (RD 317). The reconstructed levees were about 5 to 9 feet high and 25 to 40 feet wide at the base, with a crown width of 3 to 5 feet. For the most part, material used for reconstruction was imported from outside the island. Details about these imported materials were not reported in reviewed documents. Based on the NULE field reconnaissance interview with the levee district engineer, the control structures controlling the flow on Seven Mile Slough (NULE Segment 1048) were built around 1950.

Levee Past Performance

Past performance is based primarily on the DWR NULE project information which was gathered through review of available documents and interviews with levee maintenance personal. In general, the Sacramento River levee near the City of Isleton has experienced widespread erosion including bank and slope caving and wavewash erosion. Limited occurrences of cracking and landslide sloughing have also been reported. For the remainder of the BALMD basin (NULE Segments 40, 1050, 1049, and 1048) boils and seepage have been reported during past high-water events. Particularly several reports of seepage, boils, or boils moving sand are document along the levee to the southeast of Isleton, near Oxbow Marina (NULE Segment 40) in the 1996-97 and 1997-98 high water events. Occurrences of slope instability, subsidence, cracks, and settlement are also noted at locations throughout the basin. Past performance is summarized in Table 1 and shown on Figure 2.

Based on past performance and field reconnaissance, DWR's Flood System Repair Project (FSRP) identified two *critical* sites along the levees of the BALMD basin, one for through seepage along the NULE Segment 1050 and one for stability along NULE Segment 1049. Thirteen *serious* sites were also identified in the BALMD basin, nine erosion sites along the Sacramento River lever (NULE Segment 378), two stability sites along Georgiana Slough levee (NULE Segments 40), and two seepage sites along the Mokelumne River levee (NULE Segment 1050). Four of the FSRP *serious* erosion sites are along the levees directly adjacent to the City of Isleton. A map and table of the *critical* and *serious* sites from the FSRP Report (URS, 2013) are included in Appendix A.

Levee Freeboard and Geometry

The DWR NULE project freeboard review measured available freeboard against the 1955/57 design water surface profile for SPFC levees. For the Sacramento River levee protecting the City of Isleton (NULE Segment 378) the NULE review found that a minimum of 3 feet of freeboard above the 1955/57 design profile was available throughout the segment. The NULE review of the right bank of Georgiana Slough (NULE Segment 40) that a minimum of 3 feet of freeboard above the 1955/57 design profile was not available for almost 90-percent of the segment, from approximately levee mile (LM) 0.0 to 1.5 and LM 6.2. The levee crest was generally found to be 0.5- to 1-foot below the

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1955/57 design freeboard except from approximately LM 0.7 to LM 1.5 were the levee crest is approximately 2 feet below the 1955/57 design freeboard.

The levees along the North Mokelumne River (NULE Segment 1050), the San Joaquin River (NULE Segment 1049), and Seven Mile Slough (NULE Segment 1048), do not have a 1955/57 design profile as they are Non-SPFC levees, and a freeboard review was not completed.

The DWR NULE project also reviewed and summarized NULE segment geometry based on Light Detection and Ranging (LiDAR) topography collected for DWR's Central Valley Floodplain Evaluation and Delineation (CVFED) between October 2008 and February 2009. Documented geometry information for the levees surrounding the City of Isleton are summarized in Table 2.

Available Geotechnical Information

The DWR NULE project included an assessment (Phase 1 only) of the levees protecting the City of Isleton. The NULE Phase 1 study included all the levees protecting Isleton, but was based on non-intrusive studies and readily available data. No subsurface explorations were completed as a part of the NULE Phase 1 study. Assessment data such as historical reports, interviews with personnel, construction records, levee performance records, and other data provided by relevant agencies was collected and reviewed for the study. Geomorphic studies and topographical surveys were also completed. This collection of information was used to characterize the existing condition of the Non-Urban levees in the NULE Geotechnical Assessment Report (GAR). NULE GAR segment specific write-ups for each of the segments protecting the City of Isleton (NULE Segments 378, 40, 1050, 1049, and 1048) are attached in Appendix B.

Geomorphic Setting

Geomorphology mapping developed for the DWR NULE project indicates the BALMD levees along the Sacramento River and Georgiana Slough primarily overlie historical overbank deposits (Rob) which is underlain by Holocene overbank deposits (Hob). Overbank deposits likely consist of interbedded sand, silt, and clay deposited during high-stage flow, overtopping channel banks. Localized areas of historical crevasse splay deposits (Rcs), historical distributary channel deposits (Rdc), and Holocene slough deposits (Hsl) are also present. The crevasse splay deposits are likely to consist of fine to coarse sand with minor lenses of gravel deposited from breaching of natural levees. The distributary channel deposits likely contain sand, silt, and clay from channeled flow conducting sediments to floodplain. The slough deposits are likely to consist of silt, clay, and trace sand, fining upward from low-energy channel deposits. Along the landside of the southern approximately 1.3 miles if the BALMD Sacramento River left bank levee, where high ground is present, dredge spoils are mapped. Interior to the BALMD basin and below Georgiana Slough is mapped as Holocene peat and muck (Hpm), likely composed of interbedded peat and organic-rich silt and clay from former tidal marsh deposits.

The available DWR NULE geomorphology mapping for the BALMD levees along the right bank the North Mokelumne River, the right bank of the San Joaquin River, and the left bank of Seven Mile Slough is less detailed but indicates that these portions of the BALMD levee system overlie Holocene peat and muck (Hpm). For mapping and additional information, the technical memorandums for the geomorphology efforts that cover these areas are included in Appendix C.

Existing Subsurface Explorations

Based on review of existing subsurface data, there are total of five known explorations along the approximately 17.5 miles of SPFC levees in the Brannan-Andrus Levee Maintenance District.

Exploration locations are shown in Figure 3. All five investigations are along the right bank of Georgiana Slough (NULE Segment 40), no existing explorations were identified along the levee near the City of Isleton or elsewhere on the BALMD extent of the left bank of the Sacramento River (NULE Segment 378). The identified explorations along Georgian Slough were completed by USACE, four in 1991 composed of two pairs of crown and toe borings completed near Oxbow Marina and one boring completed in 1966 near Isleton Bridge that was only through the embankment. The 1991 crown borings were 40-feet deep, approximately 30 feet below the natural ground surface, and the toe borings were about 20-feet deep. These borings show a sandy levee and sandy shallow foundation with some clay to about 10 feet below the natural ground surface. The sandy shallow foundation is shown to be underlain by primarily organic clay (OH) and peat material. One of the borings terminated in sand, at about 30 feet below the natural ground surface. The 1966 boring identified a silty embankment with 54-87% fines based on laboratory sieve testing. Available log or profile information for the existing investigations is included in Appendix D.

For the SPFC levees, Caltrans bridge exploration data was also reviewed to identify if exploration data was available for the bridge north of Isleton that connects Grand Island and Brannan-Andrus Island or the Highway 12 bridge that connects from Rio Vista to Brannan-Andrus Island. No data was found for the bridge north if Isleton. Several 1958 explorations were identified for the Highway 12 bridge from Rio Vista but the borings were limited to the west approach of the bridge (the opposite bank the Sacramento River), and therefore are outside the project area.

Along the approximately 10 miles of non-SPFC levee that complete the ring levee system protecting the City of Isleton, review of existing subsurface data identified appreciably more existing explorations which are described below. Exploration locations are shown in Figure 3 and available log or profile information for the existing investigations is included in Appendix D.

Along the right bank of the North Mokelumne River BALMD levee (NULE Segment 1050) 18 explorations have been completed. Ten borings were complete by Whaler Associates in 1989, including seven through the levee crown to depths of 41 to 70 feet below the crown and three at the landside levee toe to depths around 26 feet below the ground surface. One boring was drilled through the levee by Raney Geotechnical in 1990 to a depth of 40 feet. Two landsides borings were completed by DWR as part of the 1992 North Delta Seepage Monitoring project, one at the landside toe to a depth of 20 feet and one further landward to a depth of 100 feet. Based on these explorations, the levee is primary composed of silty sand, sand, silt, and organic soil and the foundation consists primarily of peat and organic soil (organic silt and organic clay). The thickness of organic soil found in the foundation ranges from about 10 to 55 feet. Caltrans bridge exploration data from 1976 for the Highway 12 bridge across the Mokelumne River, connecting Brannan-Andrus Island to Bouldin, included five borings on the right bank, on the waterside of the levee. These borings show a waterside foundation composed of silt, sand, and silty clay.

Along the right bank San Joaquin River BALMD levee (NULE Segment 1049) 26 borings have been completed along the 2.6-mile long segment. Twenty-two of the borings were performed between 1956 and 1958 by DWR as part of the Salinity Control Barrier Investigation. Most of the borings were drilled through the levee crown with a couple each on the levee slope, landside levee toe, and landward of the landside toe. Borings generally range in depth from 20 feet to 80 feet deep with two deeper explorations going to depths of about 170 and 210 feet below the levee crown. Profiles of these explorations are available and show a levee embankment generally composed of silt, silty sand, sand, and organic silt and a foundation consisting of organic soil (peat, organic silt, and organic clay), sand, and silt. Organic soil in the foundation ranges from 2 to 40 feet in thickness.

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Four additional borings were drilled by Rainey Geotechnical in 1987. No log or profile information was found for three of the four borings. The log available is approximately 51.5 feet deep and shows materials consistent with those encountered by the Salinity Control Barrier Investigation described above. Five other explorations were drilled in 1987 by Raney Geotechnical along the landside of the levee, for private development, logs are not available.

Along the left bank Seven Mile Slough BALMD levee (NULE Segment 1048) 4 borings were drilled by J.H. Kleinfelder & Associates in September of 1977. As shown in Figure 3, three of the boring were closely spaced near the western end of the segment. The borings ranged in depth from 41.5 feet to 76 feet below the levee crown. Based on the available logs, the levee consists of primarily silt and sand, and the foundation consists of organic soil (peat, organic clay, and organic silt), sand, and some silt. The thickness of organic soil in the foundation ranged from about 15 to 20 feet.

Understanding of Existing Geotechnical Conditions

The NULE GAR assessments were based on non-intrusive studies and readily available data as discussed above. More specifically, hazard indicators and levee performance history identified during the data review process were used as the basis for categorizing each levee segment. For each levee segment, hazard indicators were assessed for four potential failure mechanisms: underseepage, slope stability, through seepage, and erosion. Assessments were made based on information about levee and foundation composition, levee geometry, hydraulic head at the assessment WSE, and the presence of penetrations, ditches, and burrowing animal activity. These hazard indicators were then compared to a levee's performance history to categorize each geotechnical potential failure mode. The NULE GAR assessments were performed at a single WSE (assessment WSE). The assessment WSE was the 1955/57 design profile, where available. Otherwise assessments were performed for a water surface at 1.5 to 6 feet below the levee crest, depending on the levee location. For Delta levees where a 1955/57 design profile was not available, the assessment WSE was set at 1.5 feet below the levee crest.

Hazard categories were assigned for each of the four potential failure mechanisms (underseepage, slope stability, through seepage, and erosion) and then were evaluated collectively to assign an overall hazard level category to each NULE segment. The NULE GAR found the NULE Segment 378 levee along Sacramento River, adjacent to Isleton to have a *moderate* likelihood of levee failure at the 1957 design WSE based on potential vulnerability to slope stability, through seepage, and erosion. The Georgina Slough levee (NULE Segment 40) was assessed to have a *high* likelihood of levee failure at the 1957 design WSE based on potential vulnerability to underseepage, slope stability, and through seepage. The non-project BALMD levees along the North Mokelumne River (NULE Segment 1050), the San Joaquin River (NULE Segment 1049), and Seven Mile Slough (NULE Segment 1048), were identified as having *moderate* to *high* likelihood of levee failure at the assessed WSE (assigned as 1.5 feet below levee crest) based on potential vulnerability to underseepage, slope stability, and through seepage as well as erosion for NULE Segments 1049 and 1050. Individual results for the four potential failure mechanisms are summarized in Table 3. More discussion of these results can be found in the GAR segment write-ups included in Appendix B.

Conclusions and Recommendations

Geotechnical understanding of the embankment and foundation will be critical to the evaluation of structural alternatives for the City of Isleton. As discussed above, some geotechnical information is available for the BALMD levee system, but no exploration information is available along the Sacramento River levee, including adjacent to Isleton. Understanding of the subsurface conditions including the blanket thickness and depth of the aquiclude layer will be critical in determining cutoff wall construction depths and requirements during evaluation of potential structural improvements.

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Therefore, additional data is recommended to complete the feasibility study. Site-specific geotechnical explorations will be outlined in a separate geotechnical investigation plan. The investigation program will include collection of soil samples and in-situ data, detailed descriptions of embankment and foundation conditions, and laboratory testing to support geotechnical evaluation and development of feasibility-level repair recommendations.

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Tables

Figures

Appendices

Acronyms

BALMD	Brannan-Andrus Levee Maintenance District
CVFED	Central Valley Floodplain Evaluation and Delineation
DWR	California Department of Water Resources
FSRP	Flood System Repair Project
GAR	Geotechnical Assessment Report
LiDAR	Light Detection and Ranging
LM	Levee mile
NAVD88	North American Vertical Datum of 1988
NULE	Non-Urban Levee Evaluation
RD	Reclamation District
RM	River Mile
SPFC	State Plan of Flood Control
USACE	United States Army Corps of Engineers
WSE	Water Surface Elevation

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Tables

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Table 1. Summary of Reported Past Performance - Levees Surrounding the City of Isleton

NULE Segment and Location	Flood Season	Reported Performance Description	Approximate Location	Mitigation
378 Left Bank Sacramento River BALMD (SPFC levee)	1931	RD expressed concern about erosion problem	Multiple locations	None documented
	1936	Bank Caving	RM 14.0 - 20.2	None documented
	1957	Rodent infestation	Multiple locations	None documented
	1957	Slope and bank caving/erosion on the waterside	LM 0.07 - 6.85	None documented
	1961	Sites experiencing caving on the waterside.	RM 12.8	None documented
	1962	Erosion repairs recommended	RM 14.7 and RM 12.8	Repair recommended
	1969	Critical erosion site	RM 12.4	Repair recommended but documentation not found
	1969	Caving 100 to 500 feet long. From RM 13.5 to 9.3, caving length increased to 1,600 to 5,000 feet long.	RM 18.7 RM 18.6 RM 18.0 RM 17.8 RM 17.1 RM 16.5 RM 15.7 RM 15.5 RM 15.3 RM 15.2 RM 15.0 RM 14.6 RM 13.5 RM 10.5 RM 9.6 RM 9.3	None documented
	1969	Critical erosion sites (Priority A and B sites) about 200 to 1,000 feet long. Recommended sites be inspected and assessed by USACE.	RM 16.8 RM 16.6 RM 15.2 RM 15.0 RM 13.7 RM 13.0 RM 12.4 RM 11.4 RM 11.2 RM 10.6 RM 9.3	None documented
	1996	Erosion on landward slope.	LM 2.02	None documented
	1997	Erosion, wavewash, scour, and/or sloughing	LM 0.43 - 0.44 LM 0.62 - 0.68 LM 0.71 - 0.72 LM 1.74 - 2.03 LM 2.06 LM 2.13 LM 2.85 - 2.97 LM 2.96 - 3.15 LM 3.23 LM 3.45 LM 4.29 - 4.36 LM 6.96 - 7.08 LM 7.24 - 7.28 LM 7.74 LM 7.96 LM 8.5 LM 8.92 LM 9.05 LM 9.1 LM 9.4 LM 9.6 LM 9.68	Repair recommended but documentation not found

Table 1. Summary of Reported Past Performance - Levees Surrounding the City of Isleton

NULE Segment and Location	Flood Season	Reported Performance Description	Approximate Location	Mitigation
378 Left Bank Sacramento River BALMD (SPFC levee)	1998	Redamaged erosion sites on the levee slope ranging from 30 to 250 feet long with a 2- to 10-foot vertical face.	LM 0.3 LM 1.33 LM 2.0 LM 5.39 LM 5.59 LM 9.15 - 9.2 LM 9.24 - 9.29 LM 9.47 - 9.51 LM 9.88 - 9.95	None documented
	1998	Scour: 2-4 feet vertical face. Pre-existing.	LM 5.42	Monitor and maintain
	1998	Scour: 50 feet long with 10 foot vertical face.	LM 9.15	Repair to pre-flood condition
	1998	Scour: 250 feet long with 4 foot vertical face.	LM 9.47	Repair to pre-flood condition
	1998	Scour: 4 feet deep and 250 feet long.	LM 9.68	No repair recommended
	1998	Wavewash damage to the revetment and upper waterside levee slope.	LM 3 - 5.5	None documented
	1998	Subsidence and cracking in paved road parallel to the levee crown	LM 1.02 - 1.22	None documented
	1999	Erosion; repairs recommended (Doc-1858).	LM 1.76 - 1.78 LM 1.79 - 1.80 LM 1.85 - 1.86	Fill erosion hole with riprap and restore levee to preflood grade
	2003-2006	Critical erosion site; erosion into the levee with two large pockets with a depth of 10 to 12 feet	LM 0.10 (RM 20.8)	None documented
	2006	Critical erosion sites along the Sacramento River.	RM 10.9 RM 11.1 RM 11.2 RM 12.5 RM 12.6 RM 12.7 RM 12.8 RM 12.9 RM 13.0 RM 13.4 RM 13.6 RM 15.3 RM 15.4	None documented
	2007-2008	Wave wash erosion on mid-bank of levee toe approximately 1,050 feet long	RM 10.8	None documented
	2008	Erosion causing a vertical bank at the highway.	RM 11.2	None documented
	2008	Erosion with oversteepened slopes and pockets of erosion	RM 16.8	Currently under design but documentation not found
	2011	Sloughing on landside slope from hinge to mid-slope, 2 feet deep, and lower half of slope is bulging.	LM 2.03	None documented
	2011	Crack on the landside shoulder with slight bulge uplift of soils on the landside slope. Crack is about 20 feet long, 4 inches wide, and about 4.5 inches of vertical displacement.	LM 9.5	None documented

Table 1. Summary of Reported Past Performance - Levees Surrounding the City of Isleton

NULE Segment and Location	Flood Season	Reported Performance Description	Approximate Location	Mitigation
40 Right Bank Georgiana Slough BALMD (SPFC levee)	1957	Sinkhole in levee crown, 2-3 feet in diameter and about 6 inches deep	LM 1.48 LM 1.49	None documented
	1961	Caving along the right bank	RM 0.3 (~LM 5.8)	None documented
	1969	Erosion approximately 400 feet long	RM 2.62 (~LM 3.38)	Recommended but documentation not found.
	1986	Chronic Seepage	RM 1.54-3.96	None documented, stability berm recommended.
	1986	Seepage and boils area.	RM 5.61-5.76	None documented, recommended to remove vegetation and backfill swamp area to a distance of 100 feet from levee toe.
	1986	Seepage and boils area.	RM 6.81-7.71	None documented, recommended to clear and backfill irrigation ditch/construct seepage berm approximately 4800 feet long.
	1994	Levee sloughing or subsidence	LM 2.07 to 2.18	None documented
	1996-1997	Severe seepage	LM 1.17	None documented
	1996-1997	Erosion	LM 0.36 LM 2.62	None documented
	1996-1997	Multiple sites with heavy seepage and boils.	LM 3.01 - 3.93	Repaired with toe drain, stabilizing berm, and relocated ditch away from toe.
	1996-1997	Multiple sites of slope stability and landside sloughing into the ditch. Sites ranged from 50 feet to 1,000 feet long along the landside slope and toe.	LM 3.05 - 3.2 LM 3.01 - 3.93 LM 3.3 LM 3.83 to 3.94	LM 3.01 - 3.93: Repaired with French drain and stability berm by USACE and BALMD.
	1996-1997	Boil	LM 4.13	Recommended but documentation not found.
	1996-1997	Boils	LM 4.86	None documented
	1997	Slump	LM 5.32	Repaired by placing drain rock. "Another area" remains unrepaired.
	1996-1997	Sloughing of the revetment	LM 5.53	None documented
	1996-1997	Subsidence on landside	LM 5.56 - 5.84	None documented
	1997-1998	Boils moving sand	LM 3.9	Repaired with bentonite plug and additional berm.
	1997-1998	Several boils landside, approximately 40 feet long, 3-foot vertical face.	LM 4.04 - 4.13	None documented
	1998	20 feet long toe slip with a 3-foot scarp extending one-third height of the landward slope. Seepage emerging from the slough debris with clear water running through.	LM 1.5	None documented
	1998	Boils appeared at the same location as the PL 84-99 Phase III rockfill repair that was placed in Nov 1997.	LM 3.9	None documented
	1998	Erosion on the levee slope	LM 0.32-0.33 LM 0.54-0.55	No repair recommended
	1998	Erosion to the levee slope <2 feet vertical face.	LM 0.74-0.76 LM 1.54-1.57	No repair recommended
	1998	Pre-existing boil site on land side.	LM 1.0-1.15	No repair recommended
	1998	Toe failure of the revetment rock with a 1-2 feet vertical face.	LM 1.11-1.18	No repair recommended
	1998	Displaced revetment rock due to boat wake wash	LM 2.62	No repair recommended

Table 1. Summary of Reported Past Performance - Levees Surrounding the City of Isleton

NULE Segment and Location	Flood Season	Reported Performance Description	Approximate Location	Mitigation
40 Right Bank Georgiana Slough BALMD (SPFC levee)	1999	Erosion	LM 1.33	PL 84-99 repair: Filled erosion with riprap
	2005	Boils about 20 feet from the landside toe, cracking 5 feet above the toe, and 1- to 2-foot subsidence about 20 feet long.	LM 2.75	Cofferdam constructed across ditch near toe to create a head against boil.
	2011	Sloughing on landside slope, up to 9 inches deep, with up to 12-foot vertical scarps.	LM 1.82 - 1.89 LM 2.55 - 2.59 LM 2.93	None documented
	2011	The ground at the lower foot of the landside berm and the toe is wet at two locations. One location is located within a 10-foot wide and 2.5 feet deep depression. The slough water level was above the landside toe elevation during the inspection. The berm was designed with a gravel drain with no collection system.	LM 3.83	None documented
1050 Right Bank North Mokelumne River BALMD (Non-SPFC levee)	Late 1980s to early 90s	Erosion	Sta. 1050+00 to 1085+00	Riprap placed in 1992.
	1997	Several cracks over a 500-foot length and possible slips on landside approximately 300 feet long.	Sta. 1085+00 to 1090+00	Berm and ballast were placed as part of an emergency repair performed by USACE.
	1998	Subsidence in crown, crack along the levee crown and slope	Near Sta. 1090+00	None documented
	1998	Wave wash erosion, “Wave wash above rip rap eroding crown, 276 feet. Almost a foot or so of dirt gone, eroded” Over 200 feet slipped riprap, earthen bank exposed, erosion underneath bermuda grass.	Near Sta. 1049+00 Sta. 1103+00 Sta. 1105+00	None documented
	2004	Seepage and boil on the landside slope	Sta. 1076+12	Seepage covered with crushed drain rocks
	2005	Seepage on the landside slope	Sta. 1077+00 to 1082+00	Seepage covered with crushed drain rocks and imported fill
	2010	Boil with clear water observed at location where there is a blocked drain issue.	Sta. 1050+00 to 1060+00	Mitigation proposed
	2010	Boil	Sta. 1090+00 to 1100+00	Mitigation proposed
1049 Right Bank San Joaquin River BALMD (Non-SPFC levee)	1972	“This failure occurred shortly after midnight on 21 June 1972, with an eventual breach of 500 feet. The levee failed at a high tide stage of about 3.7 feet mean sea level, due to instability rather than overtopping”.	Sta. 1970+00 to 1975+00	None documented
	1998	Eroding through riprap and underneath the county road into crest	Sta. 2046+00	None documented
	1998	Erosion with riprap sliding down the bank	Sta. 2034+00	None documented
	1998	Wave wash damage to the revetment and waterside levee slope	Sta. 1937+00 to 2069+00	None documented
	2006	Wave overtopping	Sta. 2030+00 to 2080+00	None documented
	2006	Wind induced wave erosion	Sta. 1940+00 to 2070+00	Riprapped
	2010	Boils observed in recurring free seepage area during flood elevation of 6 ft. (NGVD29)	Sta. 1970+00 to 1980+00	None documented
	2010	Slope instability	Sta. 1970+00 to 1980+00	None documented

Table 1. Summary of Reported Past Performance - Levees Surrounding the City of Isleton

NULE Segment and Location	Flood Season	Reported Performance Description	Approximate Location	Mitigation
1048 Left Bank Seven Mile Slough BALMD (Non-SPFC levee)	Varies	Levee subsidence	Sta. 1137+00 to 1165+00 Sta. 1200+00 to 1246+00	Portions of the levee have been raised including in 2003, 2006, and 2007.
	Early 1990s	Crack and settlement (over about 1,000 feet) reported in interview with BALMD representative	Sta. 1076+75 to 1087+00	Stability berm was constructed and levee raised by BALMD Between 1993 and 1995
	1994	A slip of approximately 600 feet in length which occurred along Brannan Island Road and Sevenmile Slough.		None documented, only monitored using two inclinometers
	1995	A slip of approximately 500 feet in length which occurred along Brannan Island Road and Sevenmile Slough about 0.8 miles easterly of Highway 160.		None documented, buttress repairs recommended
	1998	Levee subsidence and cracking. Subsidence with vertical displacement of approximately 15 inches. Cracking parallel to the levee crown, opened to about 7 inches.	Sta. 1087+00 to 1105+00	Stability berm was constructed by USACE as part of an emergency repair after 1998 flood
	1998	Erosion - slipping riprap and pocketing at Deadman's curve guardrail	Near Sta. 1260+00	None documented
	2010	Pin boils at 5 closely spaced locations 100 to 120 feet from the landside toe when farmer cut into the field to level it. Did not carry material.	Sta. 1072+15	None documented

Table 2. Summary of Levee Geometry[1] - Levees Surrounding the City of Isleton

NULE Segment	Segment Location	Approximate Levee Height	Approximate Crest Width	Approximate Landside Slopes	Approximate Waterside Slopes
378	Left Bank Sacramento River BALMD (SPFC levee)	Typically 12 to 15 feet, but range from 8 to 25 feet above the landside toe. High ground on landside for approx. southern 1.3 miles.	25 to 80 feet, except typically 20 to 25 feet from approx. levee mile (LM) 0.1 to LM 2.0 (north of Isleton)	Typically 2H:1V, but range from 1.5H:1V to 6.6H:1V	Often steeper than 3H:1V, but range from 1.1H:1V to 3.5H:1V
40	Right Bank Georgiana Slough BALMD (SPFC levee)	10 to 20 feet above the landside toe	15 to 40 feet	2H:1V to 4H:1V	2.5H:1V to 1H:1V
1050	Right Bank North Mokelumne River BALMD (Non-SPFC levee)	15 to 24 feet above the landside toe for most of segment. 10 to 12 feet above the landside toe for approx. southern 0.5 mile.	15 to 30 feet	4H:1V to 6H:1V Except 2H:1V to 5H:1V for approx. southern 0.5 mile.	2H:1V to 3.5H:1V
1049	Right Bank San Joaquin River BALMD (Non-SPFC levee)	17 to 22 feet above the landside toe, except about 12 feet above the landside toe for approx. eastern most 0.4 mills	15 to 25 feet	Typically 3H:1V, but range from 2H:1V to 4.5H:1V	2H:1V to 3H:1V
1048	Left Bank Seven Mile Slough BALMD (Non-SPFC levee)	20 to 28 feet above the landside toe	15 to 25 feet	Typically 3H:1V, but range from 2.5H:1V to 5H:1V	1.5H:1V to 3H:1V

[1] Based on summaries provided in NULE Geotechnical Assessment Report

Table 3. Summary of NULE GAR Asessement Results - Levees Surrounding the City of Isleton

NULE Segment	Segment Location	Assessment WSE	Overall Segment Categorization[1]	Results by Individual Failure Mechanism			
				Underseepage[2]	Slope Stability[2]	Through Seepage[2]	Erosion[2]
378	Left Bank Sacramento River BALMD (SPFC levee)	1957 Design WSE	Moderate	Low	Lacking Sufficient Data (Low to Moderate)[3]	Lacking Sufficient Data (Low to Moderate)[3]	Moderate
40	Right Bank Georgiana Slough BALMD (SPFC levee)	1957 Design WSE	High	High	Moderate	Moderate	Low
1048	Right Bank North Mokelumne River BALMD (Non-SPFC levee)	1.5 feet below levee crest	High	High	Moderate	Moderate	Low
1049	Right Bank San Joaquin River BALMD (Non-SPFC levee)	1.5 feet below levee crest	Moderate	Moderate	Moderate	Lacking Sufficient Data (Low to Moderate)[3]	Moderate
1050	Left Bank Seven Mile Slough BALMD (Non-SPFC levee)	1.5 feet below levee crest	High	High	High	High	Moderate

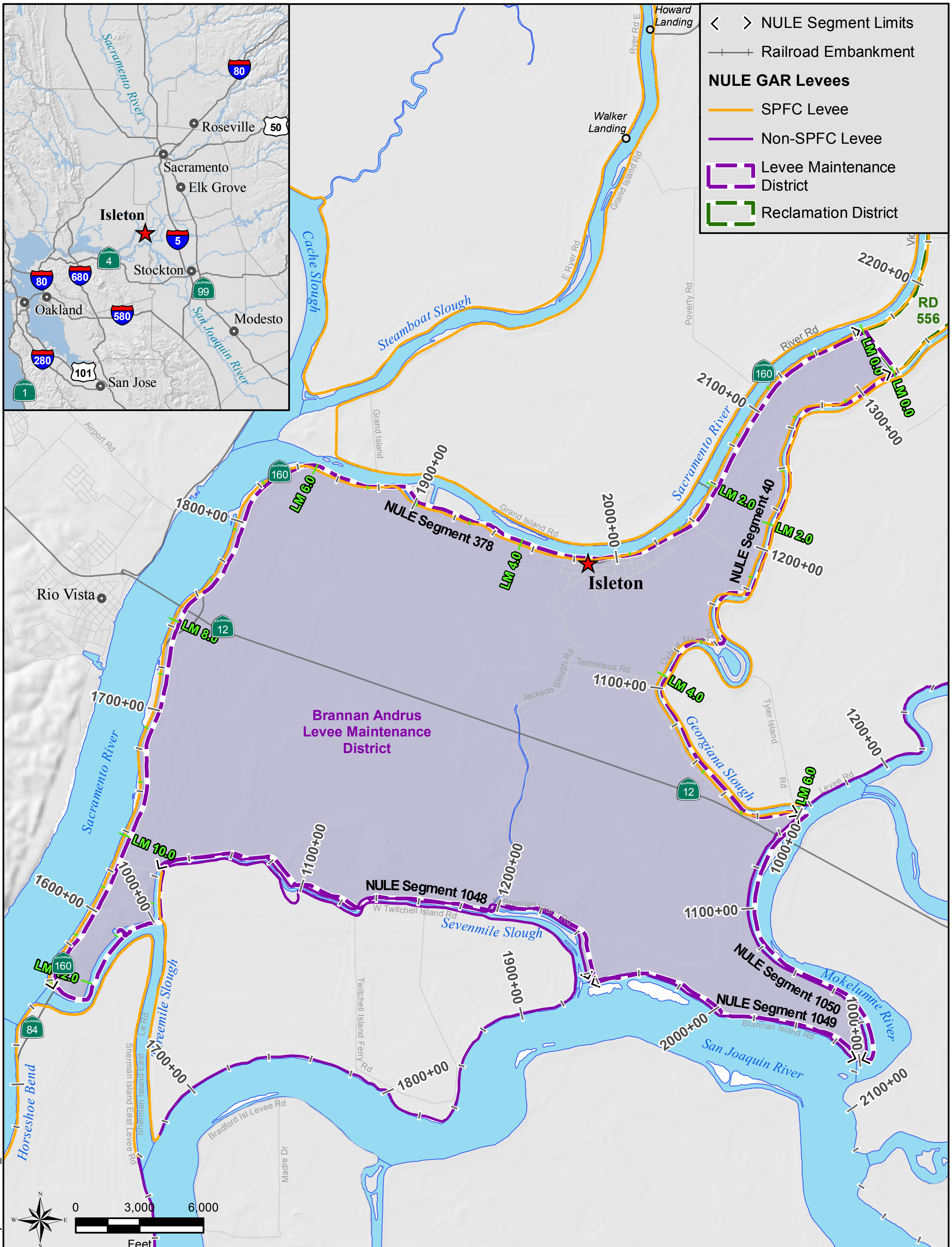
[1] As part of the NULE GAR, hazard categories for each of the four potential failure mechanisms were evaluated collectively to assign an overall hazard level category to each segment.

[2] Likelihood of either levee failure or the need to flood-fight to prevent levee failure when the water reaches the assessment WSE.

[3] The segment was lacking sufficient data about past performance or hazard indicators to assign a hazard level, or there was poor correlation between past performance and hazard indicator scores.

Figures

2868 Prospect Park Drive, Suite 310
Rancho Cordova, CA 95670
916.631.4500 fax 916.631.4501



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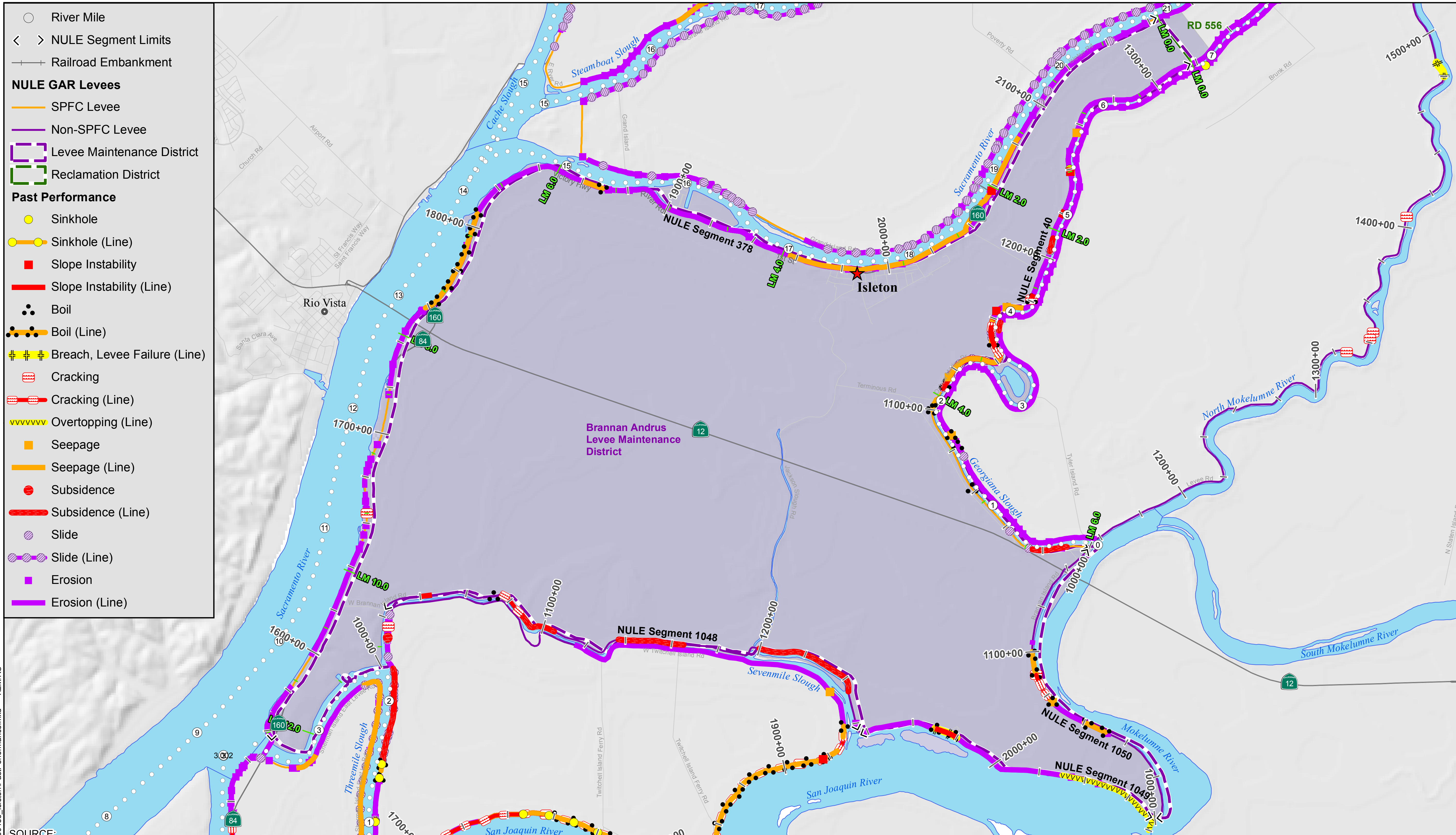
24-Jul-2018

Small Communities Flood Risk Reduction Program	GEI Consultants	CITY OF ISLETON	
City of Isleton		JULY 2018	FIGURE 1



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Small Communities
Flood Risk Reduction Program

City of Isleton

GEI Consultants

PAST PERFORMANCE
CITY OF ISLETON

MARCH 2019

FIGURE 2

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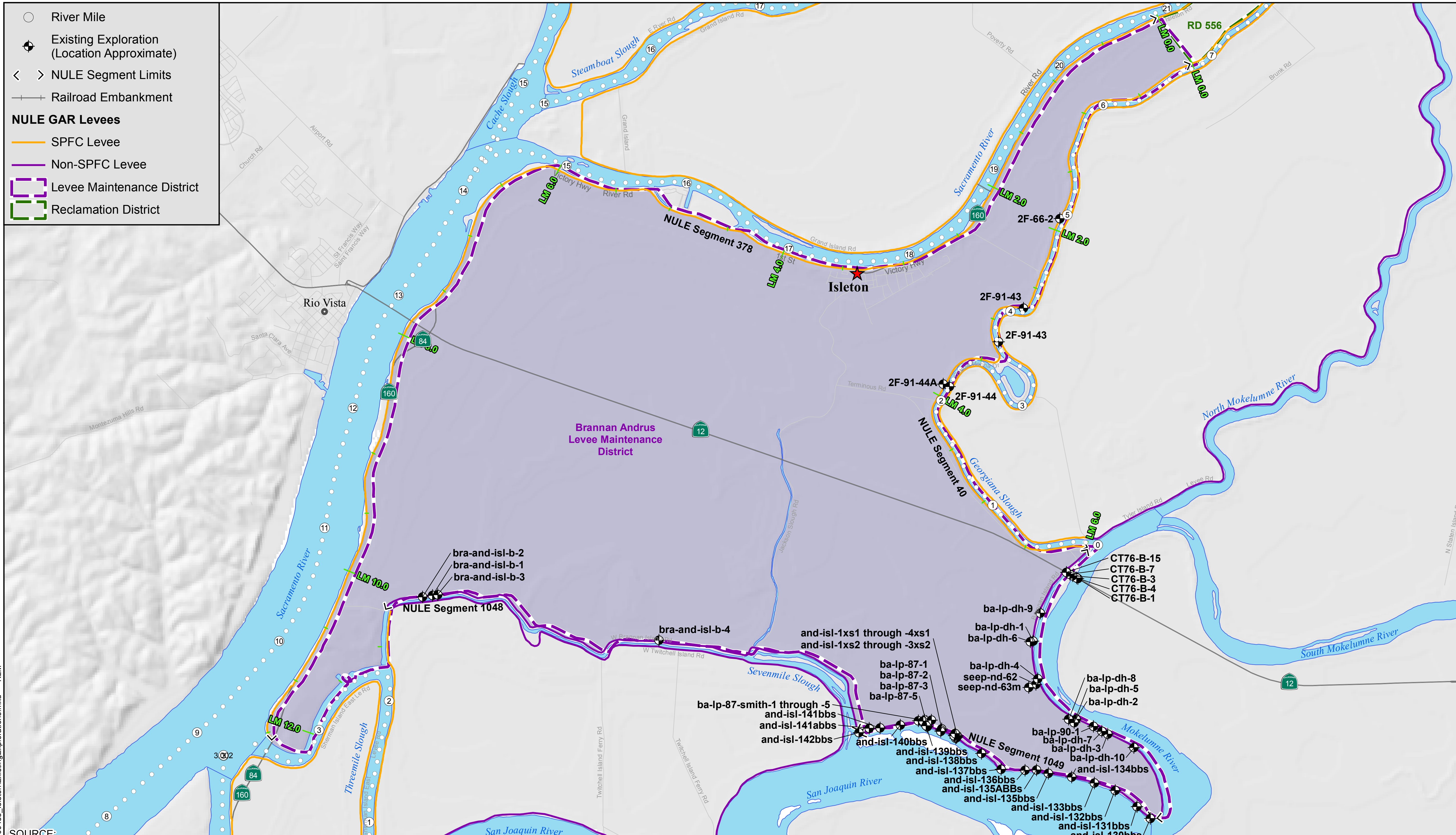

Small Communities
Flood Risk Reduction Program

City of Isleton

GEI Consultants

EXISTING EXPLORATIONS
CITY OF ISLETON

JULY 2018

FIGURE 3

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Appendix A

FSRP *Serious* and *Critical* Site Map and Table

2868 Prospect Park Drive, Suite 310
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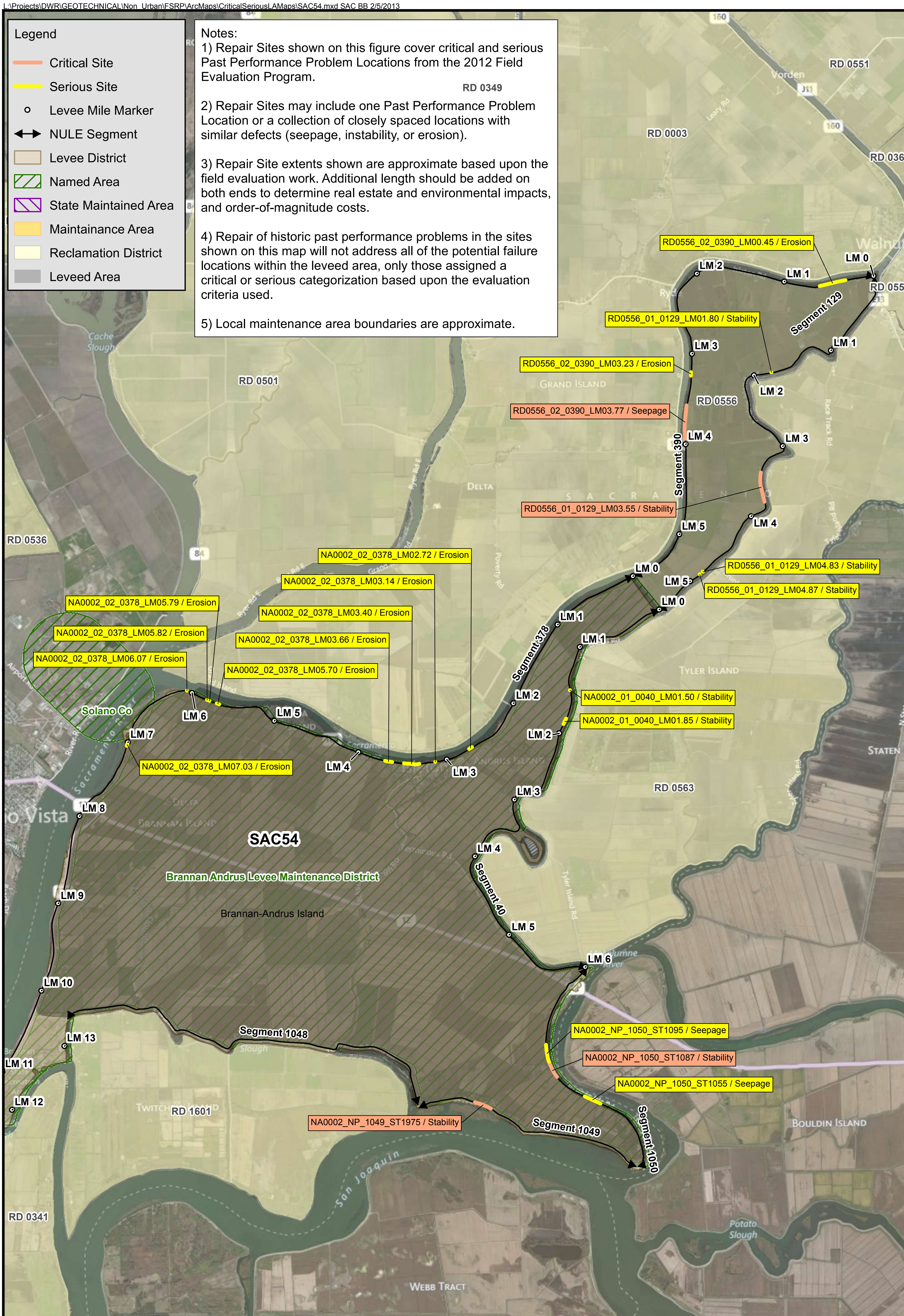
Notes:
1) Repair Sites shown on this figure cover critical and serious Past Performance Problem Locations from the 2012 Field Evaluation Program.

2) Repair Sites may include one Past Performance Problem Location or a collection of closely spaced locations with similar defects (seepage, instability, or erosion).

3) Repair Site extents shown are approximate based upon the field evaluation work. Additional length should be added on both ends to determine real estate and environmental impacts, and order-of-magnitude costs.

4) Repair of historic past performance problems in the sites shown on this map will not address all of the potential failure locations within the leveed area, only those assigned a critical or serious categorization based upon the evaluation criteria used.

5) Local maintenance area boundaries are approximate.



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Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

Critical and Serious Sites
SAC54

Flood System Repair Project

Figure SAC54-1

TABLE SAC54-2
CRITICAL AND SERIOUS SITES

SAC54

Area Name: Andrus Island | **Reconnaissance Team No. 3**

Includes Segments: 40, 129, 378, 390, 1048, 1049, 1050 | **Reconnaissance Dates: July 12 to July 27, 2012**

Table includes RD 556 and BALMD levee segments, see Segments 40, 378, 1018, 1049, and 1050 (LMA: NA 0002) for BALMD levee sites

Critical and Serious Site Name	Past Performance Problem or Observation	Segment	Unit	Waterway	LMA	Failure Mode	Site Status	Approximate Levee Mile Location	Past Performance Problem Length	Supporting Evidence for Rating	Senior Review Date
RD0556_01_0129_LM01.80	129-25	129	Unit No. 1	Georgiana Slough	RD 0556	Stability	Serious	1.8	50 ft	Bottom 1/2 of the landside slope has slumped/caved. Caving is 50 feet long, 18 inches deep, with a 12 inch near vertical scarp at mid slope. 30' wide crown, 1.5:1 landside slope. Unmitigated progressive slope deformation could cause failure during future high water event.	August 8, 2012
RD0556_01_0129_LM03.55	USACE_CESPK_UPA1_2011_p_0143 USACE_CESPK_UPA1_2011_p_0147 USACE_CESPK_UPA1_2011_p_0148	129	Unit No. 1	Georgiana Slough	RD 0556	Stability	Critical	3.42-3.75	1,600 ft	Slope failure area, landside slope for 1600 feet. There are 12 to 36 inch vertical scarps at landside hinge and mid slope. A 3.5 ft. deep ditch is present at toe, and heavy burrowing present. 2011 USACE inspection showed only 24 inches deep scarps and shorter failure length, may be progressing.	August 8, 2012
RD0556_01_0129_LM04.83	USACE_CESPK_UPA1_2011_p_0056	129	Unit No. 1	Georgiana Slough	RD 0556	Stability	Serious	4.829	40 ft	Sloughing area on the landside slope from hinge to toe for a 40 foot stretch. Depth of failure is 12 to 24 inches, with a 12 to 18 inch scarp 3 feet below the crown. A 3.5 foot deep ditch is present at the landside toe. Many 3-5 inch diameter burrows. Unmitigated progressive slope deformation could cause failure during future high water event.	August 8, 2012
RD0556_01_0129_LM04.87	USACE_CESPK_UPA1_2011_p_0050	129	Unit No. 1	Georgiana Slough	RD 0556	Stability	Serious	4.872	30 ft	Sloughing on landside slope from mid slope to toe, reportedly 24 inches deep. USACE inspection report notes some movement of toe towards ditch, but no such movement could be observed during the reconnaissance due to dense blackberry/Elderberry. A ditch is present at the landside toe, 3.5 feet deep, 7 feet wide. A 1993 USACE feasibility report noted through seepage into the ditch and slight movement of the toe. They recommended a stability/seepage berm, but this was never constructed.	August 8, 2012
RD0556_02_0390_LM00.45	DWR_RD0556_02_s _ 2012_25	390	Unit No. 2	Sacramento River	RD 0556	Erosion	Serious	0.31-0.60	1,500 ft	Erosion pockets on the bank every 50 to 150 feet, with scarps 1.5 to 8 feet deep. Many pockets extend nearly into the extended levee prism. Crown width varies from 22 to 24'. Unmitigated progressive erosion likely to extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012

TABLE SAC54-2
CRITICAL AND SERIOUS SITES

Critical and Serious Site Name	Past Performance Problem or Observation	Segment	Unit	Waterway	LMA	Failure Mode	Site Status	Approximate Levee Mile Location	Past Performance Problem Length	Supporting Evidence for Rating	Senior Review Date
RD0556_02_0390_LM03.23	DWR_RD0556_02_s _ 2012_29	390	Unit No. 2	Sacramento River	RD 0556	Erosion	Serious	3.21-3.25	200 ft	Erosion site on the waterside bank. For about 200 feet, there is a 10-14 foot near vertical face extending within levee prism. Several trees had fallen over on the toe of the slope. The erosion extends 10 to 15 feet into the bank. Failure area is now heavily vegetated. Unmitigated progressive erosion likely to further extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012
RD0556_02_0390_LM03.77	DWR_RD0556_02_R_2012_03	390	Unit No. 02	Sacramento River	RD 0556	Seepage	Critical	3.58-3.95	1,950 ft	Location of major flood fight in 1997 due to through seepage and underseepage. USACE built stability berm with drain to mitigate through seepage, however underseepage boils were not mitigated. Recurrent underseepage boils carrying material have occurred 70 to 200 feet from the toe.	August 8, 2012
NA0002_01_0040_LM01.50	40-2014	40	Unit No. 1	Georgiana Slough	NA 02	Stability	Serious	1.5	25 ft	Seepage from 1998, had a toe slip 20 feet long, one to 3 feet high at 1/3 of levee height. Currently, no seepage observed or hydrophytic vegetation. However, 6 inch scarp at mid slope is currently present, could be related to ditch that cuts into levee toe. The 1998 slip appears to have been repaired. Unmitigated progressive slope deformation could cause failure during future high water event.	August 8, 2012
NA0002_01_0040_LM01.85	USACE_CESPK_BRN1_2011_p_0301	40	Unit No. 1	Georgiana Slough	NA 02	Stability	Serious	1.82-1.89	400 ft	Sloughing on landside slope, 12 inches deep, 12 inch scarp. Not known to be related to previous flooding. 6.5' deep ditch at landside toe contributing to instability. Unmitigated progressive slope deformation could cause failure during future high water event.	August 8, 2012
NA0002_02_0378_LM02.72	USACE_CESPK_BRN2_2011_p_0160, DWR_NA0002_02_s _ 2012_18	378	Unit No. 2	Sacramento River	NA 02	Erosion	Serious	2.70-2.74	200 ft	Two erosion sites on the waterside slope and bank about 200 feet apart. Erosion areas are roughly 20 feet wide and extend 8 feet into the slope and bank, 5 to 7 ft. tall scarps. Erosion appears to be within the levee prism. Unmitigated progressive erosion likely to further extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012

TABLE SAC54-2
CRITICAL AND SERIOUS SITES

Critical and Serious Site Name	Past Performance Problem or Observation	Segment	Unit	Waterway	LMA	Failure Mode	Site Status	Approximate Levee Mile Location	Past Performance Problem Length	Supporting Evidence for Rating	Senior Review Date
NA0002_02_0378_LM03.14	DWR_NA0002_02_R_2012_01	378	Unit NO. 2	Sacramento River	NA 02	Erosion	Serious	3.14	30 ft	Erosion site on waterside slope within levee prism. The erosion is 30 feet long, extends from waterside hinge to the toe of the bank. Appears to be about 6 to 12 inches deep. The erosion area has been covered with visqueen and staked in place as a temporary control measure. DCC Engineering has repair plans drawn and is in the process of reviewing these plans with FWS and DWR. At this location, highway 160 ramps down from the levee crown and is adjacent to the levee about 3 feet below the crown. Combined crown width is 45'. Unmitigated progressive erosion likely to extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012
NA0002_02_0378_LM03.40	DWR_NA0002_02_s _ 2012_19	378	Unit No. 2	Sacramento River	NA 02	Erosion	Serious	3.32-3.49	900 ft	Erosion on the waterside bank and slope for roughly 900 feet, likely extending within levee prism. The erosion is worst at the upstream end of the area, with a 10 foot near vertical scarp at mid waterside slope. Above the erosion scarp, the levee appears to be progressively caving, since a 12 inch scarp is present about 1.5 feet below the crown. Overturned trees are present on the bank and other tree roots are exposed. The waterside slope above the scarp is steep. The crown is about 30 feet wide at this location. DCC engineering (Gilbert Labrie) has prepared design plans for repair of this site. Unmitigated progressive erosion likely to further extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012
NA0002_02_0378_LM03.66	DWR_NA0002_02_s _ 2012_20	378	Unit No. 2	Sacramento River	NA 02	Erosion	Serious	3.62-3.7	500 ft	Erosion and waterside caving site about 500 feet long, likely extending within the levee prism. There is a steepened slope 0.8:1 to 1:1 at the landside hinge, where the slope appears to have previously failed. This area appears to be progressively failing. Highway 160 is on the crown at this location. The failure area is within 5 feet of the edge of Highway 160. Tree roots are exposed with some trees leaning. DCC engineering has repair plans prepared for this site. Crown width is 31'. Unmitigated progressive erosion likely to further extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012

TABLE SAC54-2
CRITICAL AND SERIOUS SITES

Critical and Serious Site Name	Past Performance Problem or Observation	Segment	Unit	Waterway	LMA	Failure Mode	Site Status	Approximate Levee Mile Location	Past Performance Problem Length	Supporting Evidence for Rating	Senior Review Date
NA0002_02_0378_LM05.70	DWR_NA0002_02_s _ 2012_21	378	Unit No. 2	Sacramento River	NA 02	Erosion	Serious	5.68-5.71	160 ft	For about 150 ft. stretch, erosion on the waterside slope from hinge to toe. The erosion has left a steep slope 1-1.5:1. Highway 160 is on the crown at this location. A visqueen and rope barrier have been placed over the waterside slope to prevent further caving. DCC engineering has repair design plans prepared for this site and they are pursuing permits and plan approval. Appears to be within the projected prism. Crown width is 31'. Unmitigated progressive erosion likely to further extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012
NA0002_02_0378_LM05.79	USACE_CESPK_BRN2_2011_p_0392	378	Unit No. 2	Sacramento River	NA 02	Erosion	Serious	5.793	40 ft	Erosion site on the waterside slope and bank. Erosion area is roughly 40 feet long and extends 10 feet into the slope and bank, cutting into the levee prism. The erosion area left a 1.2:1 slope on the levee embankment with a 10' near vertical scarp on the bank. Tree roots exposed on the waterside bank. Crown width is 28'. Unmitigated progressive erosion likely to further extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012
NA0002_02_0378_LM05.82	USACE_CESPK_BRN2_2011_p_0395	378	Unit No. 2	Sacramento River	NA 02	Erosion	Serious	5.822	40 ft	Erosion site on the waterside slope and bank, roughly 40 feet long, 3 feet deep and extends 10 to 15 feet into the slope and bank. Erosion appears to be within the projected prism. There is a 15" vertical scarp on the waterside slope at hinge as well as cracking with vertical offsets. Levee crown width is 32' due to highway 160 on crown. Unmitigated progressive erosion likely to further extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012
NA0002_02_0378_LM06.07	USACE_CESPK_BRN2_2011_p_0402	378	Unit No. 2	Sacramento River	NA 02	Erosion	Serious	6.067	150 ft	Erosion site on the waterside slope and bank, roughly 150 feet long, up to 3 feet deep and extends up to 10 feet into the slope and bank. Erosion is within the levee prism. Visqueen used to line the waterside slope and bank at this site. Hwy 160 is on the crown at this location, and is about 30 feet wide. DCC Engineering has repair design plans prepared for this site. Unmitigated progressive erosion likely to further extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012

TABLE SAC54-2
CRITICAL AND SERIOUS SITES

Critical and Serious Site Name	Past Performance Problem or Observation	Segment	Unit	Waterway	LMA	Failure Mode	Site Status	Approximate Levee Mile Location	Past Performance Problem Length	Supporting Evidence for Rating	Senior Review Date
NA0002_02_0378_LM07.03	DWR_NA0002_02_s _ 2012_23	378	Unit No. 2	Sacramento River	NA 02	Erosion	Serious	7.01-7.04	125 ft	Erosion site on the waterside slope and bank. There is a 6 to 10 ft. high near vertical scarp on the waterside slope about 4 feet below the crown. The erosion is about 125 feet long, extends 20 feet into the bank and slope. The crown is about 26 feet wide at this location. Erosion is nearly within projected levee prism. Unmitigated progressive erosion likely to extend into levee prism during/following several future high water events, possibly causing levee failure.	August 8, 2012
NA0002_NP_1050_ST1055	1050-4	1050	-	North Mokelumne River	NA 02	Seepage	Serious	STA 1050+00 TO 1060+00	1,000 ft	Location of recurrent seepage and boils reported by the District Engineer during NULE 2010 interviews. The boils were described as running clear. He indicated that they were caused by a "blocked drain issue" and that a repair is planned but not yet designed. During the site reconnaissance, wet areas with free water were observed on the landside slope up to 10 ft. above the landside toe and at the toe. No wet areas beyond the toe. There was about 13 feet of head during the reconnaissance. No flood fight documented.	August 8, 2012
NA0002_NP_1050_ST1087	1050-5	1050	-	North Mokelumne River	NA 02	Stability	Critical	STA 1080+00 TO 1095+00	1,500 ft	Location of USACE flood fights in 1986 and 1997 due to stability. A small toe berm repair was constructed by USACE in northern part of this area in 1997 to fill in a ditch, but slope is still moving per LMA. At this area, there is slumping at mid slope that has left a 1.5 foot deep depression/scarp. This depression was wet. The slope regraded after 1987 when a flood fight occurred. Has been sinking since then, according to LMA. Other slope movement observed included slope bulging on the lower half of the slope. POI 1050-3 (Obsrv. 2096) partially overlaps this POI.	August 8, 2012

TABLE SAC54-2
CRITICAL AND SERIOUS SITES

Critical and Serious Site Name	Past Performance Problem or Observation	Segment	Unit	Waterway	LMA	Failure Mode	Site Status	Approximate Levee Mile Location	Past Performance Problem Length	Supporting Evidence for Rating	Senior Review Date
NA0002_NP_1050_ST1095	1050-3 (This site overlaps with 1050-5)	1050	-	North Mokelumne River	NA 02	Seepage	Serious	STA 1090+00 TO 1100+00	1,000 ft	During the reconnaissance, wet areas were observed throughout this area at the landside toe and lower 3 feet of the landside slope. At one location, a wet area was observed at mid slope in a depression on the slope. Hydrophytic vegetation including horsetails, cattails and Arundo were prevalent at the landside toe and on the lower half of the landside slope. Recurring seepage/boil area reported by District Engineer for BALMD. The area reportedly has through seepage/small boils year round at high tides. No reports of underseepage. The seepage and boils are reportedly clear. A flood fight occurred at the southern 400 feet of this area in 1997/1998, but reportedly due to a slope stability issue (see POI 1050-5, Obsrv-2097).There was about 11 feet of head at the time of the reconnaissance (low tide). At one location there was a depression at toe, 5 feet wide, 4 feet deep. This depression was wet and fed into ditch below. Possible evidence of seepage carrying material, but discussing with BALMD maintenance, he claims not the case.	August 8, 2012
NA0002_NP_1049_ST1975	1049-3	1049	-	San Joaquin River	NA 02	Stability	Critical	STA 1970+00 TO 1980+00	1,000 ft	Location of breach in 1970s that failed due to stability during construction work during low tide. There is 4 to 6 in vertical offset deformation in crown 20 feet from the landside hinge, with slope bulging on landside. Inclinometer present in crown near landside hinge shows progressing vertical deformation. No inclinometers in landside slope. Pin boils not carrying material also observed during high tides at this location, no flood fight after 1970s.	August 8, 2012

Note: POI same as Past Performance Problem

Appendix B

NULE GAR Segment Write-Ups

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BRANNAN-ANDRUS LMD, UNIT 2, SEGMENT 378 SUMMARY

This segment summary presents collected information and assessment results for Segment 378. The summary is based on data that were available at the time the segment was assessed. The amount of detail that was available varied. Known pertinent details are included. For details about data collection and assessment procedures, see Volume 1, Section 2.0 of this report.

This summary is organized into the following seven sections:

- Segment Description and Assessment Summary
- Levee Segment History
- General Levee Conditions
- Levee Composition and Foundation Conditions
- Geotechnical Assessment Results
- Other Levee Assessments
- Hazard Mitigation

Segment 378: Segment Description and Assessment Summary

Segment 378 is a non-urban Project levee on the left (south and east) bank of the Sacramento River in Sacramento County, California (see attached map). The segment extends along the northwest side of Brannan-Andrus Island from the confluence of the Sacramento River and Three Mile Slough, northwest to a cross levee to Georgiana Slough. The following table summarizes segment information.

Segment 378 Information

Maintenance Authority	Unit	Levee Miles*	NULE Stationing*
Brannan-Andrus LMD (formerly RD 2067 for the south and RD 407 for the north)	2	LM 0 to LM 11.58	Sacramento River Left Bank 1554+39 to 2164+20

* The levee mile and stationing alignments differ.

As directed by DWR, the segment was assessed for each potential failure mode at the 1955/1957 design water surface elevation provided by DWR. The following table presents the Segment 378 categorizations for each potential failure mode.

Segment 378 Potential Failure Mode Assessment Summary

Potential Failure Mode	Categorization
Underseepage	Hazard Level A
Stability	LD (A or B)
Through Seepage	LD (A or B)
Erosion	Hazard Level B

Based on these NULE Phase 1 levee assessments, the potential failure mode categorization for erosion is Hazard Level B. The categorization for underseepage is Hazard Level A and the categorizations for stability and through seepage are Lacking Sufficient Data. If additional data were obtained, it is very unlikely that the LD for stability and through seepage failure mode would be categorized as Hazard Level C. Because at least one of the segment’s other failure modes is already categorized as Hazard Level B, and the LD failure mode would not be categorized as Hazard Level C, the overall categorization for the segment is Hazard Level B.

Segment 378: Levee Segment History

The Levee segment history described in the following sections is based on a review of documents t in the NULE document database, and on interviews with personnel familiar with the levee and its history. The descriptions include construction history, performance, improvements, and planned improvements. The amount and quality of information varies from segment to segment. This segment summary contains pertinent information gathered during data collection. Some details may not be known.

Construction History

Segment 378 levees were initially constructed between 1860 and 1880 by Chinese laborers using shovels and wheelbarrows. Levees were later built up with side draft clamshell dredging to increase the levee height. The material used to build the levees was taken from the channel, and was likely not compacted (Doc-5171). Between 1946 and 1947, USACE constructed a setback levee with material from the existing levees (Doc-4371). The following table presents the 1953 MOU geometric criteria for Segment 378.

Segment 378 Geometric Criteria

Levee Type	Crown Width (feet)	Waterside Slope	Landside Slope
Project Levee	20	3H:1V	2H:1V

Performance

Levee performance information was obtained from reviewed documents and interviews with BALMD maintenance personnel. According to the available information, performance events in Segment 378 include multiple and recurrent erosion events. Although no documented reports of underseepage, through seepage, or slope instability were found, poor maintenance was noted in the 1950s (Doc-797). The following table summarizes reported performance events.

Segment 378 Reported Levee Performance Events

Flood Season	Reported Performance Event	Approximate Location (Levee Mile)	Mitigation
1931	RD expressed concern about erosion problem (Doc-5039).	Multiple locations	Not documented.
1953	Unstable bank conditions including portions of the levee that had been reveted by the USACE (Doc-797).	Multiple locations	Not documented.
1953	Serious rodent infestation (Doc-797).	Multiple locations	Not documented.
1957	Slope caved on the waterside (Doc-5039).	2.06-2.07	Not documented.
1961	Sites experiencing caving on the waterside (Doc-4519).	RM 12.8	Not documented.
1962	Erosion repairs recommended (Doc-4523).	RM 14.7 and RM 12.8	Repair recommended.
1969	Critical repairs needed (Doc-4702).	Multiple locations	Not documented.
1996	Erosion on waterward slope.	Multiple locations	Not documented.
1997	Multiple erosion sites and PL84-99 repairs (Doc-1581).	Multiple locations	Repair recommended.
1998	Wave wash damage to the revetment and upper water side levee slope.	Multiple locations	Not documented.
1999	Erosion repairs recommended (Doc-1858).	Multiple locations	Not documented.
2007	Wave wash erosion on mid-bank of levee toe (Doc-3822).	1,050 ft near RM10.8	Not documented.

Breaches

A levee breach occurred in 1972 on Brannan-Andrus Island, but in the non-Project levee (Segment 1049) and not along Segment 378 (Doc-8576). Historical crevasse splay deposits have been mapped in two areas along Segment 378 levees. However, whether these deposits resulted from a breach or from overtopping is unknown.

Underseepage

Although no underseepage problems were documented, poor maintenance was noted in the 1950s (Doc-797) and past performance records may be incomplete. However, no underseepage has been documented in performance records. During interviews with the Maintenance District (April 23, 2010 meeting), the District indicated there were no seepage performance problems in the past.

Stability

Although no stability problems were documented, poor maintenance was noted in the 1950s (Doc-797) and past performance records may be incomplete.

Through Seepage

Although no through seepage problems were documented, poor maintenance was noted in the 1950s (Doc-797) and past performance records may be incomplete. During interviews with the Maintenance District (April 23, 2010 meeting), the District indicated no seepage performance problems in the past.

Erosion

Multiple and recurrent erosion sites have been observed throughout Segment 378. Some critical sites were documented, as noted in the table above. One site was ranked second of 117 sites in the 2008 Ayres *Erosion Report*, and some erosion sites were described as having 6- to 9-foot vertical faces . Scallops on oversteepened waterside slopes were observed in several locations (between Stations 1555+00 and 1570+00, and near Stations 1645+00, 1767+00, 1860+00, 1970+00, and 2015+00).

Overtopping

Although no overtopping was documented, poor maintenance was noted in the 1950s (Doc-797).

Improvements

Improvements include riverbank protection work performed under the Sacramento River Bank Protection Project during Phase 1 from 1963 to 1973, and during Phase 2 in from 1976 to 2007. In 1997, fabric and drain rock were recommended between LM 3.10 and LM 3.93 (Doc-2393), but whether they were placed is unclear. In 1997, rip-rap was placed for approximately 1,000 feet near RM 10.8 (Doc-3822) (approximately LM 9.8). Emergency repairs of a 210-foot-long reach of bank at RM 16.9 were completed in 2007, The completed riverbank protection work included placement of revetment at multiple locations along the segment.

Planned Improvements

No documentation was found about planned improvements to Segment 378 levees.

Segment 378: General Levee Conditions

This section describes levee conditions based on document reviews, interviews, site reconnaissance, the LiDAR survey, and other collected data. Levee conditions include levee geometry, penetrations, and animal activity.

Levee Geometry

North of an area of anomalous high ground (north of Station 1625+00), LiDAR survey data indicate Segment 378 levee heights are typically about 12 to 15 feet, but range from about 8 to 25 feet above the landside toe. Crest widths range from 25 to 80 feet, and are typically between 20 to 25 feet from Station 2060+00 to 2160+00. Crest widths are typically between 30 and 50 feet north of Station 2160+00. The landside slopes are typically 2H:1V, and range from 1.52H:1V to 6.6H:1V. The waterside slopes are often steeper than 3H:1V, and range from 1.07H:1V to 3.5H:1V.

Penetrations

According to the DWR Pipe Inventory, more than 31 pipes penetrate the levee segment. At least 17 penetrations are below the DWSE. However, this is a minimum estimate because the database does not include the old RD 407 (i.e., the northern portion of the segment) where multiple penetrations are documented in levee logs.

Animal Activity

Animal activity along the northeastern portion of Segment 378 levees was documented as “low” in the DWR database. West of LM 6.0, no animal activity was documented. However, in the 1950s, a rodent infestation was observed and documented (Doc-797).

Maintenance

DWR assessments performed in fall 2008 rate levee maintenance as “unacceptable” for this segment primarily due to vegetation and encroachments. Additionally, poor maintenance was noted in the 1950s for this segment (Doc-797).

Other Features

Five ditches non-parallel to the levee alignment are close to the landside toe area of Segment 378 at approximately Stations 1645+00, 1653+00, 2082+00, 2105+00, and 2125+00. Ditches occur sub-parallel to the landside toe of Segment 378 from about Stations 1601+00 to 1606+00, Stations 1645+00 to 1663+00, and Stations 2082+00 to 2105+00.

Additional anomalies include high landside ground south of Station 1625+00 (between Stations 1555+00 and 1625+00) where dredge spoils have been stockpiled, Ida Island (that forms an anomaly between Stations 1890+00 and 1935+00), a gas field and several other encroachments near the town of Isleton, and the cross canal to Georgiana Slough at the northeastern end of Segment 378 (Station 2164+20).

Segment 378: Levee Composition and Foundation Conditions

The NULE team established an understanding of levee and levee foundation geotechnical conditions based on work performed by the geomorphology team, reviews of other available geologic and soil maps, data contained in reports that were reviewed, and general knowledge of levee conditions in the area. This section summarizes the team's understanding of geotechnical conditions in Segment 378.

In Segment 378, the levee foundations consist of interbedded peat, clay, silt, and sand. The levees likely consist of relatively clean sand, silty sand, and silt.

Geomorphic Setting

Segment 378 levees are constructed along the left bank of the Sacramento River in the Lower Sacramento River Basin of the Sacramento-San Joaquin Delta. Geomorphology Level 2-I mapping indicates that the deposits in this part of the Delta are primarily late Holocene tidal wetland and supratidal flood plain deposits, which consist of varying amounts of interbedded peat, organic mud, clay, silt, and sand. The flood plain or overbank deposits are adjacent to channels and sloughs, like the Sacramento River. These channel and flood deposits are generally coarser and less organic (composed of silt, sand, and clay), whereas the central parts of islands in the Delta, where elevations are typically at or below sea level, are generally covered by peat and organic mud formed by decaying wetland vegetation. The percentage and thickness of organic deposits is generally greatest in the central portion of the Delta, but also shows local variations, including some areas where pre-Holocene eolian sand dunes formed paleotopographic highs and where peat and soft mud are not present and were likely never deposited. For Segment 378 levees, the extensive post-1900 dredge deposits mapped south of LM 10.3, which form anomalously high topography along this portion of the Sacramento riverbank, are the notable exception.

Recent Level 2-II mapping is generally consistent with Level 2-I mapping along Segment 378 but shows more detail, including several distributary channel and crevasse splay deposits between LM 2 and LM 5, a crevasse splay at LM 7.8, and historical alluvium deposited along the bend between LM 6 and LM 7. Level 2-II mapping indicates Segment 378 foundation soils are primarily historical overbank deposits (silt, clay, and lesser sand), Holocene peat and mud deposited in tidal flats and wetlands, and a few historical distributary channel and crevasse splay deposits (sand, silt, and clay). Historical dredge deposits are still mapped on the high ground south of LM 10.3.

Geotechnical Investigations

The Delta Risk Management Strategy project compiled boring information for the area (Doc-8306). This compilation of information was used to evaluate subsurface conditions for this segment. The compilation of borings from the Delta Risk Management Strategy study did not include any holes drilled along Segment 378. Therefore, URS evaluated 10 borings along the right bank of the Sacramento River to infer the composition for Segment 378 and for foundation soils. The holes were as deep as 80 feet, and the logs show that the levees are predominantly sand, silty sand (with 3 to 10 percent fines), and some silt. The underlying foundation soils are 5 to 25 feet of interbedded peat, clay, silt, and sand, overlying sand. Organic material is generally thickest to the south.

Other Subsurface Information

The USCS soil map shows generally fine-grained soils (predominantly CL and CL-ML, with a small area of SC-SM east of Ida Island). The geomorphic and USCS mappings agree with available boring information in the area.

Levee Composition

No borings from the Delta Risk Management Strategy study intersected Segment 378 levees, but, according to borings through the levees on the right bank of the Sacramento River, Segment 378 levees likely consist of relatively clean sand, silty sand, and silt. The segment on the opposite bank was reconstructed in 1942, a few years before reconstruction of Segment 378 levees.

Segment 378: Geotechnical Assessment Results

The overall Segment 378 categorization is Hazard Level B. As discussed in Volume 1, Section 2.0 of this report, the overall assessment is based on the individual potential failure mode categorizations. For this segment, the potential failure mode categorization for erosion is Hazard Level B. The categorization for underseepage is Hazard Level A and the categorizations for stability and through seepage are Lacking Sufficient Data. If additional data were obtained, it is very unlikely that the LD for stability and through seepage failure mode would be categorized as Hazard Level C. Because at least one of the segment's other failure modes is already categorized as Hazard Level B, and the LD failure mode would not be categorized as Hazard Level C, the overall categorization for the segment is Hazard Level B. A summary of the LAT results and the matrix plots are attached.

A WHIS was calculated for each potential failure mode at the assessment water surface elevation: the 1955/1957 water surface elevation provided by DWR. The assessment is based on identified geologic, geometric, and other hazards. A rating for past performance based on documented performance events was assigned. The categorizations for each potential failure mode are discussed in the sections that follow.

Underseepage

Segment 378 Underseepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
56	55	56	None documented.	None documented.	None documented.	Hazard Level A

There are no documented underseepage problems. However, a history of poor maintenance suggests performance records may be incomplete. Although there is a very high underseepage susceptibility and piping potential for the foundation soils, the relatively low head-to-base-width ratio appears to limit the overall WHIS for Segment 378 levees. In particular, although the levee is generally tall there is only about 6 feet of head from the DSWE to the landside toe. In addition, during interviews with the Maintenance District (April 23, 2010 meeting), the District indicated no seepage performance problems in the past. The hazard indicators are in general agreement with the absence of documented underseepage, and Segment 378 was therefore categorized as Hazard Level A for underseepage.

Stability

Segment 378 Stability Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
71	36	71	None documented.	None documented.	None documented.	LD (A or B)

The stability hazard was categorized as Lacking Sufficient Data because of a lack of past performance problems, despite the presence of potentially soft soils, a steep and relatively high landside slope, and a probable levee composition of loose sand. Some performance problems may not have been documented. Levee maintenance assessments, except in the 1990s, were generally unacceptable due to a lack of levee maintenance and records. Given the hazard indicators, and if additional data were obtained to resolve the LD, it is very unlikely that the additional data would result in re-categorization to Hazard Level C.

Through Seepage

Segment 378 Through Seepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
63	45	63	None documented.	None documented.	None documented.	LD (A or B)

Because of the numerous levee penetrations and the inferred sandy loose levee materials, some poor performance may have been expected. No past problems are attributed to through seepage along this segment. However, some performance problems may not have been documented. Levee maintenance assessments, except in the 1990s, were generally unacceptable due to a lack of levee maintenance and records. During interviews with the Maintenance District (April 23, 2010 meeting), the District indicated no seepage performance problems in the past. The low head-to-base-width ratio for this wide levee lower the WHIS, but not sufficient enough to expect no performance problems. Therefore, based on uncertainty about the levee's composition, the moderate WHIS, and the possibility of incomplete past performance records, Segment 378 is categorized as Lacking Sufficient Data for through seepage. There is considerable uncertainty regarding levee composition. Given the hazard indicators, and if additional data were obtained to resolve the LD, it is very unlikely that the additional data would result in re-categorization to Hazard Level C.

Erosion

Segment 378 is categorized as Hazard Level B for erosion. Segment 378 is categorized as Hazard Level B because of the multiple documented erosion sites recurring throughout the segment (some are described as having 6- to 9-foot vertical faces). This categorization is also supported by the multiple locations of scallops on oversteepened waterside slopes observed in contour maps and in aerial photographs.

Segment 378: Other Levee Assessments

Freeboard

Data from the LiDAR survey indicate that the levee crest for this segment is above the 1955/1957 WSE, and there is a minimum freeboard of 3 feet present along the entire segment.

Overtopping

Overtopping was considered based only on past performance. Evaluation of flood flows, flood elevations, channel capacities, and other factors influencing overtopping risk is beyond the scope of the NULE Project. These factors should be studied by others to evaluate overtopping risk to NULE Project levees. Based on the review, there is no documentation of overtopping of this segment.

Geometry

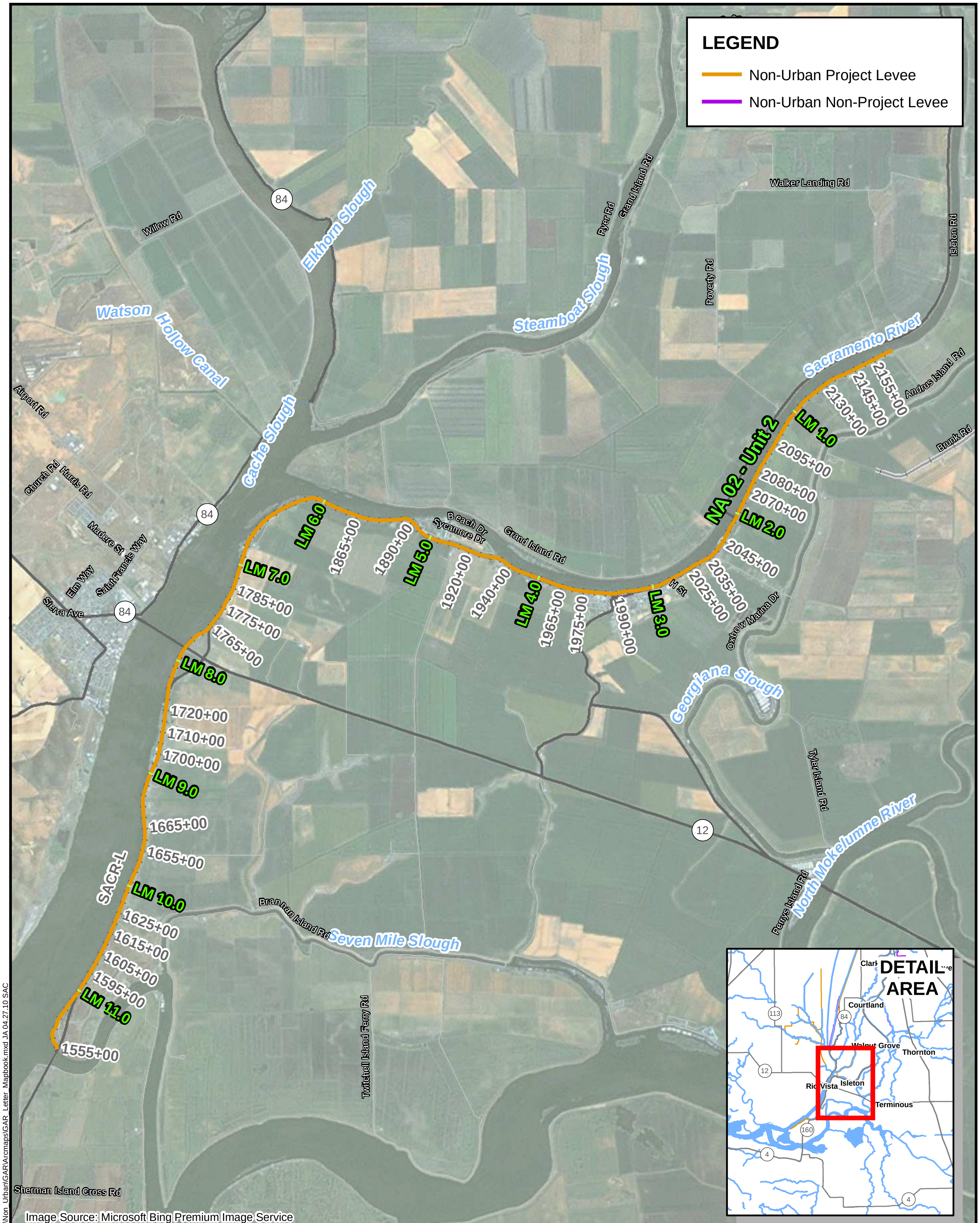
Using LiDAR data, Segment 378 levee geometry was compared to a standard levee prism as defined by the 1953 MOU. This comparison assessed whether the levee, indicated by topography developed from LiDAR data, was larger than or equal to the standard levee prism at any given cross section. Wide levees could meet this requirement even where levee slopes are steeper than those described in the 1953 MOU. All of Segment 378 is larger than the standard levee prism.

Segment 378: Hazard Mitigation

The following table identifies hazards for Segment 378, and the estimated extent of the hazard. Comments are provided to help identify potential remedial requirements.

Segment 378 Hazards

Hazard	Extent (percent)	Comments
Stability	30	Estimated extent is primarily based on the geometry check. Although the levee is tall and steep along some sections, it is generally very wide and above freeboard, and could be flattened somewhat to stabilize.
Through Seepage	30	Estimate is based on number of penetrations and inferred levee composition and is highly uncertain.
Erosion	20	Estimated areas of oversteepened slopes and erosion pockets, using LiDAR data.



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Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

Segment 378

Brannan-Andrus LMD Unit 2
Geotechnical Assessment Report

NORTH NON-URBAN LEVEE EVALUATIONS

Non Urban Levee Evaluation Program (NULE) Levee Assessment Tool, Version 1.2 (revised: 1/7/2010)

				Begin	End
Levee Segment Name:	Brannan-Andrus LMD Unit 2		NULE Station (ft):	1554+39	2164+20
Levee Segment Number:	378		Levee Mile:	11.58	0
Brief Description of Segment/Reach:	Brannan-Andrus LMD - Unit 2, Sacramento River -Previously RD 2067 (southern portion) and RD 407 (northern portion)		Segment/Reach Length:	11.5 (miles)	60981 (feet)
			Crest Width Design Criterion (ft):	20	
Local Maintenance Authority:	Brannan-Andrus Levee Maintenance District		Design Guidance Document:	MOU 1953	
Freeboard Evaluation Criterion (ft):	Not Applicable				
Water Side Slope Design Criterion:	3H : 1V	Enter Other Criterion	Project or Non-Project Levee?	Project	
Land Side Slope Design Criterion:	2H : 1V	Enter Other Criterion			
North or South NULE?	North				

LEVEE CONSTRUCTION

Describe what is known about construction of this levee segment:	The levee was initially built in between 1860 and 1880 by Chinese Laborers using hand shovels and wheel barrows (Doc-8306). The levees were later constructed with side draft-clamshell dredging to build levee to sufficient height. The material used to build the levees were taken from the channel and not likely compacted. Between 1946 and 1947 the USACE constructed a setback levee with material from the existing levees (Doc-4371).

Analysts should populate all yellow cells, and not populate grey cells; green cells store calculated values. Use the suite of available data in making ratings. See User Guide and tables for further information.

PAST PERFORMANCE

	Value (where applicable)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments (include event date and flood elevation, if available)
Underseepage		*None documented*	*None documented*	*None documented*	None documented. Extremely poor maintenance noted in the 1950s (Doc-797). Good to very good maintenance was documented in the 1990s (Doc-1581)
Landside slope stability		*None documented*	*None documented*	*None documented*	None documented. Extremely poor maintenance noted in the 1950s (Doc-797). Good to very good maintenance was documented in the 1990s (Doc-1581)
Through seepage		*None documented*	*None documented*	*None documented*	None documented. Extremely poor maintenance noted in the 1950s (Doc-797). Good to very good maintenance was documented in the 1990s (Doc-1581)

In addition to Ayres 2008/DWR 2009 studies, are there erosion occurrences identified in this study?	Yes	**If yes, please describe:**	Multiple recurring erosion sites in particular: 1957, 1962, 1969, 1996, 1997, 1998, 1999. These were documented throughout the segment					
North NULE	**Erosion sites from the Ayres 2008 study**	**Ayres Methodology 2**			**Ayres Methodology 4**			
		Rating (1 to 72)	**Ranking (out of 117)**		**Rating (1 to 47)**	**Ranking (out of 117)**		
Are there erosion occurrences compiled in the Ayres study?	Yes	52	2		22	3		
	Comments:	In addition, there are 2 other non-rated/non-ranked erosion sites within this segment			**Comments:**	In addition, there are 2 other non-rated/non-ranked erosion sites within this segment		
South NULE	**Erosion sites from the DWR 2008 study**	**DWR Prioritization 2008**						
		Rating (1 to 100)	**Ranking (out of 67)**					
Are there erosion occurrences compiled in the DWR study?								
	Comments:							

Past overtopping or near overtopping?:	Never overtopped	**Comments:**	
Past breach in area?	None Identified	**Comments:**	There was a breach 1972, but in the non-project levee of this island

HAZARD INDICATORS

I- LEVEE COMPOSITION - ***at selected cross section*** - Interpreted from Borings, Test Pits, field reconnaissance, NRCS maps, and analyst's interpretation of this assemblage of information

	Value (where applicable)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments
Composition of levee material *for through seepage assessment*		*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	*3 - SM, ML, Moderately dispersive soils; soils are silty sands or sandy silts with higher permeability than category 1 soil; soils are suspected of being moderately dispersive based on SAR or other factors*	*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	Based on borings from levee in opposite bank of Sacramento River
Composition of levee material *for stability assessment*		*4 - CH, MH; moderately dispersive soils; loose sand, sand with silt, or non-plastic silt*	*1 - SC, CL-ML, CL (LL<35); non-dispersive; soils are generally somewhat clayey such as clayey sand or clayey silt, lean sandy clay or lean clay with liquid limits less than 35.*	*4 - CH, MH; moderately dispersive soils; loose sand, sand with silt, or non-plastic silt*	Based on borings from levee in opposite bank of Sacramento River

II- GEOLOGY - ***at selected cross section***

	(Scale of mapping)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments
Underseepage susceptibility *for underseepage assessment*	1:24,000	*5 - Very high*	*5 - Very high*	*5 - Very high*	Based on 2-II
Dispersive soils *for stability assessment*	1:24,000	*1 - Not dispersive*	*1 - Not dispersive*	*1 - Not dispersive*	Based on NRCS
Piping potential *for underseepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Based on 2-II
Piping potential *for through seepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Based on 2-II
Soft soils *for stability assessment*	1:24,000	*5 - Present*	*1 - Not present*	*5 - Present*	Based on DRMS thickness of organics map. Also, from borings on right bank

III- OTHER INDICATORS - ***at selected cross section***

Animal persistence/burrows? *for through seepage assessment*		*2 -Low*	*2 -Low*	*2 -Low*	Low animal activity in the northern portion of the segment (where the analysis section was selected). In the 1950s serious rodent infestation was observed and documented (Doc-797)
Is a landside ditch or borrow pit present within 200 ft of toe? *for underseepage assessment*	No ditch	1			0
Is a landside ditch or borrow pit present within 200 ft of toe? *for stability assessment*	No ditch	1			0
Is waterside blanket present? *for underseepage assessment*	No				0
Are there locations where penetrations and historical underseepage are coincident?	No	**If yes, please describe:**	0		
Are there locations where penetrations and historical through seepage are coincident?	No	**If yes, please describe:**	0		
Have encroachments that may potentially affect levee integrity been identified?	Yes	**If yes, please describe:**	Tanks on the waterside (Stations 2050+00 to 2055+00). LM 2.03 to 2.42 Earthen fill and railroad tracks along the water ward side. (SPRR); 2.45 to 2.48 Service station on landside pad. (Doc-8114); LM 8.77 Gas well on the water ward slope (Doc-8114).		
Provide the number of levee penetrations below the evaluation water surface elevation:	5 - More than 20	**Notes:**	There are 17 documented pipe penetrations below the DWSE. However, the database does not include the old RD 407 (northern portion of the segment) where multiple penetration are documented in the levee logs.		
DWR's LMA maintenance rating from Maintenance Deficiency Summary Report:	Unacceptable	**Notes:**	Mainly due to vegetation and encroachments		

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IV- TOPOGRAPHIC & ELEVATION INFORMATION *- at selected cross section(s)*

	Default cross section (used for Underseepage assessment)		Would you like to evaluate a different cross-section for **Stability**?	Yes	Would you like to evaluate a different cross-section for **Through Seepage**?	No
	Cross-section Station	1970+00	**Cross-section Station**	1820+00	**Cross-section Station**	
	Underseepage		**Stability**		**Through Seepage**	
Report elevations in NAVD 88	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]
Levee crest elevation (ft)	23		29.5			
Levee toe elevation (landside) (ft)	7		5.5			
Levee crest width (ft)	30	1	31	1		
Evaluation water elevation (ft)	13		12.5			
Levee slope - landside (xH : 1V); **Enter x**	1.7	4	1.79	4		
Levee slope - waterside (xH : 1V); **Enter x**	1.25					
Freeboard above evaluation flood elevation (ft) (= levee crest elevation - evaluation water elevation)	10.0					
Levee height (ft) (= levee crest elevation - landside toe elevation)	16.0	4	24.0	5		
Levee prism base width (ft)	77.2					
Head (ft) (= evaluation water level - landside toe elevation)	6.0	2	7.0	2		
Head-to-base-width ratio (= head / base width)	0.078	2				
Base-width to head ratio (= base width / head)	13					

V- ANOMALIES

	Anomalies?	Description	Effect on Performance
Underseepage	Yes	High landside ground between 1555+00 and 1625+00. Five ditches non-parallel to the levee alignment.	No risk of flooding in the high ground
Stability	Yes	High landside ground between 1555+00 and 1625+00	No risk of flooding in the high ground
Through Seepage	Yes	High landside ground between 1555+00 and 1625+00	No risk of flooding in the high ground
Erosion	No	High landside ground between 1555+00 and 1625+00. Ida Island between 1890+00 to 1935+00.	No risk of flooding in the high ground. Ida Island "protects" the levee by diverting high velocity flows

MITIGATION AND PAST BREACHES

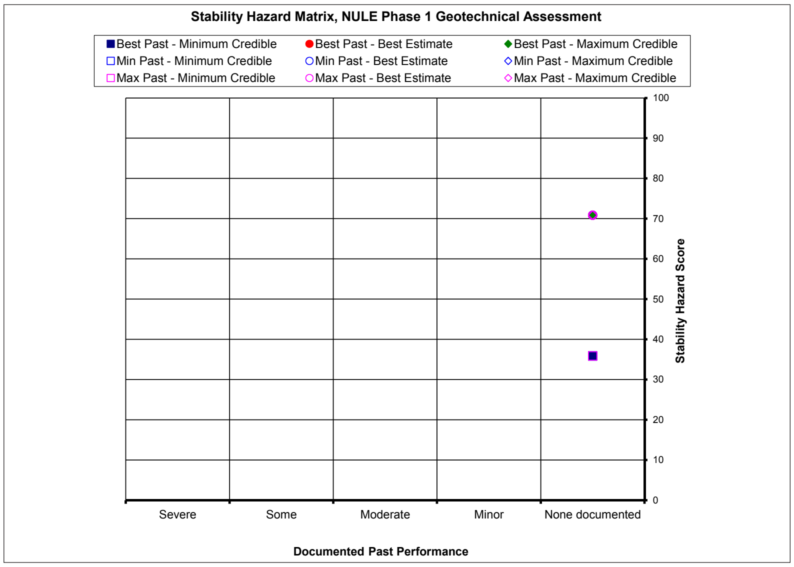
Existing constructed mitigation (List all)	Improvements include riverbank protection work performed under the Sacramento River Bank Protection Project (SRBPP) during Phase 1 from 1963 to 1973, and during Phase 2 in from 1976 to 2007. In 1997, fabric and drain rock were recommended between LM 3.10 and LM 3.93 (Doc-2393), but whether it was constructed is unclear. In 1997, rip-rap was placed for approximately 1,000 feet near RM 10.8 (Doc-3822) (approximately LM 9.8).Emergency repairs of a 210-foot-long reach of bank at RM 16.9 were completed in 2007, The completed riverbank protection work included placement of revetment at multiple locations along the segment. LM 6.90 to 6.92 Sheet piling retaining wall on water ward slope (Doc-8114)
Has there been a past breach?	None Identified
If yes, describe nature of the breach and how it has been mitigated?	

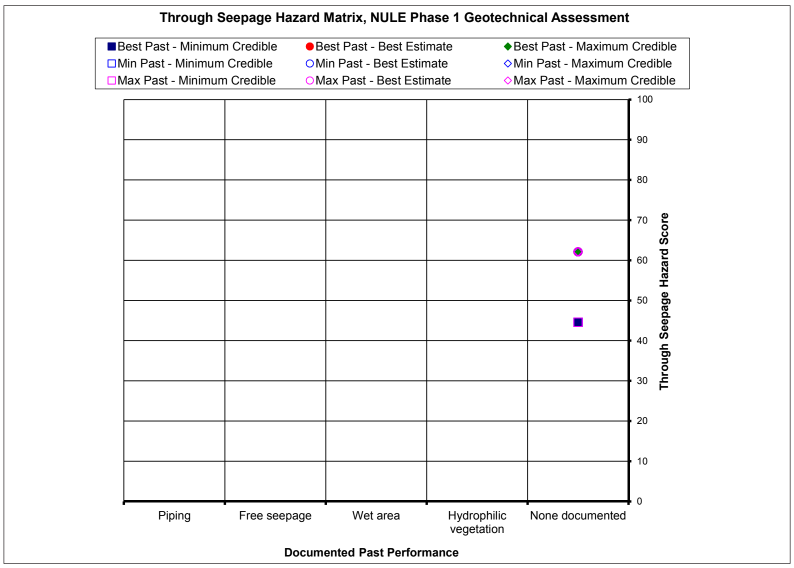
SUMMARY

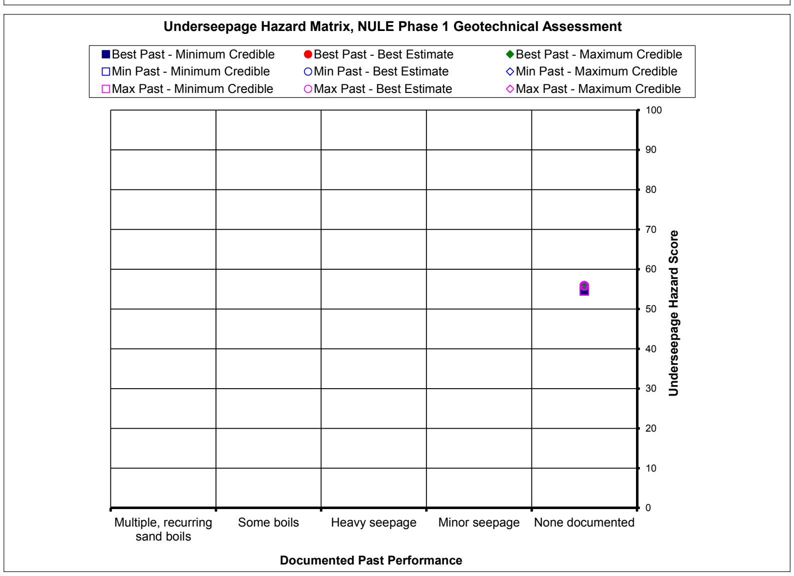
Failure Mode	Weighted Hazard Indicator Score (Best)	Weighted Hazard Indicator Score (Minimum Credible)	Weighted Hazard Indicator Score (Maximum Credible)	Past performance issues?	Are past performance and Weighted Hazard Indicator Score consistent?	Levee categorization
Underseepage	**56**	55	56	None documented	No	***Hazard Level A***
Justification:	Even though there is a very high underseepage susceptibility and piping potential, the head caused by the DWSE limits the WHIS for this broad levee. This moderate WHIS is in general agreement with no documented bad past performance. However, levee maintenance assessments have always been unacceptable (except in the 1990s) due to lack of levee maintenance and records. It is therefore possible that bad performance problems have not been documented. There are only 6 feet of head from the DWSE.					
Suggested additional data:	Additional subsurface exploration, since none is available on this bank. High water mark for the previous floods					
Stability	**71**	36	71	None documented	No	***Hazard Level LD***
Justification:	Even though there are soft soils present, the head caused by the DWSE limits the WHIS. This medium WHIS is not in general agreement with no documented bad past performance. Levee maintenance assessments have always been unacceptable (except in the 1990s) due to lack of levee maintenance and records. It is therefore possible that bad performance problems have not been documented. Given the hazard indicators, and if additional data were obtained to resolve the LD, it is very unlikely the additional data would result in a re-categorization to Hazard Level C.					
Suggested additional data:	Additional subsurface exploration, since none is available on this bank. High water mark for the previous floods					
Through Seepage	**63**	45	63	None documented	No	***Hazard Level LD***
Justification:	Medium WHIS resulting from sandy loose levee materials and numerous penetrations, but low head from the DWSE apparently tempers the score. Given this medium WHIS some bad past performance problems might have been expected. However, no serious problems appear to have happened as a result of through seepage. Levee maintenance assessments have always been unacceptable (except in the 1990s) due to lack of levee maintenance and records. It is therefore possible that bad performance problems may have not been documented. In the 1950s serious rodent infestation was observed and documented (Doc-797). Given the hazard indicators, and if additional data were obtained to resolve the LD, it is very unlikely the additional data would result in a re-categorization to Hazard Level C.					
Suggested additional data:	Additional subsurface exploration, since none is available on this bank. High water mark for the previous floods					
Erosion				Yes		***Hazard Level B***
Justification:	Categorized as Hazard Level B because of the multiple documented significant erosion sites recurring over time throughout the segment some described as 6 to 9 foot vertical faces. This is also supported by the multiple locations of scallops on oversteepened waterside slopes observed in contour maps and in aerial photographs.					
Suggested additional data:	None necessary					

Freeboard Check	Does levee pass freeboard check?	**Yes**	
Provide details about where along segment (and by how much) levee does not pass freeboard check:	Most of the segment has nearly 10-feet freeboard above the DWSE. Note that the single anomalous freeboard check point near Sta. 2000+00 (in Isleton) appears to be erroneous based on comparison to adjacent points (which exceed freeboard by more than 1 foot) and inspection of aerial photography.		
Are there anomalies along the segment with respect to freeboard?	No	Describe anomalies:	0
Levee Geometry Check	Does levee pass geometry check?	**Yes**	
Provide details about where along segment (and by how much) levee does not pass geometry check:	Levee prism fits within existing levee embankment.		
Are there anomalies along the segment with respect to geometry?	No	Describe anomalies:	0
Summary Characterization of Levee Segment	Hazard Level B	**Comment / Justification:**	The potential failure mode categorization for erosion is Hazard Level B. The categorization for underseepage is Hazard Level A and the categorizations for stability and through seepage are Lacking Sufficient Data. If additional data were obtained, it is very unlikely that the LD for stability or through-seepage would be categorized as Hazard Level C. Because at least one of the segment's other failure modes is already categorized as Hazard Level B, and the LD failure modes would not be categorized as Hazard Level C, the overall categorization for the segment is Hazard Level B.

Evaluator:	Juan F. Perri	Evaluation Date:	2/2/2010
Checked By:	Susan Olig	Check Date:	2/2/2010
Senior Reviewer:	RKG, KLK, RSA, and PCD	Review Date:	2/19/2010


Stability Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Stability Hazard Score
Severe
Some
Moderate
Minor
None documented
Documented Past Performance


Through Seepage Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Through Seepage Hazard Score
Piping
Free seepage
Wet area
Hydrophilic vegetation
None documented
Documented Past Performance


Underseepage Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Underseepage Hazard Score
Multiple, recurring sand boils
Some boils
Heavy seepage
Minor seepage
None documented
Documented Past Performance

BRANNAN-ANDRUS LEVEE MAINTENANCE DISTRICT, UNIT 1, SEGMENT 40 SUMMARY

This segment summary presents collected information and the assessment results for Segment 40. The summary is based on data that were readily available data at the time the segment was assessed. The amount of detail that was available varied. Known pertinent details are included. For details on the data collection and assessment procedures, see Volume 1, Section 2 of this report.

This summary is organized into the following seven sections:

- Segment Description and Assessment Summary
- Levee Segment History
- General Levee Conditions
- Levee Composition and Foundation Conditions
- Geotechnical Assessment Results
- Other Levee Assessments
- Hazard Mitigation

Segment 40: Segment Description and Assessment Summary

Segment 40 is a non-urban Project levee located on the right bank of Georgiana Slough (east bank of Brannan-Andrus Island) in Sacramento County, California (see attached map). The segment extends from LM 0 at about 3 miles northwest of the Oxbow Marina to LM 6.2 at the confluence of the Georgiana Slough and the North Mokelumne River. The following table summarizes information for Segment 40.

Segment 40 Information

Maintenance Authority	Unit	Levee Miles*	NULE Stationing*
Brannan-Andrus Levee Maintenance District	1	0 to 6.2	Georgiana Slough Right Bank 1000+00 to 1317+98

* The levee mile and stationing alignments differ.

As directed by DWR, the segment was assessed for each potential failure mode at the 1955/1957 design water surface elevation provided by DWR. The following table presents the Segment 40 categorizations for each potential failure mode.

Segment 40 Potential Failure Mode Assessment Summary

Potential Failure Mode	Categorization
Underseepage	Hazard Level C
Stability	Hazard Level B
Through Seepage	Hazard Level B
Erosion	Hazard Level A

Based on these NULE Phase 1 levee assessments, the overall categorization for Segment 40 is Hazard Level C.

Segment 40: Levee Segment History

The levee segment history described in the following sections is based on reviews of documents that are available in the NULE document database, and on interviews with personnel familiar with the levee and its history. The descriptions include construction history, performance, improvements, and planned improvements. The amount and quality of information varies from segment to segment. This segment summary contains pertinent information gathered during data collection. Some details may not be known.

Construction History

No information was found on initial construction of the Segment 40 levees. However, levees in this area were generally built between 1860 and 1880 by Chinese laborers using hand shovels and wheelbarrows (Doc-8306).

In 1951 the levee was reconstructed by the USACE. Borrow sites were located on the levee landside along the northern portion (Doc-612). Design drawings show an approximately 6-foot-deep inspection ditch and a 20- to 30-foot crown. The following table presents the 1953 MOU geometric criteria for Segment 40.

Segment 40 Geometric Criteria

Levee Type	Crown Width (feet)	Waterside Slope	Landside Slope
Project Levee	20	3H:1V	2H:1V

Performance

Levee performance information was obtained from reviewed documents and interviews with Brannan-Andrus Levee Maintenance District maintenance personnel. Based on the available information, performance problems in Segment 40 include erosion, seepage, boils, slumps, subsidence and sloughing that occurred at various sites and in some cases repeatedly. Reports of breeching or overtopping were not discovered. The following table summarizes reported performance events.

Segment 40 Reported Levee Performance Events

Flood Season	Reported Performance Event	Approximate Location (Levee Mile)	Mitigation
1957	Sinkhole in levee crown, 2 feet in diameter (Doc-5039).	1.48	Not documented.
1995	Boils, cracking, and 1- to 2-foot subsidence (Doc-5381).	2.75	Cofferdam constructed across ditch near toe to create a head against boil.
1996–1997	Severe seepage (Doc-54 and Doc-1581).	1.17	No mitigation recommended.
1996–1997	Seepage (Doc-1581).	2.62	No mitigation recommended.
1996–1997	Seepage, boils, cracks, landside sloughing and subsidence (Doc-54, Doc-1586, Doc-2234). 1100 feet of major area of seepage. As reported on 2-1-97, monitoring stakes indicate that slough has moved a maximum of 1 and 7/8 inches since January 28, 1997 (Doc-5586).	3.0–3.9	Repaired with toe drain, stabilizing berm, and relocated ditch away from toe.
1996–1997	Boil (Doc-1581).	4.1	Recommended but documentation not found.
1996–1997	Boils (Doc-54, Doc-1581, and Doc-1586).	4.86	No mitigation recommended.
1996–1997	Slump (Doc-5522).	5.32	Repaired by placing drain rock. “Another area” remains unrepaired.
1996–1997	Sloughing of the revetment (Doc-1581).	5.53	No mitigation recommended.
1996–1997	Subsidence on landside (Doc -54, Doc-1581, and Doc-1586).	5.56–5.84	No mitigation recommended.
1997–1998	Boils moving sand (Doc-2234).	3.9	Repaired with bentonite plug and additional berm.
1997–1998	Several boils landside, approximately 40 feet long, 3-foot vertical face.	4.04–4.13	Not documented.

Breaches

None identified in Segment 40. However, the Brannan Island area was flooded in 1972 because a break occurred in the south non-Project levee at the end of the island (Doc-54, Doc-8576).

Underseepage

Recurring boils, including some moving sand, have been observed at several sites, as noted in the table of reported performance events. Severe seepage was also documented. These underseepage problems have been the cause of serious concerns.

Stability

Some slumping, cracking, sloughing, and subsidence have been documented at various sites, as noted in the table above; these events are likely related to seepage (Doc-54, Doc-5522, and Doc-8314).

Through Seepage

Minor to severe seepage was repeatedly documented at various sites, as noted in the table of reported performance events.

Erosion

Although no erosion sites were identified in the 2008 Ayres Erosion Report, erosion has been periodically observed at various sites along Segment 40. Between LM 0 and LM 3.95 significant erosion was documented in 1957, including wave wash damage 3 to 4 feet above the water surface and 6 feet above the berm from LM 2.21 to LM 2.31 (Doc-5039). In 1961 and 1969, critical erosion sites were also identified between LM 5.4 and LM 5.5, and at LM 5.8 (Doc-4575, Doc-4519). Following the 1996-1997 flood season, erosion was documented at LM 0.36 and LM 2.62 (Doc-1581). In 1998, erosion was documented at LM 1.33 (Doc-1858).

Improvements

In 1951 the Segment 40 levees were reconstructed by the USACE with a crown width of 20 feet, and the levees were then repaved in 1973 (Doc-8114 and Doc-5039). Toe drains, a seepage blanket, stabilizing berms, plugs, and various revetments were placed at several sites (as detailed in the table above) to address underseepage, through seepage, and associated stability problems.

Planned Improvements

No documentation was found on planned improvements to Segment 40 levees.

Segment 40: General Levee Conditions

This section describes levee conditions based on document reviews, interviews, site reconnaissance, the LiDAR survey, and other collected data. These conditions include the levee geometry, penetrations, and animal activity.

Levee Geometry

Segment 40 levee heights range from about 10 to 20 feet above the landside toe. Crest width is approximately 15 to 40 feet, and LiDAR survey data indicate the landside slopes are about 2H:1V to 4H:1V. The waterside slopes are approximately 2.5H:1V to 4.5H:1V. A ditch is present along the landside toe of Segment 40 from about Station 1205+00 to Station 1310+00, and from about Station 1115+00 to Station 1155+00.

Penetrations

No penetrations were documented for Segment 40 in the DWR pipe inventory. However, nearly 30 pipe penetrations were documented for Segment 130 across the Georgiana Slough, and the 2005 Inspection Log (Doc-8114) shows approximately 40 pipes for Segment 40. Most of these appear to be 3 feet or more below the levee crest.

Animal Activity

The DWR animal persistence database indicates that in some locations of the segment, animal activity has been categorized as “Medium.” However, in this DWR database, the south end of Segment 40 has no documented animal activity.

Maintenance

Based on the DWR assessments performed in the fall of 2008, DWR rates the levee maintenance as “Acceptable” for this segment.

Other Features

Six non-parallel ditches intersect the landside toe area of Segment 40. The following table shows where they were identified:

LM	Ditch Depth (ft)
0	12
0.3	5
0.75	5
0.93	3
1.5	5
2	5

Segment 40: Levee Composition and Foundation Conditions

The NULE team established an understanding of the levee and levee foundation geotechnical conditions based on work performed by the geomorphology team, reviews of other available geologic and soil maps, data contained in reports that were reviewed, and general knowledge of levee conditions in the area. This section summarizes the team's understanding of geotechnical conditions in Segment 40.

In Segment 40, the levee foundations consist of interbedded peat, organic clay, silt, and sand. The levees consist of loose and very loose sand and silty sand.

Geomorphic Setting

Segment 40 levees are constructed along the right bank of the Georgiana Slough, which is located in the Lower Sacramento River Basin. At LM 6.2 the slough merges with the North Mokelumne River, which defines the southern boundary of the Sacramento River basin with the San Joaquin Delta to the south. Geomorphology Level 2-I mapping indicates the Segment 40 levees overlie Holocene tidal wetland and supra-tidal floodplain deposits, which consist of interbedded peats, clays, silts, and sands (Atwater, 1982). These units are consistent with the general description of sediments in the Delta.

Level 2-II mapping indicates that Segment 40 foundation soils are historical overbank deposits (silt, clay, and lesser sand), Holocene peat and mud deposited in tidal flats and wetlands, and a few historical distributary channels (sand, silt and clay). These estuarine deposits likely consist of organic fine-grained soils.

Geotechnical Investigations

The Delta Risk Management Strategy (Doc-8306) project compiled boring information for areas which include Segment 40. This compilation of information was used to evaluate subsurface conditions for this segment. The compilation of borings from the DRMS study included 9 holes drilled along Segment 40 by USACE in 1993. These borings range in depth from 12 to 40 feet. Boring logs indicate the foundation soils encountered consist of fine-grained materials (interbedded clays, silts. and sands) with varying amounts of organics (OH and peats). The thickness of organic material varies from 0 to 30 feet.

Other Subsurface Information

The USCS soil map also indicates that the existing levee overlies organic finer-grained soils (CL, CL-ML, and SC-SM; with some OH from LM 5.3 to LM 5.55). These mapping observations are consistent with information from the borings.

Levee Composition

Previous studies state that the Segment 40 levees consist of loose and very loose sands with five to nine percent fines (Doc-54). This is generally consistent with the observations in borings from the DRMS study (Doc-8306), which indicate predominantly sandy material with some sandy silt.

Segment 40: Geotechnical Assessment Results

The overall Segment 40 categorization is Hazard Level C. As discussed in Volume 1, Section 2 of this report, the overall assessment is based on the individual potential failure mode categorizations. A summary of the LAT results and the matrix plots are attached.

A Weighted Hazard Indicator Score was calculated for each potential failure mode at the assessment water surface elevation, the 1955/1957 water surface elevation provided by DWR. The assessment is based on identified geologic, geometric, and other hazards. A rating for past performance based on documented performance events was assigned. The categorizations for each potential failure mode are discussed in the sections that follow.

Underseepage

Segment 40 Underseepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
70	70	74	Multiple recurring boils.	Multiple recurring boils.	Multiple recurring boils.	Hazard Level C

Hazard indicators include high underseepage susceptibility of the foundation soils, relatively high head-to-base-width ratio, and the presence of a ditch along the landside toe. The hazard indicators are consistent with the past performance including severe seepage and recurring boils.

Stability

Segment 40 Stability Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
71	56	71	Some	Minor	Some	Hazard Level B

Hazard indicators include levee height, the levee composition (loose to very loose sand), and the presence of thick, soft, organic foundation soils along much of the segment. Overall, the past performance of some slumps and sloughing is consistent with the WHIS.

Through Seepage

Segment 40 Through Seepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
73	63	78	Free seepage	Wet area	Piping	Hazard Level B

Hazard indicators for through seepage include sandy levee composition, the large number of levee penetrations, the very high piping potential, and the relatively high head-to-base width ratio. These hazard indicators are consistent with the recurring severe seepage observed along Segment 40.

Erosion

Segment 40 is categorized as Hazard Level A for erosion. Some moderate occurrences of erosion were documented after the levee reconstruction, which is consistent with the minor scouring observed in topography and imagery along some inside bends along the waterside. In addition, wave wash damage 3 to 4 feet above the water surface and 6 feet above the berm was documented in 1957 from LM 2.21 to 2.31 (Doc-5039). However, no erosion sites were identified in the Ayres 2008 Erosion Report.

Anomalies

A ditch at LM 1.5 may have affected performance, as a 2-foot diameter sinkhole appeared in the levee crown at LM 1.48 in 1957.

Additional anomalies that have affected levee performance were noted at three locations. First, sewage disposal ponds adjacent to the landside toe from LM 2.6 to LM 3.0 may have affected the flow path because boils have occurred at LM 2.75 and major seepage has been observed from LM 3.19 to LM 3.3. Second, a pump station at LM 3.9 to LM 4.1 includes several pipe penetrations that appear to have affected through seepage, underseepage, and stability. Cracking and sloughing, major seepage, and recurring boils, including one moving sand at LM 3.9 after PL99-84 Phase III rockfill repair was placed in 1997, have occurred at this location. Finally, a major gas pipeline that connects Vista Gas Field to River Island and penetrates Segment 40 at LM 1.1 and is reportedly near severe landside seepage documented at LM 1.17 (Doc-54 and Doc-1581).

Segment 40: Other Levee Assessments

Freeboard

Based on data from the LiDAR survey, the levee crest for Segment 40 is above the 1955/1957 WSE. However, a minimum freeboard of 3 feet is not generally present from approximately Station 1000+00 to Station 1170+00, and from Station 1240+00 to the end of the segment at Station 1317+98. Where it is deficient, the crest elevation is generally 1/2 to 1 foot below the design freeboard, except between Station 1240+00 and Station 1280+00 where it is 2 feet below the design freeboard.

Overtopping

Overtopping was considered based only on past performance. Evaluation of flood flows, flood elevations, channel capacities, and other factors influencing overtopping risk is beyond the scope of the NULE project. These factors should be studied by others to evaluate the overtopping risk to the NULE levees. No documentation was found that reported overtopping.

Geometry

Using the LiDAR data, the levee geometry was compared with a standard levee prism defined by the Segment 40 1953 MOU geometric criteria. This check was performed by assessing whether the levee indicated by topography developed from the LiDAR data was larger than or equal to the standard levee prism at any given cross section. Wide levees could meet this requirement even where levee slopes are steeper than those described in the 1953 MOU. For Segment 40, approximately 90 percent of the levee is smaller than the standard levee prism.

Segment 40: Hazard Mitigation

The following table presents identified hazards for Segment 40, and the estimated extent of the hazard. Comments are provided to assist with identifying potential remedial requirements.

Segment 40 Hazards

Hazard	Extent (percent)	Comments
Freeboard Less Than Design	90	Estimated from plots and tabulated data based on LiDAR
Underseepage	90	Based on distribution of underseepage sites and underseepage susceptibility.
Stability	60	Based on soft soils present and geometry.
Through Seepage	85	Based on distribution of seepage sites and levee composition..

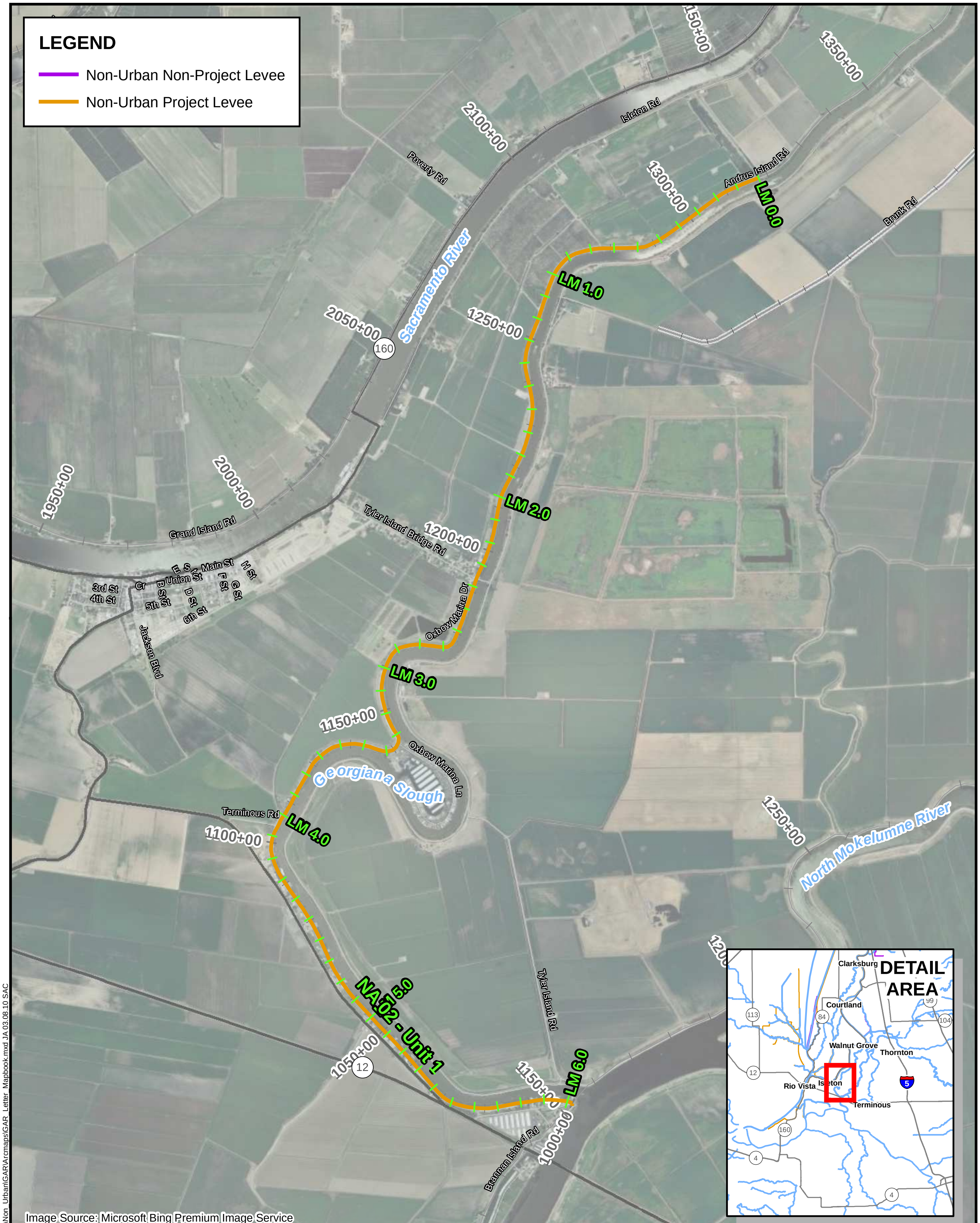
Segment 40: Anomalous Hazards

Sewage disposal ponds adjacent to the landside toe from LM 2.6 to LM 3.0 are located in the same area as boils and major seepage, which may affect the levee integrity. The boil was observed at LM 2.75 and the seepage events were observed from LM 3.19 to LM 3.3.

A pump station at LM 3.9 to LM 4.1 includes several pipe penetrations that appear to have affected through seepage, underseepage, and stability. Cracking and sloughing, major seepage, and recurring boils (including one moving sand at LM 3.9 after PL99-84 Phase III rock fill repair was placed in 1997) have occurred at this location.

A major gas pipeline that connects Vista Gas Field to River Island and penetrates Segment 40 at LM 1.1 and is reportedly near severe landside seepage documented at LM 1.17 (Doc-54 and Doc-1581).

A ditch at LM 1.5 may have affected performance, as a 2-foot diameter sinkhole appeared in the levee crown at LM 1.48 in 1957.



0 1,500 3,000
Feet

N

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

Segment 40

Brannan-Andrus LMD Unit 1
Geotechnical Assessment Report

NORTH NON-URBAN LEVEE EVALUATIONS

L:\Projects\DWR\GEOTECHNICAL\Non Urban\GAR\Arcmaps\GAR_Letter_Mapbook.mxd JA 03.08.10 SAC

Non Urban Levee Evaluation Program (NULE) Levee Assessment Tool, Version 1.2 (revised: 1/7/2010)

				Begin	End
Levee Segment Name:	Brannan-Andrus LMD Unit 1		NULE Station (ft):	1000+00	1317+98
Levee Segment Number:	40		Levee Mile:	0	6.02
Brief Description of Segment/Reach:	Brannan-Andrus LMD - Unit 1, Georgiana Slough		Segment/Reach Length:	6 (miles)	31798 (feet)
			Crest Width Design Criterion (ft):	20	
Local Maintenance Authority:	Brannan-Andrus Levee Maintenance District		Design Guidance Document:	MOU 1953	
Freeboard Evaluation Criterion (ft):	3				
Water Side Slope Design Criterion:	3H : 1V	Enter Other Criterion	Project or Non-Project Levee?	Project	
Land Side Slope Design Criterion:	2H : 1V	Enter Other Criterion			
North or South NULE?	North				

LEVEE CONSTRUCTION

Describe what is known about construction of this levee segment:	In 1951 the levee was reconstructed by United States Army Corps of Engineers. Crown width 20 feet. Repaved in 1973 (Doc-8114; 5039). No information found on initial construction. However, levees in this area were generally built in between 1860 and 1880 by Chinese Laborers using hand shovels and wheel barrows.

Analysts should populate all yellow cells, and not populate grey cells; green cells store calculated values. Use the suite of available data in making ratings. See User Guide and tables for further information.

PAST PERFORMANCE

	Value (where applicable)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments (include event date and flood elevation, if available)
Underseepage		*Multiple, recurring sand boils*	*Multiple, recurring sand boils*	*Multiple, recurring sand boils*	Recurring sand boils at LM 3.9 in 1997 and in 1998 after PL99-84 repairs (Doc-2234).
Landside slope stability		*Some*	*Minor*	*Some*	In 1997 slump partially repaired at LM 5.32 (Docs 54; 5522). Significant pavement crack shown in photo at Oxbow Marina (Interview forms)
Through seepage		*Free seepage*	*Wet area*	*Piping*	Alarming quantity of seepage during high stage flows (Doc-54). Interview forms indicate: "stability berm installed along landside in 1997. French drain was installed, but moisture is still found in the ditch".

In addition to Ayres 2008/DWR 2009 studies, are there erosion occurrences identified in this study?	Yes	**If yes, please describe:**	Between LM 0 and 3.95 there was significant erosion documented in 1957 (Doc-5039). Additionally, in 1961 and 1969 critical erosion sites were identified between LM 5.4-5.5 and at LM 5.8 (Docs 4575; 4519). Following the 1996-97 flood season, erosion was documented at LM 0.36, 2.62 (Doc-1581). In 1998, erosion was documented at LM 1.33 (Doc-1858).					
North NULE	**Erosion sites from the Ayres 2008 study**	**Ayres Methodology 2**			**Ayres Methodology 4**			
		Rating (1 to 72)	**Ranking (out of 117)**		**Rating (1 to 47)**	**Ranking (out of 117)**		
Are there erosion occurrences compiled in the Ayres study?	No	N/A	N/A		N/A	N/A		
	Comments:	N/A			**Comments:**	N/A		
South NULE	Erosion sites from the DWR 2008 study	DWR Prioritization 2008						
		Rating (1 to 100)	Ranking (out of 67)					
Are there erosion occurrences compiled in the DWR study?								
	Comments:							

Past overtopping or near overtopping?:	Never overtopped	**Comments:**	No overtopping documented
Past breach in area?	None Identified	**Comments:**	Brannan Island area flooded in 1972 due to a break in the south of the island (Doc-54).

HAZARD INDICATORS

I- LEVEE COMPOSITION - *at selected cross section* - Interpreted from Borings, Test Pits, field reconnaissance, NRCS maps, and analyst's interpretation of this assemblage of information

	Value (where applicable)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments
Composition of levee material *for through seepage assessment*		*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	Based on Doc-54 indicating loose sands and very loose sands. In agreement with borings from DRMS study.
Composition of levee material *for stability assessment*		*4 - CH, MH; moderately dispersive soils; loose sand, sand with silt, or non-plastic silt*	*1 - SC, CL-ML, CL (LL<35); non-dispersive; soils are generally somewhat clayey such as clayey sand or clayey silt, lean sandy clay or lean clay with liquid limits less than 35.*	*4 - CH, MH; moderately dispersive soils; loose sand, sand with silt, or non-plastic silt*	Based on Doc-54 indicating loose sands and very loose sands. In agreement with borings from DRMS study.

II- GEOLOGY - *at selected cross section*

	(Scale of mapping)				
Underseepage susceptibility *for underseepage assessment*	1:24,000	*5 - Very high*	*5 - Very high*	*5 - Very high*	Based on Level 2-II mapping.
Dispersive soils *for stability assessment*	1:24,000	*1 - Not dispersive*	*1 - Not dispersive*	*1 - Not dispersive*	Based on NRCS mapping.
Piping potential *for underseepage assessment*	1:24,000	*1 - None or no data*	*1 - None or no data*	*4 - High*	Mapping shows no piping potential or no data under segment 40 but across slough potential is high.
Piping potential *for through seepage assessment*	1:24,000	*5 - Very high*	*1 - None or no data*	*5 - Very high*	Mapping shows very high piping potential, but near boundary with no potential or no data.
Soft soils *for stability assessment*	1:24,000	*5 - Present*	*5 - Present*	*5 - Present*	Borings from DRMS study and geologic mapping indicate thick Holocene organic mud.

III- OTHER INDICATORS - *at selected cross section*

Animal persistence/burrows? *for through seepage assessment*		*1 - None documented*	*1 - None documented*	*2 -Low*	Selected cross section is close to boundary between "None" and "Low" animal persistence.
Is a landside ditch or borrow pit present within 200 ft of toe? *for underseepage assessment*	Ditch within 50 ft of toe	4			Observed on cross section from LiDAR contours.
Is a landside ditch or borrow pit present within 200 ft of toe? *for stability assessment*	No ditch	1			0
Is waterside blanket present? *for underseepage assessment*	No				0
Are there locations where penetrations and historical underseepage are coincident?	Yes	**If yes, please describe:**	Boils documented at LM 3.9 after PL99-84 Phase III rockfill repair placed in 1997 appear to be coincident with numerous pipe penetrations associated with a pump station at LM 3.9 to 4.1. Interview forms indicate: "Boil site near fence where gravel was placed near manhole. French drains now connect to manhole."		
Are there locations where penetrations and historical through seepage are coincident?	Yes	**If yes, please describe:**	Although no penetrations documented, database appears incomplete (see comment below on number of penetrations). A major gas pipeline penetration at LM 1.1 (connecting Vista Gas Field to River Island Gas Field) is reportedly near severe landside seepage documented at LM 1.17 (Docs 54;1581).		
Have encroachments that may potentially affect levee integrity been identified?	Yes	**If yes, please describe:**	Sewage disposal ponds adjacent to toe at LM 2.6 to 3.0 are spatially associated with boils at LM 2.75 and major seepage at LM 3.19 to 3.3. Several residential dwellings are located at or near landside toe (especially between LM 4.2 and 6.2), typically with associated access ramps and waterside docks. Additionally, 2 dwellings appear to be located waterside (LM 5.84 and 6.1). Additional ramps, boat docks, signs and power poles placed at various locations (Doc-8114). Oxbow marina located at LM 3.28 to 3.41.		
Provide the number of levee penetrations below the evaluation water surface elevation:	5 - More than 20	**Notes:**	No penetrations documented for this segment in the DWR pipe inventory. However, segment across the Georgiana Slough has nearly 30 pipes documented. 2005 Inspection Log (Doc-8114) indicates approximately 40 pipes. Most of them more than 3 feet below levee crest.		
DWR's LMA maintenance rating from Maintenance Deficiency Summary Report:	Acceptable	**Notes:**	Fall 2008. Recommendation for trimming trees and remove wild growth on levee slopes		

IV- TOPOGRAPHIC & ELEVATION INFORMATION - *at selected cross section(s)*

	Default cross section (used for Underseepage assessment)		Would you like to evaluate a different cross-section for **Stability**?	Yes	Would you like to evaluate a different cross-section for **Through Seepage**?	Yes
	Cross-section Station	1155+00	**Cross-section Station**	1095+00	**Cross-section Station**	1095+00
	Underseepage		**Stability**		**Through Seepage**	
Report elevations in NAVD 88	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]
Levee crest elevation (ft)	14.5		13.5		13.5	
Levee toe elevation (landside) (ft)	-5		-8		-8	
Levee crest width (ft)	18	2	15	3	15	3
Evaluation water elevation (ft)	12		11		11	
Levee slope - landside (xH : 1V); **Enter x**	3.64	2	2	3	2	3
Levee slope - waterside (xH : 1V); **Enter x**	3.75				3	
Freeboard above evaluation flood elevation (ft) (= levee crest elevation - evaluation water elevation)	2.5					
Levee height (ft) (= levee crest elevation - landside toe elevation)	19.5	4	21.5	5	21.5	5
Levee prism base width (ft)	162.1				122.5	
Head (ft) (= evaluation water level - landside toe elevation)	17.0	4	19.0	4	19.0	4
Head-to-base-width ratio (= head / base width)	0.105	3			0.2	4
Base-width to head ratio (= base width / head)	10				6	

V- ANOMALIES

	Anomalies?	**Description**	**Effect on Performance**
Underseepage	Yes	Sewage disposal ponds adjacent to landside toe at LM 2.6-3.0 may have affected flow path. A pump station at LM 3.9 to 4.1 includes several pipe penetrations that appear to have affected through seepage, underseepage and stability.	Sewage ponds have spatially associated boils at LM 2.75 and major seepage at LM 3.19 to 3.3. Pumping station has associated cracking and sloughing, major seepage, and recurring boils (including one moving sand at LM 3.9 after PL99-84 Phase III rockfill repair placed in 1997).
Stability	Yes	A pump station at LM 3.9 to 4.1 includes several pipe penetrations that appear to have affected through seepage, underseepage and stability.	Pumping station has associated cracking and sloughing, major seepage, and recurring boils (including one moving sand at LM 3.9 after PL99-84 Phase III rockfill repair placed in 1997).
Through Seepage	Yes	Sewage disposal ponds adjacent to landside toe at LM 2.6 to 3.0 may have affected flow path. A pump station at LM 3.9 to 4.1 includes several pipe penetrations that appear to have affected through seepage, underseepage and stability. A 5 ft deep ditch intersecting the landside toe area at LM 1.5 may have affected seepage.	Sewage ponds have spatially associated boils at LM 2.75 and major seepage at LM 3.19 to 3.3. Pumping station has associated cracking and sloughing, major seepage, and recurring boils (including one moving sand at LM 3.9 after PL99-84 Phase III rockfill repair placed in 1997). A 2-ft diameter sinkhole developed on the crown of the levee in 1957 at the location of the ditch.
Erosion	No	None observed.	None observed.

MITIGATION AND PAST BREACHES

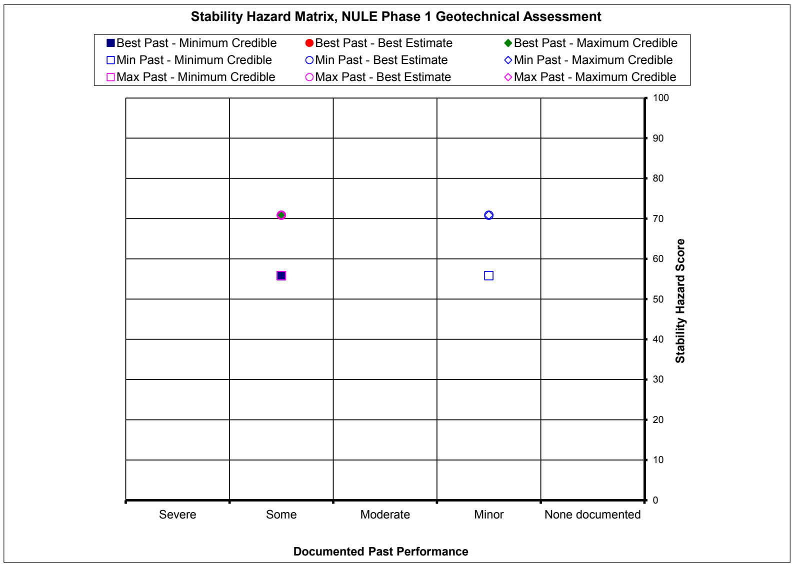
Existing constructed mitigation (List all)	Levee reconstructed by United States Army Corps of Engineers, I951 (Doc-8114). In 1997 repaired with toe drain stabilizing berm and relocated ditch away from toe. Recurring multiple revetments placed to mitigate erosion. French drain was installed to address seepage issue at undocumented location; drainage blanket, crushed rock berm, and ditch installed at oxbow (Interview Forms).	
Has there been a past breach?	None Identified	
If yes, describe nature of the breach and how it has been mitigated?		

SUMMARY

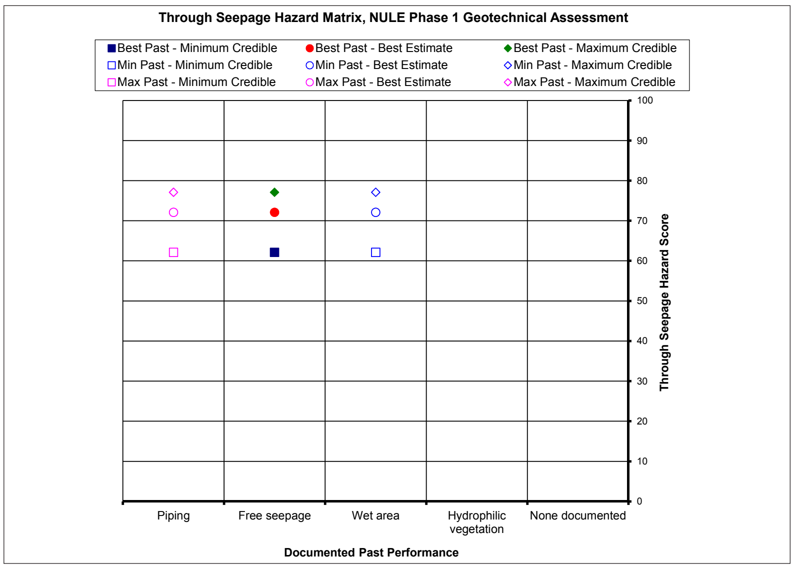
Failure Mode	**Weighted Hazard Indicator Score (Best)**	**Weighted Hazard Indicator Score (Minimum Credible)**	**Weighted Hazard Indicator Score (Maximum Credible)**	**Past performance issues?**	**Are past performance and Weighted Hazard Indicator Score consistent?**	**Levee categorization**
Underseepage	**70**	70	74	Multiple, recurring sand boils	Yes	***Hazard Level C***
Justification:	Multiple recurring boils in agreement with high WHIS. Even some repeated remediations have not been effective. The WHIS is the result of high underseepage susceptibility of foundation soils, relatively high head to base-width ratio, and the presence of a ditch along the landside toe.					
Suggested additional data:	Additional borings					
Stability	**71**	56	71	Some	Yes	***Hazard Level B***
Justification:	Some slumps and sloughing which appear to be primarily related to seepage. However, there is also documentation that levee is composed of loose to very loose sand. In addition, thick soft organic foundation soils are present along much of the segment.					
Suggested additional data:	Additional geotechnical data on levee materials.					
Through Seepage	**73**	63	78	Free seepage	Yes	***Hazard Level B***
Justification:	Recurring severe seepage in agreement with high WHIS. High WHIS due to sandy levee composition, large number of levee penetrations, very high piping potential, and relatively high head to width-base ratio.					
Suggested additional data:	Additional geotechnical data on levee materials. In addition, more information on levee penetrations.					
Erosion				Yes		***Hazard Level A***
Justification:	Some moderate occurrences of erosion documented after levee reconstruction, which is consistent with apparent minor scouring observed in topography and imagery along some inside bends. Additionally, wavewash damage 3-4 ft high, 6 ft above berm was documented at Lm 2.21-2.31 (Doc 5039). However, no erosion sites were identified in the Ayres 2008 report. Note that opposing bank had numerous significant Ayres erosion sites.					
Suggested additional data:	Better erosion repairs documentation.					

Freeboard Check	Does levee pass freeboard check?	**No**	
Provide details about where along segment (and by how much) levee does not pass freeboard check:	About 85 to 90% of length does not pass freeboard check. Freeboard deficient by as much as 2 ft (between Stations 12400+00 and 12800+00), but levee crest elevation appears consistently above design elevation.		
Are there anomalies along the segment with respect to freeboard?	No	Describe anomalies:	0
Levee Geometry Check	Does levee pass geometry check?	**No**	
Provide details about where along segment (and by how much) levee does not pass geometry check:	Along most of its length except between Stations 1035+00 to 1042+00, and between Stations 1166+00 to 1184+00. Geometry deficiency is primarily due to crest elevation.		
Are there anomalies along the segment with respect to geometry?	No	Describe anomalies:	0
Summary Characterization of Levee Segment	Hazard Level C	**Comment / Justification:**	Underseepage is Hazard Level C.

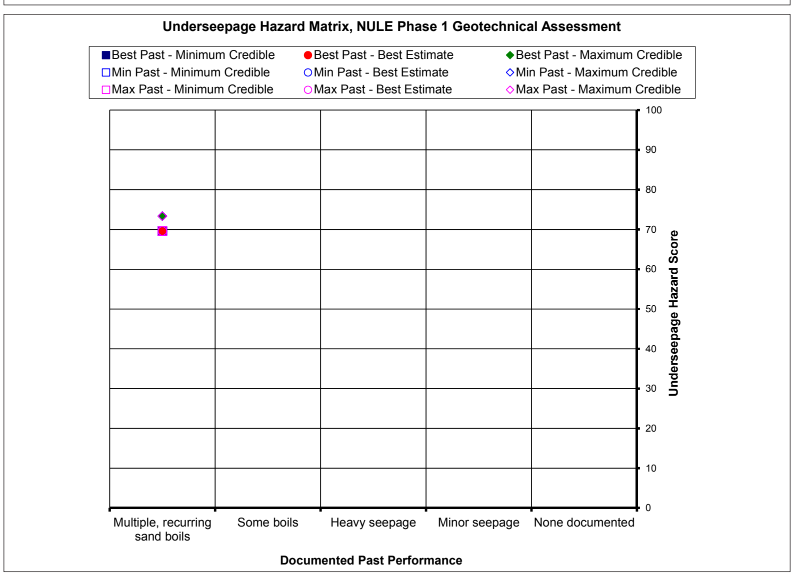
Evaluator:	Juan Perri	Evaluation Date:	1/13/2010
Checked By:	Susan Olig	Check Date:	1/13/2010
Senior Reviewer:	KLK, RKG and DM	Review Date:	1/19/2010



Stability Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Stability Hazard Score
Severe
Some
Moderate
Minor
None documented
Documented Past Performance



Through Seepage Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Through Seepage Hazard Score
Piping
Free seepage
Wet area
Hydrophilic vegetation
None documented
Documented Past Performance



Underseepage Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Underseepage Hazard Score
Multiple, recurring sand boils
Some boils
Heavy seepage
Minor seepage
None documented
Documented Past Performance

BRANNAN-ANDRUS LMD, UNIT 3, SEGMENT 1050 SUMMARY

This segment summary presents collected information and assessment results for Segment 1050. The summary is based on available data at time of assessment. The amount of detail available varied. Known pertinent details are included. For information about data collection and assessment procedures, see Volume 1, Section 2.0 of this report.

This summary is organized in seven sections:

- Segment Description and Assessment Summary
- Levee Segment History
- General Levee Conditions
- Levee Composition and Foundation Conditions
- Geotechnical Assessment Results
- Other Levee Assessments
- Hazard Mitigation

Segment 1050: Segment Description and Assessment Summary

Segment 1050 is a non-urban Non-Project levee on the right bank of Mokelumne River in Sacramento County, California. The segment extends from the confluence of the Mokelumne River and the San Joaquin River northward to the confluence of the Mokelumne River and the Georgiana Slough. The following table summarizes segment information.

Segment 1050 Information

Maintenance Authority	Unit	Levee Miles	NULE Stationing
Brannan - Andrus LMD	3	0 to 2.90	North Mokelumne River Right Bank (NMKR-R) 1000+00 to 1153+05

Since 1955/1957 design water surface elevation is not available, and as directed by DWR, the segment was assessed for each potential failure mode with water at 1.5 feet below the levee crest. The following table presents the Segment 1050 categorizations for each potential failure mode.

Segment 1050 Potential Failure Mode Assessment Summary

Potential Failure Mode	Categorization
Underseepage	Hazard Level C
Stability	Hazard Level C
Through Seepage	Hazard Level C
Erosion	Hazard Level B

Based on these NULE Phase 1 levee assessments, the overall categorization for Segment 1050 is Hazard Level C.

Segment 1050: Levee Segment History

Levee segment history described below is based on a review of documents in the NULE document database and on interviews with personnel familiar with the levee and its history. The descriptions include construction history, performance, improvements, and planned improvements. The amount and quality of information varies from segment to segment. This segment summary contains pertinent information gathered during data collection. Some details may not be known.

Construction History

Segment 1050's levee was built initially by the Tide Land Reclamation Company during 1871 and 1872 (Doc-8729). In general, the initial levee was about 4 feet high, is 15 feet wide at the base and is 8 feet wide at the crown. After flooding of Brannan-Andrus Island in 1877-78, the levee system, including Segment 1050, was reconstructed in 1878 by the newly organized Reclamation District 317. The reconstructed levees were about 9 feet high, 25 to 40 feet wide at the base, and 3 to 5 feet wide at the crown. For the most part, the levee material used for reconstruction was imported from outside the island. Details about the imported materials were not reported in reviewed documents. No data related to levee improvements was reported between 1880 and 1990 in reviewed documents.

The following table presents the 1953 MOU geometric criteria for Segment 1050.

Segment 1050 Geometric Criteria

Levee Type	Crown Width (feet)	Waterside Slope	Landside Slope
Non-Project Levee	20	3H:1V	2H:1V

Performance

Levee performance information was obtained from reviewed documents and interviews with maintenance personnel. According to the available information, performance events in Segment 1050 include erosion, through seepage, underseepage and cracking. These performance events occurred during multiple seasons. The following table summarizes reported performance events.

Segment 1050 Reported Levee Performance Events

Flood Season	Reported Performance Event	Approximate Location (NULE NMKR-R Station)	Mitigation
Late 1980s to early 90s	Erosion (Doc-8709)	1050+00 – 1085+00	Riprap placed in 1992.
January 1997	Several cracks and possible slips on landside (Doc-5501, Doc 5508)	Near 1088+00	Berm and ballast were placed as part of an emergency repair performed by USACE.
1998	Riprap slipped, "Over 200 feet riprap was slipped, earthen bank exposed and erosion underneath Bermuda grass" (Doc-5452).	1103+00 to 1105+00	Mitigation not indicated.
1998	Subsidence in crown, crack along the levee crown and slope (Doc-5452)	Near 1090+00	Mitigation not indicated.
1998	Wave wash erosion, "Wave wash above rip rap eroding crown, 276 feet. Almost a foot or so of dirt gone, eroded" (Doc-5452)	Near 1049+00	Mitigation not indicated.
2004	Seepage and boil on the landside slope (Doc-8716)	Near 1078+00	Seepage covered with crushed drain rocks
2005	Seepage on the landside slope (Doc-8716)	1079+00 – 1085+00	Seepage covered with crushed drain rocks and imported fill
2010	Boil on blocked drain. (Doc-8709)	Near 1055+00	Mitigation proposed.
2010	Boil (Doc-8709)	Near 1095+00	Mitigation proposed.

Underseepage

Segment 1050 has two documented boils observed in 2010. One of the boils was near NULE Station 1055+00 and the other boil was near NULE Station 1095+00 (Doc-8709). The boil near NULE Station 1055+00 was described as a "blocked drain issue" by the district engineer. Boils have been previously observed by the RD at this location.

Stability

Segment 1050 has two documented slope instability events. Several cracks, vertical displacement, and slips were observed in 1997 by RD personnel upstream and downstream of Delta Isle near NULE Station 1088+00 (Doc-5501, Doc-5508). This incident was reported as follows:

> *"There was an area 500 feet in length that had one set of cracks running parallel to the crown midslope. The area had a vertical displacement of 3 feet or more in places and is on the landward slope. Another crack was 300 feet in length, ran four feet from the shoulder to the crown and had a vertical displacement of two to four feet vertically. There is also a four inch hairline running horizontally. There is a bulging at the bottom of the levee. At another site on the levee a crack 180 feet in length had occurred. Crack midslope running parallel to slope, 1-1.5 feet vertically, 0-8 inches horizontally. Crack on roadway parallel to shoulder encroaching to roadway 60 feet with vertical displacement 4-5" horizontal displacement" (Doc-5501).*

USACE performed an emergency repair at this location by placing a berm and ballast (Doc-5501).

The cracks observed near NULE Station 1090+00 in 1998 were reported as "subsidence in crown, small cracks on levee slope and 146 foot longitudinal cracks in roadway" (Doc-5452). The longitudinal cracks were up to 18 inches deep, and the observed vertical difference on asphalt was 2 to 4 inches (Doc-5452).

Through Seepage

Segment 1050 has two documented through seepage events. In 2004, seepage and a boil were observed at the landside slope of the levee near NULE Station 1078+00. That same year, drain rock was placed to cover the seepage area (Doc 8716). In 2005, seepage areas were observed between NULE Stations 1079+00 and 1085+00. Crushed rock was placed to cover the seepage area (Doc 8716).

Erosion

Segment 1050 has three reported erosion events. The events were related to wave wash and reported between NULE Stations 1050+00 and 1085+00.

rosion was observed in the late 1980s and early 1990s. Rip-rap was placed in 1992 to control this erosion (Doc-8709). Between NULE Stations 1103+00 and 1105+00 in 1998, erosion was reported as "over 200 feet riprap was slipped, earthen bank exposed and erosion underneath Bermuda grass" (Doc-5452). Near NULE Station 1049+00, erosion was reported in 1998 as "wave wash above rip rap eroding crown, 276 feet. Almost a foot or so of dirt gone, eroded" (Doc-5452).

Improvements

In 1992, rip-rap was placed between NULE Stations 1050+00 and 1085+00 (Doc-8709).

In 1997, USACE performed an emergency repair by placing a berm and ballast between NULE Stations 1080+00 and 1095+00 (Doc-5501, Doc-5508).

In August 1999, the levee crown was raised to meet hazard mitigation plan standards between NULE Stations 1075+00 and 1115+00 (Doc-8716).

In May 2000, improvements including a levee raise were performed between NULE Stations 1129+00 and 1136+00 and between NULE Stations 1059+00 and 1079+00 (near Perry's ramp) (Doc-8716).

In August 2003, rip-rap was placed between NULE Stations 1063+00 and 1065+00 to mitigate problem areas identified in a survey (Doc-8716).

Planned Improvements

According to the documents reviewed, no improvements to Segment 1050 are currently planned. However, the district is considering constructing berms to mitigate seepage problems (Doc -8709).

Segment 1050: General Levee Conditions

This section describes levee conditions based on document review, interviews, site reconnaissance, LiDAR survey, and other collected data. Levee conditions include levee geometry, penetrations, and animal activity.

Levee Geometry

Segment 1050 levee heights range from about 10 to 12 feet above the landside toe from NULE Station 1000+00 to 1028+00 and from about 15 to 24 feet between NULE Stations 1028+00 and 1153+05. Crest width is approximately 15 to 30 feet. LiDAR survey data indicate the landside slope is about 4H:1V to 6H:1V between NULE Stations 1000+00 and 1028+00, and is about 2H:1V to 5H:1V between NULE Stations 1028+00 and 1153+05. The waterside slope is approximately 2H:1V to 3.5H:1V. A ditch is near the landside toe of Segment 1050 from about NULE Stations 1127+50 to 1137+00.

Penetrations

Based on the 1989 *Survey Field Book* (Doc-2667), six pipes penetrate the levee segment. The pipe diameters range from 10 to 14 inches.

Animal Activity

Animal activity was not reported in reviewed documents. However, animal activity was noted during an interview. Animal activity control is part of the routine maintenance program. Animal persistence based on data from DWR is not available for Segment 1050.

Maintenance

DWR assessments were not available for Segment 1050.

Other Features

Segment 1050 has several ditches that are at an angle to the levee. The ditches are near NULE Stations 1046+00, 1062+50, 1069+25 and 1127+50.

The Highway 12 Bridge over the Mokelumne River is across the levee at about NULE Station 1139+00.

Segment 1050: Levee Composition and Foundation Conditions

The NULE team established an understanding of levee and levee foundation geotechnical conditions based on work performed by the geomorphology team, review of other available geologic and soil maps, data contained in reports reviewed, and general knowledge of levee conditions in the area. This section summarizes the team’s understanding of geotechnical conditions in Segment 1050.

In Segment 1050, the levee foundation consists mainly of peat and organic soil (organic silt and organic clay) and the levee consists mainly of silty sand, sand, silt and organic soil.

Geomorphic Setting

According to the *Level 2-I Geomorphic Assessment*, Segment 1050 is in the Delta geomorphic domain (D). Soil deposits in the Delta geomorphic domain (D) are primarily late Holocene tidal wetland and supratidal flood plain deposits that consist of varying amounts of interbedded peat, organic mud, clay, silt, and sand. The flood plain or overbank deposits are adjacent to the channels and sloughs. These channel and flood deposits are generally coarser and less organic, whereas the central parts of islands in the Delta (where elevations are typically at or below sea level) are generally covered by peat and organic mud formed by decaying wetland vegetation. The percentage and thickness of organic deposits is generally greatest in the central portion of the Delta, but there are local variations, including some areas where pre-Holocene eolian sand dunes formed paleotopographic highs and where peat and soft mud are not present and likely were never deposited.

Based on the *Level 2-I Geomorphic Assessment*, Segment 1050 is predominantly underlain by peat and organic soil. Level 2-II geomorphic mapping is not available for Segment 1050.

Geotechnical Investigations

Geotechnical investigations for Segment 1050 include 13 borings (Doc-8306). Eight of these borings were drilled through the crest of the levee and five of these borings were drilled near the toe. These borings range in depth from 20 to 100 feet. According to these boring data, soil in the levee prism consists mainly of silty sand, sand, silt and organic soil, and the foundation consists mainly of peat and organic soil (organic silt and organic clay). The thickness of organic soil found in the foundation ranges from about 10 to 55 feet.

Other Subsurface Information

The USCS soil map indicates Segment 1050 mostly overlies fine-grained materials (OH, CL-ML) with the exception of about 2,300 feet levee between NULE Stations 1130+00 and 1153+00 that overlies silty clayey sand (SC-SM). The NRCS USCS map is generally consistent with the level 2-I mapping and borings.

Levee Composition

According to the borings described above, the levee consists mainly of silty sand, sand, silt and organic soil.

Segment 1050: Geotechnical Assessment Results

The overall Segment 1050 categorization is Hazard Level C. As discussed in Volume 1, Section 2.0 of this report, the overall assessment is based on the individual potential failure mode categorizations. For this segment, the potential failure mode categorizations for underseepage, stability and through seepage were Hazard Level C. The categorization for erosion was Hazard Level B. This results in an overall categorization of Hazard Level C.

A WHIS was calculated for each potential failure mode at the assessment water surface elevation: the top of levee less 1.5 feet, based on identified geologic, geometric, and other hazards. A rating for past performance was assigned based on documented performance events. The categorizations for each potential failure mode are discussed below.

Underseepage

Segment 1050 Underseepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
90	89	90	Some Boils	Heavy Seepage	Multiple recurring sand boils	Hazard Level C

The levee height is up to 24 feet above the levee toe, resulting in high differential water head. The levee foundation consists mainly of peat and organic soil (organic silt and organic clay) that has a very high underseepage susceptibility. Segment 1050 is categorized as Hazard Level C for underseepage based on the consistency between the WHIS, which suggests underseepage may occur, and the reported boils.

Stability

Segment 1050 Stability Assessment Results*

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
74	64	74	Severe	Some	Severe	Hazard Level C*

* Stability is assessed independently of through seepage and underseepage. Seepage might cause instability not accounted for in the stability assessment.

Segment 1050 overlies peat and organic soil (organic silt and organic clay). The levee height is up to 24 feet above the levee toe. Severe cracks have been reported along the levee, and bulging was observed at the bottom of the levee. Segment 1050 is categorized as Hazard Level C based on the consistency between the WHIS, which suggests that slope instability may occur, and reported cracks and bulging along the levee.

Through Seepage

Segment 1050 Through Seepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
80	63	85	Piping	Free Seepage	Piping	Hazard Level C

The levee is composed of silty sand, sand, silt and organic soil. The levee height is up to 24 feet above the levee toe resulting in high differential water head between the assessment water surface elevation and the levee toe. The segment has reported through seepage described as seepage and boils that occurred on the landside slope. The calculated WHIS is consistent with the past performance data. Segment 1050 is categorized as Hazard Level C for the through seepage potential failure mode.

Erosion

Segment 1050 is categorized as Hazard Level B for erosion. The segment has erosion events documented in the late 1980s and early 1990s, and in 1998. One of the erosion events reported in 1998 was described as eroding the levee crown. LiDAR data also indicate that erosion of the waterside slope may be occurring along about 10 percent of the segment.

Segment 1050: Other Levee Assessments

Freeboard

Freeboard was not assessed because a 1955/1957 water surface elevation was not available.

Overtopping

Overtopping was considered only based on past performance. Evaluation of flood flows, flood elevations, channel capacities and other factors influencing overtopping risk is beyond the scope of the NULE Project. These factors should be studied by others to evaluate overtopping risk to NULE Project levees. Segment 1050 has no reported overtopping.

Geometry

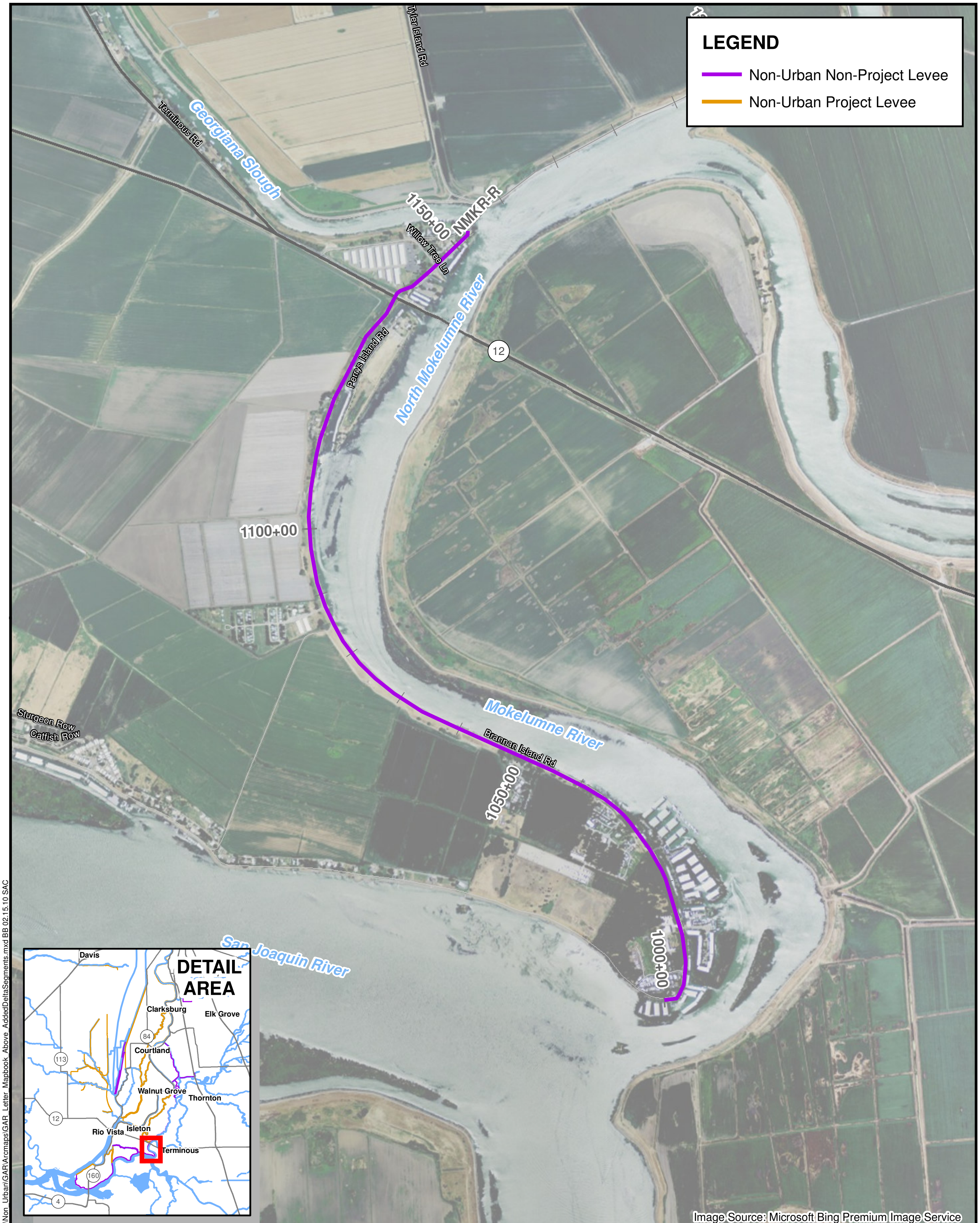
Using LiDAR data, Segment 1050 levee geometry was compared to a standard levee prism as defined by the 1953 MOU. This comparison assessed whether the levee, indicated by topography developed from LiDAR data, was larger than or equal to the standard levee prism at any given cross-section. Wide levees could meet this requirement even where levee slopes are steeper than those described in the 1953 MOU. For Segment 1050, approximately 10 percent of the levee is smaller than the standard levee prism.

Segment 1050: Hazard Mitigation

The following table identifies hazards for the levee segment and the estimated extent of the hazard. Comments are provided to help identify potential remedial requirements.

Segment 1050 Hazards

Hazard	Extent (percent)	Comments
Underseepage	60	Extent is based on portions of segment that have a relatively narrow base width, as indicated by LiDAR data.
Stability	60	The foundation consists mainly of peat and organic soil (organic silt and organic clay); extent is based on areas where the landside slope is steeper than 4H:1V.
Through Seepage	60	Levee is composed of silty sand, sand, silt and organic soil.; extent is based on areas where the landside slope is steeper than 4H:1V.
Erosion	10	Estimated based on areas of oversteepened slopes, as interpreted from LiDAR data.



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0 1,000 2,000
Feet

N

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

Segment 1050
Geotechnical Assessment Report

NORTH NON-URBAN LEVEE EVALUATIONS

Non Urban Levee Evaluation Program (NULE) Levee Assessment Tool, Version 1.2 (revised: 1/7/2010)

Levee Segment Name:	West Bank of Mokelumne River - Brannan Island Levee		
Levee Segment Number:	1050		
Brief Description of Segment/Reach:	West Bank of Mokelumne River - Brannan Island Levee, Unit 3		
Local Maintenance Authority:	BRANNAN-ANDRUS LMD		
Freeboard Evaluation Criterion (ft):	Not Applicable		
Water Side Slope Design Criterion:	3H : 1V	Enter Other Criterion	
Land Side Slope Design Criterion:	2H : 1V	Enter Other Criterion	
North or South NULE?	North		

	Begin	End
NULE Station (ft):	1000+00	1153+05
Levee Mile:	0	2.9
Segment/Reach Length:	2.9 (miles)	15305 (feet)
Crest Width Design Criterion (ft):	20	
Design Guidance Document:	1953 MOU	
Project or Non-Project Levee?	Non-Project	

LEVEE CONSTRUCTION

Describe what is known about construction of this levee segment:

Segment 1050 levee was built initially by the Tide Land Reclamation Company during 1871 and 1872 (Doc-8729). In general, the initial levee was about four feet high, fifteen feet wide at the base and 8 feet wide at the crown. After the flooding of Brannan-Andrus Island in 1877-78, the levee system including Segment 1050 was reconstructed in 1878 by newly organized Reclamation District No. 317. The reconstructed levees were about 9 feet high, twenty-five to forty feet wide at the base with a crown width of three to five feet. For the most part, the levee material for reconstruction was imported from outside the island.

Analysts should populate all yellow cells, and not populate grey cells; green cells store calculated values. Use the suite of available data in making ratings. See User Guide and tables for further information.

PAST PERFORMANCE

	Value (where applicable)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments (include event date and flood elevation, if available)
Underseepage		*Some boils*	*Heavy seepage*	*Multiple, recurring sand boils*	Boils reported 2010 (Doc 8709)
Landside slope stability		*Severe*	*Some*	*Severe*	Subsidence in crown, cracks along the levee, slips and bulging (Doc 5501, Doc 5508, Doc 5452)
Through seepage		*Piping*	*Free seepage*	*Piping*	Seepage and Boil on the landside slope reported in 2004 (Doc 8716); Seepage on the landside slope reported in 2005 (Doc 8716)

In addition to Ayres 2008/DWR 2009 studies, are there erosion occurrences identified in this study?	Yes	If yes, please describe:	Three reported erosion events: Erosion was observed in the late 1980s and early 1990s between NULE Stations 1050+00 and 1085+00 (Doc-8709); Events reported as "Over 200 feet riprap was slipped, earthen bank exposed and erosion underneath Bermuda grass" and "Wave wash above rip rap eroding crown, 276 feet. Almost a foot or so of dirt gone, eroded" in 1998.				
North NULE	Erosion sites from the Ayres 2008 study	Ayres Methodology 2			Ayres Methodology 4		
		Rating (1 to 72)	Ranking (out of 117)		Rating (1 to 47)	Ranking (out of 117)	
Are there erosion occurrences compiled in the Ayres study?	No	N/A	N/A		N/A	N/A	
	Comments:	N/A			Comments:	N/A	
South NULE	Erosion sites from the DWR 2008 study	DWR Prioritzation 2008					
		Rating (1 to 100)	Ranking (out of 67)				
Are there erosion occurrences compiled in the DWR study?							
	Comments:						

Past overtopping or near overtopping?:	Never overtopped	Comments:	No reported overtopping in the past 20 years.
Past breach in area?	None Identified	Comments:	N/A

HAZARD INDICATORS

I- LEVEE COMPOSITION - *at selected cross section* - Interpreted from Borings, Test Pits, field reconnaissance, NRCS maps, and analyst's interpretation of this assemblage of information

	Value (where applicable)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments
Composition of levee material *for through seepage assessment*		*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	*3 - SM, ML, Moderately dispersive soils; soils are silty sands or sandy silts with higher permeability than category 1 soil; soils are suspected of being moderately dispersive based on SAR or other factors*	*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	Based on availavle boring Data (Doc-8306)
Composition of levee material *for stability assessment*		*4 - CH, MH; moderately dispersive soils; loose sand, sand with silt, or non-plastic silt*	*2 - SM, ML, clean gravels; soils are silty sands or sandy silts*	*4 - CH, MH; moderately dispersive soils; loose sand, sand with silt, or non-plastic silt*	Based on availavle boring Data (Doc-8306)

II- GEOLOGY - *at selected cross section*

	(Scale of mapping)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments
Underseepage susceptibility *for underseepage assessment*	1:24,000	*5 - Very high*	*5 - Very high*	*5 - Very high*	Levee foundation consists of peat, organic soil.
Dispersive soils *for stability assessment*	1:24,000	*1 - Not dispersive*	*1 - Not dispersive*	*1 - Not dispersive*	SAR map shows soils are not likely dispersive.
Piping potential *for underseepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Available boring data and Piping potential map.
Piping potential *for through-seepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Available boring data and Piping potential map.
Soft soils *for stability assessment*	1:24,000	*5 - Present*	*5 - Present*	*5 - Present*	Available boring data.

III- OTHER INDICATORS - *at selected cross section*

Animal persistence/burrows? *for through-seepage assessment*		*2 -Low*	*2 -Low*	*3 - Medium*	Based on Interview, Animal control program exists for the segment.
Is a landside ditch or borrow pit present within 200 ft of toe? *for underseepage assessment*	No ditch	1			0
Is a landside ditch or borrow pit present within 200 ft of toe? *for stability assessment*	No ditch	1			0
Is waterside blanket present? *for underseepage assessment*	No				0
Are there locations where penetrations and historical underseepage are coincident?	No	If yes, please describe:	N/A		
Are there locations where penetrations and historical through seepage are coincident?	No	If yes, please describe:	N/A		
Have encroachments that may potentially affect levee integrity been identified?	No	If yes, please describe:	N/A		
Provide the number of levee penetrations below the evaluation water surface elevation:	3 - >5 to 10	Notes:	Based on the 1989 Survey Field Book (Doc-2667)		
DWR's LMA maintenance rating from Maintenance Deficiency Summary Report:	LMA Not rated by DWR	Notes:	Non-project levee, not rated by DWR		

IV- TOPOGRAPHIC & ELEVATION INFORMATION - *at selected cross section(s)*

	Default cross section (used for Underseepage assessment)		Would you like to evaluate a different cross-section for **Stability**?	No	Would you like to evaluate a different cross-section for **Through Seepage**?	No
	Cross-section Station	1050+00	**Cross-section Station**		**Cross-section Station**	
	Underseepage		**Stability**		**Through Seepage**	
Report elevations in NAVD 88	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]
Levee crest elevation (ft)	11					
Levee toe elevation (landside) (ft)	-10					
Levee crest width (ft)	30	1				
Evaluation water elevation (ft)	9.5					
Levee slope - landside (xH : 1V); **Enter x**	1.9	4				
Levee slope - waterside (xH : 1V); **Enter x**	2					
Freeboard above evaluation flood elevation (ft) (= levee crest elevation - evaluation water elevation)	1.5					
Levee height (ft) (= levee crest elevation - landside toe elevation)	21.0	5				
Levee prism base width (ft)	111.9					
Head (ft) (= evaluation water level - landside toe elevation)	19.5	4				
Head-to-base-width ratio (= head / base width)	0.174	5				
Base-width to head ratio (= base width / head)	6					

V- ANOMALIES

	Anomalies?	Description	Effect on Performance
Underseepage	No	NA	NA
Stability	No	NA	NA
Through Seepage	No	NA	NA
Erosion	No	NA	NA

MITIGATION AND PAST BREACHES

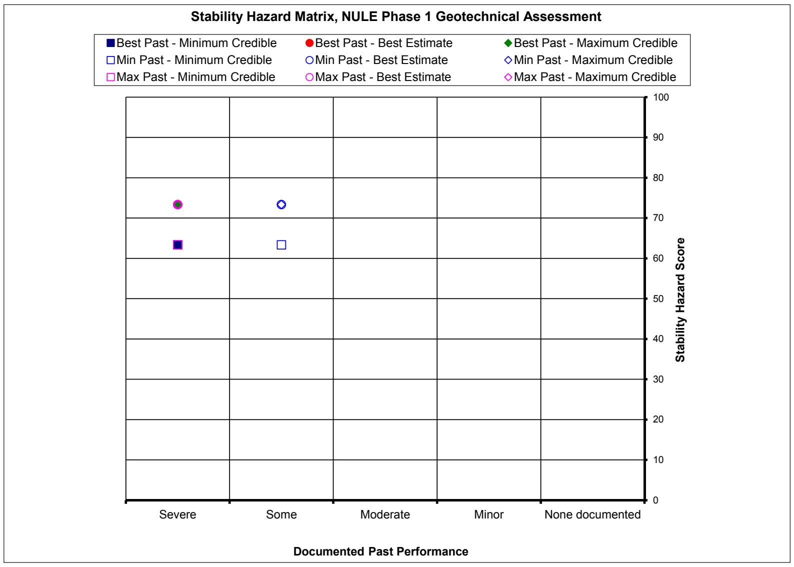
Existing constructed mitigation (List all)	USACE performed an emergency repair by placing a berm and ballast between NULE Stations 1080+00 and 1095+00 in 1997 (Doc-5501, Doc-5508); The levee crown was raised to meet the Hazard mitigation plan in August 1999 between NELE Stations 1075+00 and 1115+00 (Doc-8716); Improvements including levee raise were performed on the levee between NULE Stations 1129+00 to 1136+00 in May 2000 and between NULE Stations 1059+00 and 1079+00 (near Perry's ramp) in May 2000; Riprap was placed between NULE Stations 1050+00 and 1085+00 in 1992 (Doc-8709); Riprap was placed between NULE Stations 1063+00 and 1065+00 in August 2003 to mitigate the problem areas identified from march 2002 survey.
Has there been a past breach?	None Identified
If yes, describe nature of the breach and how it has been mitigated?	

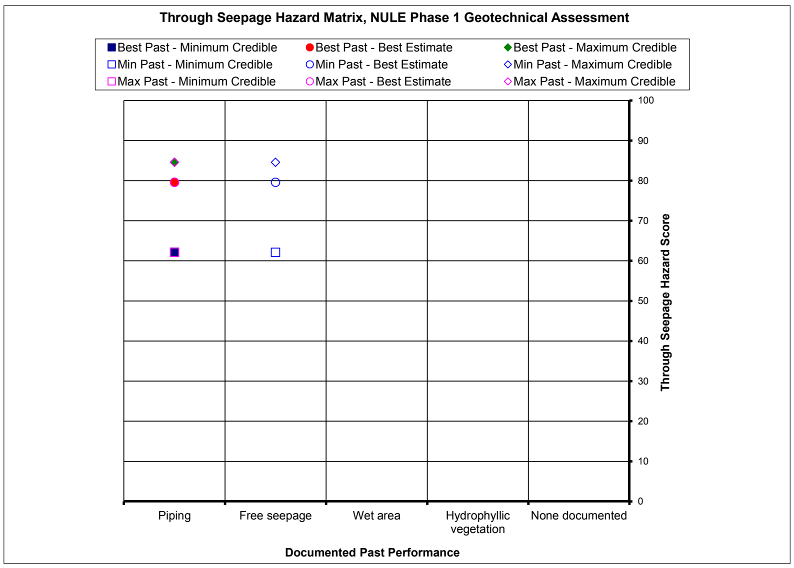
SUMMARY

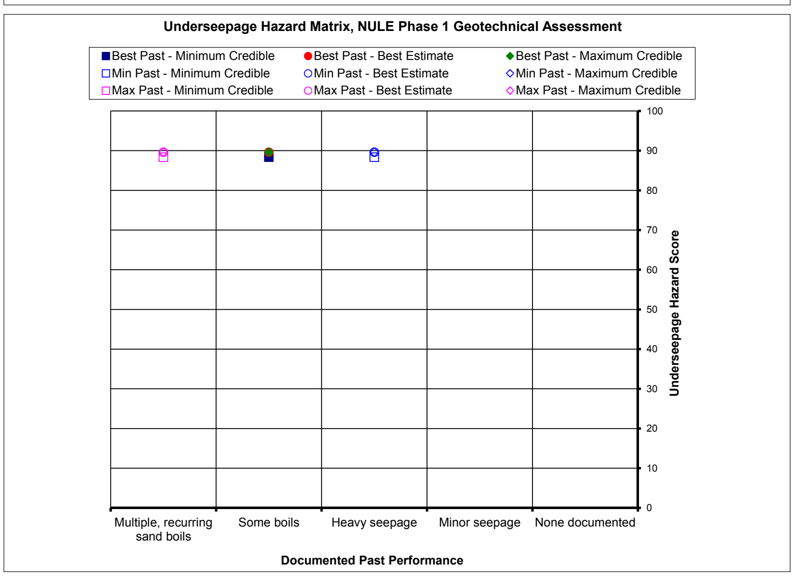
Failure Mode	Weighted Hazard Indicator Score (Best)	Weighted Hazard Indicator Score (Minimum Credible)	Weighted Hazard Indicator Score (Maximum Credible)	Past performance issues?	Are past performance and Weighted Hazard Indicator Score consistent?	Levee categorization
Underseepage	**90**	89	90	Some boils	Yes	***Hazard Level C***
Justification:	The high WHIS is consistent with the documented past performance data.					
Suggested additional data:	N/A					
Stability	**74**	64	74	Severe	Yes	***Hazard Level C***
Justification:	Segment is categorized as Hazard Level C based on the consistency between the WHIS, which suggests that slope instability may occur, and the reported past performance of cracks along the levee.					
Suggested additional data:	N/A					
Through Seepage	**80**	63	85	Piping	Yes	***Hazard Level C***
Justification:	The relatively high WHIS is consistent with the past performance data of documented through seepage on landside slope.					
Suggested additional data:	N/A					
Erosion				Yes		***Hazard Level B***
Justification:	The segment has 3 documented erosion events; one of the event occurred near NULE Station 1049+00 in 1998 was reported as "Wave wash above rip rap eroding crown, 276 feet. Almost a foot or so of dirt gone, eroded" (Doc-5452). Based on LiDAR data, about 10% of the segment has erosion on the waterside slope.					
Suggested additional data:	N/A					

Freeboard Check	Does levee pass freeboard check?	**Not Applicable**		
Provide details about where along segment (and by how much) levee does not pass freeboard check:	N/A			
Are there anomalies along the segment with respect to freeboard?	No	Describe anomalies:	0	
Levee Geometry Check	Does levee pass geometry check?	**No**		
Provide details about where along segment (and by how much) levee does not pass geometry check:	10% of the segment did not pass the geometry check. The locations that did not pass geometry check are near NULE Stations 1005+00 and 1135+00.			
Are there anomalies along the segment with respect to geometry?	No	Describe anomalies:	0	
Summary Characterization of Levee Segment	Hazard Level C	**Comment / Justification:**		

Evaluator:	Kanax	Evaluation Date:	10/18/2010
Checked By:	Sathish	Check Date:	10/18/2010
Senior Reviewer:	KLK, RSA	Review Date:	10/19/2010


Stability Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Stability Hazard Score
Severe
Some
Moderate
Minor
None documented
Documented Past Performance


Through Seepage Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Through Seepage Hazard Score
Piping
Free seepage
Wet area
Hydrophyllic vegetation
None documented
Documented Past Performance


Underseepage Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Underseepage Hazard Score
Multiple, recurring sand boils
Some boils
Heavy seepage
Minor seepage
None documented
Documented Past Performance

BRANNAN-ANDRUS LMD, UNIT 4, SEGMENT 1049 SUMMARY

This segment summary presents collected information and the assessment results for Segment 1049. The summary is based on data available at the time of assessment. The amount of detail available varied. Known pertinent details are included. For information about data collection and assessment procedures, see Volume 1, Section 2.0 of this report.

This summary is organized in seven sections:

- Segment Description and Assessment Summary
- Levee Segment History
- General Levee Conditions
- Levee Composition and Foundation Conditions
- Geotechnical Assessment Results
- Other Levee Assessments
- Hazard Mitigation

Segment 1049: Segment Description and Assessment Summary

Segment 1049 is a non-urban Non-Project levee on the right (north) bank of San Joaquin River in Sacramento County, California. The segment extends from the confluence of the Seven Mile Slough and the San Joaquin River eastward to the confluence of the Mokelumne River and the San Joaquin River. The following table summarizes segment information.

Segment 1049 Information

Maintenance Authority	Unit	Levee Miles	NULE Stationing
Brannan - Andrus LMD	4	0 to 2.62	San Joaquin River Right Bank (SJRR-R) 1936+00 to 2074+35

Since 1955/1957 design water surface elevation is not available, and as directed by DWR, the segment was assessed for each potential failure mode with water at 1.5 feet below the levee crest. The following table presents the Segment 1049 categorizations for each potential failure mode.

Segment 1049 Potential Failure Mode Assessment Summary

Potential Failure Mode	Categorization
Underseepage	Hazard Level B
Stability	Hazard Level B
Through Seepage	LD (A or B)
Erosion	Hazard Level B

Based on these NULE Phase 1 levee assessments, underseepage, stability and erosion are Hazard Level B. Through seepage is categorized as Lacking Sufficient Data. If additional data were obtained, it is very unlikely that the LD for through seepage failure mode would be categorized as Hazard Level C. Because at least one of the segment's other failure modes is already categorized as Hazard Level B, and the LD failure mode would not be categorized as Hazard Level C, the overall categorization for the segment is Hazard Level B.

Segment 1049: Levee Segment History

Levee segment history described below is based on a review of documents in the NULE document database and on interviews with personnel familiar with the levee and its history. The descriptions include construction history, performance, improvements, and planned improvements. The amount and quality of information varies from segment to segment. This segment summary contains pertinent information gathered during data collection. Some details may not be known.

Construction History

Segment 1049 levees were originally built by the Tide Land Reclamation Company between 1871 and 1872 (Doc-8729). In general, the initial levee was about 4 feet high, was 15 feet wide at the base and was 8 feet wide at the crown. These levees settled persistently, and about 1.5 to 2 feet of additional material was placed on top of the levee every year between 1873 and 1878. After flooding of Brannan-Andrus Island in 1877-78, the levee system, including Segment 1049, was rebuilt in 1878 by the newly organized Reclamation District 317. The reconstructed levees were about 5 to 9 feet high and 25 to 40 feet wide at the base, with a crown width of 3 to 5 feet. For the most part, material used for reconstruction was imported from outside the island. Details about these imported materials were not reported in reviewed documents. Data related to levee improvements occurring between 1880 and 1990 were not reported in reviewed documents.

The following table presents the 1953 MOU geometric criteria for Segment 1049.

Segment 1049 Geometric Criteria

Levee Type	Crown Width (feet)	Waterside Slope	Landside Slope
Non-Project Levee	20	3H:1V	2H:1V

Performance

Levee performance information was obtained from reviewed documents and interviews with maintenance personnel. According to the available information, performance events in Segment 1049 include a levee breach, multiple erosion events, underseepage, and slope instability. The segment has no documented through seepage. The following table summarizes reported performance events.

Segment 1049 Reported Levee Performance Events

Flood Season	Reported Performance Event	Approximate Location (NULE SJRR-R Station)	Mitigation
1972	"This failure occurred shortly after midnight on 21 June 1972, with an eventual breach of 500 feet. The levee failed at a high tide stage of about 3.7 feet mean sea level, due to instability rather than overtopping" (Doc-854, Doc-8708, Doc-8716).	Near 1965+00	Mitigation not indicated.
1998	Erosion feature. "Eroding through riprap and underneath the county road into crest" (Doc-5452).	Near 2046+00	Mitigation not indicated.
1998	Riprap sliding down (Doc-5452).	Near 2034+00	Mitigation not indicated.
1998	Wave wash damage to the revetment and waterside levee slope (Doc-5467).	1937+00 – 2069+00	Mitigation not indicated.
2006	Wave overtopping (Doc-8708).	2030+00 - 2080+00	Mitigation not indicated.
2006	Wind induced wave erosion (Doc-8708).	1936+00 – 2074+00	Riprapped.
2010	Boils observed in recurring free seepage area (Doc-8708).	1970+00 – 1980+00	Mitigation not indicated.
2010	Slope instability (Doc-8708)	1970+00 – 1980+00	Mitigation not indicated.

Breach

A series of levee repair and improvement works on Segment 1049 levee were performed by the local levee district between 1968 and 1972. In 1972, the district started rehabilitation of about 1 mile of the levee fronting the San Joaquin River. It was during this rehabilitation work in 1972 that the levee breached (Doc-8708, Doc-8716). The levee breach is documented in the USACE *Sacramento River Flood Control Project Design Memorandum*: "This failure occurred shortly after midnight on 21 June 1972, with an eventual breach of 500 feet. The levee failed at a high tide stage of about 3.7 feet mean sea level, due to instability rather than overtopping" (Doc-854).

Stability

The segment has two documented slope instabilities. The levee break near NULE Station 1965+00 in 1972 that occurred at a high tide stage of about 3.7 feet mean sea level is documented in the USACE Sacramento River Flood Control Project Design Memorandum as "The levee failed due to instability "(Doc-854).

In 2010, district personnel installed inclinometers to monitor the depression near NULE Station 1975+00. The inclinometer readings showed movement only in the vertical direction. The severity of this condition was noted as "mild" during the interview with District Engineer (Doc-8708). Details about the inclinomoters and monitoring results, other than those indicated above, were not available for this assessment.

Underseepage

The segment has one documented boil that occurred between NULE Station 1970+00 and 1980+00. The boil is described as a small-diameter boil that was observed in a recurring seepage area about 100 feet away from the landside toe of the levee during high tide events in 2010 (Doc-8708).

Erosion

The segment has erosion events documented in 1998 and 2006. According to photographs taken during and after 1998 flood event, erosion on the waterside levee slope reached the levee crown. (Doc-5452 and Doc-8708)

Overtopping

Wave-induced overtopping occurred in 2006 between NULE Stations 2030+00 and 2080+00 (Doc-8708).

Improvements

Additional rip-rap was placed along Segment 1049 levees after the 2006 flood event (Doc-8708). The levee crown was raised to meet hazard mitigation plan standards in August 1999 between NULE Stations 1967+00 and 1996 and in August 2005 between NULE Stations 1967+00 and 1974+00 (Doc-8716). In May 2000, improvements including a levee raise and placing riprap were performed along NULE Stations 1922+00 to 1967+00 and 2035+00 to 2072+00 (Doc-8716).

Planned Improvements

According to the documents reviewed, no improvements to Segment 1049 are currently scheduled. However, the RD Engineer (Doc-8707) stated in an interview that the district is considering constructing a cutoff wall to mitigate seepage and stability issues between NULE Stations 1970+00 and 1980+00.

Segment 1049: General Levee Conditions

This section describes levee conditions based on document review, interviews, site reconnaissance, LiDAR survey, and other collected data. Levee conditions include levee geometry, penetrations, and animal activity.

Levee Geometry

Segment 1049 levee heights range from about 17 to 22 feet above the landside toe except between NULE Stations 2055+00 and the eastern end of the segment, where the levee height is about 12 feet. LiDAR survey data indicate the landside slope is about 2H:1V to 4.5H:1V, with a typical slope of 3H:1V. The waterside slope is variable and ranges from 2H:1V to 3H:1V. A ditch is near the landside toe of Segment 1049 from about NULE Stations 1941+75 to 1948+50, 1952+00 to 1956+00 and 2010+00 to 2024+00.

Penetrations

According to the 1989 *Survey Field Book* (Doc-2667), six pipes penetrate the levee segment. Pipe diameters range from 10 to 30 inches.

Animal Activity

Animal activity was not reported in reviewed documents. However, animal activity was noted during an interview. Animal activity control is part of the routine maintenance program. Animal persistence based on data from DWR is not available for Segment 1049.

Maintenance

DWR assessments were not available for Segment 1049.

Other Features

Segment 1049 has several ditches that intersect the levee at an angle. The ditches are near NULE Stations1941+75, 1948+50, 1989+00, 2001+00, 2005+25, 2024+00, 2040+50 and 2060+50.

A trailer park is near NULE Station 1980+00.

Segment 1049: Levee Composition and Foundation Conditions

The NULE team established an understanding of levee and levee foundation geotechnical conditions based on work performed by the geomorphology team, a review of other available geologic and soil maps, data contained in reports, and general knowledge of levee conditions in the area. This section summarizes the team's understanding of geotechnical conditions in Segment 1049.

According to the available geotechnical explorations and geomophic data at Segment 1049, the levee foundations consist of organic soil (peat, organic silt and organic clay), sand and silt, and the levees consist mainly of silt, silty sand, sand and organic silt.

Geomorphic Setting

According to the *Level 2-I Geomorphic Assessment*, Segment 1049 is in the Delta geomorphic domain (D).

Soil deposits in the Delta geomorphic domain (D) are primarily late Holocene tidal wetland and supratidal flood plain deposits that consist of varying amounts of interbedded peat, organic mud, clay, silt, and sand. Flood plain and overbank deposits are adjacent to the channels and sloughs. These channel and flood deposits are generally coarser and less organic, whereas the central parts of islands in the Delta (where elevations are typically at or below sea level) are generally covered by peat and organic mud formed by decaying wetland vegetation. The percentage and thickness of organic deposits is generally greatest in the central portion of the Delta, but there are local variations, including some areas where pre-Holocene eolian sand dunes formed paleotopographic highs and where peat and soft mud are not present and likely were never deposited.

The present-day artificial levees are constructed on the banks of the channels and sloughs. Most of these levees rest on natural levee deposits. According to available geomorphic mapping, the levee is underlain by peat and mud.

Geotechnical Investigations

Geotechnical investigation for Segment 1049 included 16 borings for the DWR Salinity Control Barrier Study (Doc-8306) and five borings for an unknown project (Doc-8306); Eighteen of these borings were drilled through the crest of the levee and three of these borings were drilled near the toe. These borings range in depth from 20 to 170 feet. According to these boring data, the soil in the levee prism consists mainly of silt, silty sand, sand and organic silt, and the foundation consists of organic soil (peat, organic silt and organic clay), sand and silt. The organic soil found in the foundation ranges from 2 to 40 feet in thickness(Doc-8306).

Other Subsurface Information

The USCS soil map available for portions of Segment 1049 indicates the levee mostly overlies fine-grained materials (OH, CL, CL-ML) with the exception of about 3,200 feet of levee that overlies silty clayey sand (SC-SM) between NULE Stations 1993+00 and 2025+00. The NRCS USCS map does not indicate the variation of soil types found in borings.

Levee Composition

According to the borings described above, the levees consist mainly of silt, silty sand, sand and organic silt.

Segment 1049: Geotechnical Assessment Results

The overall Segment 1049 categorization is Hazard Level B. As discussed in Volume 1, Section 2.0 of this report, the overall assessment is based on the individual potential failure mode categorizations. For this segment, underseepage, stability and erosion are Hazard Level B. Through seepage is categorized as Lacking Sufficient Data. If additional data were obtained, it is very unlikely that the LD for through seepage failure mode would be categorized as Hazard Level C. Because at least one of the segment's other failure modes is already categorized as Hazard Level B, and the LD failure mode would not be categorized as Hazard Level C, the overall categorization for the segment is Hazard Level B.

A WHIS was calculated for each potential failure mode at the assessment water surface elevation: the top of levee less 1.5 feet, based on identified geologic, geometric, and other hazards. A rating for past performance was assigned based on documented performance events. The categorizations for each potential failure mode are discussed below.

Underseepage

Segment 1049 Underseepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
79	78	79	Some Boils	Heavy Seepage	Multiple, Recurring Sand Boils	Hazard Level B

The levees in Segment 1049 are 17 to 22 feet high, resulting in high differential water head. The levee foundation consists of thick peat and organic soils that have a very high underseepage susceptibility. This segment also has reported past underseepage. The WHIS is consistent with available past performance data. Segment 1049 is categorized as Hazard Level B based on the consistency between the WHIS, which suggests underseepage may occur, and the reported past performance of boils in the reach.

Stability

Segment 1049 Stability Assessment Results*

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
69	59	74	Some	Moderate	Some	Hazard Level B*

* Stability is assessed independently of through seepage and underseepage. Seepage might cause instability not accounted for in the stability assessment.

The Segment 1049 levee prism consists mainly of silt, silty sand, sand and organic silt, and the prism sits on weak organic peat soil. The levee height is up to 22 feet above the levee toe. The reach has experienced slope instability. Segment 1049 is categorized as Hazard Level B based on the consistency between the WHIS, which suggests that slope instability may occur, and the reported past slope instability.

Through Seepage

Segment 1049 Through Seepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
73	55	78	None Documented	None Documented	None Documented	LD (A or B)

The WHIS reflects a levee composition of loose sandy soils and relatively high differential water head between the assessment water surface elevation and the levee toe. The segment has no reported past performance through seepage data. Given the inconsistency between the WHIS, which suggests that through seepage is likely to occur, and the absence of past performance data, Segment 1049 is categorized as Lacking Sufficient Data for the through seepage failure mode. Given the hazard indicators, and if additional data were obtained to resolve the LD, it is very unlikely that the additional data would result in re-categorization to Hazard Level C.

Erosion

Segment 1049 is categorized as Hazard Level B for erosion. The segment has erosion events documented in 1998 and 2006. According to the photographs taken after 1998 flood event, erosion on waterside levee slope reached the levee crown. Rip-rap was placed along the levees after the 2006 flood event (Doc-8708). LiDAR data also indicate that erosion of the waterside slope may be occurring along about 10 percent of the segment. However, the waterside slope rip-rapped following the 2006 flood event has not yet experienced a major flood event.

Segment 1049: Other Levee Assessments

Freeboard

Freeboard was not assessed because a 1955/1957 water surface elevation was not available.

Overtopping

Overtopping was considered only based on past performance. Evaluation of flood flows, flood elevations, channel capacities and other factors influencing overtopping risk is beyond the scope of the NULE Project. These factors should be studied by others to evaluate overtopping risk to NULE Project levees. Documents indicate this levee segment experienced wave overtopping once in 2006.

Geometry

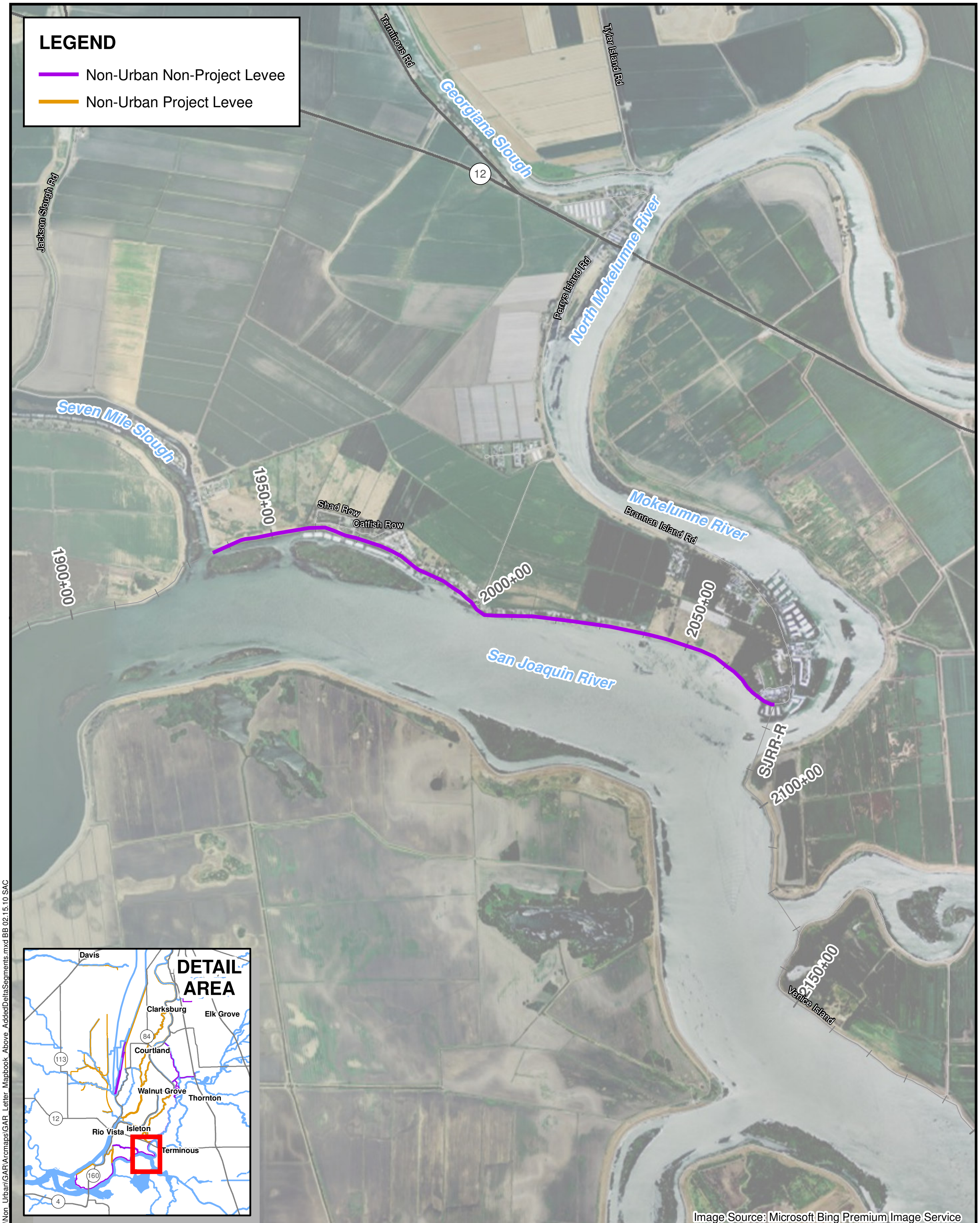
Using LiDAR data, Segment 1049 levee geometry was compared to a standard levee prism as defined by the 1953 MOU. This comparison assessed whether the levee, indicated by topography developed from LiDAR data, was larger than or equal to the standard levee prism at any given cross-section. Wide levees could meet this requirement even where levee slopes are steeper than those described in the 1953 MOU. For Segment 1049, approximately 15 percent of the levee is smaller than the standard levee prism.

Segment 1049: Hazard Mitigation

The following table identifies hazards for the levee segment and the estimated extent of the hazard. Comments are provided to help identify potential remedial requirements.

Segment 1049 Hazards

Hazard	Extent (percent)	Comments
Underseepage	100	Peat and organic foundation underlain by sand aquifer; The thickness of peat and organic soil is about 40 feet below the toe.
Stability	100	The foundation consists mainly of peat and organic soil.
Through Seepage	30	Extent is based on available boring data that shows sandy levee.
Erosion	10	Estimated based on areas of oversteepened slopes, as interpreted from LiDAR data.



L:\Projects\DWR\GEOTECHNICAL\Non_Urban\GAR\Arcmaps\GAR_Letter_Mapbook_Above_AddedDeltaSegments.mxd BB 02.15.10 SAC

0 1,500 3,000
Feet

N

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

Segment 1049

Geotechnical Assessment Report

NORTH NON-URBAN LEVEE EVALUATIONS

1049-LAT.indd RKC SAC 2011-03-25, 9:26 PM

Non Urban Levee Evaluation Program (NULE) Levee Assessment Tool, Version 1.2 (revised: 1/7/2010)

			Begin	**End**
Levee Segment Name:	North Bank of San Joaquin River - Brannan Island Levee	NULE Station (ft):	1936+00	2074+35
Levee Segment Number:	1049	Levee Mile:	Enter	Enter
Brief Description of Segment/Reach:	North Bank of San Joaquin River - Brannan Island Levee, Unit 4	Segment/Reach Length:	2.6 (miles)	13835 (feet)
		Crest Width Design Criterion (ft):	20	
Local Maintenance Authority:	BRANNAN-ANDRUS LMD	Design Guidance Document:	1953 MOU	
Freeboard Evaluation Criterion (ft):	Not Applicable			
Water Side Slope Design Criterion:	3H : 1V (Enter Other Criterion)	Project or Non-Project Levee?	Non-Project	
Land Side Slope Design Criterion:	2H : 1V (Enter Other Criterion)			
North or South NULE?	North			

LEVEE CONSTRUCTION

Describe what is known about construction of this levee segment: Levees in this segment were initially built in 1871 and 1872 (Doc-8729). In Segment 1049, persistent settling required additions of one-and-a-half or two feet to the levee's top every year between 1873 and 1878. The levees were restored in 1878, after the inundation of Brannan-Andrus Island in 1877-78, by newly organized Reclamation District No. 317. These levees ranged in height from five to nine feet. The levee prism was twenty-five to thirty and thirty to forty feet wide at ground level, with crowns three to five feet wide. For the most part, the material for levee construction was brought from outside of the Brannan-Andrus system of levees.

Analysts should populate all yellow cells, and not populate grey cells; green cells store calculated values. Use the suite of available data in making ratings. See User Guide and tables for further information.

PAST PERFORMANCE

	Value (where applicable)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments (include event date and flood elevation, if available)
Underseepage		*Some boils*	*Heavy seepage*	*Multiple, recurring sand boils*	Small boils documented in 2010 (Doc-8708)
Landside slope stability		*Some*	*Moderate*	*Some*	Slope instability documented in 2010 (Doc-8708)
Through seepage		*None documented*	*None documented*	*None documented*	No reported past performance data

In addition to Ayres 2008/DWR 2009 studies, are there erosion occurrences identified in this study?	Yes	**If yes, please describe:**	Erosion features were documented in 1998 and 2006. Based on the photos taken after 1998 flood event, the erosion on waterside levee slope reached the levee crown.

North NULE	**Erosion sites from the Ayres 2008 study**	**Ayres Methodology 2**			**Ayres Methodology 4**		
		Rating (1 to 72)	**Ranking (out of 117)**		**Rating (1 to 47)**	**Ranking (out of 117)**	
Are there erosion occurrences compiled in the Ayres study?	No	N/A	N/A		N/A	N/A	
	Comments:	N/A			**Comments:**	N/A	
South NULE	**Erosion sites from the DWR 2008 study**	**DWR Prioritization 2008**					
		Rating (1 to 100)	**Ranking (out of 67)**				
Are there erosion occurrences compiled in the DWR study?							
	Comments:						

Past overtopping or near overtopping?:	Overtopped	**Comments:**	Wave overtopping documented in 2006 (Doc 8708)
Past breach in area?	Yes	**Comments:**	In 1972, the Levee District started rehabilitation of about one mile of the levee fronting the San Joaquin river. The levee breach reported in 1972 occurred during this rehabilitation work (Doc 8708, Doc-8716).

HAZARD INDICATORS

I- LEVEE COMPOSITION - *at selected cross section* - Interpreted from Borings, Test Pits, field reconnaissance, NRCS maps, and analyst's interpretation of this assemblage of information

	Value (where applicable)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments
Composition of levee material *for through seepage assessment*		*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	*3 - SM, ML, Moderately dispersive soils; soils are silty sands or sandy silts with higher permeability than category 1 soil; soils are suspected of being moderately dispersive based on SAR or other factors*	*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	Based on available boring Data (Doc-8306)
Composition of levee material *for stability assessment*		*4 - CH, MH; moderately dispersive soils; loose sand, sand with silt, or non-plastic silt*	*2 - SM, ML, clean gravels; soils are silty sands or sandy silts*	*5 - OL, OH, Peat, dispersive soil*	Based on available boring Data (Doc-8306)

II- GEOLOGY - *at selected cross section*

	(Scale of mapping)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments
Underseepage susceptibility *for underseepage assessment*	1:24,000	*5 - Very high*	*5 - Very high*	*5 - Very high*	Levee foundation consists of peat
Dispersive soils *for stability assessment*	1:24,000	*1 - Not dispersive*	*1 - Not dispersive*	*1 - Not dispersive*	SAR map shows soils are not likely dispersive
Piping potential *for underseepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Available boring data and Piping potential map
Piping potential *for through-seepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Available boring data and Piping potential map
Soft soils *for stability assessment*	1:24,000	*5 - Present*	*5 - Present*	*5 - Present*	Available boring data.

III- OTHER INDICATORS - *at selected cross section*

Animal persistence/burrows? *for through-seepage assessment*		*2 -Low*	*2 -Low*	*3 - Medium*	Based on Interview, Animal control program exists for the segment.
Is a landside ditch or borrow pit present within 200 ft of toe? *for underseepage assessment*	No ditch	1			0
Is a landside ditch or borrow pit present within 200 ft of toe? *for stability assessment*	No ditch	1			0
Is waterside blanket present? *for underseepage assessment*	No				0
Are there locations where penetrations and historical underseepage are coincident?	No	**If yes, please describe:**	N/A		
Are there locations where penetrations and historical through seepage are coincident?	No	**If yes, please describe:**	N/A		
Have encroachments that may potentially affect levee integrity been identified?	No	**If yes, please describe:**	N/A		
Provide the number of levee penetrations below the evaluation water surface elevation:	3 - >5 to 10	**Notes:**	Based on the 1989 Survey Field Book (Doc-2667)		
DWR's LMA maintenance rating from Maintenance Deficiency Summary Report:	LMA Not rated by DWR	**Notes:**	Non-project levee, not rated by DWR		

IV- TOPOGRAPHIC & ELEVATION INFORMATION *- at selected cross section(s)*

Report elevations in NAVD 88	Underseepage Value (where applicable)	Underseepage Rating [1 (good) to 5 (bad)]	Stability Value (where applicable)	Stability Rating [1 (good) to 5 (bad)]	Through Seepage Value (where applicable)	Through Seepage Rating [1 (good) to 5 (bad)]
	Default cross section (used for Underseepage assessment)		Would you like to evaluate a different cross-section for **Stability**?	No	Would you like to evaluate a different cross-section for **Through Seepage**?	No
	Cross-section Station	1990+00	Cross-section Station		Cross-section Station	
Levee crest elevation (ft)	11					
Levee toe elevation (landside) (ft)	-10					
Levee crest width (ft)	25	1				
Evaluation water elevation (ft)	9.5					
Levee slope - landside (xH : 1V); **Enter x**	2.2	3				
Levee slope - waterside (xH : 1V); **Enter x**	2.3					
Freeboard above evaluation flood elevation (ft) (= levee crest elevation - evaluation water elevation)	1.5					
Levee height (ft) (= levee crest elevation - landside toe elevation)	21.0	5				
Levee prism base width (ft)	119.5					
Head (ft) (= evaluation water level - landside toe elevation)	19.5	4				
Head-to-base-width ratio (= head / base width)	0.163	4				
Base-width to head ratio (= base width / head)	6					

V- ANOMALIES

	Anomalies?	Description	Effect on Performance
Underseepage	No	NA	NA
Stability	No	NA	NA
Through Seepage	No	NA	NA
Erosion	No	NA	NA

MITIGATION AND PAST BREACHES

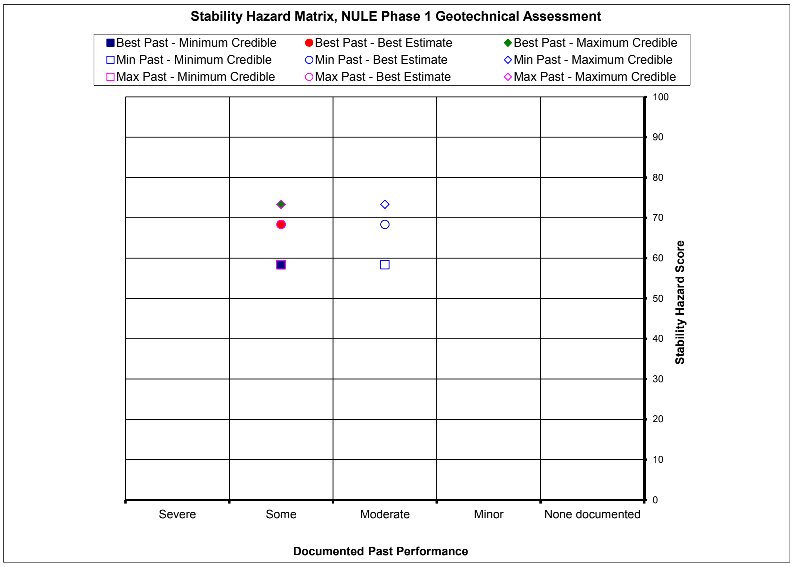
Existing constructed mitigation (List all)	Riprap was placed along the Segment 1049 levees after the 2006 flood event (Doc-8708). Levee crown was raised to meet Hazard mitigation plan in August 1999 between NULE Stations 1967+00 and 1996 and in August 2005 between NULE stations 1967+00 and 1974+00 (Doc-8716). Improvements including levee raise were performed on the levee along NULE stations 1922+00 to 1967+00 and 2035+00 to 2072+00 in May 2000.
Has there been a past breach?	Yes
If yes, describe nature of the breach and how it has been mitigated?	The levee breach reported in 1972 occurred during this rehabilitation work (Doc 8708, Doc-8716). Reviewed documents have no detailed information about the nature of the breach.

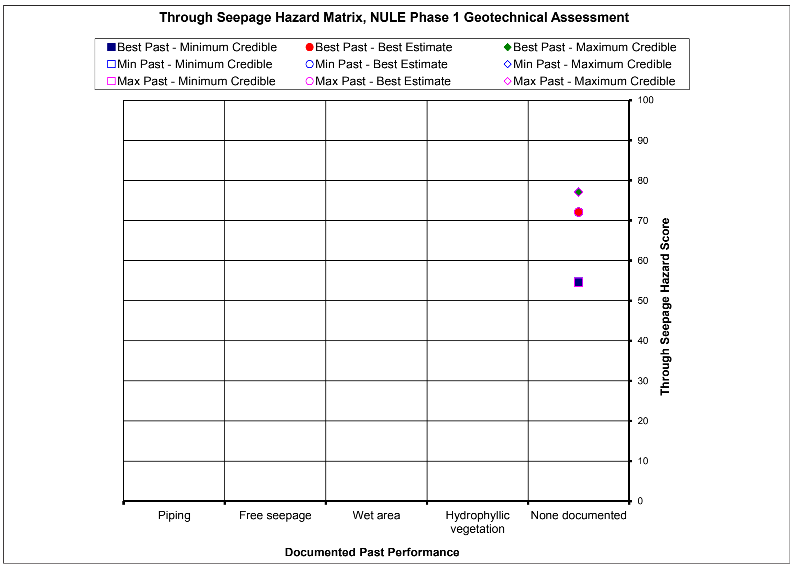
SUMMARY

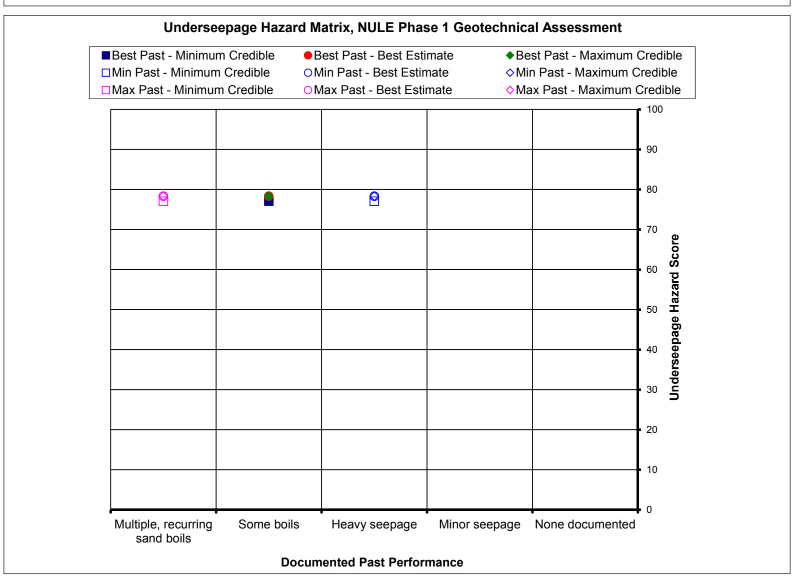
Failure Mode	Weighted Hazard Indicator Score (Best)	Weighted Hazard Indicator Score (Minimum Credible)	Weighted Hazard Indicator Score (Maximum Credible)	Past performance issues?	Are past performance and Weighted Hazard Indicator Score consistent?	Levee categorization
Underseepage	**79**	78	79	Some boils	Yes	***Hazard Level B***
Justification:	The high WHIS is consistent with the documented past performance data.					
Suggested additional data:	N/A					
Stability	**69**	59	74	Some	Yes	***Hazard Level B***
Justification:	Segment is categorized as Hazard Level B based on the consistency between the WHIS, which suggests that slope instability may occur, and the reported past performance of slope instability.					
Suggested additional data:	N/A					
Through Seepage	**73**	55	78	None documented	No	***Hazard Level LD***
Justification:	The relatively high WHIS is inconsistent with the past performance data of no documented through seepage events. Given the hazard indicators, and if additional data were obtained to resolve the LD, it is very unlikely the additional data would result in a re-categorization to Hazard Level C.					
Suggested additional data:	Perform geotechnical investigation involving lab testing.					
Erosion				Yes		***Hazard Level B***
Justification:	The segment has erosion features documented in 1998 and 2006. Based on the photos taken after 1998 flood event, the erosion on waterside levee slope reached the levee crown. Riprap was placed along the entire Segment 1049 levees after the 2006 flood event (Doc-8708), but not experienced any mayor food event.					
Suggested additional data:	N/A					

Freeboard Check	Does levee pass freeboard check?	**Not Applicable**	
Provide details about where along segment (and by how much) levee does not pass freeboard check:	N/A		
Are there anomalies along the segment with respect to freeboard?	No	Describe anomalies:	0
Levee Geometry Check	Does levee pass geometry check?	**No**	
Provide details about where along segment (and by how much) levee does not pass geometry check:	15% did not pass the geometry check. The locations that did not pass geometry check are near NULE stations 1045+00, 1055+00, 2045+00, and 2065+00		
Are there anomalies along the segment with respect to geometry?	No	Describe anomalies:	0
Summary Characterization of Levee Segment	Hazard Level B	**Comment / Justification:**	For this segment, the potential failure mode categorizations for underseepage, stability and erosion are Hazard Level B. The categorizations for through-seepage is Lacking Sufficient Data (A or B). However, based on available information and calculated WHIS for through-seepage, the segment is very likely to end up as Hazard Level B. This results in an overall categorization of Hazard Level B. If additional data were obtained, it is very unlikely that the LD for through-seepage would be categorized as Hazard Level C. Because at least one of the segment's other failure modes is already categorized as Hazard Level B, and the LD failure modes would not be categorized as Hazard Level C, the overall categorization for the segment is Hazard Level B.

Evaluator:	Kanax	Evaluation Date:	10/13/2010
Checked By:	Sathish	Check Date:	10/13/2010
Senior Reviewer:	KLK, RSA	Review Date:	10/20/2010


Stability Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Stability Hazard Score
Severe
Some
Moderate
Minor
None documented
Documented Past Performance


Through Seepage Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Through Seepage Hazard Score
Piping
Free seepage
Wet area
Hydrophyllic vegetation
None documented
Documented Past Performance


Underseepage Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Underseepage Hazard Score
Multiple, recurring sand boils
Some boils
Heavy seepage
Minor seepage
None documented
Documented Past Performance

BRANNAN-ANDRUS LMD, UNIT 5, SEGMENT 1048 SUMMARY

This segment summary presents collected information and the assessment results for Segment 1048. The summary is based on readily-available data at the time of assessment of this segment. The amount of detail available is variable. Known pertinent details are included. For information on the data collection and assessment procedures are presented in Volume 1, Section 2.0 of this report. This summary is organized in seven sections:

- Segment Description and Assessment Summary
- Levee Segment History
- General Levee Conditions
- Levee Composition and Foundation Conditions
- Geotechnical Assessment Results
- Other Levee Assessments
- Hazard Mitigation

Segment 1048: Segment Description and Assessment Summary

Segment 1048 is a non-urban Non-Project levee on the left (north) bank of Seven Mile Slough in Sacramento County, California. The segment extends from the confluence of the Three Mile Slough and Seven Mile Slough eastward to the confluence of Seven Mile Slough and the San Joaquin River. The following table summarizes segment information.

Segment 1048 Information

Maintenance Authority	Unit	Levee Miles	NULE Stationing
Brannan-Andrus LMD	5	0 to 4.57	Seven Mile Slough Left Bank (SVMS-L) 1022+55 to 1263+80

Since 1955/1957 design water surface elevation is not available, as directed by DWR, the segment was assessed for each potential failure mode with water at an elevation 1.5 feet below the levee crest. The following table presents the Segment 1048 categorizations for each potential failure mode.

Segment 1048 Potential Failure Mode Assessment Summary

Potential Failure Mode	Categorization
Underseepage	Hazard Level C
Stability	Hazard Level B
Through Seepage	Hazard Level B
Erosion	Hazard Level A

Based on these NULE Phase 1 levee assessments, the overall categorization for Segment 1048 is Hazard Level C.

Segment 1048: Levee Segment History

Levee segment history described below is based on a review of documents in the NULE document database and interviews with personnel familiar with the levee and its history. The descriptions include construction history, performance, improvements, and planned improvements. The amount and quality of information varies from segment to segment. This segment summary contains pertinent information gathered during data collection. Some details may not be known.

Construction History

The Segment 1048 levee was built initially by the Tide Land Reclamation Company during 1871 and 1872 (Doc-8729). In general, the initial levee was about 4 feet high, 15 feet wide at the base and 8 feet wide at the crown. After the flooding of Brannan-Andrus Island in 1877-78, the levee system, including Segment 1048, was rebuilt by the newly organized Reclamation District 317. The reconstructed levees were about 9 feet high, and 25 to 40 feet wide at the base, with a crown width of 3 to 5 feet. For the most part, the building material used for reconstruction was imported from outside the island. Details about the imported materials were not reported in reviewed documents.

Water in the Seven Mile Slough between NULE Stations 1022+55 and 1191+50 is controlled by a gated dam with two 48-inch-diameter pipes with gate valves on the east near the Owl Harbor and by a pump station on the west. The construction date and details of these control structures were not found in reviewed documents. However, the RD engineer noted during the field reconnaissance interview that these control structures were built around 1950. Data related to improvements to the levee segment that may have occurred between 1880 and 1990 were not reported in the reviewed documents.

The following table presents the 1953 MOU geometric criteria for Segment 1048.

Segment 1048 Geometric Criteria

Levee Type	Crown Width (feet)	Waterside Slope	Landside Slope
Non-Project Levee	20	3H:1V	2H:1V

Performance

Levee performance information was obtained from reviewed documents and interviews with maintenance personnel. According to the available information, performance events in Segment 1048 include underseepage, through seepage, slope instability and erosion. The following table summarizes reported performance events.

Segment 1048 Reported Levee Performance Events

Flood Season	Reported Performance Event	Approximate Location (NULE SVMS-L Station)	Mitigation
1993-1995	Crack and settlement (Doc-8707).	1074+00 – 1084+00	Stability berm was constructed between 1993 and 1995 (Doc-8707).
1998	Levee subsidence with cracks (Doc-5452, Doc-5466). Through seepage (Outreach Meeting Summary).	1087+00 – 1105+00	Stability berm was constructed by USACE as part of an emergency repair after 1998 flood. (Doc-5452, 5466). Repairs also made for through seepage (Outreach Meeting Summary).
1998	Erosion - slipping riprap and pocketing (Doc-5452).	Near 1260+00	Mitigation not documented.
2007	Subsidence (Doc-8707)	1137+00 – 1145+00	Levee crown raised in June 2007 (Doc-8716)
2010	Boils and wet-spots were observed near the landside toe after soil near the landside toe was removed for farming (Doc-8707).	Near 1073+00	RD engineer noted that this incident is “Not considered to be a threat.” Similar incidents occurred at multiple locations in the past, because the phreatic line is near surface. (Doc-8707).

Underseepage

Segment 1048 has one recently-documented underseepage event. Boils and wet spots were observed 100 feet away from the landside toe at five closely spaced locations in 2010. These occurred after removal of soil from the landside toe for farming activity, and was “not considered to be a threat” by the RD (Doc-8707).

Through Seepage

Segment 1048 had two or three instances of through seepage. One of these was repaired as part of a landside stabilization berm constructed by USACE in 1998 (Outreach Meeting Summary).

Stability

Cracking and settlement of the levee between NULE Stations 1074+00 and 1084+00 occurred in early 1990s. A stability berm was constructed by the RD between 1993 and 1995. This incident was noted during the interview with the RD engineer (Doc-8707).

Levee subsidence between NULE Stations 1087+00 and 1105+00 occurred in 1998. This incident was documented in a levee incident report as “Subsidence with cracks to the levee crown on Seven Mile Slough approx 1.45 miles upstream of three mile plug. The cracks are 300 feet long and run parallel to the crown. The levee subsided about four inches” (Doc-5466). A stability berm on the landside was constructed by USACE as part of an emergency repair (Doc-8716).

Erosion

Segment 1048 has one reported erosion event near NULE Station 1260+00. This incident was documented in the1998 *Flood Damage Assessment Inspection Report* (Doc-5452) as "Deadman's Curve guardrail to about 5.523, slipping riprap and pocketing."

Improvements

A landside stability berm was constructed between 1993 and 1995 by the RD to mitigate cracking and settlement observed between Stations 1074+00 and 1084+00.

A landside stabilization berm was constructed between NULE Stations 1149+00 and 1165+00 by USACE as part of the Slip Site Emergency Repair Project in 1998 (Doc-8701).

In August 2003 between NULE Stations 1198+00 and 1217+00, the levee crown was raised to meet the Hazard Mitigation Plan, The crown was raised again in August 2005 between NULE Stations 1217+00 and 1241+00. In September 2006, the crown was raised between NULE Stations 1136+00 and 1164+00 and between NULE Stations 1215+00 and 1245+00 (Doc-8716). In June 2007, the levee crown was raised between NULE Stations 1137+00 and 1145+00 (Doc-8716).

Planned Improvements

According to available documents, no improvements to Segment 1048 are currently planned.

Segment 1048: General Levee Conditions

This section describes levee conditions based on document review, interviews, site reconnaissance, LiDAR survey, and other collected data. Levee conditions include levee geometry, penetrations, and animal activity.

Levee Geometry

Segment 1048 levee heights range from about 20 to 28 feet above the landside toe. Crest width is approximately 15 to 25 feet and LiDAR survey data indicate the landside slopes are about 2.5H:1V to 5H:1V with a typical slope of 3H:1V. The waterside slopes are approximately 1.5H:1V to 3.0H:1V. A ditch is along the landside toe of Segment 1048 from about NULE Station 1026+50 to 1040+00, 1048+50 to 1054+50, 1086+00 to 1093+00, 1104+00 to 1124+00, 1132+00 to 1137+00, 1146+00 to 1154+25 and 1155+00 to 1238+00.

Penetrations

Based on the 1989 *Survey Field Book* (Doc-2667), 23 pipes penetrate the levee segment. The pipe diameters range from 10 to 30 inches. The pipes are approximately 0 to 6 feet below the levee crown. Gas pipelines penetrate through the levee at an unknown depth near NULE Station 1154+00.

Animal Activity

Animal activity was not reported in reviewed documents. However, animal activity was noted during an interview. Animal activity control has been included as part of the segment's routine maintenance program. Animal persistence based on data from DWR is not available for Segment 1048.

Maintenance

DWR assessments were not available for Segment 1048.

Other Features

Segment 1048 has several ditches that are at an angle to the levee. The ditches are near NULE Stations 1039+00, 1054+50, 4082+50, 1104+00, 1155+00, 1162+50, 1169+00, 1176+00, 1196+00, 1197+50, 1204+00, 1243+00, 1249+50 and 1259+00.

Near NULE Station 1191+50 there is a gated dam with two 48-inch-diamater pipes and gate valves on the east side near Owl Harbor and a pump station on the west side of the gated dam.

Segment 1048: Levee Composition and Foundation Conditions

The NULE team established an understanding of levee and levee foundation geotechnical conditions based on work performed by the geomorphology team, review of other available geologic and soil maps, data contained in reports reviewed, and general knowledge of levee conditions in the area. This section summarizes the team's understanding of geotechnical conditions in Segment 1048.

In Segment 1048, the levee foundations consist of organic soil (peat, OH, OL), sand and silt and the levees consist of mainly silt and sand.

Geomorphic Setting

According to the *Level 2-I Geomorphic Assessment*, Segment 1048 is in Delta geomorphic domain (D). Soil deposits in the Delta geomorphic domain (D) are primarily late Holocene tidal wetland and supratidal flood plain deposits that consist of varying amounts of interbedded peat, organic mud, clay, silt, and sand. The flood plain or overbank deposits are adjacent to the channels and sloughs. These channel and flood deposits are generally coarser and less organic, whereas the central parts of islands in the Delta (where elevations are typically at or below sea level) are generally covered by peat and organic mud formed by decaying wetland vegetation. The percentage and thickness of organic deposits is generally greatest in the central portion of the Delta, but there are local variations, including some areas where pre-Holocene eolian sand dunes formed paleotopographic highs and where peat and soft mud are not present and likely were never deposited.

Recent geomorphology level 2-II mapping is only available between NULE Stations 1022+55 and 1092+00 and is generally consistent with level 2-I mapping along Segment 1048. However, level 2-II mapping shows more detail, including artificial fill along the levee alignment. Level 2-II also mapping indicates Segment 1048 foundation soils are primarily Holocene peat and mud deposited in tidal flats and wetlands, with a few historical distributary channel and crevasse splay deposits (sand, silt, and clay).

Geotechnical Investigations

Geotechnical investigations for Segment 1048 include four borings performed in 1977 (Doc-8306). These borings range in depth from about 40 to 75 feet and were drilled through the levee crest. According to these boring data, the soil in the levee prism consists mainly of silt and sand, and the foundation consists of organic soil (peat, OH, OL), sand and silt. The thickness of organic soil found in the foundation ranges from about 15 to 20 feet.

Other Subsurface Information

The USCS soil map is available between NULE Stations 1022+55 and 1147+50 and indicates the existing levee may overlie finer-grained surface soils (CL-ML, OH, ML). The soil types indicated in the USCS soil map are consistent with soil types indicated in the level 2-I mapping and with soils found in the borings.

Levee Composition

The available boring data indicate that the levee in Segment 1048 predominantly consists of silt and sand.

Segment 1048: Geotechnical Assessment Results

The overall Segment 1048 categorization is Hazard Level C. As discussed in Volume 1, Section 2.0 of this report, the overall assessment is based on the individual potential failure mode categorizations. For this segment, the potential failure mode categorization for underseepage is Hazard Level C, and the categorization for both through seepage and stability were all Hazard Level B. The categorization for Erosion is Hazard Level A. This results in an overall categorization of Hazard Level C.

A WHIS was calculated for each potential failure mode at the assessment water surface elevation: the top of levee less 1.5 feet, based on identified geologic, geometric, and other hazards. A rating for past performance was assigned based on documented performance events. The categorizations for each potential failure mode are discussed below.

Underseepage

Segment 1048 Underseepage Assessment Results

WHIS			**Performance Summary**			**Categorization**
Best Estimate	**Minimum Credible**	**Maximum Credible**	**Best Estimate**	**Minimum Credible**	**Maximum Credible**	
98	96	98	Some Boils	Some Boils	Multiple, recurring sand boils	Hazard Level C

The levee foundation consists predominantly of organic soil (peat, OH, OL) that has very high underseepage susceptibility. The levee section is relatively narrow for the differential head between the assessment water surface elevation and the levee toe. The WHIS is consistent with past performance data of documented boils and wet spots in the segment. Segment 1048 is categorized as Hazard Level C for the underseepage potential failure mode based on the WHIS and the past performance data of underseepage boils and wet spots in the segment.

Stability

Segment 1048 Stability Assessment Results*

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
69	59	69	Some	Moderate	Some	Hazard Level B*

* Stability is assessed independently of through seepage and underseepage. Seepage might cause instability not accounted for in the stability assessment.

Hazard indicators suggesting levee instability include a levee composition of loose silt and sand, a levee height of up to 25 feet above the levee toe and the presence of soft soil in the foundation. Segment 1048 is categorized as Hazard Level B due to the consistency between hazard indicators, suggesting that levee instability may occur, and the past performance history of levee cracking in the segment.

Through Seepage

Segment 1048 Through Seepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
85	68	90	Free Seepage	Wet Area	Piping	Hazard Level B

The levee is composed of silt and sand, and has a high differential water head between the assessment water surface elevation and the levee toe. However, the segment includes stability berms constructed as past of levee improvements. The segment has reported past through seepage. The through seepage events occurred on levees in the controlled portion of Seven Mile Slough. Given the consistency between the WHIS, which suggests that through seepage is likely to occur, and the presence of past reported through seepage, Segment 1048 is categorized as Hazard Level B for the through seepage failure mode.

Erosion

Segment 1048 is categorized as Hazard Level A for erosion. The segment has one reported erosion feature involving slippage of the rip-rap. No other past performance data were reported for this segment. Accroding to the LiDAR data, minor erosion of the waterside slope may be occurring along about 20 percent of the segment.

Segment 1048: Other Levee Assessments

Freeboard

Freeboard was not assessed because a 1955/1957 water surface elevation was not available for the assessment.

Overtopping

Overtopping was considered only based on past performance. Evaluation of flood flows, flood elevations, channel capacities and other factors influencing overtopping risk is beyond the scope of the NULE Project. These factors should be studied by others to evaluate overtopping risk to NULE Project levees. Segment 1048 has has no documented overtopping in the last 20 years.

Geometry

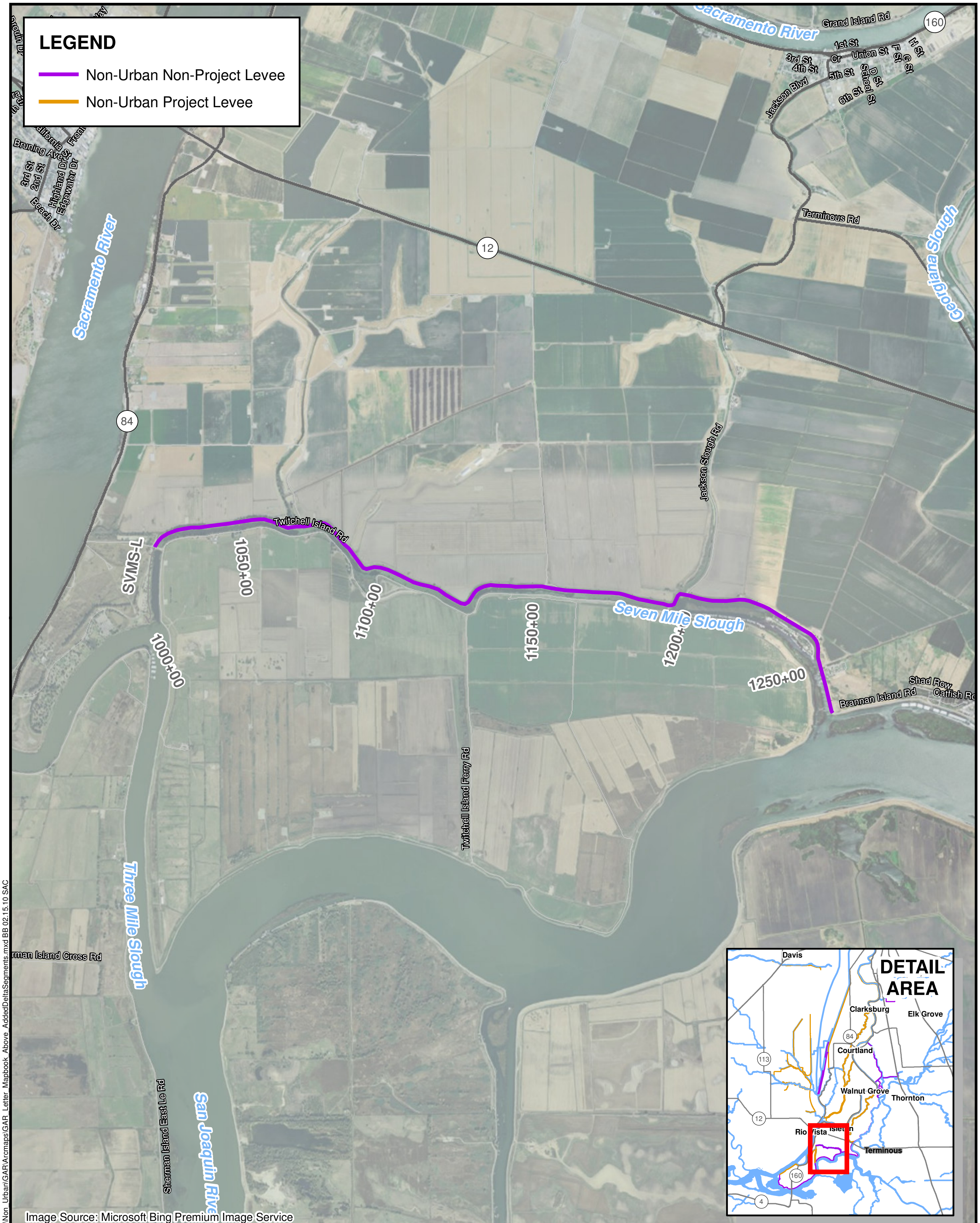
Using LiDAR data, Segment 1048 levee geometry was compared to a standard levee prism as defined by the 1953 MOU. This comparison assessed whether the levee, indicated by topography developed from LiDAR data, was larger than or equal to the standard levee prism at any given cross-section. Wide levees could meet this requirement even where levee slopes are steeper than those described in the 1953 MOU. For Segment 1048, approximately 55 percent of the levee is smaller than the standard levee prism.

Segment 1048: Hazard Mitigation

The following table identifies hazards for the levee segment and the estimated extent of the hazard. Comments are provided to assist with identifying potential remedial requirements.

Segment 1048 Hazards

Hazard	Extent (percent)	Comments
Underseepage	70	The levee foundation consists of peat and organic soil that extends up to 20 feet below the toe, underlain by predominantly sand and silty sand up to 50 feet below the toe. The extent is estimated considering the past improvements and existing levee geometry, as indicated by LiDAR data.
Stability	70	The levee foundation consists of peat and organic soil. The extent is estimated considering the past improvements and existing levee geometry, as indicated by LiDAR data.
Through Seepage	70	Extent is based on portions of the segment that have landside slopes steeper than about 4H:1V, as indicated by LiDAR data.



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0 2,000 4,000
Feet

N

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

Segment 1048
Geotechnical Assessment Report

NORTH NON-URBAN LEVEE EVALUATIONS

Non Urban Levee Evaluation Program (NULE) Levee Assessment Tool, Version 1.2 (revised: 1/7/2010)

				Begin	End
Levee Segment Name:	North Bank of Seven Mile Slough - Brannan Island Levee		NULE Station (ft):	1022+55	1263+80
Levee Segment Number:	1048		Levee Mile:	Enter	Enter
			Segment/Reach Length:	4.6 (miles)	24125 (feet)
Brief Description of Segment/Reach:	North (left) Bank of Seven Mile Slough - Brannan Island Levee		Crest Width Design Criterion (ft):	20	
Local Maintenance Authority:	BRANNAN-ANDRUS LMD		Design Guidance Document:	1953 MOU	
Freeboard Evaluation Criterion (ft):	Not Applicable				
Water Side Slope Design Criterion:	3H : 1V	Enter Other Criterion	Project or Non-Project Levee?	Non-Project	
Land Side Slope Design Criterion:	2H : 1V	Enter Other Criterion			
North or South NULE?	North				

LEVEE CONSTRUCTION

Describe what is known about construction of this levee segment:	Segment 1048 levee was built in 1871 and 1872 (Doc-8729). The levee system that was restored in 1878, after the inundation of Brannan-Andrus Island in 1877-78, by newly organized (1877) Reclamation District No. 317, ranged in height from five to nine feet. Water in the Seven Mile Slough between NULE stations SVMS-L 1022+55 and 1191+50 is controlled by a gated dam with two 48" pipes and gate valves on the east near the Owl Harbor and by a pump station on the west.

Analysts should populate all yellow cells, and not populate grey cells; green cells store calculated values. Use the suite of available data in making ratings. See User Guide and tables for further information.

PAST PERFORMANCE

	Value (where applicable)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments (include event date and flood elevation, if available)
Underseepage		*Heavy seepage*	*Minor seepage*	*Heavy seepage*	Boils and wet-spots were observed near the landside toe after soil near the landside toe was removed for farming (Doc 8707).
Landside slope stability		*Some*	*Moderate*	*Some*	Cracks observed along the levee (Doc-8707, Doc 5452, Doc-5466)
Through seepage		*Free seepage*	*Free seepage*	*Piping*	Segment had 2 or 3 instances of through seepage (Outreach Meeting Summary).

In addition to Ayres 2008/DWR 2009 studies, are there erosion occurrences identified in this study?	Yes	If yes, please describe:	Erosion - slipping riprap and pocketing near NULE Station 1260+00 (Doc 5452).					
North NULE	Erosion sites from the Ayres 2008 study	Ayres Methodology 2			Ayres Methodology 4			
		Rating (1 to 72)	Ranking (out of 117)		Rating (1 to 47)	Ranking (out of 117)		
Are there erosion occurrences compiled in the Ayres study?	No	N/A	N/A		N/A	N/A		
	Comments:	N/A			Comments:	N/A		
South NULE	Erosion sites from the DWR 2008 study	DWR Prioritization 2008						
		Rating (1 to 100)	Ranking (out of 67)					
Are there erosion occurrences compiled in the DWR study?								
	Comments:							

Past overtopping or near overtopping?:	Never overtopped	Comments:	No reported overtopping in the past 20 years.
Past breach in area?	None Identified	Comments:	N/A

HAZARD INDICATORS

	Value (where applicable)	Best Estimate Rating	Minimum Credible Rating	Maximum Credible Rating	Explanation & Comments
I- LEVEE COMPOSITION - *at selected cross section* - Interpreted from Borings, Test Pits, field reconnaissance, NRCS maps, and analyst's interpretation of this assemblage of information					
Composition of levee material *for through seepage assessment*		*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	*3 - SM, ML, Moderately dispersive soils; soils are silty sands or sandy silts with higher permeability than category 1 soil; soils are suspected of being moderately dispersive based on SAR or other factors*	*5 - Loose: SP, SP-SM, SM, NP ML; documented loose high permeability fill; loose sand, sand with silt, silty sand, non-plastic silt*	Based on available boring Data (Doc-8306)
Composition of levee material *for stability assessment*		*4 - CH, MH; moderately dispersive soils; loose sand, sand with silt, or non-plastic silt*	*2 - SM, ML, clean gravels; soils are silty sands or sandy silts*	*4 - CH, MH; moderately dispersive soils; loose sand, sand with silt, or non-plastic silt*	Based on available boring Data (Doc-8306)
II- GEOLOGY - *at selected cross section*	(Scale of mapping)				
Underseepage susceptibility *for underseepage assessment*	1:24,000	*5 - Very high*	*5 - Very high*	*5 - Very high*	Levee foundation consists of peat.
Dispersive soils *for stability assessment*	1:24,000	*1 - Not dispersive*	*1 - Not dispersive*	*1 - Not dispersive*	SAR map shows soils are not likely dispersive (SAR mapped for two-third of the segment).
Piping potential *for underseepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Available boring data and Piping potential map (piping potential mapped for two-third of the segment).
Piping potential *for through-seepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Available boring data and Piping potential map (piping potential mapped for two-third of the segment).
Soft soils *for stability assessment*	1:24,000	*5 - Present*	*5 - Present*	*5 - Present*	Available boring data.
III- OTHER INDICATORS - *at selected cross section*					
Animal persistence/burrows? *for through-seepage assessment*		*2 -Low*	*2 -Low*	*3 - Medium*	Based on Interview, Animal control program exists for the segment.
Is a landside ditch or borrow pit present within 200 ft of toe? *for underseepage assessment*	Ditch within 50 ft of toe	4			An irrigation ditch located at about 25 feet from landside levee toe.
Is a landside ditch or borrow pit present within 200 ft of toe? *for stability assessment*	Ditch within 50 ft of toe	4			An irrigation ditch located at about 25 feet from landside levee toe.
Is waterside blanket present? *for underseepage assessment*	No				0
Are there locations where penetrations and historical underseepage are coincident?	No	If yes, please describe:	0		
Are there locations where penetrations and historical through seepage are coincident?	No	If yes, please describe:	0		
Have encroachments that may potentially affect levee integrity been identified?	No	If yes, please describe:	0		
Provide the number of levee penetrations below the evaluation water surface elevation:	5 - More than 20	Notes:	Based on the 1989 Survey Field Book (Doc-2667)		
DWR's LMA maintenance rating from Maintenance Deficiency Summary Report:	LMA Not rated by DWR	Notes:	Non-project levee, not rated by DWR		

IV- TOPOGRAPHIC & ELEVATION INFORMATION *- at selected cross section(s)*

	Default cross section (used for Underseepage assessment)		Would you like to evaluate a different cross-section for **Stability**?	No	Would you like to evaluate a different cross-section for **Through Seepage**?	No
	Cross-section Station	1035+00	**Cross-section Station**		**Cross-section Station**	
	Underseepage		**Stability**		**Through Seepage**	
Report elevations in NAVD 88	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]	**Value** (where applicable)	**Rating** [1 (good) to 5 (bad)]
Levee crest elevation (ft)	10					
Levee toe elevation (landside) (ft)	-10					
Levee crest width (ft)	20	1				
Evaluation water elevation (ft)	8.5					
Levee slope - landside (xH : 1V); **Enter x**	2.4	3				
Levee slope - waterside (xH : 1V); **Enter x**	1.8					
Freeboard above evaluation flood elevation (ft) (= levee crest elevation - evaluation water elevation)	1.5					
Levee height (ft) (= levee crest elevation - landside toe elevation)	20.0	5				
Levee prism base width (ft)	104.0					
Head (ft) (= evaluation water level - landside toe elevation)	18.5	4				
Head-to-base-width ratio (= head / base width)	0.178	5				
Base-width to head ratio (= base width / head)	6					

V- ANOMALIES

	Anomalies?	Description	Effect on Performance
Underseepage	No	NA	NA
Stability	No	NA	NA
Through Seepage	No	NA	NA
Erosion	No	NA	NA

MITIGATION AND PAST BREACHES

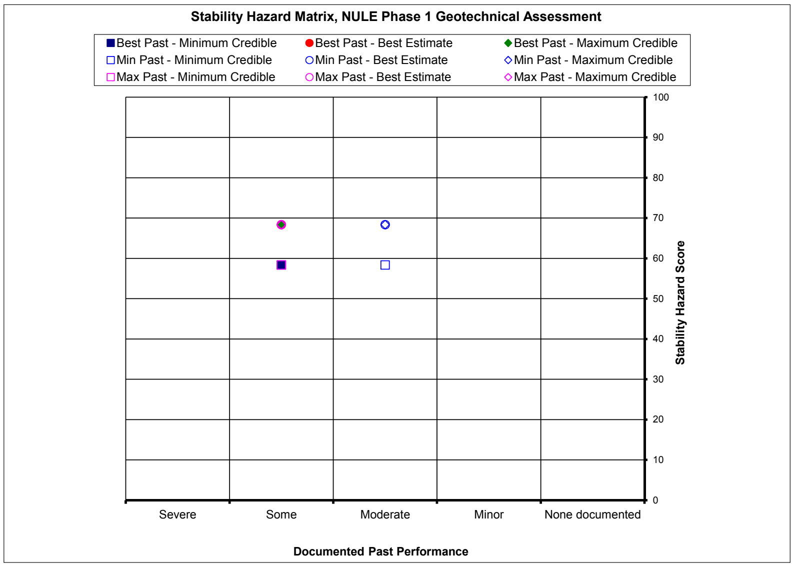
Existing constructed mitigation (List all)	Landside stabilization berm between NULE stations 1149+00 and 1165+00 was constructed by the USACE in 1998 (Doc-8701); Levee crown was raised in August 2003 between NULE stations 1198+00 and 1217+00, in August 2005 between NULE stations 1217+00 and 1241+00, and in September 2006 between NULE stations 1136+00 and 1164+00 and between NULE stations 1215+00 and 1245+00; Levee crown between NULE stations 1137+00 and 1145+00 was raised in June 2007.
Has there been a past breach?	None Identified
If yes, describe nature of the breach and how it has been mitigated?	

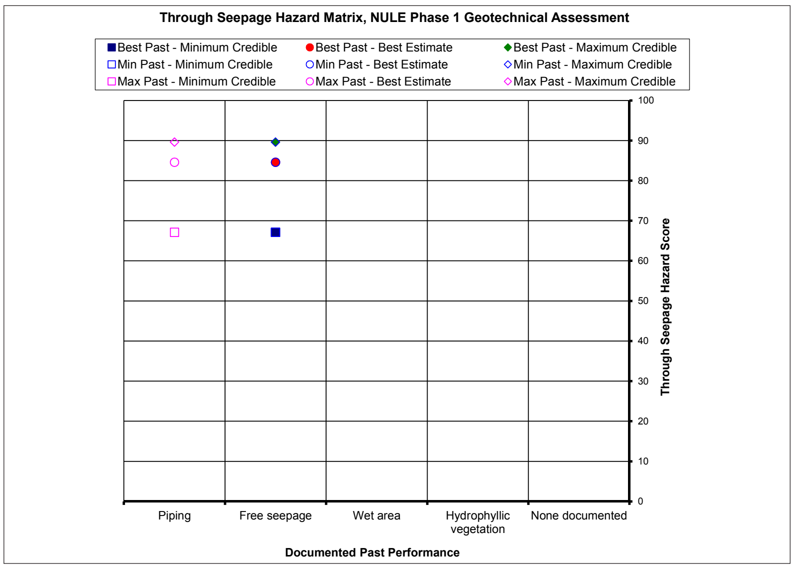
SUMMARY

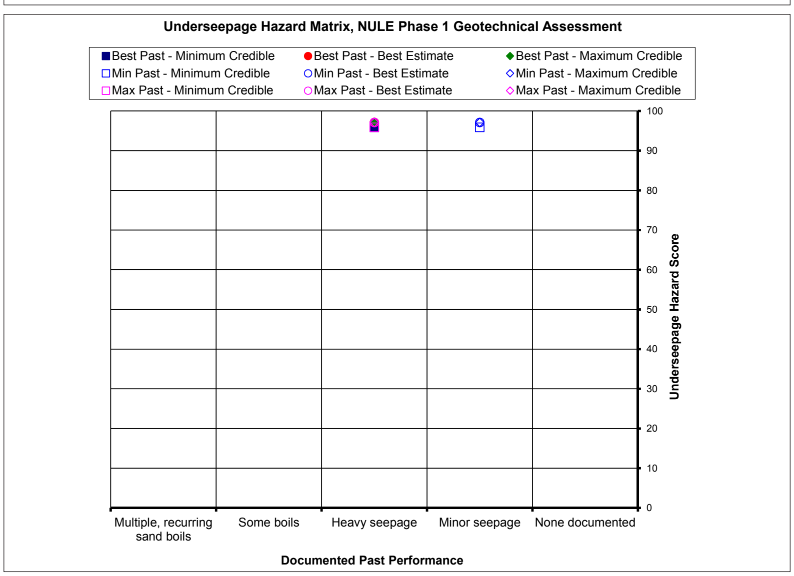
Failure Mode	Weighted Hazard Indicator Score (Best)	Weighted Hazard Indicator Score (Minimum Credible)	Weighted Hazard Indicator Score (Maximum Credible)	Past performance issues?	Are past performance and Weighted Hazard Indicator Score consistent?	Levee categorization
Underseepage	**98**	96	98	Heavy seepage	Yes	***Hazard Level B***
Justification:	The high WHIS is consistent with the documented past performance data.					
Suggested additional data:	N/A					
Stability	**69**	59	69	Some	Yes	***Hazard Level B***
Justification:	Segment is categorized as Hazard Level B based on the consistency between the WHIS, which suggests that slope instability may occur, and the reported past performance of cracks along the levee.					
Suggested additional data:	N/A					
Through Seepage	**85**	68	90	Free seepage	Yes	***Hazard Level B***
Justification:	The segment had 2 or 3 instances of through-seepage (Outreach Meeting Summary). The events occurred on levees that are located in the controlled portion of the Seven Mile Slough. The relatively high WHIS is consistent with the reported past performance.					
Suggested additional data:	N/A					
Erosion				Yes		***Hazard Level A***
Justification:	One reported erosion feature involving slippage of riprap was reported in 1998. No other reported past performance data available for erosion.					
Suggested additional data:	N/A					

Freeboard Check	Does levee pass freeboard check?	**Not Applicable**	
Provide details about where along segment (and by how much) levee does not pass freeboard check:	N/A		
Are there anomalies along the segment with respect to freeboard?	No	Describe anomalies:	0
Levee Geometry Check	Does levee pass geometry check?	**No**	
Provide details about where along segment (and by how much) levee does not pass geometry check:	55% did not pass the geometry check. The locations that did not pass geometry check are 1025+00 to 1040+00, 1050+00, 1075+00 to 1090+00, 1100+00, 1115+00 to 1125+00, 1130+00 to 1145+00, 1160+00, 1170+00 to 1190+00, 1235+00 to 1240+00, and 1250+00 to 1255+00.		
Are there anomalies along the segment with respect to geometry?	No	Describe anomalies:	0
Summary Characterization of Levee Segment	Hazard Level B	**Comment / Justification:**	The potential failure mode categorizations for underseepage, through seepage and stability were Hazard Level B. The categorization for erosion is Hazard Level A. This resulted in the overall categorization of Hazard Level B.

Evaluator:	Kanax	Evaluation Date:	10/13/2010
Checked By:	Sathish	Check Date:	10/13/2010
Senior Reviewer:	KLK, RSA, RKG	Review Date:	10/18/2010


Stability Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Stability Hazard Score
Severe
Some
Moderate
Minor
None documented
Documented Past Performance


Through Seepage Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Through Seepage Hazard Score
Piping
Free seepage
Wet area
Hydrophyllic vegetation
None documented
Documented Past Performance


Underseepage Hazard Matrix, NULE Phase 1 Geotechnical Assessment
Best Past - Minimum Credible
Best Past - Best Estimate
Best Past - Maximum Credible
Min Past - Minimum Credible
Min Past - Best Estimate
Min Past - Maximum Credible
Max Past - Minimum Credible
Max Past - Best Estimate
Max Past - Maximum Credible
100
90
80
70
60
50
40
30
20
10
0
Underseepage Hazard Score
Multiple, recurring sand boils
Some boils
Heavy seepage
Minor seepage
None documented
Documented Past Performance

Appendix C

Geomorphology Technical Memorandums

2868 Prospect Park Drive, Suite 310
Rancho Cordova, CA 95670
916.631.4500 fax 916.631.4501

2870 Gateway Oaks Drive, Suite 150
Sacramento, CA 95833
Tel: 916.679.2000 Fax: 916.679.2900

In association with:
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Subject Level 2-II Geomorphic Assessment and Surficial Mapping Along a Portion of the Sacramento River and Three Sloughs South of Courtland Study Area

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INTRODUCTION

This technical memorandum presents the results of surficial geologic mapping and geomorphic assessment in the North Non-Urban Levee Evaluations (NULE) Project's Study Area along a portion of the Sacramento River and three sloughs south of Courtland, California (Figure 1). Surficial geologic mapping and geomorphic assessment were completed by NULE Project team member Fugro William Lettis & Associates, Inc.

North NULE's South of Courtland Study Area (Study Area) includes approximately 100 miles of non-urban Project levees along Sacramento River, Georgiana Slough, Steamboat Slough, and Sutter Slough (Figure 1) in parts of Solano and Sacramento Counties, California. The river and sloughs in the Study Area are the lowest reaches of the Sacramento Valley fluvial network and extend into the tidally influenced Sacramento–San Joaquin Delta (Bryan, 1923).

The primary goal of this study is assessment of levee foundation underseepage susceptibility hazard through characterization of the type and distribution of surficial and near-surface geologic deposits that underlie the Non-Urban Project levees. Secondarily, this study develops an initial conceptual model that describes the primary geomorphic processes in the Study Area that, in turn, facilitates process-based stratigraphic interpretations. Plate 1, Sheet 1 (northern portion) and Plate 1, Sheet 2 (southern portion) present the surficial geologic map and levee foundation underseepage susceptibility results.

TECHNICAL APPROACH

The geomorphic assessment involved the integration and analysis of aerial photography, topographic maps, geologic maps, soil maps, historical documents, and field reconnaissance. Synthesis of these data informed the development of a detailed surficial geologic map, assessment of the primary geomorphic processes responsible for distributing or modifying surficial deposits in the Study Area, and creation of levee underseepage susceptibility hazard maps.

The Project team analyzed the following data:

- 1937 aerial photography (Table 1a)

Table 1a. Aerial Photography.

County Code	Roll Number	Frame Numbers
ABC	49	1 through 4
ABC	49	33 through 45
ABC	50	1 through 15
ABB	112	72 through 87
ABC	53	30 through 36
ABO	53	72 through 79

- Early and modern topographic maps (Table 1b)
- Published surficial geologic maps (Atwater, 1979, 1982; Helley and Harwood, 1985)
- Early and modern soil survey maps (Holmes et al., 1913; Carpenter and Cosby, 1930; Tugel et al., 1992)

Table 1b. USGS Topographic Maps.

Quadrangle Name	Publication Date	Photo Revision Date	Series	Scale	Survey Date
Courtland	1908	N/A	15-Minute	1:62,500	N/A
Isleton	1910	N/A	7.5-Minute	1:31,680	N/A
Rio Vista	1910	N/A	7.5-Minute	1:31,680	N/A
Jersey Island	1910	N/A	7.5-Minute	1:31,680	N/A
Courtland	1978	1993	7.5-Minute	1:24,000	N/A
Isleton	1978	1993	7.5-Minute	1:24,000	N/A
Rio Vista	1978	1993	7.5-Minute	1:24,000	N/A
Jersey Island	1978	1993	7.5-Minute	1:31,680	N/A

Through surficial geologic mapping, primary geomorphic features and associated surficial geologic deposits such as distributary channels, former tidal marsh sediments (peat and mud), and Holocene through historical flood deposits are identified.

WLA conducted field reconnaissance to confirm the nature of the geologic units and their geomorphic relationships. Areas of close inspection included the natural levee landforms and deposits along the Sacramento River, Georgiana Slough, and Steamboat Slough, peat and muck deposits in the island interiors, and slough deposits in the island interiors including Beaver Slough and Jackson Slough. General geomorphic features and relationships were reviewed for the larger study area from Highway 12 to the Paintersville bridge over the Sacramento River, near Courtland, California.

The Study Area's surficial geologic map (Plate 1 (Sheets 1 and 2)) was developed at the nominal scale of 1937 aerial photography (approximately 1:20,000) and is presented at 1:24,000-scale. The map should not be used or displayed at scales greater than 1:24,000. Solid map unit boundaries shown on the surficial geologic map should be considered approximate, and are accurate to within about 100 feet on either side of the line shown on the map; dashed contacts are accurate to within about 250 feet on either side of the line. Contacts that occur within the same geologic unit delineate allostratigraphic units. Allostratigraphic units are mappable layers or bodies identified on the basis of bounding discontinuities (Boggs, 1995). This approach is used to provide insight on surficial depositional history and activity within age categories.

Mapping shown on Plate 1 (Sheets 1 and 2) is based on analysis of 1937 aerial photography, along with early and modern soil surveys, and early topographic maps. A site visit was conducted to field check the office-based mapping. The 1937 aerial photographs are the primary data set for interpreting surficial geologic deposits because they are the oldest available high-quality images pre-dating much of the cultivation and landscape alteration in present-day Solano and Sacramento Counties. Therefore, the map depicts geologic deposits laid down before 1937. When synthesized, the map and photographic data provide key insights to the characteristics of deposits beneath the levees and serve as a technical framework for assessing underseepage susceptibility in the South of Courtland Study Area.

Levee foundation underseepage hazard analysis involves the spatial intersection of surficial geologic map data with NULE Project levee lines. Underseepage susceptibility category assignments (Table 2) are based on geologic age and depositional environment, as well as inferred relative permeability. The hazard assignments were tested during the Level 2-I geomorphology work phase by analyzing levee past performance data as an indicator of future underseepage susceptibility.

GEOLOGIC SETTING

The Study Area lies near the downstream end of the Sacramento River where the river flows through the Sacramento-San Joaquin River Delta. Fluvial and deltaic processes interact to produce the characteristic deposits of this area. Although the entire Study Area lies within the boundary of the Delta as established by the California State Lands Commission (Section 12220 of the Water Code) (Figure 1), surficial deposits and geomorphic processes grade from those characteristic of a more fluvial environment in the northern part of the Study Area to those characteristic of a more deltaic environment in the southern part of the Study Area.

This Study Area includes about 24 miles of the lower-most Sacramento River and sloughs, between Courtland and Rio Vista (Figure 1). Within this Study Area, the Sacramento River flows into and through the legal and physiographic Sacramento–San Joaquin Delta (the Delta). The Delta is aptly named because when inundated by floods, the rivers, tributary creeks and slough channels discharged into a wide body of relatively motionless water (Vaught, 2006).

The Delta has been the subject of many scientific, engineering, and policy studies over the last several decades. The intent of the following paragraphs is to summarize the primary geologic and geomorphic aspects of the Delta to provide general context for the physical setting. This section therefore provides an overview of the Delta's geologic evolution, a description of the natural Delta island and tidal marsh environment, and summarizes the ways in which hydraulic gold mining, reclamation of marshes, and construction of levees have contributed to present-day conditions within the Delta.

Geologic Evolution

The San Francisco Bay and Sacramento–San Joaquin Delta developed over the past 1 million years (Helley et al., 1979), shaped by active tectonic and geologic processes. The present configuration of the Delta is an inland tidal marsh that drains to the ocean through a series of bays and straits. Because the area is very near sea level, major changes in sea level and shoreline caused by global climactic fluctuations over the Quaternary (past approximately 2 million years) have left their geologic imprint on the Bay and Delta (Atwater et al., 1977). Under glacial conditions sea level was at a low-stand, alluvial plains were exposed, wind-blown sand dunes accumulated, and rivers incised to grade to an ocean level 300 to 400 feet below present elevations and a coastline several miles west of its present day position (Shlemon, 1967). During climactic warm periods (i.e. Holocene), sea levels achieved high-stands that filled or partially filled the Bay and Delta, with consequent deposition of alluvial, deltaic, and estuarine sediments.

About 15,000 years ago at the close of the last glacial period, sea level began to rise as glaciers in the higher latitudes began to melt. Subsequent vertical changes and eastward-transgression in sea level in the San Francisco Bay area are recorded by tidal-marsh deposits located at the base of Holocene estuarine sediments (Atwater et al., 1977; Atwater, 1980). The local geologic record of Holocene sea-level changes indicates that the rising sea entered the Golden Gate 10,000-11,000 years ago (Helley et al., 1979). The then newly formed bay spread across land areas as rapidly as 100 feet (30 m) per year. The ocean reached its present level at about 6,000 year ago (Helley et al., 1979). As sea level rose throughout the early Holocene, the base levels of the streams in the bay region were raised slightly, the younger alluvial sediments were deposited on the supratidal flood plains around the growing bay, and the younger bay mud was deposited beneath the rising water. Delta inundation rates decreased substantially since about 6,000 years ago (Malamud-Roam et al., 2007) such that the pace of sea level rise was slow enough to allow tidal marshes and ecosystems to form in close connection with sea level position (URS, 2007). The geologic evolution of the Delta thus results in Holocene (interglacial) peat and mud that have spread across and over coarser-grained latest Pleistocene alluvium. Another result of sea-level rise is silty and clayey Holocene river alluvium that extends into and overrides the Delta peat and mud as natural levees (Atwater, 1982). The height and breadth of the natural levee landforms decreases in the downstream direction in the Study Area (W.E.T., 1990).

Delta Islands and Tidal Marsh Environment

Prior to 1850, the Delta included landforms that are typical of many classic deltas – distributary channels bordered by natural levees and separated by tidal marshes and wetland islands (Atwater, 1980). The center of each Delta island was nearly flat to gently saucer-shaped, and at a few feet above or below sea level. The saucer-like island interiors were covered with thickets of tules that high tides inundated with 6 to 12 inches of water for 1/2 to 2 hours, twice a day (Thompson, 2006). Under natural conditions these islands were covered with water throughout a large part of the year and were always flooded at river high stage.

Tules, reeds, and other fibrous aquatic plants growing at water level were preserved as peat beds when sea levels slowly rose and inundated the present Delta. Organic material in the Delta accumulated faster than it could decay, allowing peat deposits to persist (Atwater and Belknap, 1979). The high groundwater table and standing surface water kept the peat wet and supported the marsh plants and shrubs. The water and plant life protected the peat from wasting by oxidation, shrinkage and deflation. The Delta's tidal wetlands were rooted in beds of fibrous plant material that graded downward into peat, deposits of which are thickest under the Delta's west-central islands (USACE, 1987). Along the upland margin of the Delta, freshwater marshes merged with flood basin marshes of slightly higher elevations. Although the wetland vegetation species in freshwater marshes were similar to those in flood basin marshes, the underlying soils are different because the flood basins dried out every summer, preventing peat accumulation (URS, 2007). The deepest known peat in the Delta underlies Sherman Island and extends 60 feet below sea level (USACE, 1987).

Mining Debris Sedimentation

Significant alteration of the Sacramento River and its watershed began in the mid-to-late 1800s with the onset of gold mining. Gold-rich gravel deposits underlie watersheds of the Sacramento River basin including the Mokelumne, American, Bear, Yuba, and Feather Rivers, as well as Butte and Cherokee Creek watersheds in the Redding area (Domagalski et al., 2000). Hydraulic mining activity in the watersheds draining the Sierra Nevada began with earnest in 1852-3 with the development of high-pressure water hoses and nozzles also called "monitors" (Gilbert, 1917). The detrital material, initially fines with sand (called slickens), and later gravel and larger clasts, was washed from the hillsides and into the river valleys. This, in combination with large flood events (e.g.,1862, 1867-8, 1881 floods) transported the mining debris downstream and supplied a substantial amount of sediment to many rivers draining into the lower Sacramento River, and the Sacramento River itself, in a very short period of time. The excessive sediment supplied resulted in aggradation (i.e. backfilling) of the channel and consequent decrease in channel cross section area that exacerbated flooding and deposition of mining debris (James, 1999). The discharging or dumping of hydraulic mining debris and tailings into rivers drainages was "enjoined" or halted in 1884 by a lawsuit decision from Judge Lorenzo Sawyer (Ellis, 1939). Further legal decisions in 1893 (i.e. the Caminetti Act) created the California Debris Commission (CDC), under which hydraulic mining was regulated in such a way as to prevent "injury" to the navigable waters of the Sacramento River. In short, hydraulic mining was allowed when licensed by the CDC which required the impoundment of the mine tailings (e.g. debris dams).

Gilbert (1917) estimated 1,400,000,000 cubic yards of sediment were delivered by the tributaries to the Sacramento River over a 65-year period from 1850 to 1915. Some of this material was washed to the San Francisco Bay, some of the material was deposited in stream valleys, some on the floodplains and flood basins, some within the river and slough channels, and some in the Delta marshes and islands. Gilbert (1917) estimated the volume of mining sediment deposits on "inundated lands, including tidal marshes" at about 294,000,000 cubic yards as of 1914.

The influx of mining detritus also filled the Study Area sloughs and channels such that mechanized dredging was required to maintain channel cross-section area for navigation and flood conveyance (Thompson, 2006). Commonly, the dredge spoils taken from the river were used as material to construct or augment flood control levees in the Study Area (DWR, 1995). Dredging technology and efficiency dramatically improved with the advent of hydraulic dredges in 1879, but clam-shell and bucket dredgers also were used to dredge channels. As the reach of the long-boom clamshell dredge increased, so did the ability to dredge from the river and build the artificial levee. Long-boom clamshell dredges performed much of the levee building in the formerly swampy bottomlands (Thompson and Dutra, 1983). Furthermore, it was common practice to mantle or "top dress" the fragile levee systems with fresh dredged material at intervals of 1 to 3 years (Thompson, 2006). The frequency and extent of levee dressing dropped in the 1930s and 1940s.

The transport and deposition of mining debris sediment within major and tributary channels and on floodplains had three results: (1) early complaints, and ultimately legal action, from valley farmers that the deposition of mining debris sediment (slickens) destroyed or impaired agriculture; (2) the construction of levees very close to river banks in order to protect arable land and also to encourage fluvial scour of the aggraded channel material; (3) dredging and widening of channels and sloughs in the Delta to remove accumulated sediment, build up levee prisms (top dressing), and improve navigation (Gilbert, 1917; James, 1999; Thompson, 2006; James et al., 2009).

Delta Reclamation, Levees, and Subsidence

While an exhaustive description of detailed levee construction history is beyond of the scope of this study, a brief qualitative synopsis of key events is important in understanding the surface evolution and foundation deposits laid down prior to the construction of the levees. Within the Study Area, levee construction is closely tied to "reclamation" of the tule swamps that covered the Delta's islands. Under the Swamp and Overflowed Land Act of 1850, marshland was converted to agricultural land through burning of tule vegetation, construction of drainage ditches, and construction of levees and drainage pumps. The government-sanctioned "reclamation" destroyed the original depositional environment and arrested natural geomorphic processes. The Swamp and Overflowed Land Act of 1850 allowed the State to sell land cheaply, which it did so with the caveat that it be reclaimed for cultivation. Land owners quickly realized that drainage and artificial levees would need to be constructed to make and keep the reclaimed land viable for cultivation.

Early levee systems in the Delta were made from blocks of peat during the 1860s (DWR, 1995), and were very short and the materials very weak. These discontinuous levees were easily eroded or destroyed by the tides and waves. A major flood occurred in 1862 that inundated nearly all of the Delta area, as described in Vaught (2006): *"From east to west, the waters of the Sacramento River spread well beyond the Tule, drowning the region in a torrent twelve miles wide and ten feet deep."* Another major flood also occurred in 1867; both floods transported and deposited sediment on the land surface, including upstream-sourced mining debris.

In 1868, the State legislature removed limitations on acreage of swamp and overflowed land that an individual could hold and there after the process of reclaiming the land (i.e., leveeing, burning tules) progressed with earnest. Sherman Island levees, the first to completely enclose an island, were constructed by 1869 and averaged 12 feet wide at the base and 3 to 4 feet tall (Thompson and Dutra, 1983). Levees along other Delta islands were also constructed soon afterwards, with Twitchell Island levees completed 1870-71. Steamboat Slough levees were still under construction by steam-powered dredges during the large flood of the Sacramento River in 1889[1].

Therefore, there was a period of about 16 years (between about 1852-3 and 1869) wherein mining debris likely was emplaced over the streams and sloughs natural levees. This period corresponds to the dramatic increase in hydraulic mining efficiency and massive sediment delivery to channels coupled with extremely large flood events prior to systematic leveeing.

Because of soil draining, conversion to farming, and construction of levees, most islands in the Study Area (and greater Delta) lie well below sea level (Figures 2 and 3). This land subsidence[2] primarily is the result of the loss of organic soil (peat) (Ingebritson et al., 2000). When peat soils are drained, outside air fills the pore spaces and the organic materials aerobically decompose, oxidize, lose volume and compact. In addition, intentional burning of the fields causes loss of peat through combustion, and agricultural tilling of organic and peaty soils exposes these light-weight organic materials to wind erosion resulting in deflation of the land surface (Mount and Twiss, 2005). Much of the enclosed areas of the central islands now are 10 or 15 feet below sea level; some places are closer to 20 feet below sea level (Figure 3). The shallow-saucer shaped islands of 150 years ago have become deep bowls. Much of the elevation loss occurred between 1897 and1918, when tracts and islands were first enclosed with levees built by dredges and kept free of water by use of pumps. Since then, the island floors have continued to subside (Figures 2 and 3). The elevation difference between the river or slough on one side of the levee and the lower island surface on the other side of the levee has resulted in increased hydrostatic pressure against the levees and underlying porous peat (Mount and Twiss, 2005).

SURFICIAL GEOLOGIC MAPPING

Previous Quaternary geologic mapping in the North NULE Delta Study Area includes 1:250,000-scale mapping by Strand and Koening (1965) and Wagner et al., (1981), 1:62,500-scale mapping by Helley and Harwood (1985), and Atwater's mapping (Atwater, 1979; 1982) at 1:24,000-scale. These data are used as an overall framework for more detailed mapping of surficial geologic deposits at a scale of 1:24,000 (Plate 1 (Sheets 1 and 2)). This study synthesizes Atwater's (1982) seminal

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[1] Sacramento Daily Record-Union newspaper, December 14, 1889, page 5 column 4.

[2] The American Geological Institute's Glossary of Geology defines the term subsidence as: "A local mass movement that involves principally the gradual downward settling or sinking of the solid Earth's surface with little or no horizontal motion and that dos not occur along a free surface (such as landslide). The movement is not restricted in rate, magnitude, or area involved. Subsidence may be due to: natural geologic processes such as solution, erosion, oxidation, thawing, lateral flow, or compaction of subsurface materials; earthquakes, slow crustal warping, and volcanism; or man's activity such as removal of subsurface solids, liquids, or gasses and wetting of some types of moisture-deficient loose or porous deposits."

mapping and delineates additional individual deposits based on relative age and depositional process or environment. The mapping depicted on Plate 1 (Sheets 1 and 2) are based on synthesis of existing mapping, detailed analysis of 1937 aerial photography, and early soil survey and topographic maps, and limited field reconnaissance. The mapping, therefore, is essentially a snapshot of geologic conditions circa 1937. The following paragraphs describe the mapping shown on Plate 1 (Sheets 1 and 2) including the general distribution of units, mapping criteria, characteristic soil relationships and geologic observations based on the mapping.

River, flood basin, and tidal marsh processes are not entirely separate. Rather, the processes represent a continuum across which the depositional environments are hydrologically and geomorphically linked. Because there is a continuum between river, flood basin, and tidal marsh depositional processes, the geologic contacts between the two deposits (or environments) often is gradational (transitional) rather than discrete.

Distribution of units

The deposits within the Study Area are from floodwaters of the Sacramento River and its distributaries, and were modified in low-lying areas by deltaic and estuarine processes. Micro-depositional environments within this setting have produced mappable deposits that differ from one another in grain size, sorting, or organic content. Channel natural levees, flood basins, and fresh water marshes are all components of the floodplain that itself is traversed by distributary, slough, and abandoned channels. Natural levees flank the margins of many active channels and sloughs. Associated overbank and crevasse splay deposits are present along the natural levee and extend toward the adjacent Delta. The overbank and crevasse splay deposits vary in lateral extent. Freshwater marsh deposits are present northwest of Sutter Island and northeast of Walnut Grove. Flood basin deposits are within Sutter Island and directly west of Sutter Island (Plate 1, Sheet 1).

Within the margins of the Delta the natural levee deposits grade laterally into peat and muck deposits of the tidal marsh islands (Plate 1 (Sheets 1 and 2); Ryer, Grand, Andrus, Brannan, and Twitchell Islands). Peat and muck deposits locally are crossed by river distributary and tidal slough channel deposits (Plate 1 (Sheets 1 and 2)).

Unit descriptions and mapping criteria

Map unit descriptions and criteria for mapping surficial deposits shown on Plate 1 (Sheets 1 and 2) are described herein, in order of oldest to youngest. Deposits of the same relative age are described based on depositional environment or process.

The oldest unit present in the Study Area is wind-deposited (eolian) sediment (map unit Qe) that may span from latest Pleistocene to Holocene in age (Atwater, 1982). It is present as relatively small local bodies, thought to have been derived from wind transport of fluvial sediments near the end of the Pleistocene. Mapping of eolian sediments is adapted from Atwater (1982) with map refinements and additions based on analysis of 1937 aerial photos and the mapped extent of Tyndall soils of Tugel et al., (1992). The eolian deposits likely consist of poorly to moderately cemented fine sand.

Eolian deposits do not directly underlie the levees in the Study Area, but should be expected in the subsurface as laterally discontinuous well-sorted (poorly graded) sandy lenses.

Surficial deposits mapped in the Study Area primarily are Holocene to historical in age. Holocene deposits underlie the modern floodplain and Delta island surfaces. Freshwater marsh, flood basin, and tidal marsh deposits are similar and grade laterally into one another, but with increasing organic content from basin to marsh to tidal mud and peat. In this study these deposits are categorized as Holocene because deposition in these environments was active up until the mid 1800s.

Holocene deposits

Fresh water marsh deposits (map unit Hs) consist of silt and clay with occasional thin organic lenses. Marsh deposits were perennially or seasonally submerged, and host Sacramento clay loam soils that contain near-surface lenses of partly decayed organic matter (Carpenter and Cosby, 1930). Marsh deposits are similar in texture to basin deposits, but are mapped based on bush-like symbols depicted on early U.S. Geological Survey topographic maps indicating marsh environments. Marsh deposits also are mapped based on the presence of standing water bodies surrounded by dark tones on 1937 aerial photographs.

Flood basin deposits (map unit Hn) consist of soft to stiff silt and clay laid down by slow-moving water in a relatively low-energy depositional environment. The deposit usually does not contain substantial organic material (Helley and Harwood, 1985), and fine-grained materials present in this map unit may have high plasticity. Criteria for mapping flood basin deposits include depression topography, relatively featureless surface morphology on topographic maps and aerial photos, and fine-grained inorganic soils. In this Study Area, flood basin deposits host Egbert clay loam soils (Tugel et al., 1992).

Tidal marsh deposits (map units Htm and Hpm) are Holocene peat and muck deposits consisting of beds of organic matter (plant remains) interbedded with alluvial silt and clay, that accumulated in the freshwater tidal marsh of the Sacramento-San Joaquin Delta. Organic material comprises at least 50 percent of the deposit. Tidal marsh deposits are encountered at or below present-day sea level. Most of these deposits pre-date the reclamation projects of the late 1800s and early 1900s when the extensive tidal freshwater marsh of the Delta was drained for agriculture.

Peat typically accumulates in fresh or brackish water swamps, marshes, or bogs where stagnant, anaerobic conditions prevent oxidation and bacterial decay of organic matter (Boggs, 1995). True peat generally has greater than 75 percent moisture content, visible vegetal matter (e.g, roots, leaf veins), and when dried will burn freely (Bates and Jackson, 1984). Just as common in the Study Area are beds of silt and clay with 10 to 50 percent organic matter (peaty mud). The term “muck” is applied to mixed mineral and organic deposits where the plant parts are not recognizable. The amount and thickness of organic matter varies across the Study Area, and generally increases to the south (DWR, 1995).

Historical tidal marsh deposits (Rpm) are mapped in active estuarine environments near sea level where accumulation of marsh vegetation, silt, and clay continued to take place at least as late as

1937. Some of these areas of tidal marsh persist today, including a large area along Snodgrass Slough near the town of Locke (Plate 1, Sheet 1).

Holocene peat and muck deposits (Hpm) are those tidal marsh deposits that were enclosed by levees and drained for farming before 1937 (Figure 3). In the island interiors they have been highly impacted by aeration, decomposition, compaction, burning, and erosion. Because of the extensive draining and plowing of the surficial peaty deposits for cultivation, as well as subsequent farming uses, much of the original surficial geologic and geomorphic character of the former tidal wetland was destroyed as of 1937. Therefore, mapping of Hpm for this study draws heavily from Atwater (1982), whose mapping estimated 1850 tide line extent and data included shallow cores augered for stratigraphic analysis. This study also uses early and modern soil maps, and review of aerial photographs to refine the delineation of unit Hpm and Htm on Plate 1 (Sheets 1 and 2). Peat and muck deposits usually bear the Egbert mucky loam soil or muck and peat of Carpenter and Cosby (1930), and the Gazwell mucky clay or peat and muck of Tugel et al. (1992).

Four categories of Holocene channels are mapped: sloughs (Hsl), distributary (Hdc), overflow (Hofc), and undifferentiated (Hch). Deposits within these channels may be similar texturally, but bear differences based on process. Criteria for differentiating among channel categories are based on map pattern, channel extent, and inter-connectivity with other channels.

Sloughs within the Delta islands were tidally-influenced features, and usually are channels that may or may not have “arms.” Slough channels commonly connect, or would have connected, two different channels during high-stage flows. Beaver Slough (Plate 1, Sheet 1) and Tomato Slough (Plate 1, Sheet 2) are examples of now-abandoned tidal slough channels. Deposits within these now abandoned or drained slough channels (Hsl) likely are relatively fine-grained, silt and clay with lesser fine sand, and are associated with the Scribner clay loam soil (Tugel et al., 1992). Sedimentary structures consistent with bi-directional tidal water flow may be present within the deposit.

Distributary channel deposits (Hdc) are floodplain channels that emanate from a main channel commonly at a sub-perpendicular trend, and traverse the floodplain for some distance before ending. Distributary channels may or may not deposit significant sediment as distributary fans (map unit Hdf), depending on the ratio of sediment to water and flow velocity within a given channel. It is inferred that the deposits within a distributary channel are made of similar textures as the sediment provided by the main channel, that is, likely silt, clay and lesser fine sand.

Overflow channels traverse the floodplain on the inside of a river bend, and were active during high-stage flow events. Overflow channels collect and direct water downstream over the floodplain for some distance before re-entering the channel of origin. Based on this hydrologic connectivity, it is inferred that overflow channel deposits (Hofc) are similar in texture to the sediments in the originating channel; that is, likely sand, silt, and clay, with possible traces of fine gravel.

Undifferentiated Holocene channel deposits (map unit Hch) in the Study Area likely consist of soft to stiff clayey silt, silty clay, with silty and clayey sand. This map unit is not extensive in the Study Area, and the map designation is used for channel deposits that cannot easily be placed into the aforementioned categories.

Holocene crevasse splay deposits (map unit Hcs) and overbank deposits (map unit Hob) together make up the natural levee landform that flanks the Sacramento River and its sloughs. These deposits likely consist of mixtures of silt, clay, and fine sand; the relative proportion of each texture varies across the Study Area, as well as within any individual deposit. Because of hydraulic sorting processes, floodplain deposits grade laterally into the adjacent lowland deposit and the geologic contacts between floodplain and lowland deposits are also gradational, as indicated by the dashed contact line. Crevasse splay deposits form from breaching of a river bank levee (natural or artificial) during high stages and deposition on the floodplain via narrow channels. Crevasse splay deposits commonly are lobate, fan-shaped, or birds-foot shaped in plan view. Overbank deposits are formed from the localized overtopping of channel banks or natural levees, and deposition from shallow sheet flow. Soils developed on the natural levees include Columbia silty clay loam (Carpenter and Cosby, 1930), Scribner clay loam, and the Sailboat silty loam (Tugel et al., 1992). The natural levees in the Study Area generally consist of interbedded and laterally discontinuous lenses of silt or clay, and silty or sandy clay.

Historical deposits

Historical deposits mapped in the Study Area include channel and floodplain deposits, as well as artificial fill deposits (Plate 1 (Sheets 1 and 2)). The term “historical” denotes deposits laid down since about 1849; these deposits are indicated with an “R” in the map unit symbol. These sediments were deposited by the same geomorphic processes as their Holocene counterparts. Many of the historical deposits are derived, at least in part, from re-working, transport, and deposition of hydraulic mining detritus (Gilbert, 1917; Bryan, 1923; James, 1999).

Historical deposits are differentiated from older deposits based on several criteria: (1) presence of bare soil or soil with sparse vegetation, shown as bright tones on 1937 aerial photographs, indicating the deposit has had insufficient time for substantial vegetation colonization, (2) tonal brightness and contrast patterns on 1937 aerial photos within orchards planted along natural levees that suggests post-orchard deposition, (3) stippled patterns on early topographic maps that are inferred to represent historical sand deposition on the floodplain; (4) association with soils having very little horizon development suggesting youthful deposition (e.g. Columbia fine sand; Homes et al., 1913); (5) anecdotal descriptions of historical flood events (e.g. early newspaper accounts), and (6) fresh or sharp geomorphic expression on aerial photographs, for example: sharply-defined distributary channel margins that suggest recency of scouring flow or lack of substantial modification from cultivation processes. Historical deposits are mapped where inferred to be about 3 feet thick or greater. Historical deposits include crevasse splay and overbank deposits along the Sacramento River and sloughs, and distributary channel and fan deposits that extend onto the floodplain, away from the river (Plate 1 (Sheets 1 and 2)).

Historical artificial fills are man-made heterogeneous deposits, with varying amounts of clay, silt, sand, and gravel from local borrow or source areas. These deposits include levee structures and canal levee systems (map unit L) as well as dredge spoils (map unit DS), which is material dredged from nearby channels and emplaced on the land surface.

Site-specific geologic observations

The following paragraphs summarize site-specific geologic observations based on the mapping of surficial deposits. This section does not include a point-by-point account of all of the important surficial and near-surface deposits and features, but rather summarizes key observations that warrant additional description that may not be gleaned from reviewing Plate 1 (Sheets 1 and 2).

Directly east of the head of Steamboat Slough[3], at the toe of the Holocene crevasse splay deposit on the eastern flank of the Sacramento River (Plate 1, Sheet 1, star symbol), a radiocarbon age of peat taken directly beneath a 5-foot-thick Holocene crevasse splay deposit (Hcs) yielded an age (in 14C years) of 1,910 +/-55 years before A.D. 1950 (Atwater, 1982). This suggests that the Sacramento River natural levee building process (vertical accretion) was active at least about 2,000 years ago. If this age is correct, Holocene crevasse splay and overbank deposits mapped in the Study Area are on the order of about 2,000 years old.

An abandoned channel (Hch) is mapped downstream from Isleton, north of the present-day Sacramento River (Plate 1, Sheet 2). The channel, not shown on Atwater (1982), is mapped based on 1937 aerial photographs (Figure 4). The gently arcuate map pattern of the abandoned channel suggests that it may be a former natural meander of the river; diverging from the present river directly upstream of Ida Island (Figure 4). Soils that are spatially associated with the channel deposit are recognized by Carpenter and Cosby (1930), but do not appear to be differentiated by Tugel et al. (1992) perhaps due to plowing of the surface layer over time. The soil type recognized on the abandoned channel deposit is the Sacramento mucky loam and consists of two main layers: an upper layer of fine-textured mucky material of high organic content, and a lower layer with lacustrine-like sediment and little organic material (Carpenter and Cosby, 1930). This stratigraphy suggests erosion of a fluvial channel, abandonment and subsequent development of an oxbow lake environment, followed by change to marsh environment. This also suggests that channel fill predominantly is fine-grained material from post-abandonment infilling in the upper several feet of the deposit; however, it is also possible that the soil survey pits did not explore deep enough to assess the texture of channel bottom deposits.

Also shown on Figure 4 are tidal marsh deposits and in-channel bar sediment that were present in 1910, but gone by 1937. These areas are shown with a diagonal hatch pattern on Figure 4. The change was identified by comparison of 1910 topographic maps (Table 1) against 1937 aerial

[3] Steamboat Slough in 1848 was referred to as the "Middle Fork" or branch of the Sacramento River (Ringgold, 1948). Other records show Steamboat Slough was preferred over the "old river" Sacramento River route because it was more than 8 miles shorter and several hours less travel by steamship. Due to hydraulic mining, by the late 1850's Steamboat Slough was less traveled by the larger steamers, yet still the preferred route for flat bottomed boats that would stop at the landings.

photographs. It is likely that the sediments accumulated as a response to the influx and downstream transport of hydraulic mining debris. It is also likely that the in-channel sediment was subsequently removed from the channel by mechanical dredging of the river for navigation purposes (e.g., Thompson, 2006).

CONCEPTUAL GEOMORPHIC MODEL

Based on a synthesis of surficial geologic mapping, early topographic maps, soil surveys, and geologic maps, a preliminary conceptual model has been developed to describe dominant geomorphic processes that controlled surface and subsurface geologic deposits in the Delta Study Area (Figure 1). This conceptual model provides a consistent basis for understanding the types and distribution of surficial geologic deposits, primary geomorphic processes, and the shallow subsurface stratigraphy in the Study Area.

The Study Area includes Project levees along four waterways: the lower Sacramento River, Sutter Slough, Steamboat Slough, and Georgiana Slough. The lower Sacramento River is the master stream in the Study Area; however, flows through the Delta naturally were distributed among a network of channels and sloughs including the river. Near Clarksburg, the Sacramento River spawns a number of lesser distributary channels that flow independently for a short distance and then join with other channels, sloughs or with the main river. Fresh and salty estuarine waters mix through complex hydrologic interaction of the tidal prism. Channels currently are scoured and channel form maintained by tidal currents, but less dynamically as compared to “pristine” Delta conditions.

As described by Atwater (1982), the Delta during the late Quaternary can be likened to a stage on which two related and cyclical plays are presented simultaneously. In one play, wetlands, tidal marshes, and supratidal floodplains appear and grow as sea level encroaches from the west, then become areas of erosion and dissection upon sea level retreat and subaerial exposure. In the other play, sediment eroded from the Sierra Nevada originally by glaciers accumulates to build alluvial fans and when re-worked by wind-driven (eolian) process creates extensive sand dunes. Other lesser actors contribute to occupying or modifying the landscape, such as fluvial processes constructing terraces along streams or steady growth of tule swamps.

The Study Area is geomorphically distinct from other North NULE areas because the depositional history includes deltaic / tidal marsh processes in addition to fluvial processes. From these combined processes, the margins of the islands are slightly elevated rims made of overbank and splay deposits; whereas the slightly lower center of the islands were covered by peat formed by decaying tidal marsh vegetation. The beds of peat laterally merge with inorganic soils toward the Delta’s periphery at the regional scale, as well as towards the alluvial bank margins along islands at the local scale (Thompson, 2006).

As described in previous section, the Study Area reach of the Sacramento River, the river’s banks and adjoining land areas were impacted by the upstream hydraulic gold mining activities. In the mid to late 1800s, much of the Study Area was covered in fine-grained sediment with sand (slickens) derived from upstream mining activities and downstream fluvial transport and deposition of detritus. The influx of mining detritus also filled the Study Area sloughs and channels such that mechanized dredging was required to maintain channel cross-section area (Thompson, 2006). Commonly, the dredge spoils from the river were used as material to construct or augment flood control levees in the Study Area (DWR, 1995). Steamboat Slough levees were still under construction by steam-powered dredges during the large flood of the Sacramento River in 1889[4]. Therefore, based on the history of mining, reclamation, and flooding, historical deposition of mining debris sediment on the river's banks overprints and buries most of the Holocene natural levee deposits, and the present-day levees thus sit atop the historical mining debris that overlies Holocene alluvium, which in some places overlies peat.

Generalized subsurface stratigraphy

Synthesis of surficial mapping, the conceptual geomorphic model, and readily available geotechnical exploration data allow development of generalized geologic cross sections that depict likely subsurface distributions of deposits. Subsurface data were compiled from Atwater (1982) and USACE (1987). The conceptual cross sections are not intended to represent site-specific subsurface conditions. Plate 1 (Sheets 1 and 2) and Figure 2 show where two schematic cross sections were developed in the Study Area; the illustrations are shown on Figures 5 and 6. The cross section locations illustrate the inferred stratigraphy in the northern non-tidal part of the Study Area and the stratigraphy in the southern former tidal marsh part of the Study Area.

Figure 5 illustrates the inferred stratigraphy across Sutter Slough, Steamboat Slough, and the Sacramento River in the northern part of the Study Area. The generalized cross section shows the interfingering of Holocene basin and tidal marsh deposits in the subsurface, with tapering blankets of Holocene and historical natural levee deposits present adjacent to the channels. Historical and Holocene natural levee deposits are encountered directly beneath the Non-Urban levees. The lateral extent of the surficial deposits may be estimated from Plate 1 (Sheets 1 and 2), and the thickness of the historical and Holocene overbank and crevasse splay deposits decreases with distance away from the river or slough (Figure 5). By extension, this lateral pinching and interfingering geometry likely is present between the Holocene subsurface deposits (e.g., Hob-Hpm). In addition, relatively coarser-grained buried channels schematically shown on Figure 5 likely have limited lateral extent, but may be more continuous in the river-parallel direction. Late Pleistocene fluvial or alluvial fan deposits are interpreted to underlie the Holocene deposits based on the presence of relatively sandy and dense sediments at depth in boreholes. The thick beds of peat seen in cross section B-B' (Figure 6), located closer to the center of the Delta, are not encountered in this area. Unit Hpm here is relatively rich in silt and clay.

Figure 6 presents inferred subsurface stratigraphy along the southern portions of Grand Island (see Figure 2 for location). In contrast to the northern portions of Grand Island, a thick (up to 25 feet) bed of peat is present in the subsurface and is schematically shown as laterally extensive, but the layer may also be less extensive. Additional subsurface data may constrain the actual extents and continuity of the peat layer. The peat bed probably thins and is interpreted to laterally pinch out

[4] Sacramento Daily Record-Union newspaper, December 14, 1889, page 5 column 4.

toward the Sacramento River at the margin of the island (Figure 6). In contrast, the peat bed is relatively thick beneath and adjacent to Steamboat Slough (Figure 6). Localized sand-rich deposits interpreted as buried channels are encountered in bore holes adjacent to Steamboat Slough (USACE, 1993). Surficial and near-surface deposits are likely similarly distributed laterally and vertically as described for Figure 5, having limited extents with thinning and interfingering boundaries.

APPLICATIONS TO STUDY AREA LEVEES

The preceding sections summarize the major map units constituting levee foundations and the shallow stratigraphic relationships in the Study Area. These factors (sediment texture, permeability, and shallow stratigraphic relationships) exert controls on underseepage processes and are incorporated into the underseepage susceptibility analysis.

Underseepage susceptibility analysis considers geologic deposits underlying present-day levees, the characteristics of soils developed on those deposits, and the surficial landscape features that may influence or control underseepage. The underseepage susceptibility classes listed in Table 2 were assigned based on geologic age, depositional environment, stratigraphic relationships, and inferred relative soil permeability. Table 3 lists the units present beneath Study Area levees; underseepage assignments are not listed for deposits present elsewhere in the North NULE Study Area. The susceptibility assignments are shown graphically on Plate 1 (Sheets 1 and 2).

Almost all levee foundations in the Study Area (96.5 percent) are judged to have very high susceptibility to underseepage (97.3 miles). These foundations consist of historical overbank deposits (Rob) derived from upstream gold mining activities, and to a lesser extent dredge spoils derived from adjacent channels (DS) or Holocene peat and mud deposits (Hpm) (Table 2).

Historical overbank deposits laid down by large floods on the Sacramento River before levee construction (e.g., 1862, 1881, 1889) blanket older sediments and therefore directly underlie much of the present-day levees. Dredge spoils underlie the Non-Urban levee at the southern end of the map area at the confluence of Steamboat Slough and the Sacramento River (Plate 1, Sheet 2). Peat and muck deposits directly underlie only 1.4 miles of levee foundations (Table 2), however, peat and muck likely are present in the subsurface (Figures 5 and 6).

Table 2. Underseepage Susceptibility Summary.

Unit Symbol	Unit Name	Susceptibility Rating	Mileage	Percent
Rob	Historical overbank deposits	Very High	87.6	87.6
Rcs	Historical crevasse splay deposits	Very High	6.0	6.0
Hpm	Holocene peat and mud	Very High	1.4	1.4
DS	Dredge spoils derived from channel	Very High	1.3	1.3
Rdc	Historical distributary channel deposits	Very High	0.8	0.8
Rofc	Historical overflow channel deposit	Very High	0.2	0.2

Table 2. Underseepage Susceptibility Summary.

Unit Symbol	Unit Name	Susceptibility Rating	Mileage	Percent
Hob	Holocene overbank deposits	High	2.6	2.6
Hch	Holocene channel deposits	High	0.6	0.6
Rsl	Historical slough deposits	High	0.2	0.2
Hsl	Holocene slough deposits	Moderate	0.1	0.1
Rch	Historical channel deposits	Very High	0.0	0.0
Rdf	Historical distributary fan deposits	Very High	0.0	0.0
Rpm	Historical peat and mud	Very High	0.0	0.0
Ra	Historical alluvium (undifferentiated)	Very High	0.0	0.0
Rb	Historical channel bar deposits	Very High	0.0	0.0
Hcs	Holocene crevasse splay deposits	High	0.0	0.0
Hs	Holocene marsh deposits	Moderate	0.0	0.0
Qe	Quaternary eolian deposits	Moderate	0.0	0.0
Hn	Holocene basin deposits	Low	0.0	0.0

Existing geomorphic studies indicate that bank stratigraphy in the Study Area generally consists of a cohesive (fine-grained) tidal mud / flood basin overlain by relatively more granular natural levee deposits that, in turn, are overlain by the artificial levee (W.E.T., 1990). There is, therefore, a likely permeability contrast occurs between the lower cohesive layers at the channel bank toe and the overlying relatively sandier natural levee layers (e.g., Sutter Slough, Figure 6). This model indicates that bank stratigraphy and property contrasts at geologic contacts may influence foundation underseepage pathways (i.e., flow at the contact between the layers).

Performance data for the Study Area levees (URS, 2009) show a record of underseepage-related problems generally consistent with the assigned levee foundation underseepage susceptibility. Documented levee performance problems include foundation seepage, boils, sand boils, and levee failure. Performance points (seeps, boils) are present along both banks of Sutter Slough, Steamboat Slough, Georgiana Slough, and the Sacramento River. Several documented performance problems are clustered along the lower third of Georgiana Slough levees and along Steamboat Slough at and near the junction with Miner’s Slough.

SUMMARY

The Study Area includes levees along four waterways in the Sacramento–San Joaquin Delta: the lower Sacramento River, Sutter Slough, Steamboat Slough, and Georgiana Slough. The surficial geologic mapping and levee underseepage susceptibility assessment is based on the analysis of early aerial photography, topographic maps, existing Quaternary geologic mapping, soil maps, limited subsurface data, and historical documents. These data have been used to construct a conceptual model that describes the dominant late Quaternary and historical geomorphic processes in the Study Area and their influence on near-surface and shallow subsurface stratigraphic relationships.

This Study Area is distinct from other North NULE levee areas in that the geologic evolution over the late Quaternary involves both fluvial and deltaic (tidal marsh) processes. The result of these combined processes is the construction of Delta islands separated by tidal channels. The islands, formerly at sea level, hosted freshwater tidal marsh environments that produced beds of organic-rich sediment and peat material. Reclamation of the Delta islands and the construction of artificial levees has altered the natural processes, and promoted the decay and compaction of the organic-rich material resulting in island subsidence. Transport and deposition of sediment derived from upstream gold mining activities occurred just before, or during, the initial construction of the Non-Urban levees in the Study Area. As a result of large floods in the late 1800s, historical overbank sediments blanketed the older deposits, and therefore directly underlie most of the present-day levees in the Study Area.

The presence of historical overbank and crevasse splay deposits beneath the levees has resulted in a very high susceptibility to underseepage along 93 percent of the levee mileage within the Study Area. In addition to the presence of these young, unconsolidated deposits, bank stratigraphy and property contrasts at geologic contacts may influence foundation underseepage pathways (i.e., flow at the contact between the layers). Performance data for the Study Area levees (URS, 2009) show a record of underseepage-related problems consistent with the assigned underseepage susceptibility.

LIMITATIONS

This geomorphic assessment has been performed in accordance with the standard of care commonly used as the state-of-practice in the engineering profession. Standard of care is defined as the ordinary diligence exercised by fellow practitioners in this geographic area performing the same services under similar circumstances during the same time period.

Discussions of shallow subsurface conditions in this technical memorandum are based on interpretation of geomorphic data supplemented with very limited subsurface exploration information. Variations in subsurface conditions may exist between those shown on maps and actual conditions. Due to the scale of mapping, the project team may not be able to identify all adverse conditions in levee foundation materials.

No warranty, either express or implied, is made in the furnishing of this technical memorandum that is the result of geotechnical evaluation services. URS makes no warranty that actual encountered site and subsurface conditions will exactly conform to the conditions described herein, nor that this technical memorandum's interpretations and recommendations will be sufficient for construction planning aspects of the work. The design engineer or contractor should perform a sufficient number of independent explorations and tests as they believe necessary to verify subsurface conditions rather than relying solely on the information presented in this report.

Fugro does not attest to the accuracy, completeness, or reliability of maps, data sources, geotechnical borings and other subsurface data produced by others that are included in this technical memorandum. Fugro has not performed independent validation or verification of data reported by others.

Data presented in this technical memorandum are time-sensitive in that they apply only to locations and conditions that were identified at the time of preparation of this report. The maps produced generally present conditions as they occurred in the early 1900s, as primary data interpreted for this report are from this period. Data should not be applied to any other projects in or near the area of this study nor should they be applied at a future time without appropriate verification, at which point the one verifying the data takes on the responsibility for it and any liability for its use.

This technical memorandum is for the use and benefit of DWR. Use by any other party is at their own discretion and risk.

This technical memorandum should not to be used as a basis for design, construction, remedial action or major capital spending decisions.

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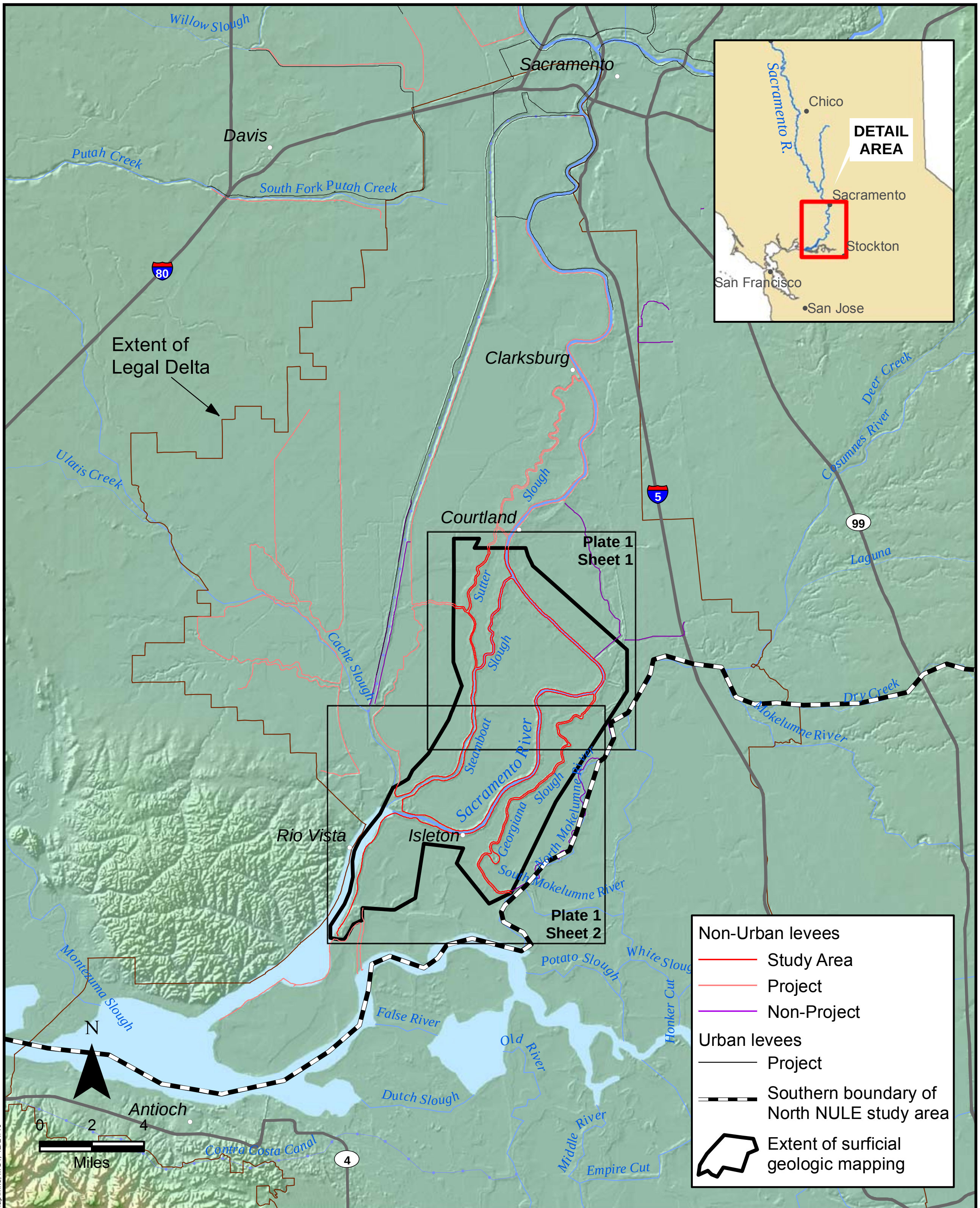

1965_2_NULE_GroupB_LocationMap.mxd, MGT, 12/21/10

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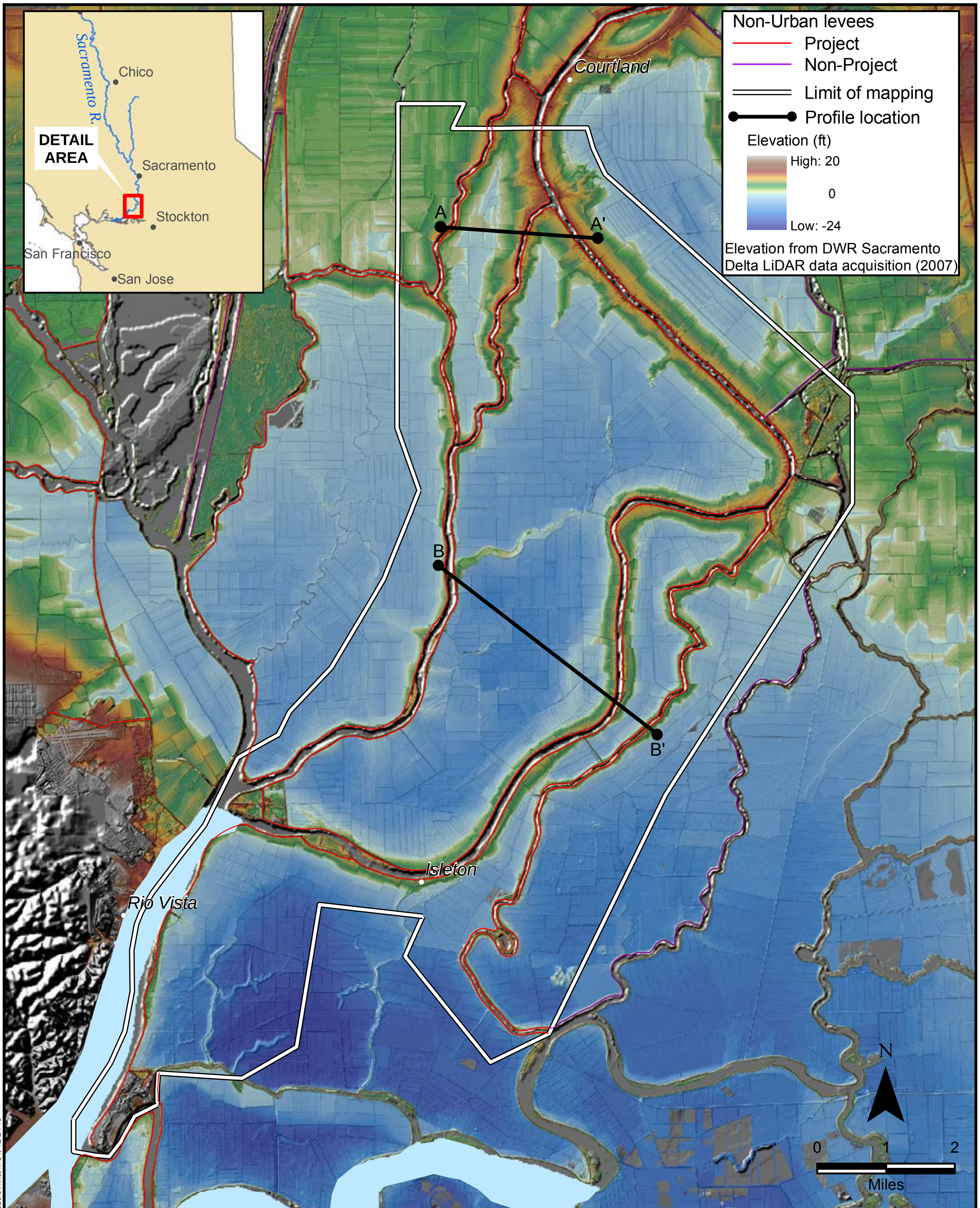
Location Map

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 1



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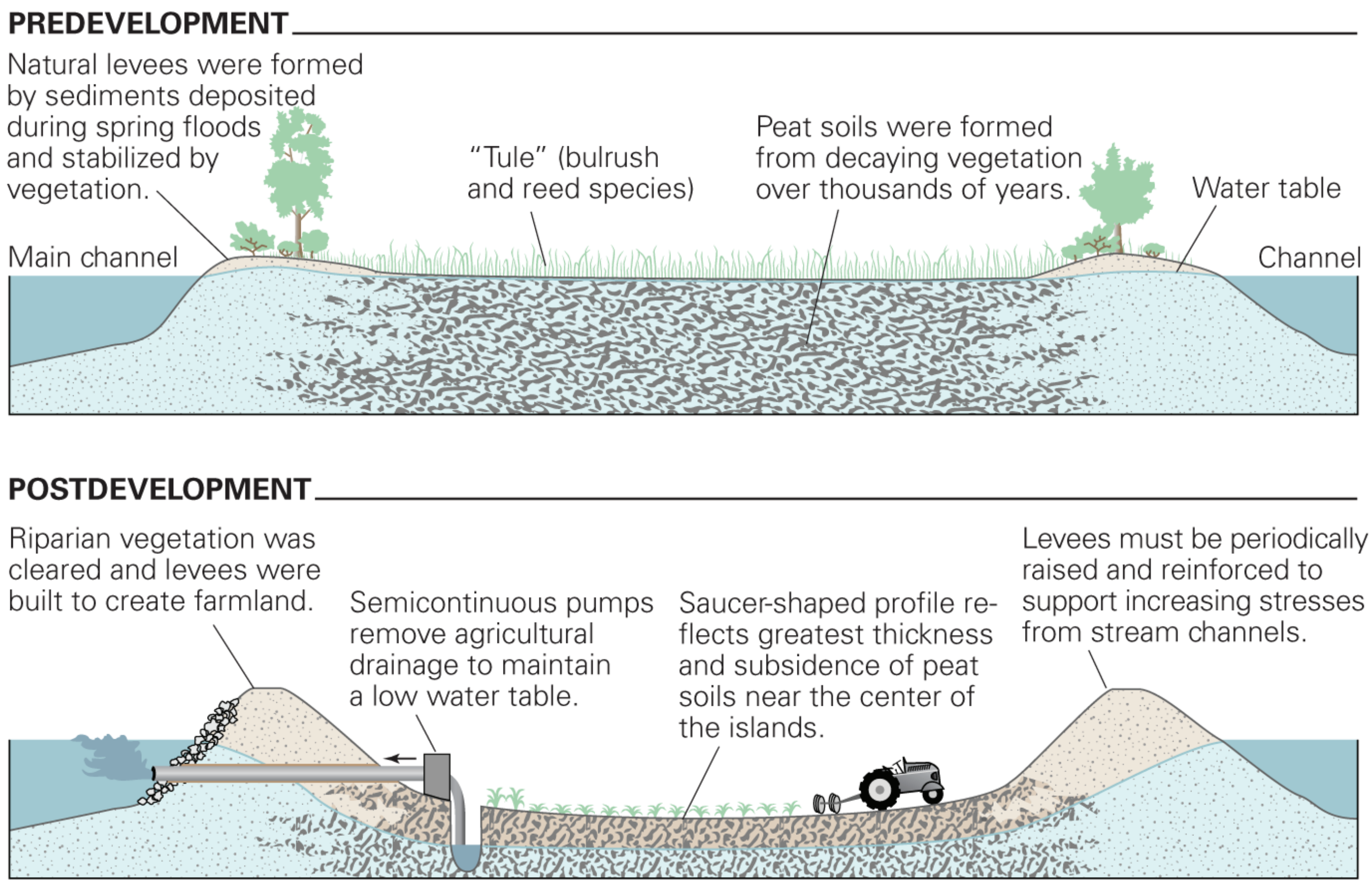
DEM of South of Courtland Study Area Colored to Illustrate Sub-zero Elevation Area

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 2



From: Ingebritson et al. (2000); U.S. Geological Survey Fact Sheet 00-500.

Not to scale

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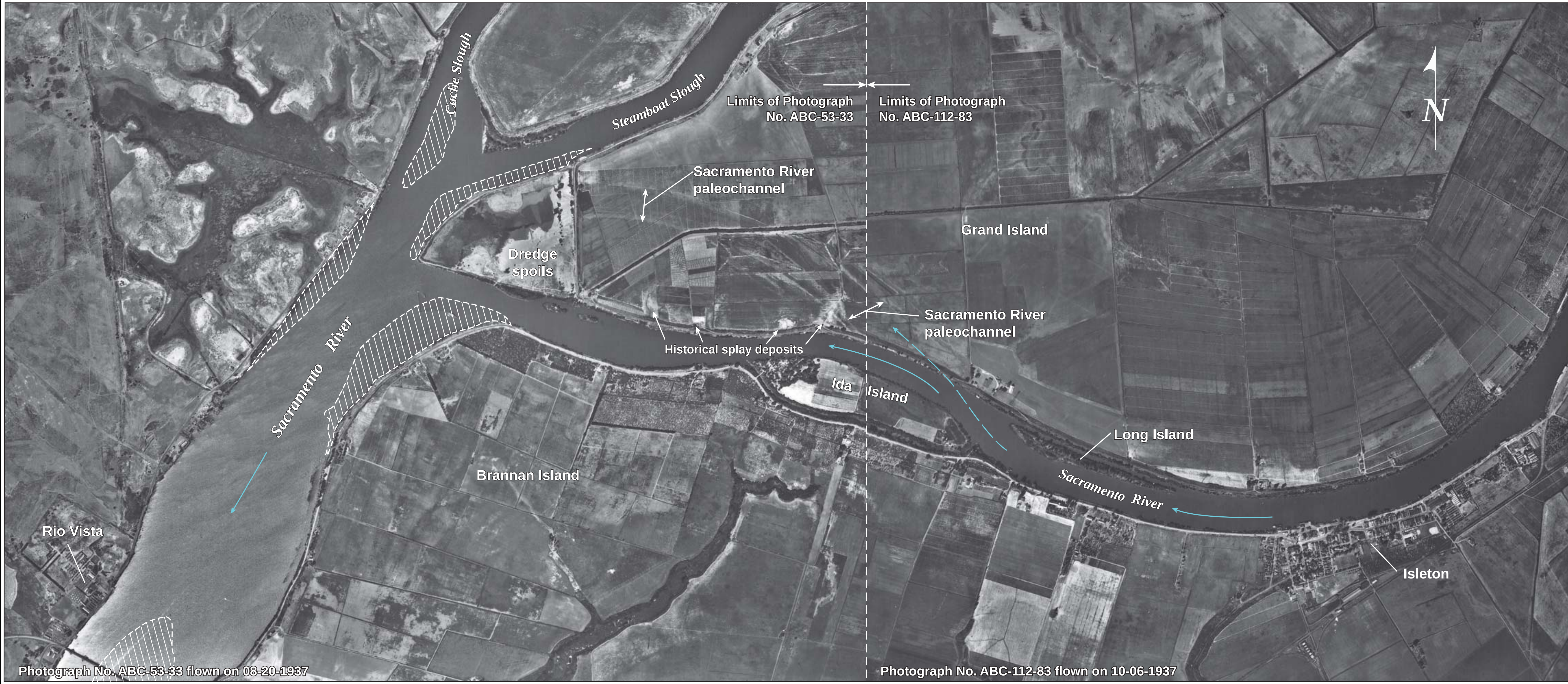
Delta Island, Peat, and Subsidence

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 3



Explanation

Land shown on 1910 (surveyed 1906 - 1908) Rio Vista historical topographic map; not present in 1937

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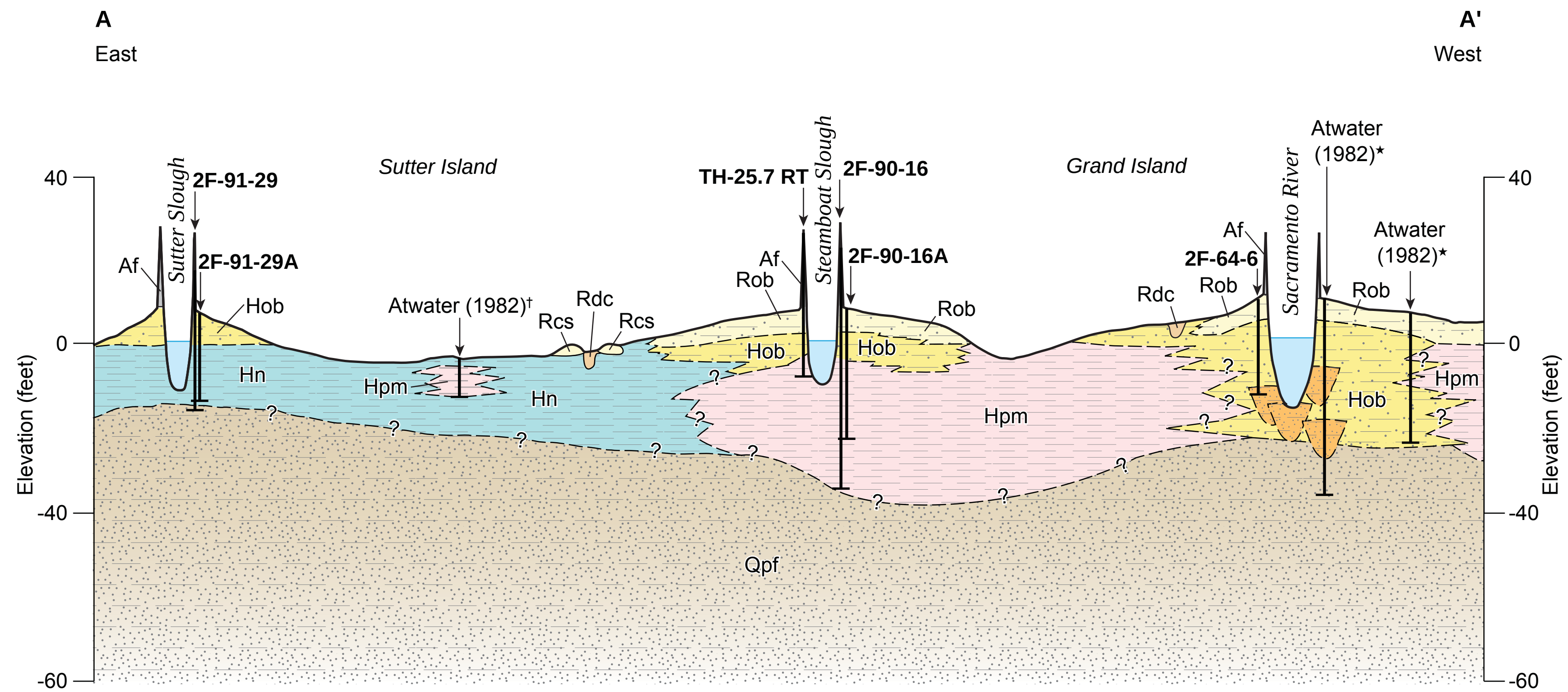
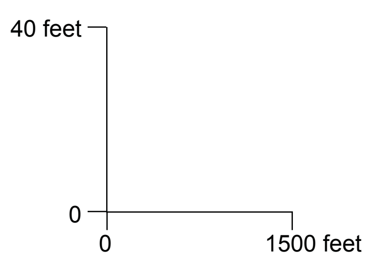
1937 Aerial Photograph of the Sacramento River near Isleton

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 4





Vertical exaggeration = 37.5x

Explanation

Af	Artificial fill
Rob	Historical overbank deposits (fine sand, silt, and clay)
Hob	Holocene overbank deposits (fine sand, silt, and clay)
Hpm	Holocene peat and mud of tidal wetlands (interbedded organic-rich soft silt and clay)
(symbol)	Buried channel (sandy silt and silty sand)
Hn	Holocene basin deposits (fine sand, silt, and clay)
Qpf	Late Pleistocene alluvial fan deposits (poorly graded dense sand and silty sand)
Rcs	Historical crevasse splay deposits (fine sand and silt)
Rdc	Historical distributary channel deposits (sand, silt, and clay)

Atwater (1982)†	Soil core by Atwater (1982)
Atwater (1982)*	Subsurface data from other sources, presented in Atwater (1982)
TH-25.7 RT 2F-90-16	Borehole data, USACE (1993)
– – – – – – –	Contact, approximately located
– –?– – –?– –	Contact, location uncertain

Notes:
1. Topography from USGS 7.5' topographic maps, 5-foot contour interval.
2. Lithologic information shown has been generalized and simplified and may not necessarily represent actual ground conditions at the site-specific level.

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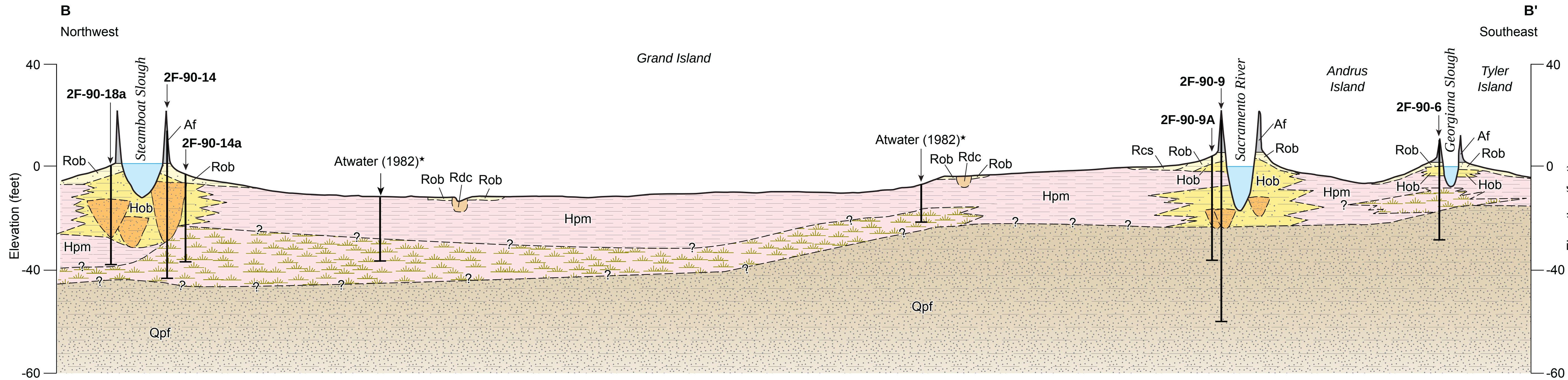
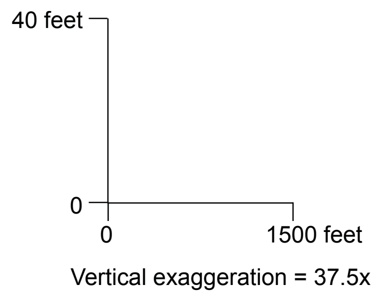
Conceptual Geologic Cross Section A - A'

NORTH NON-URBAN LEVEE EVALUATIONS

Figure
5

Graphics, Projects, 1965 North Urban Levees, 8._Group B Levees Delta, modified 10.20.10





Explanation

Af	Artificial fill
Rob	Historical overbank deposits (fine sand, silt, and clay)
Hob	Holocene overbank deposits (fine sand, silt, and clay)
Hpm	Holocene peat and mud of tidal wetlands (interbedded organic-rich soft silt and clay)
	Thick peat bed
Qpf	Pleistocene alluvial fan deposits (poorly graded dense sand and silty sand)
	Buried channel (sandy silt and silty sand)
Rdc	Crevasse splay deposits (fine sand and silt)

Atwater (1982)†	Soil core by Atwater (1982)
Atwater (1982)*	Subsurface data from other sources, presented in Atwater (1982)
TH-25.7 RT **2F-90-16**	Borehole data, USACE (1993)
– – – – – –	Contact, approximately located
– –?– – –?– –	Contact, location uncertain

Graphics, Projects, 1965 North Urban Levees, 8_ Group B Levees Delta, modified 10.20.10

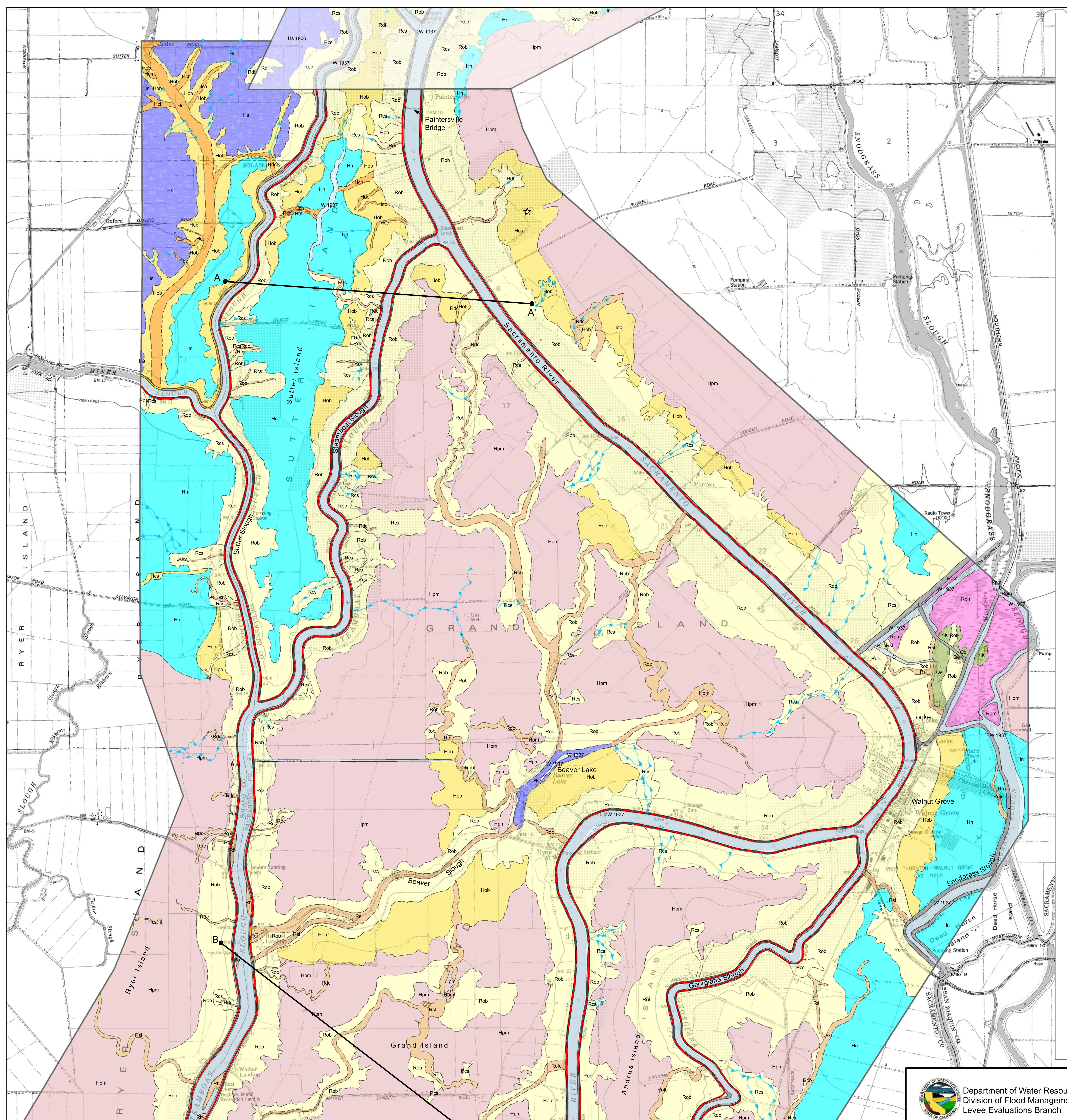
Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS
in association with:
WLA
William Lettis & Associates, Inc.

Conceptual Geologic Cross Section B - B'

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 6



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). 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 (not present in this study area)

Geologic contact; dashed where approximate, dotted where concealed, queried where uncertain; solid contacts are accurate to within about 100' on either side of line shown on map. Dashed contacts are accurate to within about 250', and are generally gradational.

Narrow channel, generally <100 ft in width; dashed where approximate.

A — A' Cross section location

☆ Location of radiocarbon age date reported in Atwater (1982).

W 1937 — Water; date indicates year of historical dataset.

C — Canal, circa 1937.

Geologic Units

	Unit	Description
	L	Levee (made of artificial fill), circa 1937.
HISTORICAL	Rob	Overbank deposits; silt, clay, and lesser sand; 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.
	Rdf	Distributary fan deposits; sand, silt and clay laid by distributary channels.
	Rch	Channel deposits; well-sorted sand, silt, clay, and trace scattered fine gravel.
	Rb	Channel bar deposits; fine gravel, sand, and silt deposited in or along channel lateral margins.
	Rdc	Distributary channel deposits, sand, silt, and clay; channelized flow conducting sediment to floodplain.
	Rofc	Overflow channel deposits; sand, silt, and clay deposited in floodplain channels occupied primarily when high-stage water overtops channel banks and returns to river.
	Rsl	Slough deposits; silt, clay, and sand, fining upward facies, low-energy channel deposits.
	Rpm	Tidal marsh deposits; peat and muck, interbedded peat and organic-rich silt and clay.
HOLOCENE	Hob	Overbank deposits; silt, clay, and lesser sand; 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.
	Hch	Channel deposits; poorly graded sand and trace fine gravel.
	Hdc	Distributary channel deposits, sand, silt, and clay; channelized flow conducting sediment to floodplain.
	Hsl	Slough deposits; silt, clay, and trace fine sand, fining upward facies, low-energy tidally or formerly tidally influenced channel deposits.
	Hpm	Peat and muck; interbedded peat and organic-rich silt and clay, former tidal marsh deposits, now drained and farmed.
	Hn	Basin deposits; fine sand, silt and clay.
	Hs	Marsh deposits; silt and clay, possibly with organic-rich beds; perennially or seasonally submerged, as shown by bush symbols on early USGS topographic maps, or where appear inundated or saturated on 1937 photos.
PLEISTOCENE	Qe	Eolian deposits; poorly to moderately cemented sand and silt.

Stratigraphic Correlation Chart

Time: Epoch	Channel deposits	Floodplain and alluvial-fan deposits	Flood basin deposits	Cultural deposits
Historical	Rch; Rb, Rdc; Rofc, Rsl	Ra; Rob; Rcs, Rdf	Hn, Hs; Rpm	L
Holocene	Hch; Hsl; Hdc	Ha; Hob; Hcs	Hn, Hs; Hpm	
Pleistocene		Qe		

(Depositional Environment)

Map projection: UTM NAD83 Zone 10N

Topographic base USGS 7.5' quadrangles:
Bruceville (ID: 38121-C4), published 1968, revised 1980; map scale 1:24,000, five foot contour interval.
Courtland (ID: 38121-C5), published 1978, revised 1993; map scale 1:24,000, five foot contour interval.
Isleton (ID: 38121-B5), published 1978, revised 1993; map scale 1:24,000, five foot contour interval.
Liberty Island (ID: 38121-C6), published 1978, revised 1993; map scale 1:24,000, five foot contour interval.
Rio Vista (ID: 38121-B6), published 1978, revised 1993; map scale 1:24,000, five foot contour interval.
Thornton (ID: 38121-B4), published 1978; map scale 1:24,000, five foot contour interval.

Geologic Mapping by S. Dee, G. Van Etten, A. Wade
Digital Cartography by M. Ticci and J. Finley

N

0 — 2,000 ft
0 — 1 km
1:24,000

Scale is 1 in = 2,000 ft when printed at 23 inch by 30 inch page size

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS
in association with:
Fugro William Lettis & Associates, Inc.

Surficial Geologic Map of South of Courtland Study Area

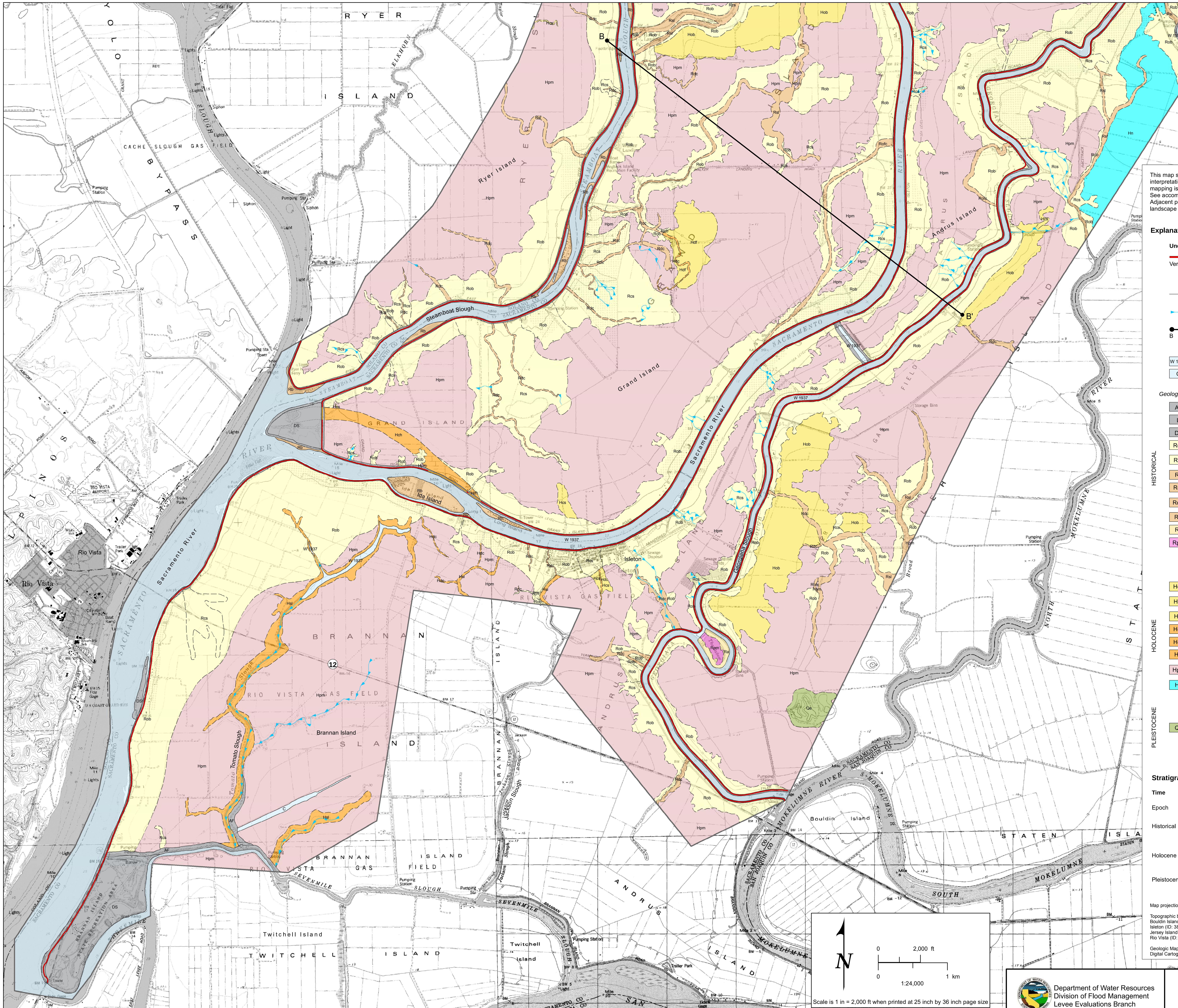
NORTH NON-URBAN LEVEE EVALUATIONS

Plate 1

Sheet 1

NULE Level 2-II: Group B Levees Geomorphic Assessment

1965_2_NULE_GroupB_Plate_North.mxd MGT 12/21/10



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). 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 (not present in Plate 2)	Low (not present in this Study Area)

Geologic contact; dashed where approximate, dotted where concealed, queried where uncertain; solid contacts accurate to within about 100' on either side of line shown on map. Dashed contacts accurate to within about 250', and are generally gradational.

Narrow channel, generally <100 ft in width; dashed where approximate.

B — B' Cross section location

W 1937 — Water; date indicates year of historical dataset.

C — Canal, circa 1937.

Geologic Units

	Unit	Description
	AF	Artificial fill, circa 1937.
	L	Levee (made of artificial fill), circa 1937.
	DS	Dredge spoils; material from channel dredging and typically hydraulically emplaced.
HISTORICAL	Rob	Overbank deposits; silt, clay, and lesser sand; deposited during high-stage water flow, overtopping channel banks.
HISTORICAL	Rcs	Crevasse splay deposits; fine sand and silt with clay deposited from breaching of natural or artificial levees.
HISTORICAL	Rb	Channel bar deposits; fine gravel, sand, and silt deposited in or along channel lateral margins.
HISTORICAL	Rdc	Distributary channel deposits, sand, silt, and clay; channelized flow conducting sediment to floodplain.
HISTORICAL	Rofc	Overflow channel deposits; sand, silt, and clay deposited in floodplain channels occupied primarily when high-stage water overtops channel banks and returns to river.
HISTORICAL	Rsl	Slough deposits; silt, clay, and sand, fining upward facies, low-energy channel deposits.
HISTORICAL	Ra	Alluvial deposits undifferentiated; sand, silt, and minor lenses of fine gravel.
HISTORICAL	Rpm	Tidal marsh deposits; peat and muck, interbedded peat and organic-rich silt and clay.
HOLOCENE	Hob	Overbank deposits; silt, clay, and lesser sand; deposited during high-stage water flow, overtopping channel banks.
HOLOCENE	Hcs	Crevasse splay deposits; fine sand and silt with clay deposited from breaching of natural levees.
HOLOCENE	Hdf	Distributary fan deposits; sand, silt and clay.
HOLOCENE	Hch	Channel deposits; poorly graded sand and trace fine gravel.
HOLOCENE	Hdc	Distributary channel deposits, sand, silt, and clay; channelized flow conducting sediment to floodplain.
HOLOCENE	Hsl	Slough deposits; silt, clay, and trace fine sand, fining upward facies, low-energy tidally or formerly tidally influenced channel deposits.
HOLOCENE	Hpm	Peat and muck; interbedded peat and organic-rich silt and clay, former tidal marsh deposits, now drained and farmed.
HOLOCENE	Hn	Basin deposits; fine sand, silt and clay.
PLEISTOCENE	Qe	Eolian deposits; poorly to moderately cemented sand and silt.

Stratigraphic Correlation Chart

Time (Epoch)	Channel deposits	Floodplain and alluvial-fan deposits	Flood basin deposits	Cultural deposits
Historical	Rch; Rb, Rdc, Rofc, Rsl	Ra; Rob, Rcs	Hn; Rpm	L, AF, DS
Holocene	Hch; Hsl, Hdc	Ha; Hob, Hcs, Hdf	Hn; Hpm	
Pleistocene		Qe		

Map projection: UTM NAD83 Zone 10N

Topographic base USGS 7.5' quadrangles:
Bouldin Island (ID: 38121-A5), published 1997; map scale 1:24,000, five foot contour interval.
Isleton (ID: 38121-B5), published 1978, revised 1993; map scale 1:24,000, five foot contour interval.
Jersey Island (ID: 38121-A6), published 1978; map scale 1:24,000, five foot contour interval.
Rio Vista (ID: 38121-B6), published 1978, revised 1993; map scale 1:24,000, five foot contour interval.

Geologic Mapping by S. Dee, G. Van Etten, A. Wade
Digital Cartography by M. Ticci and J. Finley

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS in association with: Fugro William Lettis & Associates, Inc.

Surficial Geologic Map of South of Courtland Study Area

NORTH NON-URBAN LEVEE EVALUATIONS

Plate 1

Sheet 2

NULE Level 2-II: Group B Levees Geomorphic Assessment

1965_2_NULE_GroupB_Plate_South.mxd MGT 12/21/10

TECHNICAL MEMORANDUM

Level 2-I Geomorphic Assessment North NULE Area

Non-Urban Levee Evaluations Project
Contract 4600008101

April 2010

Prepared for:

DEPARTMENT OF WATER RESOURCES
Division of Flood Management
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Tables

Figures

Figures

Appendices

Acronyms and Abbreviations

Term	**Description**
CBDC	Colusa Basin Drainage Canal
CLD	California Levee Database
CVFPP	Central Valley Flood Protection Plan
DWR	Department of Water Resources (California)
GER	Geotechnical Evaluation Report
GIS	geographic information system
HSG	hydrologic soil groups
KLRC	Knights Landing Ridge Cut
NRCS	National Resource Conservation Service
NULE	Non-Urban Levee Evaluations Project
POI	point of interest
RCE	Resource Consultants & Engineers, Inc.
RMS	root mean square
SPT	standard penetration test
SSURGO	Soil Survey Geographic

Acronyms and Abbreviations

Term	Description
UC	University of California
ULE	Urban Levee Geotechnical Evaluations Program
URS	URS Corporation
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WET	Water Engineering and Technology
WLA	William Lettis & Associates

1.0 EXECUTIVE SUMMARY

The California Department of Water Resources' (DWR) Non-Urban Levee Evaluations (NULE) Project evaluates over 1,300 miles of non-urban state/federal Project levees and over 400 miles of appurtenant non-urban non-Project levees. URS Corporation (URS), under the North NULE Project contract with DWR, is in the process of evaluating over 810 miles of state/federal Project levees and 90 miles of non-Project levees in the north portion of the study area covering the Sacramento Flood Control System. Kleinfelder, Inc., under the South NULE Project contract with DWR, is in the process of evaluating the remaining non-urban levees in the southern portion of the study area covering the San Joaquin River Flood Control System.

Geomorphic analyses for the NULE project consist of two main levels (Level 1 and Level 2) and are part of Phase 1 geotechnical evaluation for the NULE project. Level 1 geomorphic analysis was completed in October, 2008, and provided a reconnaissance-level assessment of geomorphic domains and characteristics in the Northern NULE study area with respect to underseepage hazard. Level 2 analyses consist of two tiers (Level 2-I and Level 2-II). Level 2-I provides additional technical detail to improve and supersede Level 1 analysis results and provides a technical basis for recommending additional, more detailed geomorphic analysis and assessment. Level 2-I mapping is based primarily on the compilation and analysis of existing regional geologic and geomorphic information (e.g., soil survey maps, geologic maps). The North NULE Level 2-1 Geomorphic Assessment was completed December 23, 2009. Level 2-II studies yield detailed geologic and geomorphic information for use during future levee assessments.

Level 2-I analyses provide geologic and geomorphic maps at a regional scale, provide preliminary assessments of the hazard of levee underseepage and also provide information on soft soil areas and subsidence. The technical approach for geomorphic analysis in the North and South NULE areas is coordinated to develop consistent analytical results over the entire NULE region. Level 2-I analyses assess regional levee underseepage susceptibility via a criteria matrix based on existing geologic and soil data using a consistent framework applied to both North and South NULE areas.

Maps of underseepage susceptibility generated by Level 2-I analysis are being used during the selection of areas for additional, more detailed geomorphic or geotechnical analyses. Selection is based on several factors as outlined in the NULE work flow process chart. Regional underseepage susceptibility maps developed as part of Level 2-I analysis also will be used as screening tools to develop preliminary geotechnical analysis or exploration plans.

The Level 2-I approach is based on the principle that analysis and interpretation of existing geologic and geomorphic mapping can provide a regional assessment of underseepage susceptibility for NULE levees throughout the Central Valley. The map scale of 1:62,500 is chosen because it is between the reconnaissance-style Level 1 1:100,000 map scale and the Urban Levee Evaluation (ULE) project mapping or NULE Level 2-II studies map scale of 1:24,000.

Underseepage hazard for the NULE levees is assessed via an underseepage susceptibility map in which levee segments are assigned a susceptibility class. Susceptibility classes are assigned using a matrix involving several geologic and geomorphic criteria. The criteria matrix combines information about Quaternary geologic deposits, channel features mapped from historical topographic maps, and National Resource Conservation Service (NRCS) hydrologic soil groups (HSG). Input data are imported into a GIS and spatially analyzed with North NULE levee lines; susceptibility categories (very high, high, moderate, and low) are assigned to levee lengths according to the criteria matrix. In areas previously mapped for the ULE project, or in future North NULE Level 2-II mapping, susceptibility classes are assigned using a one-to-one correlation between an underseepage susceptibility class and the detailed geologic map unit.

Because the Sacramento Valley is large and contains many miles of levees, it is subdivided into geomorphic domains having relatively consistent characteristics. Primary geomorphic domains include: older and younger alluvial fans, river floodplains and their natural levees, alluvial flood basins, and the Sacramento-San Joaquin Delta. Within each domain are individual geologic deposits that possess certain lithologic or soil characteristics. Much of the North NULE levees overlie geologic deposits belonging to natural levee or flood basin domains.

Level 2-I geomorphic analyses result in a series of maps delineating interpreted foundation susceptibility to underseepage. The Level 2-I study confirms the conceptual model of geomorphic domains generated for the Level 1 study, but improves the model's level of detail and available information. Within the North NULE area, 14 percent of the non-urban levee lengths are assessed to have very high underseepage susceptibility (128 miles); 50 percent are assessed to have high underseepage susceptibility (459 miles); 10 percent are assessed to have moderate underseepage susceptibility (89 miles); and 26 percent are assessed to have low underseepage susceptibility (237 miles).

Preliminary levee performance information developed in the North NULE area is analyzed to compare documented occurrences of underseepage to the mapped distribution of geologic deposits and susceptibility classes. The frequency of documented underseepage events (i.e., points per mile exposed) provide input for the assignment and testing of susceptibility classes to specific deposit types. In general, historical levee performance and interpreted underseepage susceptibility correlate.

This technical memorandum presents mapping and analyses for North NULE Project as well as non-Project levees, and supersedes the September, 2009 submittal that included only maps and analyses of non-urban Project levees in the North NULE area.

2.0 INTRODUCTION

2.1 DWR Levee Evaluations Program Overview

As an essential first step in providing improved flood protection for communities in California's Central Valley, DWR is conducting geotechnical evaluation of state/federal (Project) levees in the Sacramento and San Joaquin Flood Control Systems under the Levee Evaluations Program. This program supports the Central Valley Flood Protection Plan (CVFPP) and other flood management-related programs in evaluating state/federal Project levees and appurtenant non-Project levees. The Levee Evaluations Program also evaluates whether levees meet defined geotechnical criteria and, if appropriate, identifies remedial measures for meeting those criteria. Depending on the population protected by a particular levee, program evaluations are conducted under either the ULE Project or the NULE Project.

2.2 NULE Project Scope and Phasing

DWR's NULE Project is evaluating over 1,300 miles of non-urban state/federal Project levees and over 400 miles of appurtenant non-urban Non-project levees to assess whether they meet defined geotechnical criteria. The NULE Project will also, where needed, identify remedial measure(s) and develop corresponding cost estimates that may help identified levees to meet those criteria. URS, under the North NULE Project contract, is in the process of evaluating over 810 miles of state/federal Project levees and 90 miles of non-Project levees in the north portion of the study area covering the Sacramento Flood Control System. Kleinfelder, Inc., under the South NULE Project contract with DWR, is evaluating the non-urban levees in the southern portion of the study area covering the San Joaquin River Control System. URS also is contracted to provide technical oversight for the entire NULE project. Levees included in the North NULE project area are shown on Figure 1.

The NULE Project is being implemented in two major phases. The first phase consists of collecting levee historical and performance data, geomorphic studies, preliminary assessment of geotechnical performance of levees, and developing conceptual remediation alternatives and associated cost estimates. The second phase involves field explorations, additional geomorphic and geotechnical evaluations, refining remediation alternatives, refining cost estimates and preparing a Geotechnical Evaluation Report (GER).

Geomorphic analyses for the NULE Project consist of two main levels (Level 1 and Level 2). Level 1 geomorphic analysis was completed on October 21, 2008, and provided a reconnaissance-level assessment of geomorphic characteristics in the Northern NULE study area with respect to underseepage hazard. Level 2 analyses consist of two tiers: Level 2-I and Level 2-II. Level 2 analyses provide additional technical detail to improve and supersede Level 1 analyses and provide a technical basis to recommend locations for additional, more detailed geomorphic analysis and assessment that will occur as part of Level 2-II analysis. Level 2-I analysis is primarily based on the compilation and analysis of existing regional information (e.g., soil survey maps, geologic maps). The North NULE Level 2-1 Geomorphic Assessment was completed December 23, 2009. North NULE Level 2-II studies are developing original, detailed information and analysis based on interpretations of early aerial photography, early historical topographic maps and other available data.

An understanding of alluvial processes and recognizing deposits and depositional environments in the geologic record is important for identifying locations along levees where underseepage is most likely to occur (Llopis et al., 2007). This Level 2-I geomorphic assessment focuses on an analysis of surficial geologic deposits, including soils developed on those deposits, and their relationship with documented past levee performance history to assess levee foundation susceptibility to underseepage.

Geomorphology and surficial geology are intimately related to this understanding because sediments in the NULE Project study area are deposited (and landforms are constructed or modified) by rivers and streams during flow events over hundreds to thousands of years. The dominant geologic processes of the last several tens of thousands of years (e.g., climate fluctuations, base-level rise and fall, changes in sediment supply) drive fluvial geomorphic responses (e.g., aggradation, incision, changes in stream gradient) that in total result in the present-day suite of geologic deposits and geomorphic landforms (Shlemon, 1967).

2.3 Geomorphic Assessment Purpose

The primary purpose of Level 2-I analysis is to assess, on a regional scale, the hazard of levee underseepage. Level 2-I analyses also delineate areas of potential soft soils and ground subsidence. The Level 2-I study relies on the compilation and interpretation of existing data. The technical approach for geomorphic analysis in the North and South NULE Project areas was coordinated to develop consistent analysis results over the entire NULE region. Level 2-I analyses assess regional levee underseepage susceptibility via a criteria matrix based on existing geologic and soil data using a consistent framework applied to the North and South NULE areas.

This technical memorandum presents map figures at 1:62,500-scale. However, the primary product from this Level 2-I analysis is a geographic information system (GIS) database that can be analyzed or queried by other members of the NULE Project team beyond this geomorphic assessment.

Level 2-I maps of underseepage susceptibility can be used during selection of critical levee areas for additional, more detailed geomorphic or geotechnical analyses. The development of regional underseepage susceptibility maps satisfies the geomorphic assessment objectives noted above, and these maps also can be used as screening tools to develop geotechnical analysis, exploration plans, remedial alternatives, or cost estimates.

2.4 Geomorphic Assessment Scope of Work

The scope of work for this Level 2-I analysis was developed to complete a regional geomorphic assessment of the North NULE study area. This study established a foundation for future, more-focused geomorphic analyses for the Northern NULE area.

The scope of work for Level 2-I study is:

1. Compiling existing geologic and soils mapping
2. Developing a criteria matrix
3. Mapping levee underseepage susceptibility

4. Preparing a technical report and GIS database

The Level 2-I assessment is based primarily on compiling and analyzing geologic data collected during the Level 1 data collection task. To add detail relevant to underseepage hazard where only regional geologic mapping was available, channel features and water bodies adjacent to existing non-urban levees are mapped from historical topographic maps and digitized as part of the Level 2-I geologic compilation. The analysis includes development of a criteria matrix that assigns relative susceptibility categories (very high, high, moderate, low) to levees based on combinations of geologic unit and soil type present beneath the levees.

2.5 North NULE Project Study Area

The North NULE Project study area lies in the broad Sacramento Valley comprising the northern third of California's 350-mile-long Central Valley. The study area includes non-urban Project and non-Project levees that extend as far north as Red Bluff, and as far south as the Sacramento-San Joaquin Delta (Figure 1).

2.6 General Geologic and Geomorphic Setting

The Sacramento Valley is bordered on the west by the Coast Range, on the north by the Cascade Range, and on the east by the Sierra Nevada (Figure 1). The valley is low in elevation and has little relief with the exception of Sutter Buttes, a volcanic plug that rises 2,000 feet above the valley floor. Alluvial fans flank the margin of the valley and consist of topographically higher, geologically older and erosionally dissected surfaces, and topographically lower, younger and less dissected alluvial plains. Two major rivers traverse the Sacramento Valley floor flowing from north to south: the Sacramento River and the Feather River (Figure 1). These rivers and their tributaries drain the entire Sacramento Valley and, prior to construction of modern flood control features (dams, levees), provided floodwater and sediment into adjacent, topographically-lower flood basins during times of large runoff. The rivers are separated from the flood basins by natural levees adjacent to the river. Natural levees are low ridges built of sandy and silty sediment deposited during flood-stage conditions. They are highest adjacent to the river and slope gently away from the river toward the flood basins.

Riverine deposits in the Central Valley are highly variable, although relatively homogeneous flood basin deposits underlie large areas. The western margin of the valley is bordered by east-sloping alluvial fans derived from watersheds in the Coast Range; west-sloping alluvial fans derived from the Sierra Nevada and the southernmost part of the Cascade Range border the eastern valley margin. These alluvial fans are highly variable and stratigraphically complex. At the southern end of the valley is the Sacramento-San Joaquin Delta, where salty water from the San Francisco Bay extends landward and mixes with fresh water and sediment carried by the Sacramento and San Joaquin Rivers. The Delta area is at about sea level, and consists of low elevation marsh islands separated by channels or sloughs. Because of their geomorphic position, Delta islands consist mostly of fine-grained sediment (silt and clay) intermixed and interbedded with organic-rich material (peat), and commonly overlie older granular deposits (USACE, 1987). The entire North NULE Project study area is highly variable, both as a region and locally within several smaller areas. This technical memorandum divides North NULE Project study areas into geomorphic domains in which overall stratigraphic characteristics may be relatively consistent (Figure 2).

3.0 APPROACH AND METHODOLOGY

Because North NULE levees are constructed on a wide variety of geologic deposits within a large region, the project team developed a regionally consistent approach for assessing underseepage susceptibility that relies on geology and geomorphology to characterize the materials likely underlying the levees. This geomorphic assessment considers landforms, related geologic deposits, characteristics of soils developed on those deposits, and the surficial landscape features that may influence the phenomena of underseepage or settlement.

3.1 General Approach and Methods

The Level 2-I assessment is based on the principle that analysis and interpretation of existing geologic and geomorphic mapping can provide a regional assessment of underseepage susceptibility for NULE levees. The 1:62,500 scale selected is between the reconnaissance–level Level 1 study's 1:100,000 scale, and the ULE project mapping or NULE Level 2-II studies' scale of 1:24,000. Most of the geologic data for the Level 2-I study were collected during the Level 1 data collection task and then compiled for Level 2-I study. In areas where 2007 and 2008 ULE project mapping areas overlapped NULE levees, the ULE 1:24,000-scale mapping is included in the compilation.

To add detail relevant to underseepage where existing mapping do not provide it, channel features and water bodies adjacent to existing non-urban levees are mapped from historical topographic maps and digitized as part of the Level 2-I geologic compilation. Channel features (and inferred coarse-grained deposits) are interpreted from early U.S. Geological Survey (USGS) 1:31,680 maps on the basis of topographic expression and morphology, or in the case of very small channels, the presence of a stream channel line on the map. Also included from the early topographic maps are abandoned meanders that typically lie landside of, or intersect present-day levees, as well as smaller (narrower) distributary or secondary channels. The smaller distributary channels likely also contain some unconsolidated granular material (Saucier, 1994), but this is an inference that requires confirmatory testing. Water features (e.g., marshes) also were mapped. Channels that are present within a 3,000-foot-wide band on either side of the present-day levee were mapped. Channel initiation points are located as precisely as possible given the scale and quality of the maps. For GIS analysis, widths of secondary channels are measured from original map data and single lines are buffered to develop a polygon of the appropriate width.

Underseepage hazard for the NULE levees is assessed via an underseepage susceptibility matrix in which levee segments are assigned a susceptibility class. Susceptibility classes are assigned using either this criteria matrix, or for areas covered by ULE mapping, an assignment table. The criteria matrix combines information about Quaternary geologic deposits, channel features mapped from historical topographic maps, and NRCS HSG (Appendix A). Data are imported into a GIS and spatially intersected with NULE levee lines; susceptibility categories were assigned to levee segments according to the cells in the matrix. Underseepage susceptibility category assignments were based on geologic age and depositional environment, as well as relative hydraulic conductivity. The assessment approach and categories are developed in coordination with the South NULE team to maintain consistent analytical results. For areas in the North NULE study area where HSG data do not exist, susceptibility is assigned based on the underlying geologic unit and comparison with adjacent soil types. Where detailed ULE mapping is available, susceptibility is assigned based on the underlying geologic unit using an assignment table.

The Level 2-I analysis also include a regional assessment of soil settlement and ground subsidence. Subsidence is a lowering of land surface elevation with respect to a fixed datum, and may be caused by natural or human-induced processes. Subsidence may occur as a result of sediment pore fluid extraction (e.g., subsurface fluid or water mining) or from deformation related to deep-seated tectonic processes (Harwood and Helley, 1987). Many of the floodways, levees and canals of the Sacramento Valley traverse long distances with very gentle gradients, and may be strongly affected by small subsidence-related elevation changes. Subsidence poses a hazard to a levee system by decreasing levee crest elevations, by differential settlement of the soil beneath the levee, or by changing local channel gradients, causing local aggradation (increasing flood stage) or degradation (erosion and undermining of levee foundations).

3.2 Data Sources

Basic relevant geomorphic data collected for the North NULE geomorphic assessment include:

- Early and modern USGS topographic maps, scales ranging from 1:24,000 to 1:100,000
- Early and modern soil survey maps of the Sacramento Valley published by the USDA, scales ranging from 1:24,000 to 1:250,000
- Early topographic maps of the Sacramento and Feather Rivers published by the California Debris Commission, variable scales, published 1909-1910
- 1937 black and white stereo-paired aerial photographs, approximately 1:20,000-scale
- Geologic and geomorphic maps and data published from 1981 to 2008, scales ranging from 1:20,000 to 1:62,500

A complete list of topographic map data sources is provided in Table 3-1. Geologic and soil data are listed and described in Subsections 3.2.1 through 3.2.6 below.

3.2.1 Available Geologic Mapping

Available geologic mapping is incorporated from the following sources:

- Helley and Harwood (1985)
- Atwater (1982)
- DWR Northern District (Buer, 1994)
- William Lettis & Associates (WLA) (2007, 2008)

The sources and extents of geologic map data are shown on Figure 3. Helley and Harwood (1985) map data were published at 1:62,500-scale, and later digitized by Jonathan Mulder (DWR Northern District) in GIS format. For the most part, Helley and Harwood mapping is incorporated without modification, with one important exception. Quaternary stream channel deposits (map unit Qsc) is merged with undifferentiated Quaternary alluvium (map unit Qa) south of the town of Colusa. There are substantial misalignments of the contact between these deposits, probably due to a combination of imprecision in the original maps and errors associated with converting paper maps to a digital format. These inaccuracies cause erroneous results in the susceptibility assessment and, for this reason, the two map units are merged.

Mapping by Atwater (1982) is compiled in the southern portion of the map area (Figure 3). These maps were developed at 1:24,000-scale, a more detailed scale then the Helley and Harwood (1985) maps. Map units by Atwater were correlated to Helley and Harwood mapping based on interpreted age, topographic position, and environment of deposition (Table 3-2). Where Atwater's map overlapped with Helley and Harwood's, Atwater's (1982) mapping is used.

Surficial geologic mapping by DWR's Northern District is incorporated along the Sacramento River north of Colusa (Buer, 1994). This mapping delineated surficial geologic deposits as well as historical margins of the Sacramento River meanders from 1896 through 1997. These channel maps were updated by DWR staff through 2006 primarily from topographic maps supplemented with aerial photography. The individually mapped channel margins are enveloped, and a new map unit, Sacramento River meanders topographic channels (SRtc), is added to the geologic layer in the GIS database.

Detailed surficial geologic mapping recently developed at 1:20,000 scale is included where available. This surficial geologic mapping was developed for the Urban Levee Geotechnical Evaluations (ULE) Program (WLA, 2007; 2008) based on analysis of early aerial photographs, topographic and soil maps. This ULE mapping is used wherever it overlapped with NULE levee studies (Figure 3) in lieu of Helley and Harwood (1985) or Atwater (1981). A correlation of the surficial geologic map units to Helley and Harwood (1985), Atwater (1981), and Buer (1994) is presented in Table 3-2.

3.2.2 NRCS Soil Survey Maps and Data

Both historical and modern soil survey data are evaluated. Early soil map data for the entire Sacramento Valley were compiled by Holmes et al. (1913), which provides a regional distribution of soil types. Modern soil data at a detailed 1:24,000 scale were obtained for the North NULE Project study area from the NRCS soil survey maps and data. These data are provided as GIS files and databases, are mapped by county, and are distributed as a Soil Survey Geographic (SSURGO) Database (Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture [USDA]). These digital files were downloaded from *http://soildatamart.nrcs.usda.gov* in October 2008. Counties and publication dates included with the soil data for North NULE Project study area are listed in Table 3-3.

The soil map units are grouped by HSG using a GIS tool for underseepage susceptibility analysis. The soil data layers from SSURGO are GIS shape files are based on soil mapping units. Each soil mapping unit is assigned to a particular HSG: A, B, C, or D. For example, soils in group A (gravels and sands) are characterized by rapid infiltration (i.e., > 0.001 cm/sec), and those in group D (clays) by very slow infiltration (e.g., < 0.00004 cm/sec). Detailed documentation about NRCS HSG assignments is provided in Appendix A.

3.2.3 Historical Topographic Maps

Early topographic maps (1895 to 1923) were obtained as full-size digital scans from Chico State University's Merriam Library and the UC Berkeley Library. Fifty-four topographic maps have been compiled and spatially geo-referenced into GIS. Table 3-1 lists the individual maps collected, map scales, original and modern quadrangle names, survey date, publication date, year reprinted (if any), and root mean square (RMS) error in meters associated with the georeferencing process. RMS error is a measure of the accuracy of a map's spatial registration in GIS. An RMS value represents the average registration error (1-sigma) of the ground control points associated with each historical image as calculated in GIS during the georeferencing process. The magnitude of uncertainty via the RMS and the delineated channel positions reflect inherent inaccuracy in the original unreferenced dataset. Large RMS error values indicate poor spatial registration; small RMS values indicate more accurate spatial registration.

Historical topographic maps provide information about the features at or near the ground surface prior to present-day agricultural modification of the land. These data also depict the presence of channels or smaller water courses that may have been obliterated or obscured by land reclamation or development.

3.2.4 Historical Documents

Historical documents collected and reviewed for this study include geomorphic reports completed for the U.S. Army Corps of Engineers (USACE) Sacramento District (RCE, 1992; WET, 1990, 1991), geomorphic reports completed by the USGS (Brice, 1977), and regional hydrogeologic reports (Bryan, 1923; Olmstead and Davis, 1961).

3.2.5 Aerial Photography and Imagery

Black and white stereo-paired aerial photographs taken in 1937 were obtained from the National Archives in Washington, D.C. via private vendor services. These photos cover the extent of the non-urban Levees in the North NULE Project study area. These aerial photographs were visually inspected when necessary to assist with analysis but interpretive mapping was not developed from these data for the Level 2-I study. These 1937 photographs were however relied upon in developing ULE Program maps (WLA 2007, 2008) that were incorporated into Level 2-I geologic compilation.

3.2.6 Levee Performance Database

Preliminary levee performance information developed for the North NULE Project study area is analyzed to compare documented occurrences of underseepage to the mapped distribution of geologic deposits. The frequency of documented underseepage occurrences provides verification of the assignment of susceptibility classes to specific deposit types.

Two historical levee performance databases in GIS format are used in this geomorphic assessment:

- California Levee Database (CLD) created by DWR, 2008. Period of observation is 1955 to 2007.

- Point of Interest data (POI) collected by North NULE team, January, 2009. Period of observation is 1926 to 2008.

The maximum period of record in the databases extends at least 52 years. However, not all levees necessarily have received the same level of performance documentation over time and not all years in the record may have performance recordings (e.g., drought years). Many of the database's entries are from observations made in the 1980s and 1990s.

For this geomorphic assessment, performance data are combined and edited to create a single performance database containing documented occurrences of seepage, boils, and probable seepage-related failures. These performance data are considered preliminary and are subject to change based on additional quality checks or new information. Analysis based on these performance data for this geomorphic assessment are thus preliminary in nature. However, the North NULE Project team considers the data sufficiently complete to analyze.

Levee performance data consist of on-the-ground observations typically made by Reclamation District staff and Maintenance Area personnel. Some observations were made during routine inspections and others were made as a response to prolonged high flow conditions. Some performance records were documented via levee repair applications. Because the databases contain a variety of levee distress classes and events (e.g., erosion, overtopping, sand boils), the POI database and the CLD were filtered to reflect data that are attributable or likely related to underseepage alone. The specific types of information used from each database are described below.

3.2.6.1 California Levee Database (CLD)

Only data points describing boils, seepage, and levee breaches likely attributable to the underseepage process were selected from the CLD. While boils are directly related to underseepage, the term "seepage" as used in the CLD is interpreted for the purposes of this assessment as representing levee underseepage.

In the CLD, many occurrences of levee failure are ascribed to erosion or overtopping processes and these are filtered out of analysis. Failures attributed to levee slumping mechanisms also are removed. Where levee failure observations lacked a description of the failure mechanism, it is assumed they are related to underseepage processes. This assumption is conservative as it may over-represent underseepage related failures; however additional justification from the data may not be forthcoming.

3.2.6.2 Point of Interest (POI) Database

The POI database includes both point and line-based observations. This analysis uses performance data from the POI database that was described as "seepage," "boil," or "breach, levee failure" only. As with the CLD data, where levee failure observations lacked a description of the failure mechanism, it is assumed they are related to underseepage processes.

3.2.6.3 Data Tabulation

The CLD database contains a variety of well- and poorly-attributed data in a point file. Analyses of these variable and diverse data required a combination of manual analysis and automated analysis in ArcGIS. Specifically, the CLD and POI point data were viewed onscreen along with the NULE underseepage susceptibility classes in ArcGIS; analysis was conducted onscreen. The spatial distribution and association of the levee performance data is analyzed with respect to underseepage susceptibility classes, HSG, and geologic map units. Results were reduced manually.

Performance data are tabulated by susceptibility class (very high, high, moderate, low). Next, the total number of performance points (occurrences) for each susceptibility class is divided by the number of levee miles in each susceptibility class (i.e., normalized by exposure). Line data are similarly normalized by dividing the number of miles affected by the levee miles of the susceptibility class, resulting in a percent of levee affected.

3.3 Data Gaps

Data gaps are conditions of missing or unavailable data, partial/incomplete data, or inadequate data. Data are considered missing if they were likely collected or produced at some time in the past, but could not be located at time of analysis. Data are considered unavailable if they were never collected or compiled in the first place, or if they were not collected. Incomplete or inadequate data are those data that exist and are available, but require improvement, refinement, or replacement with better information.

Specific data gaps identified through Level 2-I analysis include:

- Unavailable early 1:31,680 topographic maps
- Small-scale (1:62,500) geologic map data
- Preliminary status of levee performance case history data
- Absence of direct subsurface information on shallow stratigraphic conditions
- Lack of field verification of the sedimentologic characteristics within small channels identified through Level 2-I mapping

3.3.1.1 Unavailable Early Topographic Maps

A search for topographic map data was performed at the California State Archives, as well as at the UC Davis, UC Berkeley, and Chico State University libraries. Early 1:31,680-scale topographic maps were unavailable for the following 7.5-minute quadrangles:

- Vina (east side Sacramento River, near Red Bluff)
- Glenn (upper Sacramento River, west side)
- Colusa (near town of Colusa); Dunnigan (covers Colusa Drain)
- Vernon (covers Pleasant Grove Cross Canal and parts of Sacramento River, west side
- Taylor Monument (parts of Sacramento River, west side)
- Courtland (lower Sacramento River and sloughs)

Based on discussion with librarians and archive staff, it is likely these areas were never topographically mapped at 1:31,680 scale.

3.3.1.2 Small-Scale Geologic Map Data

Geologic map data covering a majority of the North NULE Project study area was published at 1:62,500 scale (Helley and Harwood, 1985), and are only of limited adequacy for the assessment of surficial and near-surface geologic deposits. Typical geologic hazard assessments (e.g., liquefaction hazard) rely on larger-scale map data that are commonly published at 1:24,000-scale. The 1:62,500-scale geologic data used in this study are a gap in the analytical data because the small scale limits precision, accuracy, and level of detail in mapping. These data exist and are available, but require improvement, refinement, or replacement with better (1:24,000 scale) map data and information.

3.3.1.3 No Direct Subsurface Information on Shallow Stratigraphic Conditions

Absence of direct subsurface information on shallow stratigraphic conditions (e.g., via geotechnical explorations) also is considered a data gap under Level 2-I geomorphic assessment. Once compiled, these data will help constrain and verify interpretations of foundation conditions beneath present-day levees, and would extend the ability to anticipate locations likely prone to underseepage processes. These data also are necessary to establish correlations across similar geologic deposits. Past subsurface exploration data may exist but may not have been collected or compiled by the NULE Project team.

3.3.1.4 Lack of Field Verification of Sedimentologic Characteristics

Field verification of the sedimentologic characteristics within small channels identified through Level 2-I mapping would improve and enhance understanding of the geologic and geotechnical characteristics of these features and deposits, and would refine assessment of their likely controls on underseepage processes. Field verification techniques could consist of hand auguring or sediment coring, shallow test pits, or shallow trenching.

3.4 Limitations of Analytical Procedures and Maps

Appropriate application of the information presented in this geomorphic assessment requires an understanding of the limitations of the analytical procedures used and resultant maps. The primary limitations fall into the following categories:

- Spatial inconsistency in the nature of available geologic, topographic, and soils data
- Limited precision of mapping due to the use of a regional scale (1:62,500)
- Inherent variability and complexity of geologic deposits
- Failure to account for factors – in addition to geologic materials – that may affect levee underseepage susceptibility

These limitations are discussed below.

Level 2-I mapping is a compilation and interpretation of geologic, topographic, and soils data developed by different workers at different times using different scales and covering different parts of the NULE Project study area. Geologic mapping schemes and styles differ among workers. This Level 2-I map compilation attempts to integrate all the various data into a unified mapping scheme, but the nature of the diverse source data is reflected in the final product. There are limitations with respect to the accuracy of the geomorphic data and to interpretations of hazard susceptibility.

The regional scale of the susceptibility mapping (1:62,500) limits data precision and the ability to show detail. This scale is selected to provide a reasonable balance between levels of detail and scope of analysis. At this scale, map unit boundaries are considered about 300 feet on either side of the line shown, or about two pencil widths at the 1:62,500 scale. It is important that Level 2-I maps and GIS files are not displayed or used at scales larger than 1:62,500, as this may introduce apparent inaccuracies or imply a greater level of detail or map precision than intended.

Because analysis is executed in a GIS environment, the effects of scale and the precision of input data merits further elaboration. Within the GIS, polygon lines (soil units or geologic contacts) are infinitely narrow; small discrepancies (over- and underlaps) between input data layers may produce local artifacts in susceptibility that are locally inaccurate. This effect is most pronounced when lines or contacts are sub-parallel or oblique to the levee. This effect is less obvious when contacts are oriented orthogonally to the levee. Underseepage susceptibility maps are presented at a scale of 1:62,500 (1 inch to about 1 mile), and the thickness of the levee line shown is equivalent to about 210-feet-width in real space. It is difficult to visually detect levee susceptibility segments that are shorter than about 0.5 mm on the figures (about 100 feet in real space).

Geologic deposits in the NULE Project study area have been deposited by rivers and streams during high flow events over hundreds to thousands of years. Each mapping unit is a composite of numerous smaller deposits, each of which may originate from a different flow event and each of which will be slightly different in characteristics from its neighbor. The underseepage susceptibility at specific locations within a given deposit is expected to vary spatially in unpredictable ways. Also, because this is a regional-level assessment, there may be unique or unusual site-specific conditions that are not captured by this analysis. The maps described in this Level 2-I assessment serve as guidance-level information for future, more detailed geomorphic and geotechnical analyses.

This geomorphic assessment focuses on geologic conditions that may affect levee underseepage. However, other factors affect levee underseepage, including water surface elevation and stage duration or biologic factors such as burrowing animals. The stability of levee materials, slope stability, levee erosion, and seismic performance factors are addressed by in-parallel geotechnical studies for the NULE Project. In addition, this study does not consider existing underseepage mitigation measures that may be planned along NULE levee systems or may already exist.

Interpretations of levee susceptibility do not necessarily reflect expectations of levee performance, and are not an evaluation of levee design suitability or future adequacy.

4.0 GEOLOGIC AND GEOMORPHIC DOMAINS

The previous Level 1 study provided a reconnaissance-level overview of the Sacramento Valley's geology and geomorphology. The technical approach for that study was based on the delineation of geomorphic domains, or areas within which surface and shallow subsurface features and deposits likely have similar characteristics due to similar geologic history and depositional processes. Development of these domains began with the collection and analysis of:

- Early and modern USGS topographic maps
- Early and modern USDA soil maps
- Early and modern geologic maps
- Other available scientific or engineering reports

Synthesis of these data provides a broad understanding of primary geomorphic processes active in the study area during recent geologic and historical time. Identification and characterization of these regional geomorphic domains is a first logical step toward assessing underseepage susceptibility in non-urban levees in the Sacramento Valley.

Because the Sacramento Valley is large and contains many miles of levees, the area is subdivided into geomorphic domains having relatively consistent characteristics (Figure 2). This section presents the criteria used for identifying geomorphic domains having similar foundation material characteristics.

This Level 2-I study employs three primary criteria for delineating geomorphic domains:

- Dominant geomorphic processes based on large-scale landforms and landscape relationships
- General texture (grain size) of the surficial materials (a proxy for permeability)
- General age of geologic deposits (a proxy for consolidation and permeability)

Geomorphic landforms and landscape relationships provide an indication of the dominant geomorphic processes and near-surface deposits. Primary geomorphic domains include older and younger alluvial fans, river floodplains and their natural levees, alluvial flood basins, and the Sacramento-San Joaquin Delta. These domains are further divided based on landscape position; for instance, alluvial fans and plains on the eastern side of the Central Valley differ from those on the western side, primarily as a result of the differences in source lithology, deposit texture, watershed size and relief, and glacial history.

Early regional soil maps (Mann et al., 1911; Strahorn et al., 1911; Holmes et al., 1913) provide basic data on the dominant texture of surficial materials, which is important because of the influence of grain size on soil permeability. These early soil maps help synthesize numerous county-specific soil surveys into a regionally consistent framework. Early maps do not depict some of the intricate soil relationships shown on modern maps. Soil textures in the North NULE Project study area generally include: gravelly loam, fine sand, sandy loam, silt loam, and clay. Other textures also are encountered in the area, and may locally be primary constituents.

The general age of a surficial geologic deposit provides a reasonable basis for assessing the density or consolidation of the deposit. Density generally describes geologic consolidation; older deposits tend to be more compacted, consolidated, or cemented than younger deposits, and so are commonly less permeable than younger deposits. In some instances, older geologic deposits may possess unique characteristics that could influence underseepage processes (e.g., laterally extensive, low-permeability duripan horizons). This Level 2-I analysis considers three primary geologic ages:

- Pliocene (between 5.3 million years to 1.6 million years old)
- Pleistocene (between less than 1.6 million years and 11,000 years)
- Holocene (less than 11,000 years)

Associated deposits are considered consolidated (Pliocene), semi-consolidated (Pleistocene), and unconsolidated (Holocene), respectively. At this very coarse scale of approximation, differences in lateral vs. vertical conductivity are ignored, but should be considered in future, more detailed analyses. Because of the large areal extent of the North NULE project and the approach using regional geomorphic domains as a screening tool, it is not appropriate to develop quantitative estimates of hydraulic conductivity for the domains at this scale.

The Sacramento Valley is subdivided into 11 geomorphic domains based on the characteristics of:

- Geologic age
- Environment of deposition
- Topographic position
- Geomorphic process
- Deposit grain size

Foundation materials most likely to be encountered beneath present-day levees are characterized within each domain on Table 4-1, and the anticipated variability in subsurface stratigraphy is also described. Foundation materials are characterized based on a synthesis of geologic and soils information; subsurface variability is inferred based on the dominant geomorphic processes within the domain that were likely in effect at, or immediately prior to, the time of levee construction. Subsurface stratigraphic variability is the homogeneity or heterogeneity of sedimentary beds or layers in the vertical direction, and the continuity or discontinuity of sedimentary beds or layers in the lateral direction. Subsurface stratigraphic variability is assessed based on the environment of deposition and geomorphic processes responsible for the deposit. Figure 4 conceptually illustrates some depositional environments (e.g., a flood basin). Figure 4 also conceptually illustrates lateral interfingering of discontinuous relationships in the subsurface (e.g., zig-zag contacts, isolated channel lenses) that likely contribute to stratigraphic variability.

The North NULE project area's geomorphic domains are described below. The domains are described in general order from north to south, and then in order of increasing distance away from the valley floor (i.e., from domains near the North NULE Project levees to older alluvial fans and foothill areas farther from the levees). A summary map of the domains is provided as Figure 2, and a schematic block diagram of general stratigraphic relationships is shown on Figure 4. Domain characteristics are summarized in Table 4-1.

4.1 Sacramento River Meander Belt (SRm)

The Sacramento River meander belt domain extends from the northern boundary of the study area near the town of Los Molinos downstream to the town of Colusa (Figure 2). The meander belt is a corridor within which the river channel is free to move laterally and longitudinally; it includes the present-day extent of the river meanders, meander scrolls, and point-bar deposits. The belt also includes abandoned meander scroll features and oxbow lakes that mark former positions of the Sacramento River (DWR, 1994). This geomorphic domain reflects the relatively steep channel gradient of the river between Hamilton City and Colusa. Geologic deposits within this domain are generally coarse-grained, consisting of cobbles, gravel, and sand, with lesser amounts of silt and clay (Schumm and Harvey, 1986). Because of the spatially variable position of the river through time, subsurface stratigraphy in this domain is highly variable (Table 4-1; WET, 1990) and is characterized by laterally discontinuous strata and abrupt vertical changes in grain size (e.g., coarse-grained buried channels, fine-grained oxbow lakes). Strata are unconsolidated, although cobble-rich strata may result in anomalously high standard penetration test blow counts. Bulk permeability is probably variable because of the variability in subsurface textures and distributions (DWR, 2006a), but overall, deposits within this domain are considered highly permeable. This domain ends at the marked change in the Sacramento River plan form at the town of Colusa, south of which the river channel becomes much narrower, and the meander belt pattern disappears (Figure 2). Historically, the river in this domain was fed by groundwater (i.e., it is a gaining stream; Bryan, 1923), and was characterized by an absence of a laterally extensive shallow low-permeability materials that would impede groundwater contributions to the river channel (e.g., a confining bed).

Presently, there are three flood relief structures in this domain, two of which are engineered weirs (DWR, 2003). The first structure occurs at the upstream end of the North NULE Project levee along the east (left) bank of the Sacramento River near the latitude of Glenn, California. Flood waters are allowed to escape over the east bank of the river and overflow into the Butte Basin. The other two structures are engineered weirs that serve a similar flood relief purpose: Moulton Weir and Colusa Weir. As such, the flood relief structures could have an influence on downstream water surface elevation and thus be a limiting hydraulic control on underseepage.

4.2 Sacramento River Floodplain and Natural Levees (SR)

Flanking the Sacramento River meander belt (SRm) north of Colusa and the river itself south of Colusa is the Sacramento River floodplain and natural levees domain (SR; Figure 2). This domain chiefly consists of overbank sediments laid down by flood flows and distributary channels of the Sacramento River. This domain extends along the length of the river, and as noted above, directly abuts the river from Colusa southward into the Delta. Broadly, the sediments comprising the floodplain and natural levee deposits consist of mixtures of sand, silt, and clay (Table 4-1, Holmes et al., 1913). Prominent distributary channels also possess natural levees, and include levees of Butte Slough and Sycamore Slough that are present near Colusa. The surficial deposits are late Holocene, unconsolidated, and sandy fluvially-laid sediment that are likely to be highly permeable (Olmstead and Davis, 1961; Helley and Harwood, 1985; WET, 1991). Anticipated subsurface variability in the natural levee deposits is moderate, meaning that there are probably grossly similar overall textures and compaction along the flank of the river in the upper 15 to 20 feet of soil within this domain. However, layers are probably laterally discontinuous. Sediments are bedded and may have layers from 2 to 5 feet thick. While there is site-specific lateral variability, the shallow subsurface stratigraphic relationships should be relatively basic. Historically, the river in this domain between Colusa and the latitude of Robbins (Figure 2) recharged the groundwater aquifer, meaning that the river bottom was slightly above the water table (i.e., it is a losing stream; Bryan, 1923).

4.3 Feather River Floodplain and Natural Levees (FR)

Similar to the Sacramento River, the Feather River floodplain and natural levees encompass and flank the channel of the Feather River. Within this domain (FR; Figure 2), the Feather River meanders in a wide valley entrenched into Pleistocene deposits. The river itself flows through Holocene deposits. The Feather River has less prominent natural levees and distributary channels compared to the Sacramento River. The Feather River and its tributaries were substantially impacted by gold mining activities in the late 1800s and early 1900s (Table 4-1). These activities, including hydraulic mining, introduced large quantities of sediment to the river in a short period of time, resulting in aggradation of the river bed and deposition of sediment derived from mining debris along the course of the river and the adjacent floodplain. The rapid deposition of coarse-grained sediment in a relatively high-energy environment over existing Holocene and older deposits resulted in substantial subsurface stratigraphic variability. The historical sediments are probably massive (not bedded), and may show an inverted stratigraphy where finer-grained silts (or slickens) are overlain by coarser-grained sediment. Surficial deposits are late Holocene, unconsolidated, and granular fluvially-laid sediments that likely are highly permeable (Olmstead and Davis, 1961).

4.4 Sierran Tributaries (ST)

Sierran tributaries are the principal west-flowing creeks that join either the Feather River or the Sacramento River south of its confluence with the Feather River (Figure 2). These tributaries include, from north to south, Honcut Creek, Yuba River, Bear River, and American River. Prior to 19th century human influence, these tributaries were narrow and incised into the adjacent, older alluvial deposits (Ellis, 1939). The tributaries were then substantially impacted by sediment derived from gold mining debris, resulting in aggradation of the channel beds. Historical flood events deposited this mining-derived sediment on the adjacent floodplain prior to the construction of the present-day levees (Ellis, 1939). The sediment in this domain is Holocene to historical, unconsolidated and coarse-grained (Helley and Harwood, 1985; Busacca et al., 1989), ranging from cobbles to sand and silt with high permeability (DWR, 2006b). Subsurface stratigraphic variability is probably high because of significant and rapid channel deposition, erosion and re-working of sediment derived from hydraulic mining activities. Based on the geologic history of Sierran tributaries (Shlemon, 1967), buried west-trending channels may be present in the subsurface. The present-day levee structures in this domain are oriented approximately parallel to the geomorphic fabric.

4.5 Flood Basins (FB)

The flood basin domain occupies the low lands on either side of the Sacramento River in broad and topographically low-relief areas between the river's natural levees and adjacent alluvial fans (Figure 2). During times of flood, these flood basins filled with water delivered by distributary creeks or channels from the river, or by shallow sheet flow passing over the river's natural levees creating slow moving inland seas. Five flood basins are recognized in the Sacramento Valley (Olmstead and Davis, 1961):

- Butte Basin
- Colusa Basin
- Sutter Basin
- Natomas (or American) Basin
- Yolo Basin

Because of the similarity in geomorphic process and geologic deposits, these basins are characterized as one generalized domain, but delineated as individual basins on Figure 2.

Deposition in the flood basins was from slow moving or standing water as opposed to channelized flow, so sediments are primarily silt and clay (Table 4-1). These deposits have low permeability (DWR, 2006a, c). However, these deposits also may be locally interbedded with higher-permeability stream deposits adjacent to the Sacramento River and lenses of sediment from alluvial fan lobes coming from west- or east-flowing streams in the Sierra Nevada and Coast Ranges (Figure 4). Flood basin deposits are unconsolidated and late Holocene in age (Helley and Harwood, 1985). Because of the relatively low-energy environment of deposition, the subsurface stratigraphy should at most places have low variability and relatively laterally-extensive deposits.

Two prominent natural levees extend into and over the Colusa flood basin deposits. The first is the natural levee of Sycamore Slough, a distributary channel of the Sacramento River (Figure 2). This channel ridge (natural levee) of silty and sandy sediment extends out across the clay soils of the basin. The present-day Colusa Drain and its associated levee traverse parts of the Sycamore Slough deposits. Sycamore Slough rejoins the Sacramento River directly north of Knight's Landing. It was funneled into the Sacramento River at this location because of the second natural levee, a channel ridge of Cache Creek Slough (Bryan, 1923; Olmstead and Davis, 1961). Cache Creek Slough is an abandoned arm of Cache Creek, and its channel ridges extend to the town of Colusa. This topographic feature separates Colusa Basin from the Yolo Basin to the south.

4.6 Sierra Nevada Fans (SNF)

Sierra Nevada fans consist of alluvial fans and terraces on the west side of the Sierra Nevada Range, and are divided into older and younger alluvial fans. The older fans (SNFo, generally Pliocene age) are topographically higher and exhibit erosional modification and dissection. Although coarse in grain size, older fan deposits (SNFo) are fairly consolidated and cemented (Marchand and Allwardt, 1981), with low to moderate permeability. Geologic units present in the SNFo domain include the Tertiary Laguna Formation, Mehrten

Formation, and Lovejoy basalt (Helley and Harwood, 1985). While older fans do not directly underlie the North NULE Project study area levees, their deposits probably are present in the subsurface beneath the younger alluvial deposits.

The younger alluvial fans and terraces (SNFy, generally late Pleistocene in age), are topographically lower and exhibit only moderate dissection. The younger alluvial fans are composed of Riverbank Formation and Modesto Formation deposits (Helley and Harwood, 1985), and each deposit contains one or more hardpan or duripan horizons at the top of the formation. Duripan horizons are silica-iron cemented zones, not more than 5 feet thick, which are laterally extensive and are of low permeability (Table 4-1). The Pleistocene deposits are semi-consolidated and possess a wide range of grain sizes from gravel to clay. They generally decrease in grain size with increasing distance from the foothills. Deposition in an alluvial fan environment is characterized by multiple erosional fan channels separated by depositional surfaces, as well as changing location of fan channels through time. It is likely there is wide lateral and vertical variability in the subsurface stratigraphy (e.g., buried paleochannels). With the exception of duripan or hardpan horizons, the Modesto Formation is likely moderate to highly permeable; the Riverbank Formation is likely low to moderately permeable (DWR, 2006b). Overall, the deposits within SNFy are considered highly variable in texture (grain size) and permeability.

4.7 Sierra Nevada Fan – Flood Basin (SNF-FB)

This domain is a transitional domain between the SNF and FB domains (Figure 2). It encompasses the gently southwest-sloping distal alluvial plain west of the Feather River and east of the Butte and Sutter Flood Basins. This domain contains Pleistocene and Holocene alluvium consisting of silt, sand, gravel and clay (Helley and Harwood, 1985). These southwest-dipping permeable alluvial deposits (Modesto Formation) are overlain by fine-grained flood basin deposits that may have extended as far upslope as 60 feet in elevation (Bryan, 1923). A veneer of fine-grained basin deposits overlies consolidated, sandier, older alluvial deposits and thickens toward the Butte and Sutter Basins but is overall thinner than flood basins to the south (e.g., Yolo Basin). Early soil maps depict this area as Stockton clay loam and clay adobe (black soils over heavy yellow subsoils) and Madera clay loam (dark grey soils with a somewhat thin duripan horizon (Holmes et al., 1913). Deposit permeability within this domain is layered, based on general surficial soil texture and underlying strata. Finer-grained basin deposits overlie coarser-grained strata of older alluvial fans, and the surficial deposits are substantially less permeable than the underlying fan deposits (perhaps constituting a geotechnical blanket layer). Subsurface stratigraphic variability may be moderate (Table 4-1) because the basin deposits overlie eroded fan deposits. The present-day levee structures in this domain are oriented approximately perpendicular to the geomorphic fabric.

4.8 Coast Range Fans (CRF)

The Coast Range fan domain consists of alluvial fans and low alluvial plains on the western side of the Sacramento Valley, between the uplands of the Coast Range and the flood basins of the Sacramento River (Figure 2). Along the range front, the fans coalesce and interfan boundaries are not discrete. The alluvial fan sediments are composed of relatively fine-grained, weathered clastic materials eroded from weak shales, sandstones, and low-grade metamorphic rocks of the eastern Coast Ranges. Much of the soil textures at the surface of the Coast Range fans are loams, clay loams, and clay (Table 4-1; Holmes et al., 1913). Coast Range fan deposits are proximal to the Sacramento River floodplain in two areas: at the north end of the study area near Stony Creek, and near the middle of the study area near Knight's Landing (Cache Creek alluvial fan). While the Stony Creek alluvial fan surface is chiefly fine grained, the creek proper transports sand and gravel-sized sediment and conveys it to the Sacramento River (Schumm and Harvey, 1986). Moreover, alluvial deposits underlying the Stony Creek fan are substantially coarse-grained (Page, 1986).

Coast Range fan deposits include a complex arrangement of Pleistocene and Holocene alluvial deposits. Surficial deposits are abundantly silt and silty clay, and were probably transported as mudflows before deposition on the alluvial fan surface. Coast Range fans are coarser-grained upslope (i.e., gravels and sands) and finer-grained downslope (i.e., silts and clays). Natural levee deposits (channel ridges) are present on the larger alluvial fans like Cache Creek, Putah Creek, Petroleum Creek, and Cortina Creek. The deposits adjacent to these creeks are Holocene and unconsolidated alluvium (map unit Qa of Helley and Harwood, 1985). Based on previous studies in the Woodland and Davis areas (WLA, 2008a, b), subsurface stratigraphy is moderately variable with lenses or lobes of coarser-grained deposits in the subsurface from past positions of the fan distributary channels. The lobes typically are localized in extent, typically elongate in the down-fan direction (west to east), and lenticular in the cross-fan direction (north to south, Figure 4). The geomorphic fabric generally trends eastward, and the North NULE Project study area levees lie parallel to this fabric (e.g., a levee along Cache Creek north bank), as well as perpendicular to this fabric (e.g., a western levee of the Yolo Bypass). Overall, the permeability of the deposits in this domain varies and range from low to high.

4.9 Sutter Buttes Fans (SBF)

Sutter Buttes fans emanate from the Sutter Buttes uplands, and form an apron of sediment that surrounds the roughly circular remnant volcanic dome (Figure 2). The fans are dominantly Pleistocene (Helley and Harwood, 1985), and may be semi-consolidated. The Sutter Buttes' alluvial deposits consist of fine gravel, sand, silt and clay (DWR, 2006c) derived from erosion, reworking, and transport of the volcanic rocks that form the Buttes. Although the North NULE Project levees do not directly overlie these fans, fan deposits probably extend laterally away from the Buttes in the subsurface, and may interfinger or underlie parts of the adjacent flood basin. Stratigraphic variability of the Sutter Buttes fans is probably moderate to high based on their proximity to the source area and dynamic nature of alluvial fan deposition processes. Deposit permeability in SBF likely ranges from low to high, and is extremely variable from place to place (Olmstead and Davis, 1961).

4.10 Cascade Range Fan (CF)

Cascade Range fans consist of alluvial surfaces located on the west side of the Cascades (Figure 2). These are divided into older and younger surfaces. Pleistocene alluvial fan surfaces (CFo) are restricted to the foothills region, are consolidated and are relatively coarse grained (Helley and Harwood, 1985). Holocene alluvial fans (CFy) are present generally west and south of the town of Chico, and were deposited by Little Chico Creek, Chico Creek, and Butte Creek. The creek channels are relatively deep and narrow, generally less than 50 feet wide and less than 25 feet deep (Bryan, 1923). The channels transport coarse-grained material although the fan surface itself consists chiefly of fine sand and sandy silt deposited during the overflow of the creeks (Holmes et al., 1913). Deposit permeability in this domain likely ranges from low to high (Olmstead and Davis, 1961). The variability of the subsurface stratigraphy is moderate based on the environment and deposition process.

4.11 Delta (D)

The Delta geomorphic domain is at the southern end of the study area (Figure 2). This domain consists of islands separated by fluvial channels and tidal sloughs that, prior to construction of artificial levees and dredge cuts, were intimately connected with fluvial and estuarine hydrology and sediment fluxes. The islands are saucer-shaped in cross section, and possess elevated flanks consisting of silt and loam from overflow of the directly-adjacent channels and sloughs. At a few feet above and below sea level prior to reclamation, the central part of the islands was covered by peat originally formed from decaying vegetation. Delta island deposits are late Holocene, unconsolidated and fine-grained muck (organic-rich silt and clay with high water content) and peat (Atwater, 1982). Because of the relatively uniform processes of delta island construction, and the relatively low-energy environment of deposition, the anticipated subsurface stratigraphic variability within this domain is probably low (Table 4-1). Directly adjacent to the watercourses, Sacramento River supratidal alluvium and sloughs overlie Delta islands peat and mud (Atwater, 1982). The alluvium forms natural levee ridges paralleling the river and distributary sloughs that extend into the Delta domain (Figure 2). Because the present-day artificial levees are constructed on the banks of the river and distributary sloughs, most of them rest on the natural levee deposits, and only locally do they rest on peat and mud deposits. Natural levee deposits and peat and mud deposits interfinger in the subsurface, creating vertical interbeds of silt and sand with organic-rich material. The deposits in the Delta domain are moderately permeable, with peat conservatively considered more abundant and more permeable than clay. The percentage of organic material (peat) is highest near the center of the Delta, and decreases in the direction of higher elevations of the delta rim (Atwater, 1982).

5.0 GEOMORPHIC ASSESSMENT AND ANALYSIS

This section summarizes NULE Project Level 2-I geomorphic assessment and analysis results. It describes the geologic mapping and characteristics of the major map units and the analysis of underseepage, settlement, and subsidence hazards for the north NULE Project study area.

Intermediate in detail compared to the previous Level 1 study and the anticipated Level 2-II studies, this Level 2-I geomorphic assessment relies on the compilation and interpretation of existing data to produce a map of the entire NULE study area. Future, more focused Level 2-II studies will be undertaken at selected areas to develop a more detailed analysis of levee foundation materials in the North NULE Project study area (Figure 5).

5.1 Geomorphic and Surficial Geologic Analysis

This section provides a description of the existing mapping used for analysis and a brief characterization of major map units. This is the basis of the framework applied to develop the underseepage susceptibility matrix and assignments.

Level 2-I analysis results are shown on susceptibility maps as described in Section 3.0 These maps are a compilation and interpretation of existing published and unpublished data. Most geologic units are compiled from previous mapping of Quaternary geology. The Level 2-I study generally confirms the conceptual model of geomorphic domains generated during the Level 1 study. Via Level 2-I assessment, geologic detail is added that enables an analysis of underseepage hazard for specific NULE levees.

5.1.1 Geology and Geomorphology

Existing geologic maps used in this study (Atwater, 1982; Helley and Harwood, 1985; DWR, 1994) recognize individual map units within five main depositional environments: flood plain, flood basin, alluvial fan, Delta, and channel. Much of the North NULE levees overlie flood plain or flood basin deposits (Table 4-1). Existing published mapping depicts these deposits as Qa or Qb; however, these can be further subdivided with closer inspection (i.e., crevasse splays or distributary deposits). Generally, river natural levee deposits are mapped as Qa, and slackwater deposits in topographic lows are mapped as Qb.

Natural levees are formed as floodwaters overtop channel banks, depositing fine sand and silt-rich alluvium along the flanks of the river bank, then carrying finer-grained clay and silt in suspension onto the distal floodplain. This depositional sorting process creates a “natural levee” landform with a topographic gradient sloping away from the river.

Natural levees (map unit Qa of Helley and Harwood, 1985; Ql of Atwater, 1982) are a composite of many individual deposits accumulated over thousands of years. As currently depicted in published maps, map units Qa and Ql are a generalization of the complex deposits that make up natural levee landforms. Detailed mapping subdivides these units as historical or Holocene overbank or crevasse splay deposits (Saucier, 1994; WLA 2007). Also, detailed mapping identifies smaller distributary channels on the floodplain that commonly are not recognized by the general Qa (Table 3-2). Natural levee deposits are extensive over the north NULE Project study area (SR, FR; Figure 2) and commonly are associated with HSG soil group C (low permeability silt; Figures 10 through 36). Conceptually, the present-day silty natural levee deposits overlie older, buried, coarser-grained deposits of latest Pleistocene river channel alluvium (Shlemon, 1967).

Flood basins were frequently inundated swamplands prior to reclamation. River flood overflow and tributary fan contributions drained into thousands of acres of sloughs, swamps, and dense marshes of bulrushes creating a region then known generally as the Tule. During high flows, this environment was akin to an inland sea of slow-moving, broad bodies of water. Flood basin deposits created by these bodies (map unit Qb) consist of very fine sand, silt, and clay laid in a relatively low-energy depositional environment. Basin and marsh deposits are present in the topographically low areas west of the present-day Sacramento and Feather Rivers (Figure 2). Soils associated with these deposits are the Sacramento silt loam, heavy clay, and clay adobe. Heavy clay is prone to shrink-swell; clay adobe is prone to desiccation cracking. Prior to cultural draining of the land, basin deposits were generally saturated and often thick with tule or bulrush vegetation in the latest Holocene environment, and organic-rich clay may be present. Existing mapping (Helley and Harwood, 1985) identifies basin deposits in topographic lows as well as on gently dipping slopes. Mapping of Qb gently dipping slopes is probably inappropriate; these areas would more appropriately be mapped as distal alluvial fan facies that consist of silt and clay. The application of the unit Qb is more appropriately used in actual topographic depressions directly adjacent to the major rivers (Yolo Basin, Natomas Basin).

Along the flanks of the study area and buried beneath parts of the valley are mid- to late-Pleistocene Riverbank and Modesto Formation deposits (map units Qrl, Qru, Qml, Qmu). Alluvial fan map units derived from the Sierra Nevada to the east of the study area have a distinct geologic watershed, history and geomorphic relationship as compared to those derived from the west side of the NULE Project study area (Shlemon, 1967; Atwater, 1982).

Deposits from the Sacramento-San Joaquin Delta directly underlie the non-urban levees in the southern part of the study area. The delta deposits (map unit Qp of Helley and Harwood, 1985; Qpm of Atwater, 1982) are chiefly peat and peaty mud of tidal wetlands and waterways. The deposits of the former wetlands commonly contain organic matter from plant detritus, and generally the organic content is highest in the central and south-central Delta. The formerly high groundwater table kept peat wet and inhibited organic material decay. Historical draining of soils and water table decline promoted oxidation and organic material decay. The maximum thickness of peat in the Delta is about 50 feet near Sherman Island (Atwater, 1982), where the peat overlies unmapped sand and silt deposits of latest Pleistocene age. Where peat is thicker, it could have been deposited in depressions carved by Pleistocene channels. Granular soils underlie much of the Delta peat, and are likely highly permeable (USACE, 1987).

Channel deposits are mapped by Helley and Harwood (1985) as map unit Qsc, which is an encompassing unit including point and in-channel bars, meander scrolls, oxbows, bed material, and other sediments from the active river channel. Geomorphic mapping by DWR (1994) identifies these deposits in some detail north of Colusa, and shows channel meander migration of the Sacramento River over the past hundred or so years. Individual map units from DWR (1994) were grouped to delineate historical Sacramento River channel positions (map unit SRtc), and to delineate older river deposits from former meander positions of the river (late Pleistocene – early Holocene, map unit SRm). The sediments in these deposits, both SRm and SRtc, primarily consist of cobbles, gravel and sand from the relatively steep gradient channel sediment transport interbedded with sand, silt, and clay from overbank sedimentation. By definition, deposits of SRtc are younger than SRm.

The preceding discussion of geomorphic domains briefly summarizes the major map units comprising levee foundations in the North NULE Project study area. These summary characterizations provide a context for interpretation of general sediment grain sizes that are encountered in the shallow subsurface. Sediment type, permeability and shallow stratigraphic relationships exert controls on underseepage processes and are incorporated into the underseepage susceptibility analysis and assessment.

5.1.2 Underseepage Susceptibility of Mapped Geologic Units

This underseepage susceptibility assessment considers geologic deposits underlying present-day levees, the characteristics of soils developed on those deposits, and the surficial landscape features that may influence or control underseepage. To assess underseepage hazard, underseepage susceptibility maps are constructed using a criteria matrix (Table 5-1). The criteria matrix combines information about late Quaternary geologic deposits from published map sources, channel features mapped from historical topographic maps, and NRCS HSG. Where detailed surficial geologic mapping was available (1:20,000-scale or better), underseepage susceptibility classes were assigned based on geologic age, depositional environment, stratigraphic relationships and inferred relative soil permeability. This univariate assignment (Table 5-2) is used because detailed surficial geologic mapping interprets and incorporates soil survey data as part of the map development, and using HSG would be redundant. The underseepage susceptibility of mapped geologic deposits is described below by susceptibility class. In some instances, underseepage susceptibility is interpreted to decrease slightly as surface soil permeability decreases (Table 5-1). Examination of the interpreted underseepage susceptibility classes based on associations with levee performance case histories is presented in Section 6.1.

5.1.2.1 Very High Susceptibility

Geologic deposits interpreted to have very high underseepage susceptibility are:

- Historical and active stream channel deposits (map units SRtc and ac)
- Hydraulic dredge spoils (map unit Qds)
- Quaternary channel meander zone (map unit SRm)
- Peat and mud deposits (map unit Qp, Qpm)

Stream deposits, both SRtc and SRm, consist chiefly of coarse-grained sediment and have relatively high permeability. They also have very high susceptibility to underseepage. Stream deposits in the shallow subsurface are considered to have promoted failure of the Linda levee near Marysville, and have a documented influence on underseepage (subsurface flow pathways).

Hydraulic dredge spoils are known to consist of silty and fine sand material that typically were sucked from the river channel and hydraulically emplaced on the ground surface immediately prior to levee construction. These deposits are known to be permeable, and have generally poor engineering characteristics due to their method of emplacement (Bryan, 1923).

Peat and mud deposits are interpreted to have very high underseepage susceptibility based on the fact that much of the peat and mud are underlain by older and more-permeable strata (Atwater, 1982, USACE, 1987). The stratigraphic relationship of relatively fine-grained sediment overlying relatively coarser-grained sediment presents a geotechnical blanket condition, reducing head loss in the soil column and promoting relatively high exit gradients.

Detailed mapping (WLA 2007, 2008a, 2008b) interprets historical deposits as having very high underseepage susceptibility (map unit Rob; Table 5-2). The basis for this assignment is the likelihood that these sediments consist of granular material derived from the transport and deposition of debris from hydraulic mining higher in the watershed; the sediments likely are relatively permeable.

5.1.2.2 High Susceptibility

Mapped geologic units interpreted to have high susceptibility include: tailings from hydraulic mining (map unit “t”), natural levee deposits (map units Qa, Ql; Table 5-1), latest Pleistocene alluvial fans (map units Qmu; Tables 5-1 and 5-2) and Holocene age floodplain and channel deposits (map unit Hob; Table 5-2).

Tailings from hydraulic mining are restricted to areas near the margin of the valley floor. These deposits are derived from re-working and re-mining gold flecks in river alluvium, and were emplaced in long “mole track”-type mounds by mechanized equipment. Typically these are coarse-grained deposits, but their exact sedimentologic consistency is not known at this time. As a result, this unit is conservatively assigned a high underseepage susceptibility. Tailing deposits are different from hydraulic dredge spoils in that hydraulic dredge spoil sediment (unit Qds) were commonly sucked out of the river channel and hydraulically emplaced on the adjacent ground to widen, deepen, or straighten the Sacramento River. (Atwater, 1982). The majority of hydraulic dredge spoils deposits are mapped between Collinsville and Cache Slough.

As described previously, natural levees consist chiefly of interbedded silt, clay, and fine sand. In some instances, these natural levee deposits overlie thick granular sands of much older river deposits, and may represent a relatively finer-grained layer over coarser strata. These units, Qa and Ql, are interpreted to have high susceptibility to underseepage (Table 5-1). Again, as currently depicted in published maps, map units Qa and Ql are a generalization of complex deposits making up natural levee landforms. Detailed mapping subdivides and delineates additional deposits not recognized in the broad Qa or Ql unit by Helley and Harwood (1985) or Atwater (1982). Detailed mapping interprets much of the surficial geology of the natural levees as either historical and therefore of very high susceptibility, or of Holocene age, and so of moderate susceptibility (Table 3-2; Table 5-2). While map units Qa and Ql are interpreted as having high susceptibility, they actually encompass a range of underseepage susceptibility states from very high to moderate.

5.1.2.3 Moderate Susceptibility

Map units interpreted as having moderate susceptibility to underseepage include flood basin deposits (map unit Qb with HSG A or B; Table 5-1), Holocene alluvial fan deposits from the Coast Ranges (map unit Hf; Table 5-2), and mid- to late-Pleistocene alluvial fan deposits (map units Qml, Qop with HSG A or B; Table 5-1). Flood basin deposits with HSG A and B are interpreted as having moderate susceptibility because of their generally fine-grained texture, but apparent permeability is based on NRCS HSG mapping. Map unit Qa with HSG A or B comprises less than 2 percent of the total North NULE Project levee miles. Holocene alluvial fan deposits are interpreted as having moderate susceptibility because of their silty and sandy consistency, which is derived from erosion, transport, and weathering of sedimentary Great Valley rocks in the Coast Ranges (WLA, 2008a; 2008b). Mid- to late-Pleistocene alluvial fan deposits (map unit Qml, Qop with HSG A or B) are similarly assigned moderate susceptibility to underseepage.

5.1.2.4 Low Susceptibility

Deposits mapped as having low susceptibility include flood basin deposits with HSG C or D (Table 5-1), and early Pleistocene to Pliocene deposits (map units Qru, Qrl, Qrb, Qtl; Tables 5-1 and 5-2). Flood basin deposits commonly consist of lean or fat clay, with thickness greater than about 10 feet. These deposits have low permeability strata with low permeability soils, and are interpreted to have low susceptibility to underseepage. Similarly, early Pleistocene to Pliocene deposits are interpreted as having low susceptibility based on their age and consolidation, which usually correlates with low permeability strata.

5.2 Hazard Susceptibility Analysis

The susceptibility of NULE Project study area levees is assessed in this section with respect to three types of hazards: underseepage, settlement, and subsidence. The larger part of the effort in this Level 2-I study was applied to the analysis of underseepage; discussion of this hazard is presented in detail by geographic area in subsection 5.2.1. Level 2-I analysis also included a regional assessment of soil settlement and subsidence based on available data, and is presented below in subsections 5.2.2 and 5.2.3.

5.2.1 Assessment of Levee Underseepage Susceptibility Hazard

The underseepage hazard is in large part a function of the presence beneath the levee of permeable geologic materials. The underseepage susceptibility map is based on the assessment of the relative permeability of the mapped geologic units, as detailed in the criteria matrix (Table 5-1) and assignment table (Table 5-2), and described in subsection 5.1.2.

This discussion of levee underseepage susceptibility hazard is organized by NULE Project study area region and then by sub-areas within each region. The North NULE Project study area is subdivided first into Regions 1 and 2 (Figure 3). Beginning in the north with Region 1, sub-areas within each region are discussed in order from north to south. For each sub-area, a summary of geomorphic and geographic setting, geologic conditions beneath the NULE levees, and an assessment of underseepage hazards based on these conditions is presented. Seven sub-areas are described in Region 1 and eight sub-areas are described in Region 2.

5.2.1.1 Region 1

Red Bluff to Vina (Figures 10 and 11)

NULE levees and underseepage susceptibility in the area of Red Bluff and southward to Vina are shown on Figures 10 and 11. Locations and extents of non-urban non-Project levees are shown on Figure 9, and are present on Figure 10. The Sacramento River flows southerly along this stretch, meandering laterally, creating oxbows and depositing sediment as sandy to gravelly point bars and mid-channel bars. The non-urban Project and non-Project levees near Blackberry Island, Sacramento Bar, and Copeland Bar overlie alluvium and meander-laid Sacramento River deposits. The Sacramento River is dynamic in this area and the channel changes location on timescales of tens of years, based on map data (map unit SRtc). As a result, deposits in these areas (SRm, SRtc) are young and coarse and of variable consolidation resulting in very high underseepage susceptibility (Figures 10 and 11). The Project levees along east-flowing Elder Creek (Figure 10) overlie Modesto-age alluvial fan material along the west, and Quaternary alluvium (Qa) of the Sacramento River upon traversing the floodplain. The underseepage susceptibility in this area is moderate along the alluvial fan deposits, and high along the floodplain. Levee failures have been documented along Elder Creek (Figure 10). Southwest-flowing Deer Creek NULE Project levees overlie alluvial fan material of Riverbank and Modesto ages. The mapped extent of these moderately to well-consolidated deposits, in conjunction with mapped historical fan channels, results in a range from low to very high underseepage susceptibilities along this creek (Figure 11).

Chico Area (Figures 12 and 28)

NULE levees in the Chico area include those along Mud Creek, Sycamore Creek, and a length of canal and associated levee that diverts water from Big Chico Creek into Sycamore Creek (Figure 12). Non-urban non-Project levees lie southwest of Chico, along southwesterly-flowing Little Chico Creek and Comanche Creek (Figure 12), and overlie foundations that range from high to low susceptibility. Mud Creek flows across a low relief, slope angle alluvial fan surface that emanates from the mountains and slopes gently to the valley floor adjacent to the Sacramento River. In the past, the creek was part of a complex anastomosing fan-channel network that meandered, forked, and re-joined repeatedly down the alluvial fan, as indicated by the channels mapped from historical topographic maps (Figure 12). Mud Creek is currently confined between two levees spaced approximately 250 to 400 feet apart. The bulk of foundation materials along Mud Creek levees are semi-consolidated Riverbank and Modesto-age alluvial fan deposits that are surficially cross cut by the now-abandoned channel network (Figure 12). Farther upstream on the alluvial fan (Figure 28), the flood diversion levee diverting water from Big Chico Creek into Sycamore Creek mostly overlies Pliocene-aged Tuscan Formation, and has low susceptibility to underseepage based on interpreted low permeability and overall consolidation of the Tuscan Formation. These spatially variable foundation conditions in the Chico area (Figures 12 and 28) result in a range of underseepage susceptibilities from low to moderate to high and very high.

Butte Creek and Cherokee Canal (Figures 28 to 31)

Butte Creek (Figures 28 and 29) and Cherokee Canal (Figures 30 and 31) are similar fluvial systems; they both collect water from drainages emerging from the Cascade foothills and direct water across a low relief, low slope alluvial fan surface into a flood basin east of the Sacramento River (Figures 29 and 31). The alluvial fan surface grades into the flood basin east of the Sacramento River very gradually and, prior to levee construction, the middle to lower reaches of these watercourses exhibited anastomosing channel networks. Based on soil and geologic data, the upstream third to half of the levees along Butte Creek rest on upper Modesto Formation, and are assessed as having high susceptibility (Figure 28). Tailings from hydraulic mining are mapped along upper Cherokee Canal and are assessed as having moderate underseepage susceptibility (Figure 30). The lower sections of both systems have mostly low underseepage susceptibilities (Figure 29 and 31) based on the presence of fine-grained flood basin deposits. Few to no performance problems are documented along low susceptibility foundations. However, where present-day levees cross over channel deposits from anastomosing lower stream sections, underseepage susceptibility is interpreted to be very high.

Sacramento River—Ordbend to Colusa (Figures 13 and 14)

From Ordbend (Figure 13) to directly north of Colusa (Figure 14), the Sacramento River dynamically meanders within a meander zone generally confined by erosion-resistant lower Modesto Formation (DWR, 1994). Evidence of persistent river overtopping is observed in the soil HSG map pattern in distributary fingers of coarser-grained material flanking the east and west sides of the river (Figure 13 and 14). Narrow distributary channels mapped from historical topographic maps also attest to this pre-levee fluvial process. In this sub-area, NULE Project levees overlie channel deposits (SRm), undifferentiated Quaternary alluvium (map unit Qa, overbank sediments), and lower Modesto Formation (map unit Qml). Based on the distribution of geologic units and the soil HSG, NULE Project levee foundation susceptibility along this sub-area correspondingly is very high, high, moderate, and low (Figures 13 and 14). NULE non-Project levees are present west of the Sacramento River (Figure 13), with one stretch oriented north-south, and the other east-west. The non-Project levees lie directly north of Princeton, chiefly on Pleistocene alluvial fan deposits (lower member of the Modesto Formation) or fine-grained basin deposits. The non-Project foundation underseepage susceptibility is low and moderate (Figure 13).

Sacramento River—Colusa to Knights Landing (Figures 15 and 16)

In contrast to the Sacramento River north of Colusa, the Sacramento River south of Colusa has a narrower channel closely bordered by artificial levees constructed over river natural levee deposits (map unit Qa). The Sacramento River does not laterally meander or migrate as much in this sub-area compared to upstream of Colusa (Figures 15 and 16). The river is sinuous and, as a consequence, subdued natural levees (map unit Qa) parallel the channel; a few abandoned and cut-off meanders lie outboard of the levees. In this setting, sandy alluvium is deposited by crevasse splays and distributary channels that overtop or breach the natural levees. The NULE Project levees rest atop this sandy alluvium and the underseepage susceptibility is correspondingly high through the entire length, and past levee performance problems have been documented (e.g., Figure 15). The NULE non-Project levees lie west of the city of Colusa (Figure 9, Figure 15), and overlie part of the Sacramento River natural levee and extend southerly across fine-grained basin deposits. The foundation underseepage susceptibility of the non-Project levee west of Colusa is high along the river natural levee alluvium, and low along the basin deposits.

Butte Slough, Sutter Bypass, Wadsworth Canal, and Tisdale Bypass (Figures 15, 16, and 19)

The NULE levee along Butte Slough sits on the right bank (southwest side) of the channel. Butte Slough channel historically funneled high water discharges from the Sacramento River southeastward into the Sutter Basin (Sutter Bypass). The Butte Slough levee sits chiefly on Holocene alluvium (map unit Qa) and basin deposits directly adjacent to the channel, resulting in high underseepage susceptibility (Figure 15).

Sutter Bypass conveys flood water from Butte Slough across the Sutter Basin, merges with the Feather River, and ultimately discharges into the Sacramento River and Yolo Bypass (Figures 16 and 19). The Sutter Bypass traverses the gently southwest-sloping transition from Sierra Nevada fan to flood basin (Figure 2; Section 4). Along this levee a thin veneer of fine-grained basin deposits (about 8 to 10 feet) overlies a coarse-grained Modesto-age alluvial fan that contains shallow, moderately developed hardpans. This specific stratigraphic relationship likely represents a geotechnical blanket condition. Sutter Bypass foundation materials are Basin over Modesto (map unit Hn/Qm; Table 5-2), and are assigned high underseepage susceptibility (Figures 16 and 19).

Wadsworth Canal lies in a similar geomorphic environment to Sutter Bypass, but is oriented sub-orthogonally to the Sutter Bypass (Figure 16). The canal runs down the gently southwest-sloping Sutter Basin where a thin veneer of fine-grained basin deposits overlies a Modesto-age alluvial surface containing moderately developed hardpans and sandy deposits. The right bank levee foundation's susceptibility to underseepage is high because of these near-surface stratigraphic conditions that could represent a geotechnical blanket layer, namely laterally extensive fine-grained soils over sandy alluvial fan deposits.

Tisdale Bypass conveys flood water from the Sacramento River eastward to the Sutter Bypass (Figure 16). The western third of the two NULE levees along the Tisdale Bypass sit atop sandy historical and Holocene alluvium deposited in crevasse splays and flood events that overtopped the natural levees of the Sacramento River. This section of the foundation deposits beneath NULE levees is assigned high underseepage susceptibility. Farther to the east, the susceptibility to underseepage abruptly changes to low based on published geologic data (Helley and Harwood, 1985). It is likely there is not an absolute change from high to low susceptibility (Figure 16), but rather a transition across this change over some distance.

Colusa Basin Drainage Canal and Knights Landing Ridge Cut (Figures 15, 17, 18, and 20)

The Colusa Basin Drainage Canal (CBDC) flows from north to south from near the town of Colusa, along the eastern margins of the alluvial fans emanating from the Coast Range, to Knights Landing on the Sacramento River (Figures 15, 17, 18, and 20). Helley and Harwood

(1985) map basin deposits extending from the Colusa Basin up the alluvial fans for several miles in some cases. These deposits also show fine-grained distal alluvial fan sediments in this area. While the CBDC lies at the edge of the alluvial fans, NRCS soils mapping indicates near-surface materials are fine-grained (Figures 15, 17, 18, and 20). As a result of the geologic unit and the HSG class, the foundation deposits beneath the CBDC are assigned low underseepage susceptibility. Underseepage levee distress has not been recorded along the CBDC. A non-urban non-Project levee ties-in to the Sacramento River and the CBDC directly south of Kirkville (Figure 18). The foundation of the north-trending levee chiefly is fine-grained basin deposits (low underseepage susceptibility), except for the northern-most part that overlies part of the Sacramento River sandy alluvium and narrow channels (Figure 18).

The Knights Landing Ridge Cut canal transports water from the CBDC to the Yolo Bypass (Figure 20). The Knights Landing Ridge Cut was excavated though several topographically high abandoned arms of the Cache Creek alluvial fan and the levees that bound the canal overlie alluvial fan sediments, basin deposits, and natural levee deposits of the Sacramento River near Grays Bend. These foundation conditions generally result in low and moderate underseepage susceptibilities but also locally very high underseepage susceptibilities where the levees cross abandoned historical or Holocene channels.

5.2.1.2 Region 2

Honcut Creek, Middle Feather River, and the Western Pacific Rail Line (Figure 32)

The NULE levees along Honcut Creek, the middle Feather River, and the Western Pacific rail line all lie north of the city of Marysville and directly east of Sutter Buttes (Figure 32). The NULE levee along Honcut Creek's southern bank is set back from the main channel of the creek, and sits on slightly higher elevation deposits of Modesto- or Riverbank-age. This foundation has mostly low susceptibility to underseepage, but there are areas of moderate and high susceptibility where the levee overlies the lower member of the Modesto Formation with HSG type B, and the upper member of the Modesto Formation with HSG type B, respectively (Figure 32). The NULE levee alignments along the middle Feather River run along the east bank of the river from the confluence with Honcut Creek southward to the city of Marysville. In most locations the levee rests atop alluvium of the Feather River (map unit Qa) or Modesto-age alluvial fan material at the top of the entrenched channel's banks. Though variable, underseepage susceptibility through this section is generally high. In contrast, the levee along the Western Pacific rail line north of Marysville does not lie adjacent to a large river (Figure 32), but rather appears to protect the railroad grade from high flows that overwhelm the adjacent Simmerly Slough and other small foothill-derived creeks. The levee sits almost entirely on Modesto and Riverbank-age alluvial fan deposits that are moderately to well-consolidated. As a result, the foundation of the levee along Western Pacific rail line generally is assigned low underseepage susceptibility (Figure 32).

Bear River, Best Slough, and Feather River (Figures 33 and 34)

This group of levees includes levees along the Bear River and its tributaries (Dry Creek, Grasshopper Slough, and Yankee Slough), levees along Best Slough as well as a levee adjacent to the Western Pacific rail line (Figure 33), and the levee on the east bank of the

Feather River from the Feather's confluence with the Bear River south to the Feather's confluence with the Sutter Bypass (Figure 34). The levees of the Bear River and its tributaries generally constrain these watercourses to narrow and straight channels (Figure 33). These levees typically overlie extensive historical alluvium and stream channel deposits derived from upstream hydraulic mining debris, and therefore are interpreted as very high to high underseepage susceptibility (map units Rob, Qa, respectively). In contrast, the levees along nearby Best Slough and the Western Pacific rail line sit on older, consolidated alluvial fan deposits of the Riverbank Formation with low permeability soils and have low underseepage susceptibility. The levee along the east bank of the Feather River south of the Feather's confluence with the Bear River generally overlies historical alluvium of crevasse splay and overbank deposition (Rcs, Rob; Table 5-2), which is assessed as having high susceptibility to underseepage. Underseepage has been recorded in the performance databases along the levees assessed as having high and very high susceptibility in this area.

Woodland (Figure 20)

NULE levees near the town of Woodland sit on the north bank of Cache Creek north and east of the town (Figure 20). This levee parallels Cache Creek as the creek flows eastward across a broad alluvial fan and eventually enters the flood basin adjacent to the Sacramento River. Cache Creek regularly overtops its banks to deposit low-relief lobes of sandy alluvium across the alluvial fan; thus, many historical deposits are mapped along this creek. Even where the NULE levee along the northeast side of the Cache Creek Settling Basin approaches the low-lying flood basin, young distal alluvial fan deposits underlie the levee, as indicated by map unit Rf (Figure 20). These unconsolidated historical deposits are assigned very high underseepage susceptibility.

Davis (Figure 22)

NULE levees in the Davis area include the southern levee along the South Fork of Putah Creek, the north levee along the Willow Slough Bypass canal, and a length of levee on the west side of the Yolo Bypass (Figure 22).

The South Fork of Putah Creek is an entirely man-made canal constructed after the town of Davis was repeatedly flooded by waters from the original Putah Creek channel in the late 1800s (Vaught, 2006). These levees are built directly on sandy and silty historical alluvial fan and channel deposits resulting from overbank sedimentation and flood flows emanating from the creek (units Rob, Rf, Rb, etc. on Figure 22). Holocene alluvial fan deposits probably underlie the historical deposits in the shallow subsurface, and may have local pockets of coarser distributary channel alluvium. As a result of this historical sedimentation, the foundation deposits along this section of levee are assigned very high underseepage susceptibility. Although there are no documented underseepage problems along this stretch (Figure 22), these deposits elsewhere in the study area are coincident with boils and seepage features.

Willow Slough Bypass is a canal flanked by NULE levees and carries water from Dry Slough and Willow Slough around the north side of the city of Davis to the Yolo Bypass (Figure 22). The levees overlie Holocene alluvial fan and channel deposits until they reach the Yolo Bypass where the levees enter a flood basin, and overlie generally finer-grained deposits consisting of silts and clays. The section of NULE levee in the alluvial fan setting north of Davis has moderate underseepage susceptibility and the length of levee along the west side of the Yolo Bypass has low underseepage susceptibility, due to the generally finer materials in the shallow near subsurface.

East Side Canal and the Natomas Basin Cross Canal (Figures 21 and 34)

The East Side Canal lies northeast of the American Basin (Figures 21, 34). The canal flows from north to south (Figure 34), collecting water from the small creeks draining the piedmont adjacent to the town of Lincoln. The levee adjacent to the canal overlies deposits of the Modesto Formation and so the foundation has low underseepage susceptibility.

The Natomas Basin Cross Canal is the downstream extension of the East Side Canal and flows across a variety of deposits ranging from Modesto Formation in its upper extent to Holocene basin and Sacramento River natural levee deposits in its lower extent (Figure 21). The fine-grained and moderately consolidated deposits along the northern length of the canal result generally in low underseepage susceptibility, but coarser and younger overbank deposits directly adjacent to the Sacramento River are assigned high to very high underseepage susceptibility.

At the southeastern extent of Figure 21, non-urban non-Project levees flanking drainage canals traverse generally north-south across the valley floor. The foundations sediments are interpreted as historical marsh deposits that are assigned high susceptibility to underseepage based on the potential presence of organic matter and associated permeable strata.

Sacramento-Feather River Confluence and Yolo Bypass Region (Figure 21)

This section includes NULE levee foundations along the Sacramento River from Knights Landing downstream to the Sacramento Bypass, along the lower Feather River, and along the northern and eastern Yolo Bypass (Figure 21). The levees adjacent to the Sacramento River from Knights Landing downstream to the Sutter/Yolo Bypass floodway sit on natural levee deposits (Qa, Figure 21). These deposits are assessed as high underseepage susceptibility. Moving downstream along the Sacramento River, only the levee on the west bank is a NULE levee. Just north of Interstate 5 (I-5), the natural levee deposits thin laterally and vertically, and the levee approaches the flood basin environment and underlying fine-grained basin deposits. Otherwise, this levee overlies natural levee deposits (Qa) directly adjacent to the river and has high underseepage susceptibility.

NULE levees along the lower Feather River lie on the east bank of the Feather River and also bound the Sutter Bypass on its western margin (Figures 34 and 21). Both of these levees overlie alluvium derived from overbank deposition and crevasse splay formation common to the large rivers in the Sacramento Valley. As a result of this variable and sandy material under the levees, these foundations are assigned high underseepage susceptibility. The levee along the east side of the Yolo Bypass traverses a flood basin setting and overlies fine-grained flood basin deposits. As a result, the foundation underseepage susceptibility is low. In contrast, levees along the northern Yolo Bypass adjacent to the Knights Landing Ridge Cut traverse distal portions of the Cache Creek alluvial fan (Figure 21).

The Lower Sacramento River and Sloughs in the Delta (Figures 23, 25 to 27)

This section describes NULE levees along the Sacramento River from directly south of the City of Sacramento downstream though the Delta to Sherman Island, the many sloughs within the Delta, and the Deep Water Ship Canal (Figures 23, 25, and 27). The levees along the lower Sacramento River overlie Holocene natural levee (Qa, Ql) and basin (Qb) deposits in the upstream areas, but these deposits transition to natural levee deposits that overlie organic-rich peat and mud deposits (Qpm) as the river approaches the Delta near Courtland and Paintersville (Figure 25). Non-urban non-Project levees are present directly east of Freeport around the Sacramento Regional Wastewater Treatment Plant, as well as along Snodgrass Slough (Figures 9 and 25). Non-urban non-Project levees east of Freeport principally overlie Pleistocene Riverbank Formation deposits that is assigned low susceptibility to underseepage. Along Snodgrass Slough, a former distributary channel of the Sacramento River, non-urban non-Project levees overlie a range of deposits and soil types, from sandy peat to fine-grained basin deposits, and the foundation underseepage susceptibility similarly ranges from very high to low (Figure 25). The non-urban Project levee along the Deep Water Ship Canal (Figure 25) traverses a flood basin that lies between the distal Putah Creek alluvial fan and the Sacramento River and related sloughs. Because the NULE levee along the Deep Water Ship Canal overlies thick flood basin materials, foundation underseepage susceptibility is low.

Generally throughout the Delta region (e.g., Figures 25 to 27), silty-sandy natural levee deposits accumulate proximal to the active channels, forming rings of higher ground around lower elevation islands of organic-rich peaty material (Atwater, 1982). As deposition of natural levee material decreases away from the channels, the component of peat and mud material increases. The natural levees along sloughs such as Elk, Sutter, Steamboat, Miner, Georgina, and Threemile Sloughs generally are mapped as Qa or Ql. As a result, NULE levees along the Sacramento River and nearby sloughs are assigned high underseepage susceptibilities except in locations where underseepage susceptibilities are very high because levees overlie peat and mud materials (map unit Qpm) or spoils from the dredging of channels (map unit Qds; west side of Figure 27). At the southeastern extent of Figure 27, non-urban non-Project levee flanks the North Mokelumne River. Much of the levee overlies peat deposits that are Group A HSG types. This foundation condition is assigned very high susceptibility to underseepage.

Cache Slough, Lindsey Slough, and other levees north of the Montezuma Hills (Figures 24 and 26)

The levees along the upper extent of Cache Slough, as well as its tributaries—Shag and Hass Sloughs—generally overlie older distal alluvial fan deposits from Putah Creek (map unit Qop) and flood basin deposits (map unit Qb) (Figures 24 and 26). These deposits are probably fine-grained resulting in low underseepage susceptibility for the levees that overlie those deposits. Locally, where the levees overlie historical slough channels, very high underseepage susceptibilities are mapped. The downstream extents overlie deposits of organic-rich peaty material (map unit Qpm) that are assigned very high underseepage susceptibilities. The levees along Lindsey and Barker Sloughs and the related canals also have similar foundation conditions. The upstream extents of these levees also are assigned low underseepage susceptibilities because of the fine-grained basin and Putah Creek alluvium, and the downstream sections have very high underseepage susceptibilities because of the presence of peat deposits. Much of the non-urban non-Project levees along the Deep Water Ship Channel (Figure 9, Figure 24) overlie fine-grained basin deposits that are interpreted to be low underseepage susceptibility foundations. Farther south, the foundation deposits change to organic-rich peat and mud that is assigned very high susceptibility to underseepage (Figure 24).

Lake Almanor Levees (Figure 35)

The North Fork of the Feather River flows into Lake Almanor near the town of Chester on the northwestern margin of Lake Almanor (Figure 35). At about 3 miles west of the lake shore, the North Fork Feather River channel becomes unconfined and deposits coarse sediment, building an alluvial fan-delta into Lake Almanor (map unit Qa; Figure 35). The alluvial fan consists of alluvial fan-delta deposits with generally coarse sediment (i.e., sand and gravel). Quaternary alluvium (map unit Qa) is coarse-grained here and interpreted as having high susceptibility to underseepage based on inferred permeability.

Clear Lake Levees (Figure 36)

Present-day levees north of Clear Lake parallel Rodman Slough, Middle Creek, the Tule Lake drainage, and a diversion canal for Clover and Alley Creeks (Figure 36). In the Clear Lake area (Figure 36), non-urban levees are interpreted to be underlain by about 10 feet of fine-grained lacustrine deposits (silt; map unit Qla). The lacustrine sediment was probably deposited during a high-level stage of Clear Lake that completely inundated the system of broad and flat valleys surrounding present-day Clear Lake. Floodplain width along each of the primary drainages appears greater than the erosion and sediment transport potential and meander pattern of the present-day creeks (Figure 36). This difference points to the presence of older (and now buried) alluvial sediments that were deposited during or shortly after valley incision and erosion that created the present-day landforms. It is inferred, based on the valley floor morphology, that the surficial lacustrine deposits are likely underlain by coarser-grained alluvial deposits. This inference is supported by McNitt’s (1968) mapping that identified fine-grained lake deposits underlain by the alluvial Cache Formation directly south of Clear Lake. The fine-grained silty lake sediment overlying coarser-grained alluvium likely represents geotechnical blanket-layer conditions and is assigned high susceptibility to underseepage. At the southern extent of the Clear Lake levees, historically reclaimed wetland and marsh deposits underlie the present-day levees. These deposits contain organic material that, upon draining, becomes prone to compaction and settlement.

5.2.2 Assessment of Levee Foundation Soft Soils

The Level 2-I analysis provides a regional assessment of potential soft soil levee foundations based on available data (Figures 37a and 37b). For this analysis, areas of marshes, former marshes and water bodies, organic (soft) soils, and peat deposits are mapped, and it is inferred that these areas are more likely to contribute to levee instability (e.g., circular failure planes beneath levees) compared to other North NULE foundations. Marshes, former marshes and water bodies are identified by mapping from early topographic maps. Organic-rich soft soils are identified from NRCS soil maps. Peat deposits are identified from geologic maps of Helley and Harwood (1985) and Atwater (1982).

5.2.3 Assessment of Regional and Local Ground Subsidence

Subsidence is a decrease of land surface elevation with respect to a fixed datum, and may be caused by natural or human-induced processes. Subsidence may occur as a result of sediment pore fluid extraction (e.g., subsurface fluid or water mining) or from deformation related to deep-seated tectonic processes (Harwood and Helley, 1987). Many of the floodways, levees and canals of the Sacramento Valley traverse long distances with very gentle gradients, and may be strongly affected by small subsidence-related elevation changes. Subsidence poses a hazard to a levee system by decreasing levee crest elevations, or by changing local channel gradients driving local aggradation (which may increase flood stage) or degradation (which may cause erosion of levee foundations).

Subsidence due to groundwater extraction in the Sacramento Valley has occurred, but not as dramatically as in the San Joaquin Valley to the south, primarily because more groundwater is extracted in the San Joaquin Valley (Lofgren and Ireland, 1974). Subsidence may increase in extent or become accelerated if groundwater pumping escalates in the future. Survey data collected in the Sacramento Valley over a five-year period (1985-1989; Ikehara, 1994) showed subsidence rates ranging from less than 0.02 meters per year to greater than 0.05 meters per year (about 0.8 to 2 inches per year; Figure 38). Subsidence is greatest near the western Sacramento Valley towns of Zamora, Woodland, and Davis (Figure 38), probably because of long and sustained groundwater extraction (Lofgren and Ireland, 1974), as well as some component of tectonic down-warping (Harwood and Helley, 1987). Long-term changes in land surface elevation may affect potential flood hazard in this area.

6.0 IMPLICATIONS FOR NON-URBAN LEVEES

This section presents additional analysis and discussion of the levee underseepage mapping to help assess the significance and usefulness of these maps. First is a review of the available levee performance data to evaluate susceptibility class assignments in light of these data.

A key question is: are documented cases of underseepage phenomena more frequent along levees assigned to the higher susceptibility classes? In general, there is a reasonably good correlation between performance and underseepage susceptibility class.

Second, this study examines the sources of uncertainty to identify possible improvements that could help refine susceptibility hazard analysis. An overview map of North NULE Project levee historical performance and interpreted underseepage susceptibility is presented as Figure 6.

6.1 Associations with Historical Levee Performance

North NULE Project levee performance data are analyzed to evaluate how well underseepage performance history correlates with underseepage susceptibility mapping. A good correlation would support the geologic model and susceptibility assignments, and a poor correlation may indicate that adjustments are needed to the geologic model or to the assignment of susceptibility classes. Performance data only were available for the Project levees, therefore the analysis of historical levee performance does not include North NULE non-Project levees. However, given that the relative mileage of Project levees is about one order of magnitude greater than the non-Project levees in the North NULE area, it is judged that the analysis of only Project levees is sufficient for the 2-I analysis phase.

Preliminary performance data, described in Subsection 3.2.6, consist of documented underseepage-related performance problems totaling 55 miles of levee (line data) and 496 points (point data) along the NULE Project levees. Line and point data for seeps, boils, and failures are tabulated for each of the four susceptibility classes (Table 6-1) and graphed (Figures 7 and 8).

Point data document locations along the levees where specific seepage, boils, or failures were observed. Each performance point is assigned to a geologic unit and susceptibility class based on its location. The points are then totaled for each susceptibility class. The totals are divided by the number of miles of levee in the corresponding susceptibility class to obtain a frequency in points per mile (Table 6-1).

Line data document reaches of levees, measured in miles, where performance problems were observed. These data were edited so overlapping and duplicate lines were deleted. In addition, lines were broken into segments where they crossed geologic unit contacts. Each line segment is then assigned to a geologic unit and susceptibility class. The line segment lengths are then tabulated for each susceptibility class, and divided by the number of levee miles in the corresponding susceptibility class to obtain the percentage of levee affected.

The performance data (Table 6-1) show that documented underseepage-related performance observations are concentrated along levees mapped as having high or very high susceptibility. Performance problems (seeps, boils, and failures) in very high and high classes represent 88 percent of the total reported line-based data, and 91 percent of the point-based data. Thus, about 90 percent of recorded performance problems occur along levees designated as having very high or high susceptibility to underseepage.

Consistent with the susceptibility assignments presented in Tables 5-1 and 5-2, geologic units with the greatest concentration of underseepage-related performance problems are:

- Holocene and active channels and meanders (SRtc, SRm, ac, Hch, Rch)
- The Sutter Bypass area where Holocene fine-grained basin deposits overlie older coarse deposits of the Modesto Formation (Hn/Qm)
- Quaternary alluvium (Qa) along the banks of the Sacramento River
- Peat deposits (Qpm) in the Delta area

As expected, the data show a far greater recorded incidence of seeps and boils relative to failures. Of the total 496 performance points, 87 percent are seeps and boils, and 13 percent are failures. Similarly with the line data, about 97 percent of levee miles with documented seepage-related problems are characterized by seeps and boils, and only 3 percent are failures.

Performance data normalized for the total length of levee mapped in each class are plotted for each susceptibility class in Figures 7 and 8. Expressing performance on a per mile basis allows comparison of the frequency of problems documented along levees in each of the four susceptibility classes.

The correlation between performance and susceptibility class is relatively good, but not exact. In general, the higher the susceptibility class, the greater the frequency of performance problems. Notable exceptions are discussed below.

As shown on Figure 7, the line and point data sets both show a higher frequency of seeps and boils in the high susceptibility class relative to the very high class. Several data limitations may account for this. First, some long stretches of levee designated as having very high susceptibility have no documented performance problems, diluting their frequency in the very high susceptibility class. These stretches of very high susceptibility levees that have not experienced poor past performance include 7 miles of the Putah Creek levee, 5 miles of the Cache Creek levee, and 4 miles of discontinuous levees in the northern Sacramento River channel. The reason for a lack of documented performance problems is not clear. It may be that performance data were not gathered for these levees (the performance data are preliminary and so may not be complete), that hydraulic conditions do not drive substantial underseepage, that a high flow event sufficient to stress these levees has not occurred during the time interval of observation, or that the deposits mapped are actually less susceptible than the geologic models suggest.

Two other factors probably account for most of the observed anomalies in performance between the high and very high susceptibility classes. First, the assignment of geologic unit Hn/Qm in the Sutter Bypass area to a class of high rather than very high susceptibility results in anomalously high frequency failure value (Figure 7) for the high susceptibility class. This geologic unit has the highest frequency per mile of performance problems of any on the map. Second, geologic unit Qa is a widely distributed unit mapped by Helley and Harwood (1985), and is assigned to the high susceptibility class. Where this unit has been mapped in more detail for ULE Program levees, it is subdivided into up to eight subunits, some of which are designated as having high susceptibility and some as having very high susceptibility. More detailed mapping that subdivides unit Qa throughout the larger NULE Program study area should result in an improved relationship between performance data and susceptibility classes.

Limitations associated with use of previous regional-scale mapping also show up in greater-than-expected failure frequency in levees designated as having low susceptibility (Figure 8). Most failures in the low susceptibility class (eight of 10 points) occur within geologic unit Qb, a unit with a similar regional scope to Qa discussed above. Inspection of relevant topographic and soils data surrounding these failure points suggests that detailed mapping would probably show that these geologic units should be assigned a higher susceptibility class.

In sum, preliminary performance data analysis for the North NULE Project levees generally support susceptibility class assignments. Approximately 90 percent of recorded underseepage-related performance problems occur along levees designated as having high and very high susceptibility. More importantly, the frequency of occurrence on an average per-mile basis is highest in levee reaches designated as having high and very high susceptibility (Figures 7 and 8). The frequency of failures is greatest in very high susceptibility (Figure 8).

Additional refinement of the geologic mapping and susceptibility assignments would probably improve the correlation between performance and susceptibility. Mapping at a detailed scale in areas covered by regional-scale mapping is indicated.

6.2 Sources and Degrees of Uncertainty

This section discusses the primary sources of uncertainty affecting analysis and results interpretation. Generally, the analyses and results of this Level 2-I study are affected by two types of uncertainty. Epistemic uncertainty can be reduced by additional data or research. Aleatory uncertainty reflects inherent, natural variations in the system and likely cannot be reduced by further study.

Sources of epistemic uncertainties involve:

- The relative underseepage susceptibility classes
- Resolution and quality of existing 1:62,500-scale geologic map data
- Inferences on subsurface conditions
- Discrete changes in susceptibility class results

Aleatory uncertainty is inherent to geologic, geomorphic and stratigraphic variability.

The project team judges that the relative degrees of contribution to uncertainty are greatest in the areas of resolution and quality of the existing 1:62,500 map data and aleatory uncertainty. The lowest contribution to uncertainty are discrete changes in susceptibility class results.

These uncertainties are discussed in more detail below.

6.2.1 Relative Underseepage Susceptibility Classes

The susceptibility classes developed for this analysis are internally consistent relative to each other. However, there is some uncertainty in the application of this relative scale to the actual underseepage hazard. For example: does the high susceptibility class truly reflect a significant underseepage hazard or likelihood of failure?

This study addressed possible sources of inaccuracy by analyzing levee performance case history data with respect to interpreted susceptibility classes. This provided an improved understanding of the relative susceptibility of levee foundations and offered preliminary insight on the general magnitude of poor performance in susceptibility classes (i.e., distress points per mile). Uncertainty could be further reduced through additional analysis of levee performance case history data that includes data from all categories of levee (urban or non-urban).

It is important to recognize that the susceptibility classes are considered relative to each other. Very low levee underseepage susceptibility does not mean that no underseepage will occur. Rather, it means that the other assigned classes are relatively more susceptible to levee underseepage based on their interpreted characteristics. There may be local areas of higher (or lower) underseepage susceptibility in all of the classes, although the likelihood of susceptibility is greater in areas with relatively higher susceptibility. Conversely, there may be local areas with very high susceptibility that are unlikely to experience underseepage as a result of local or site-specific geologic or geotechnical conditions. Additional characterization (more detailed geologic and geomorphic mapping) could help address and reduce local sources of uncertainty.

6.2.2 Resolution and Quality of Existing 1:62,500-Scale Geologic Map Data

The precision and accuracy limitations of the existing geologic map data are detailed in Section 3.4. These limitations carry through the underseepage analysis and contribute uncertainties to analysis and results. Additionally, the quality of geologic map unit interpretation in existing 1:62,500-scale geologic data in some places may be poor.

As an example, levees constructed on upper Riverbank Formation (map unit Qru) may appear to have case histories of boils. However, close inspection of photographic, topographic, and soil information could reveal that a veneer of younger unconsolidated deposits overlying unit Qru, which should be mapped as a different geologic unit and may result in the area having a different susceptibility class. These uncertainties in existing geologic map data affect underseepage analysis results as well as contribute error into the analysis of past performance data with respect to interpreted susceptibility. These uncertainties could be reduced by improving the resolution and quality of existing geologic map data.

6.2.3 Inferences on Subsurface Conditions

A lack of reliable data about subsurface conditions and geologic deposits contributes uncertainty to the underseepage analysis. The regional scale of this study requires developing reasonable inferences on the likely character of near-surface and shallow subsurface deposits. These inferences are based on available maps and an understanding of geomorphic processes involved in the deposition or modification of sediments. These inferences are then extended to underseepage susceptibility interpretations. In some instances, no data are presently available to help constrain or verify the geologic characteristics of the deposits (e.g., narrow floodplain channels). A lack of data about subsurface conditions contributes uncertainty to susceptibility results; little supporting information exists to constrain office-based interpretations of near surface sediments.

6.2.4 Gradational Deposits and Mapped Contacts

Based on the Level 2-I technical approach, changes in assigned susceptibility results occur at geologic or soil unit contacts. Abrupt changes in susceptibility class results are an outcome of performing analyses in a GIS environment. In a GIS environment, geologic or soil contacts are modeled as categorical changes when in reality, changes in geologic or soil type are likely more transitional or gradational.

An abrupt local change in the susceptibility class may be present where an actual variation in susceptibility class is gradual. A gradual change in soil type or geologic deposit over some distances reflects, at a minimum, the limiting accuracy of input data. Steps toward reducing this uncertainty could consist of developing transitional susceptibility classes (e.g., moderate-to-high) that would not necessarily simplify geotechnical evaluations of levee stability.

6.2.5 Map Border Effects

Changes in assigned susceptibility can occur at boundaries between map data sources (e.g., between geologic authors, or counties of soil surveys). Changes in assigned susceptibility (e.g., from low to high) at map boundaries should be treated carefully. For example, Figure 33 shows a NULE levee on the north side of Dry Creek abruptly changing from green (low susceptibility) to red (very high susceptibility). This change occurs at the border between 1:20,000-scale mapping and 1:62,500-scale mapping. A concerted effort was made to minimize border effects but because of the regional scale of analysis, some discrepancies remain.

6.2.6 Stratigraphic Variability

Analysis of geomorphic landforms and landscape relationships provide an indication of the dominant geomorphic processes operating to create or modify landforms and underlying deposits. The Sacramento Valley is aerially extensive and contains many miles of levees that extend across different landforms and deposits. Near-surface and shallow stratigraphic variability can correspondingly range from complex (high variability) to relatively simple (low variability). Stratigraphic variability at this regional scale should consider the history of deposition, geomorphic processes and the environment of deposition (e.g., high energy vs. low energy). Subsurface variability is inferred based on the dominant geomorphic processes that were likely in effect at, or immediately prior to, the time of levee construction. Interpretations of stratigraphic variability provide information for the geotechnical engineer or geologist that may need to plan an appropriate number of subsurface borings with finite resources.

Generally, low energy depositional environments exhibit low stratigraphic variability, both vertically and laterally. For example, flood basins tend to have low stratigraphic variability in the lateral and vertical directions.

High-energy depositional environments include stream channels and alluvial fans, and generally exhibit greater stratigraphic variability. Alluvial fans may exhibit even greater stratigraphic variability both laterally and vertically because the locus of deposition shifts up and down and side to side across the fan surface through geologic time (Figure 4).

Geomorphic construction of natural levees results in moderate stratigraphic variability, because the deposits result from many individual depositional overbank events. Because of the limited range in grain sizes given the depositional process, regional variability is low in the sediments of a natural levee – less than that of alluvial fans and stream channels, but probably greater than that of flood basins.

In the Delta, variability exists in the stratigraphy of the peat and mud deposits (geologic map unit Qpm). As noted earlier, the thickness of the peat strata varies in the North NULE study area, and generally is thicker near the center of the Delta and thinner near the margins of the Delta (USACE, 1987). Additionally, the percentage of organic material in the “peat and mud” unit is variable in the subsurface (USGS, 2000). The percentage of peat encountered beneath Delta islands is variable from island to island, but also within an island. Moreover, natural levee alluvium interfingers with peat and mud deposits, and can produce interspersed layers of peat and alluvium (Atwater, 1982). Lateral and vertical variability exists in peat(y) deposits.

This natural and stochastic stratigraphic variability may create conditions where, for example, there are localized low-susceptibility deposits within a given length of levee assessed as having high susceptibility. Conversely, there may also be localized very high susceptibility deposits in a given length of levee assessed as having low susceptibility.

7.0 SUMMARY AND RECOMMENDATIONS

7.1 Summary

The primary purpose of this Level 2-I analysis is to assess (at a regional scale) the hazard of levee underseepage, and to a lesser degree, soil settlement and ground subsidence. The technical approach for geomorphic analysis in the North and South NULE Project study areas is coordinated to develop consistent analysis results over the entire NULE region. The rationale for Level 2-I analysis is to assess regional levee underseepage susceptibility via a criteria matrix. The criteria matrix combined information about Quaternary geologic deposits, channel features mapped from historical topographic maps, and NRCS HSG. Input data were imported into a GIS and spatially intersected with NULE levee lines; susceptibility categories (very high, high, moderate, and low) were assigned to levee segments according to the cells in the matrix or table.

Because the Sacramento Valley is large, has diverse physiography, and contains many miles of levees, this assessment subdivides the North NULE Project study area into geomorphic domains having relatively consistent characteristics. Primary geomorphic domains include: older and younger alluvial fans, river floodplains and their natural levees, alluvial flood basins, and the Sacramento-San Joaquin Delta. Within each domain are individual geologic deposits that possess certain lithologic or pedogenic characteristics. Much of the North NULE levees overlie geologic deposits belonging to either natural levee or flood basin domains.

Results of the Level 2-I geomorphic analysis are depicted on a series of maps delineating interpreted foundation susceptibility to underseepage based on available soil and geologic data. The Level 2-I assessment generally confirms the conceptual model of geomorphic domains generated for the Level 1 study, but improves the level of detail and information available to assess underseepage susceptibility.

Geologic deposits interpreted as having very high underseepage susceptibility include:

- Historical and active stream channel deposits
- Hydraulic dredge spoils
- Quaternary channel meander zone
- Peat and mud deposits

Mapped geologic units interpreted as having high susceptibility include:

- Tailings from hydraulic mining
- Natural levee deposits
- Latest Pleistocene alluvial fans
- Holocene floodplain and channel deposits

Map units interpreted as having moderate susceptibility to underseepage include:

- Some flood basin deposits

- Holocene fan deposits from the Coast Ranges
- Middle to late Pleistocene alluvial fan deposits

Deposits mapped as low susceptibility include:

- Flood basin deposits with HSG C or D
- Early Pleistocene to Pliocene deposits

Levee underseepage susceptibilities within the North NULE Project study are assessed as follows:

- 14 percent are assessed as having very high underseepage susceptibility (128 miles)
- 50 percent are assessed as having high underseepage susceptibility (459 miles)
- 10 percent are assessed as having moderate underseepage susceptibility (89 miles)
- 26 percent are assessed as having low underseepage susceptibility (237 miles)

Preliminary levee performance information developed in the North NULE Project study area is analyzed to compare documented occurrences of underseepage to the mapped distribution of geologic deposits and susceptibility classes. The frequency of documented occurrences of underseepage (i.e., points per mile exposed) provide important input into the assignment and testing of susceptibility classes to specific deposit types. Consistent with the susceptibility assignments presented in Tables 5-1 and 5-2, geologic units with the greatest concentration of performance problems are:

- Holocene and active channels and meanders (SRtc, SRm, ac, Hch, Rch)
- The Sutter Bypass area where Holocene fine-grained basin deposits overlie older coarse deposits of the Modesto Formation (Hn/Qm)
- In Quaternary alluvium (Qa) along the banks of the Sacramento River
- In peat deposits (Qpm) in the Delta area.

While the correlation between performance and susceptibility class is relatively good, it is not exact.

Subsidence is greatest near the western Sacramento Valley towns of Zamora, Woodland, and Davis, probably because of long and sustained groundwater extraction (Lofgren and Ireland, 1974), as well as some component of tectonic down-warping (Harwood and Helley, 1987. Organic-rich peat deposits or former marshes are more likely to contribute to levee instability or experience settlement than foundations in other parts of the North NULE Project study area.

7.2 Recommendations

Based on an analysis of available data to date recommendations are as follows.

- Complete detailed surficial geologic mapping in very high and high susceptibility areas to assess the type and distribution of susceptible deposits that might be present beneath levee materials. This will help reduce uncertainty inherent in Level 2-I analyses.

- Consider additional analysis of historical levee performance data with respect to individual geologic deposits to refine the accuracy of the susceptibility framework.
- Field verify sedimentologic characteristics in small channels identified through Level 2-I mapping to improve and enhance understanding of the geologic and geotechnical characteristics of these features and deposits, refining the assessment of their likely controls on underseepage processes. Field verification techniques could consist of conventional drilling techniques (e.g., hollow stem auger, rotary wash borings), hand augering, shallow test pits (“potholes”), or shallow trenching.

8.0 CREDITS AND LIMITATIONS

8.1 Credits

This technical memorandum was prepared by the following personnel:

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8.2 Limitations

This geomorphic assessment has been performed in accordance with the standard of care commonly used as the state-of-practice in the engineering profession. Standard of care is defined as the ordinary diligence exercised by fellow practitioners in this geographic area performing the same services under similar circumstances during the same time period.

Discussions of subsurface conditions summarized in this technical memorandum are based on interpretation of geomorphic data supplemented with very limited subsurface exploration information. Variations in subsurface conditions may exist between those shown on maps and actual conditions. Due to the scale of mapping, the project team may not be able to identify all adverse conditions in levee foundation materials.

No warranty, either express or implied, is made in the furnishing of this technical memorandum that is the result of geotechnical evaluation services. URS makes no warranty that actual encountered site and subsurface conditions will exactly conform to the conditions described herein, nor that this technical memorandum’s interpretations and recommendations will be sufficient for all construction planning aspects of the work. The design engineer or contractor should perform a sufficient number of independent explorations and tests as they believe necessary to verify subsurface conditions, rather than relying solely on the information presented in this report.

URS does not attest to the accuracy, completeness, or reliability of maps, data sources, geotechnical borings and other subsurface data produced by others that are included in this technical memorandum. URS has not performed independent validation or verification of data reported by others.

Data presented in this technical memorandum are time-sensitive in that they apply only to locations and conditions existing at the time of preparation of this report. The maps produced generally present conditions as they occurred in the early 1900s, as primary data interpreted for this report are from this period. Data should not be applied to any other projects in or near the area of this study nor should they be applied at a future time without appropriate verification, at which point the one verifying the data takes on the responsibility for it and any liability for its use.

This technical memorandum is for the use and benefit of DWR. Use by any other party is at their own discretion and risk.

This technical memorandum should not to be used as a basis for design, construction, remedial action or major capital spending decisions.

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TABLES

A. Topographic Maps at 1:24,000 Scale.

Original Quad Name	Current Quad Name	Date Surveyed	Date Published	Year Reprinted	Geo-Reference RMS Error
Gerber	Gerber	1947	1950	n/a	2.7 m
Los Molinos	Los Molinos	1947	1952	n/a	2.6 m
Red Bluff East	Red Bluff East	1947	1951	n/a	3.4 m

B. Topographic Maps at 1:31,680 Scale.

Original Quad Name	Current Quad Name	Date Surveyed	Date Published	Year Reprinted	Geo-Reference RMS Error
Chico Landing	Ord Ferry	1904-1910	Nov. 1912	1931	14.7 m
Durham	Chico	1910	Nov. 1912	n/a	16.3 m
Florin	Florin	1907	Oct. 1909	n/a	7.9 m
Butte City	Butte City	1909-1910	Mar. 1912	n/a	15.0 m
Collinsville	Antioch North	1906-1907	1918	n/a	7.3 m
Arbuckle	Arbuckle	1905	1918	n/a	11.8 m
Biggs	Biggs	1909-1910	Apr. 1912	n/a	11.7 m
Bruceville	Bruceville	1907-1908	Jul. 1910	n/a	18.1 m
Babel Slough	Clarksburg	1906	1916	n/a	33.9 m
Maine Prairie	Dozier	1906	1916	n/a	10.9 m
Gilsizer Slough	Gilsizer Slough	1909	Sep. 1911	n/a	14.2 m
Grimes	Grimes	1905-1909	Aug. 1911	n/a	12.6 m
Honcut	Honcut	1909-1910	Jan. 1912	n/a	15.2 m
Isleton	Isleton	1906-1908	Apr. 1910	n/a	15.3 m
Jersey	Jersey Island	1906-1908	Jun. 1910	n/a	7.9 m
Kirkville	Kirkville	1905	May. 1905	n/a	36.3 m
Cache Slough	Liberty Island	1906	1916	n/a	20.5 m
Llano Seco	Llano Seco	1904-1910	May. 1912	n/a	8.6 m
Compton Landing	Moulton Weir	1904	1917	n/a	11.9 m
Nelson	Nelson	1910	May. 1912	n/a	12.1 m
Rio Vista	Rio Vista	1906-1908	1910	n/a	25.2 m
Sanborn Slough	Sanborn Slough	1909-1910	Dec. 1911	n/a	18.0 m
Saxon	Saxon	1906	1916	n/a	16.2 m
Dry Creek	Shippee	1910	Jun. 1912	n/a	13.4 m
Sutter	Sutter	1909	Sep. 1911	n/a	15.8 m
Tisdale Weir	Tisdale Weir	1905-1910	Feb. 1912	n/a	9.7 m
Landlow	West of Biggs	1909-1910	Dec. 1911	n/a	13.1 m
Wheatland	Wheatland	1908	Nov. 1910	n/a	16.9 m

B. Topographic Maps at 1:31,680 Scale.

Original Quad Name	Current Quad Name	Date Surveyed	Date Published	Year Reprinted	Geo-Reference RMS Error
Zamora	Zamora	1905	1916	1920	15.1 m
Hamilton	Hamilton City	1904	Feb. 1914	n/a	4.5 m
Keefers	Richardson Springs	1910	Jun. 1912	1922	7.1 m
Knights Landing	Knights Landing	1905-1908	Aug. 1910	n/a	23.2 m
Marcuse	Sutter Causeway	1908	Aug. 1910	n/a	9.6 m
Marysville Buttes	Sutter Buttes	1909-1911	Nov. 1912	1943	11.8 m
Meridian	Meridian	1905 and 1909-1910	Apr. 1912	n/a	7.0 m
Nicolaus	Nicolaus	1908	Aug. 1910	n/a	4.8 m
Nord	Nord	1910	Aug. 1912	1947	9.1 m
Pennington	Pennington	1909-1911	Nov. 1912	n/a	6.3 m
Princeton	Princeton	1904	1918	n/a	5.5 m
Sheridan	Sheridan	1908	Aug. 1910	n/a	8.3 m
Yuba City	Yuba City	1909	Jul. 1911	n/a	8.5 m

C. Topographic Maps at 1:62,500 Scale.

Original Quad Name	Current Quad Name	Date Surveyed	Date Published	Year Reprinted	Geo-Reference RMS Error
Antioch	n/a	1906-1907	Nov. 1908	1951	14.5 m
Colusa	n/a	1904-1905	1907	1916	6.0 m
Courtland	n/a	1906	Mar. 1908	n/a	7.4 m
Davisville	n/a	1905	Mar. 1907	n/a	39.8 m
Dunnigan	n/a	1905	Feb. 1907	n/a	5.6 m
Vina	n/a	1903-1904	Nov. 1904	Sep. 1911	25.8 m
Marysville Buttes and Vicinity	n/a	1905 and 1909-1911	Nov. 1913	n/a	13.4 m
Oroville	n/a	1941-1942	1944	n/a	1.4 m
Rio Vista	n/a	1952-1953	1958	n/a	n/a
Willows	n/a	1904	Jan. 1906	Apr. 1914	13.6 m

D. Topographic Maps at 1:125,000 Scale.

Original Quad Name	Current Quad Name	Date Surveyed	Date Published	Year Reprinted	Geo-Reference RMS Error
Chico	n/a	1886-1888	May 1895	1932	n/a
Marysville	n/a	1886	Jan. 1895	Nov. 1904	n/a

Table 3-1. List of Topographic Maps.

D. Topographic Maps at 1:125,000 Scale.

Original Quad Name	Current Quad Name	Date Surveyed	Date Published	Year Reprinted	Geo-Reference RMS Error
Smartsville	n/a	1885-1886	Apr. 1895	1917	n/a

Age	Helley and Harwood (1985)[1]		Department of Water Resources (1994)[2]		Atwater (1982)[3]		WLA Urban Levee Mapping (2007, 2008)[4]	
	Symbol	Name	Symbol	Name	Symbol	Name	Symbol	Name
Holocene	t	Tailings (from gold mining, post–1849)					DT	Dredge tailings from gold mining
					Qds	Dredge spoils (from hydraulic dredging of channels post–1900)		
	Qsc	Stream channel deposits	SRtc	Sacramento River channels (post-1896)[5]			Rch	Historical channel deposits
			SRm	Sacramento River meander belt (pre-1896)[6]			Rb	Historical channel bar deposits
							Hch	Holocene channel deposits
	Qa	Alluvium					Rch	Historical channel deposits
					Ql	Natural levee deposits	Ra	Historical alluvial deposits, undifferentiated
							Rdf	Historical distributary fan deposits
							Rcs	Historical crevasse splay deposits
							Rdc	Historical distributary channel deposits
							Rob	Historical overbank deposits
							Rsl	Historical slough deposits
							Rb	Historical channel bar deposits
							Rf	Historical alluvial fan deposits
							Rob/Qru	Historical overbank deposits overlying Upper Riverbank Fm
							Hchy	Late Holocene channel deposits
							Hfy	Late Holocene alluvial fan deposits, undifferentiated
							Hffy	Late Holocene fine-grained alluvial fan deposits
							Hch	Holocene channel deposits
					Ql	Natural levee deposits	Ha	Holocene alluvial deposits, undifferentiated
							Ha(Agr)	Holocene alluvial deposits, cultivated in 1937
							Hdf	Holocene distributary fan deposits
							Hcs	Holocene crevasse splay deposits
							Hob	Holocene overbank deposits
							Hf	Holocene alluvial fan deposits
							Hff	Holocene fine-grained alluvial fan deposits
							Qa	Quaternary alluvial deposits, undifferentiated
	Qb	Undivided basin deposits			Qyp	Younger alluvium of Putah Creek	Hffy	Late Holocene fine-grained alluvial fan deposits
							Hff	Holocene fine-grained alluvial fan deposits
							Hn	Holocene basin deposits
							Hn(Agr)	Holocene basin deposits, cultivated in 1937
							Hs	Holocene marsh deposits
							Hn/Qm	Holocene basin deposits overlying shallow Modesto Fm
	Qp	Peat deposits			Qpm	Peat and mud		
Middle to late Pleistocene	Qmu	Modesto Formation, Upper Member			Qom	Older alluvium of Montezuma Hills	Qmu	Modesto Formation, Upper Member
							Pf	Pleistocene alluvial fan deposits
	Qml	Modesto Formation, Lower Member			Qop	Older alluviium of Putah Creek	Qml	Modesto Formation, Lower Member
							Pf	Pleistocene alluvial fan deposits
	Qru	Riverbank Formation, Upper Member					Qru	Riverbank Formation, Upper Member
	Qrl	Riverbank Formation, Lower Member					Qrl	Riverbank Formation, Lower Member
Older	Qrb, Qtl, Tla/b, Ttc	Red Bluff, Turlock Lake, and Tuscan Formations						

*Not all geologic units are listed in this chart. All geologic units present beneath levees are listed.

[1]Helley, E.J., and Harwood, D.S., 1985, Geologic map of the late Cenozoic deposits of the Sacramento Valley and Northern Sierran foothills, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1790, scale 1:62,500, 5 sheets. Maps were digitized and made available by Jonathan Mulder, DWR Northern District.

[2]Department of Water Resources (DWR), 1994, Surface geology along the Sacramento River; Compiled by Koll Buer, Northern District DWR; obtained from Stacey Cepello from DWR Red Bluff, viewable on line at http://www.sacramentoriver.org/website/recwebims/viewer.htm; Red Bluff to Colusa. This data source replaces Helley and Harwood (1985) along the Sacramento River north of Colusa.

[3]Atwater, B.F., 1982, Geologic Maps of the Sacramento-San Joaquin Delta, California, U.S. Geological Survey Miscellaneous Field Studies Map MF-1401, scale 1:24,000, 21 sheets.

[4]Geologic mapping by WLA in 2007 and 2008 as part of the Urban Levee Evaluation Project.

[5]Map data spanned 1896–1991; unit boundary envelopes the lateral extent of the channels, and is slightly modified from original map unit based on supplemental data from 1999 and 2004.

[6]Belt of meander scrolls, oxbow lakes, and channels associated with former river positions. This unit lies outside of the SRtc, and represents older (late Holocene) deposits of the Sacramento River. Individual morphologic units not delineated.

County	Soil Survey Publication Date	Time Period of Content (Corresponds to Currentness Reference)
Tehama	1967	2004-2006
Glenn	1968	2003-2006
Yolo	1972	1999-2005
Solano	1977	2001-2006
Placer	1980	1998-2006
Colusa	1983	2001-2005
Butte	1984	2005-2006
Sutter	1988	1998-2006
Sacramento	1993	1998-2006
Yuba	1997	2000-2006

Domain (Figure 2)	General Description	Age of Deposits	Geologic Consolidation	General Surface Deposit Textures	Stratigraphic Variability	Relative Permeability	Comments	Northern NULE	
								Miles	%
CRF	Coast Range alluvial fans	Holocene	Unconsolidated	sand to clay	Moderate	Low to High	East-flowing	33	4
CFo	Cascade alluvial fans (older)	Pleistocene	Semi-consolidated	sand, silt, clay, fine gravel	Moderate	Low to High	West-flowing	43	5
CFy	Cascade alluvial fans (younger)	Pleistocene	Semi-consolidated	silt and clay	Moderate	Low to High	West-flowing	18	2
CRH	Coast Range hills	Pliocene	Consolidated	gravel to clay	High	Low to Moderate	Uplands	0	0
D	Delta	Holocene	Unconsolidated	peat and clay	Low	Moderate	Saturated, organic rich	75	8
FB	Flood Basins	Holocene	Unconsolidated	silt and clay	Low	Low	Low-energy environment	193	22
FR	Feather River floodplain and natural levees	Holocene	Unconsolidated	sand, silt, and clay	High	High	South-flowing; strongly affected by mining debris	19	2
SR	Sacramento River floodplain and natural levees	Holocene	Unconsolidated	fine gravel, sand, silt and clay	Moderate	High	South-flowing; silty natural levees	315	36
SBF	Sutter Buttes fans	Pleistocene	Semi-consolidated	sand, silt, clay, fine gravel	Moderate	Low to High	From Sutter Buttes	0	0
SNFo	Sierra Nevada fans (older)	Pliocene	Consolidated	gravel to clay	High	Low to Moderate	Duripans near surface	0	0
SNFy	Sierra Nevada fans (younger)	Pleistocene	Semi-consolidated	gravel to clay	High	Low to High	Hardpans near surface	36	4
SNFy-FB	Sierra Nevada fan (y) - Flood Basin	Holocene-Pleistocene	Unconsolidated to semi-consolidated	sand, silt and clay	Low	Moderate	Transitional domain, fine-grained over coarse-grained	57	6
SRm	Sacramento River meander belt	Holocene	Unconsolidated	cobbles, gravel, sand, silt and clay	High	High	South-flowing	55	6
ST	Sierran Tributary	Holocene	Unconsolidated	gravel, sand, silt, and clay	High	High	West-flowing; strongly affected by mining debris	45	5
STs	Sierran Tributary (small)	Holocene	Unconsolidated	sand and silt	Moderate	Moderate	West-flowing	0	0

Geologic Map Unit Symbols	Geologic Deposit	NRCS Hydrologic Soil Group		
		A	B	C, D
ac, SRtc	Active stream channel	VH	VH	VH
Qds	Hydraulic dredge spoils	VH	VH	H
t	Tailings from hydraulic mining	H	H	M
Qsc, SRm	Quaternary stream channel, Late Holocene channel meander zone	VH	VH	VH
Qa, Ql	Holocene alluvium and natural levee deposits, undifferentiated	H	H	H
Qp, Qpm	Peat deposits	VH	VH	VH
Qb, Qyp	Flood basin deposits, and younger alluvium of Putah Creek	M	M	L
	Alluvial fan deposits (west side, San Joaquin valley)			
	Alluvial Fan Terrace deposits (east side, San Joaquin valley)			
Qmu, Qom	Modesto Fm (upper) (Pleistocene to Holocene) and older alluvium of the Montezuma Hills (late Pleistocene)	H	H	M
Qml, Qop	Modesto Fm (lower) (Pleistocene) and older alluvium of Putah Creek (Pleistocene)	M	M	L
Qr	Riverbank Fm (Pleistocene)	L	L	L
Qrb, Qtl, Tla/b, Ttc	Pre-Riverbank Fm deposits and bedrock	L	L	L

Notes

Underseepage susceptibility classes:

VH = Very High
H = High
M = Moderate
L = Low

Grey shading indicates map unit that has not been shown on existing maps in the North NULE region.

Unit Symbol	Unit Name	Susceptibility Rating
DT	Dredge tailings from hydraulic mining	M
Ra	Historical alluvial deposit, undifferentiated	VH
Rb	Historical channel bar deposits	VH
Rch	Historical channel deposits	VH
Rcs	Historical crevasse splay deposits	VH
Rdc	Historical distributary channel deposits	VH
Rdf	Historical distributary fan deposits	VH
Rf	Historical alluvial fan deposits	VH
Rofc	Historical overflow channel	VH
Rob	Historical overbank deposits	VH
Rsl	Historical slough deposits	H
Rla	Historical lacustrine deposits, Clear Lake	H
W 1937	Water in 1937	H
Ha	Holocene alluvial deposits, undifferentiated	H
Ha (Agr)	Holocene alluvial deposits, cultivated in 1937	H
Hch	Holocene channel deposits	H
Hcs	Holocene crevasse splay deposits	H
Hob	Holocene overbank deposits	H
Hdf	Holocene distributary fan deposits	H
Hchy	Late Holocene channel deposits	M
Hf	Holocene alluvial fan deposits	M
Hff	Holocene fine-grained alluvial fan deposits	M
Hffy	Late Holocene fine-grained alluvial fan deposits	M
Hfy	Late Holocene alluvial fan deposits	M
Hn/Qm	Holocene basin deposits, shallow over Modesto Fm'n	H
Hn	Holocene basin deposits	L
Hn (Agr)	Holocene basin deposits, cultivated in 1937	L
Hs	Marsh deposits	H
Qa	Quaternary alluvial deposits undifferentiated	H
Qla	Quaternary lacustrine deposits, Clear Lake	M
Qa/b	Quaternary alluvium over basalt, Clear Lake	M
Pf	Pleistocene alluvial fan deposits	L
Qml	Modesto Formation; lower member	L
Qmu	Modesto Formation; upper member	M
Qrl	Riverbank Formation; lower member	L
Qru	Riverbank Formation; upper member	L
Rob/Qru	Historical overbank deposits over upper Riverbank	M

Point Data

Performance Problem	Susceptibility Class	Count	Percent Total Points	Points per Levee Mile
Failure	VH	12	18	0.11
	H	41	62	0.09
	M	3	5	0.04
	L	10	15	0.05
	All classes	66	100	0.08
Seepage/Boils	VH	68	31	0.62
	H	329	61	0.75
	M	17	4	0.23
	L	16	4	0.08
	All classes	430	100	0.52

Line Data

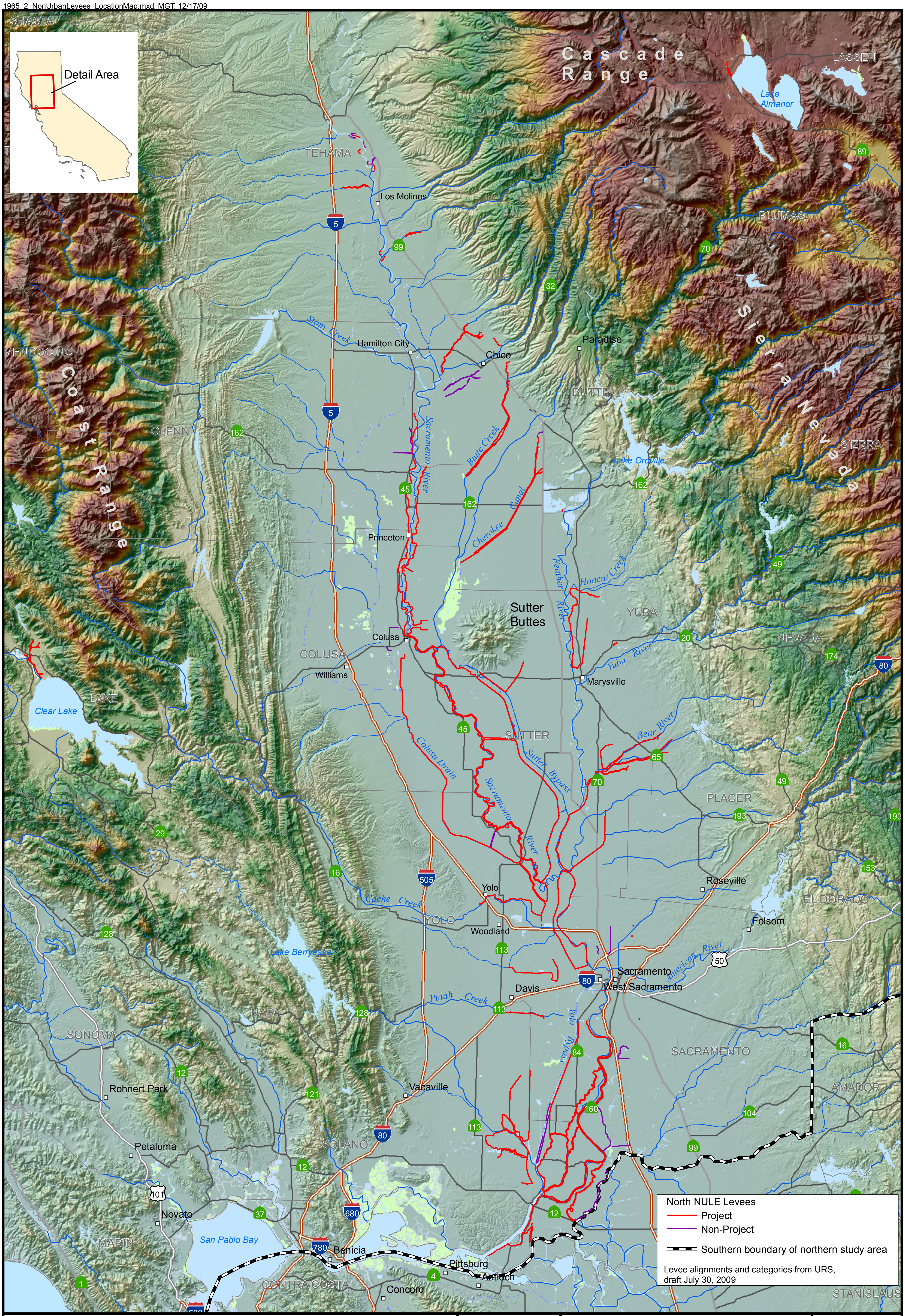
Performance Problem	Susceptibility Class	Miles Affected Levee	Percent Total Miles Affected	Affected Miles per Levee Mile (%)
Failure	VH	0.67	36	0.61
	H	0.64	35	0.15
	M	0.14	8	0.19
	L	0.39	21	0.20
	All classes	1.85	100	0.22
Seepage/Boils	VH	6.82	13	6.20
	H	40.84	76	9.27
	M	3.70	7	4.95
	L	2.20	4	1.11
	All classes	53.56	100	6.51

Levee Mileage

Susceptibility Class	Levee Miles	Percent Total Miles
VH	110	13
H	440	54
M	75	9
L	198	24
All classes	823	100

FIGURES

1965_2_NonUrbanLevees_LocationMap.mxd, MGT, 12/17/09



N

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Miles

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Division of Flood Management
Levee Evaluations Branch

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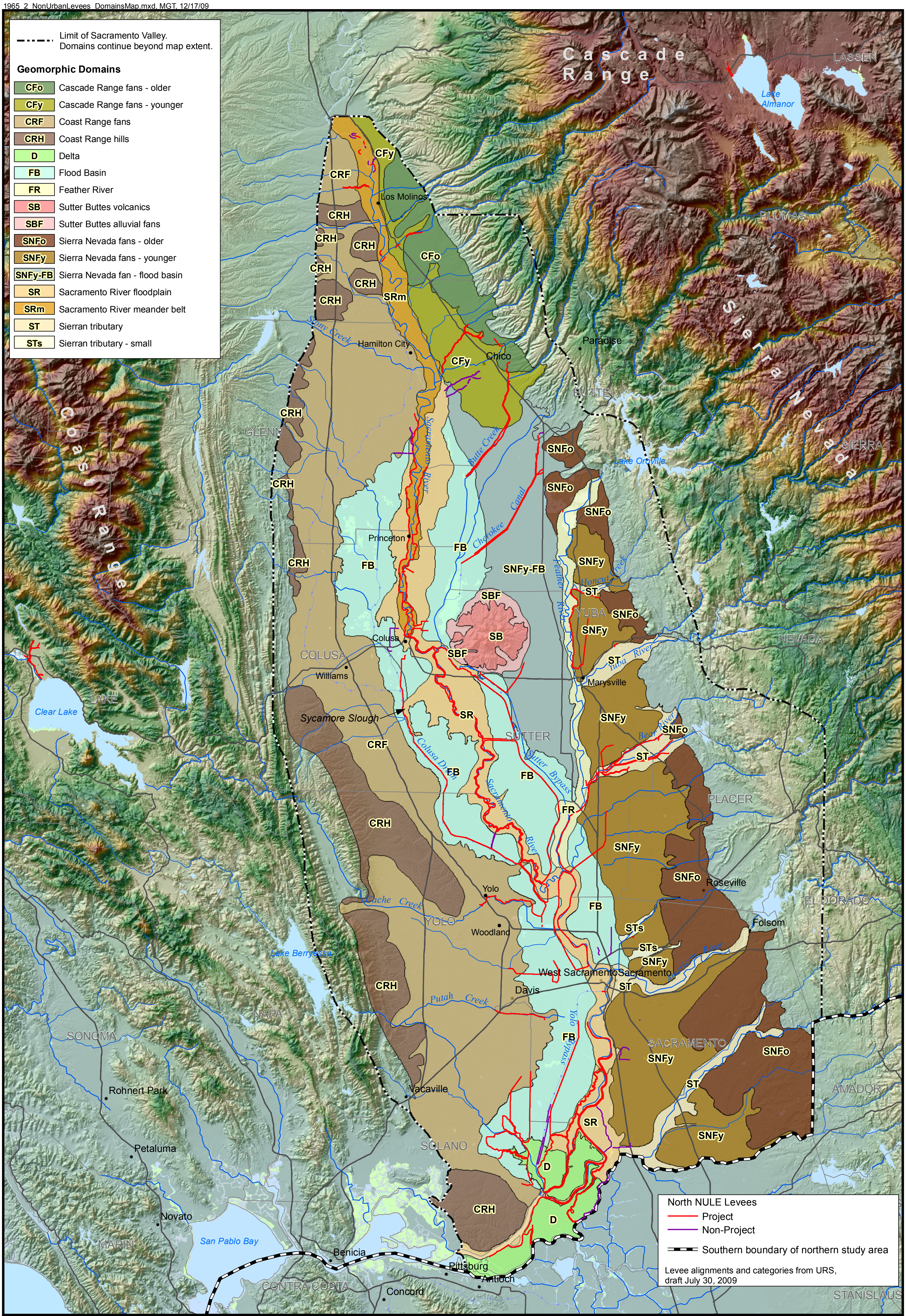
North NULE Levees

North Non-Urban Levee Evaluations

Figure 1

1965_2_NonUrbanLevees_DomainsMap.mxd, MGT, 12/17/09



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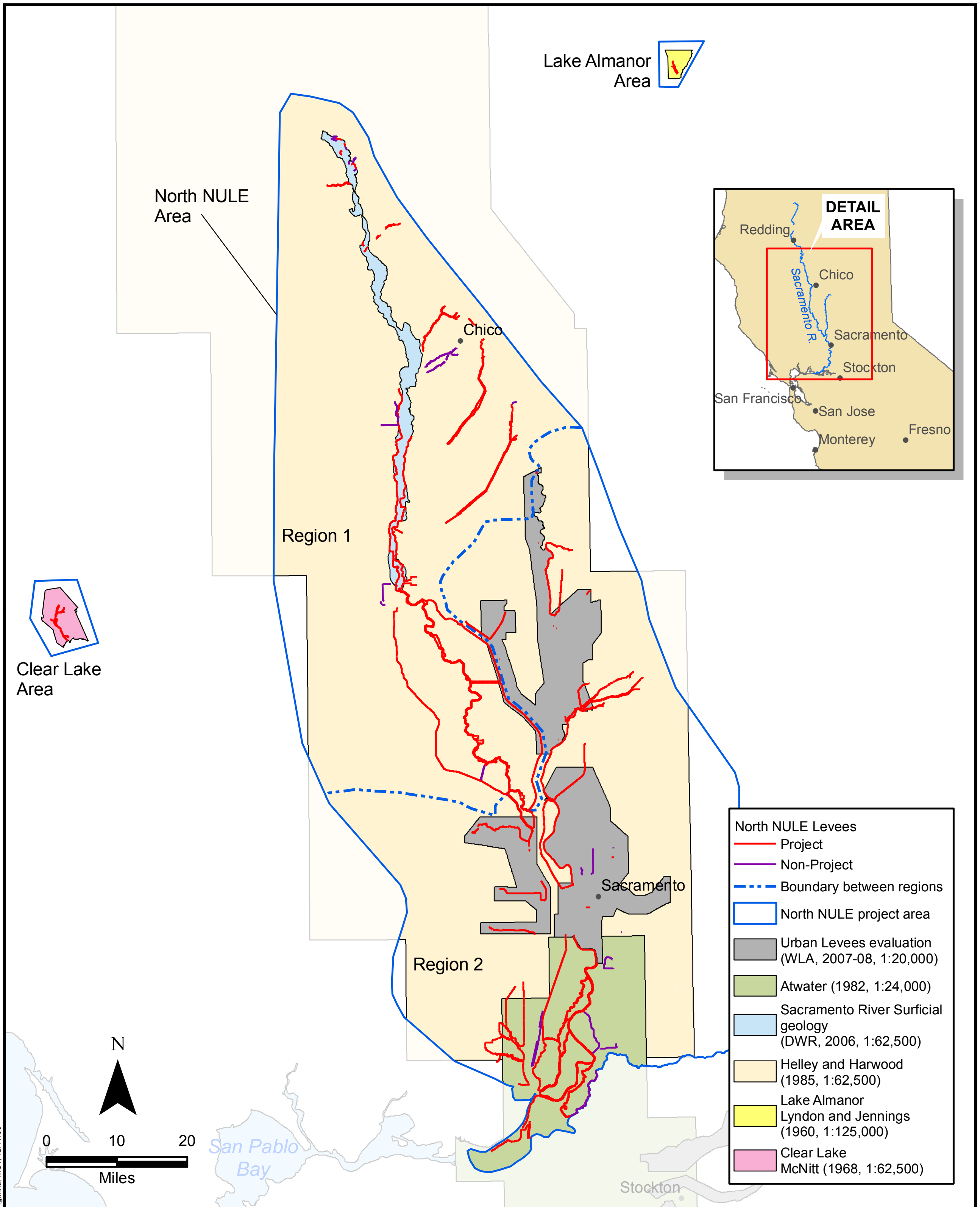
North NULE Geomorphic Domains

North Non-Urban Levee Evaluations

Figure 2



1965_NULE_2_GeologySources_Fig.mxd, MGT, 12/17/09

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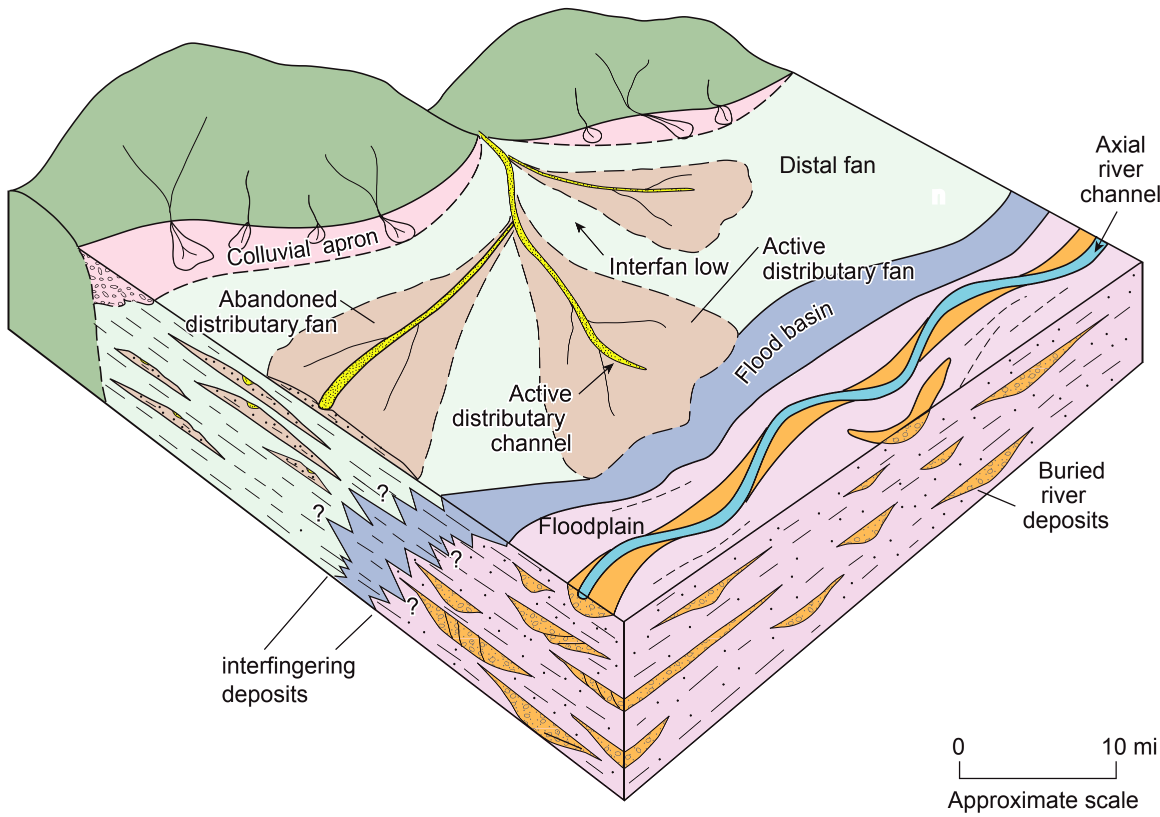
Index of Geologic Source Data

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 3



Explanation

Facies	*Unit*	*Geologic Material*
Interfan and distal fan		Clay and silt with lesser sand
Proximal fan		Sand, silt, and clay
Distributary channel		Sand and fine gravel with lesser silt and clay
Flood basin		Clay with lesser silt and sand
Floodplain		Silt and sand with clay
Channel and bar		Well sorted gravel and sand
Colluvial apron		Poorly sorted gravel and sand
		Bedrock

1965_NULEF5-block ai jtp.Modified 07.08.09

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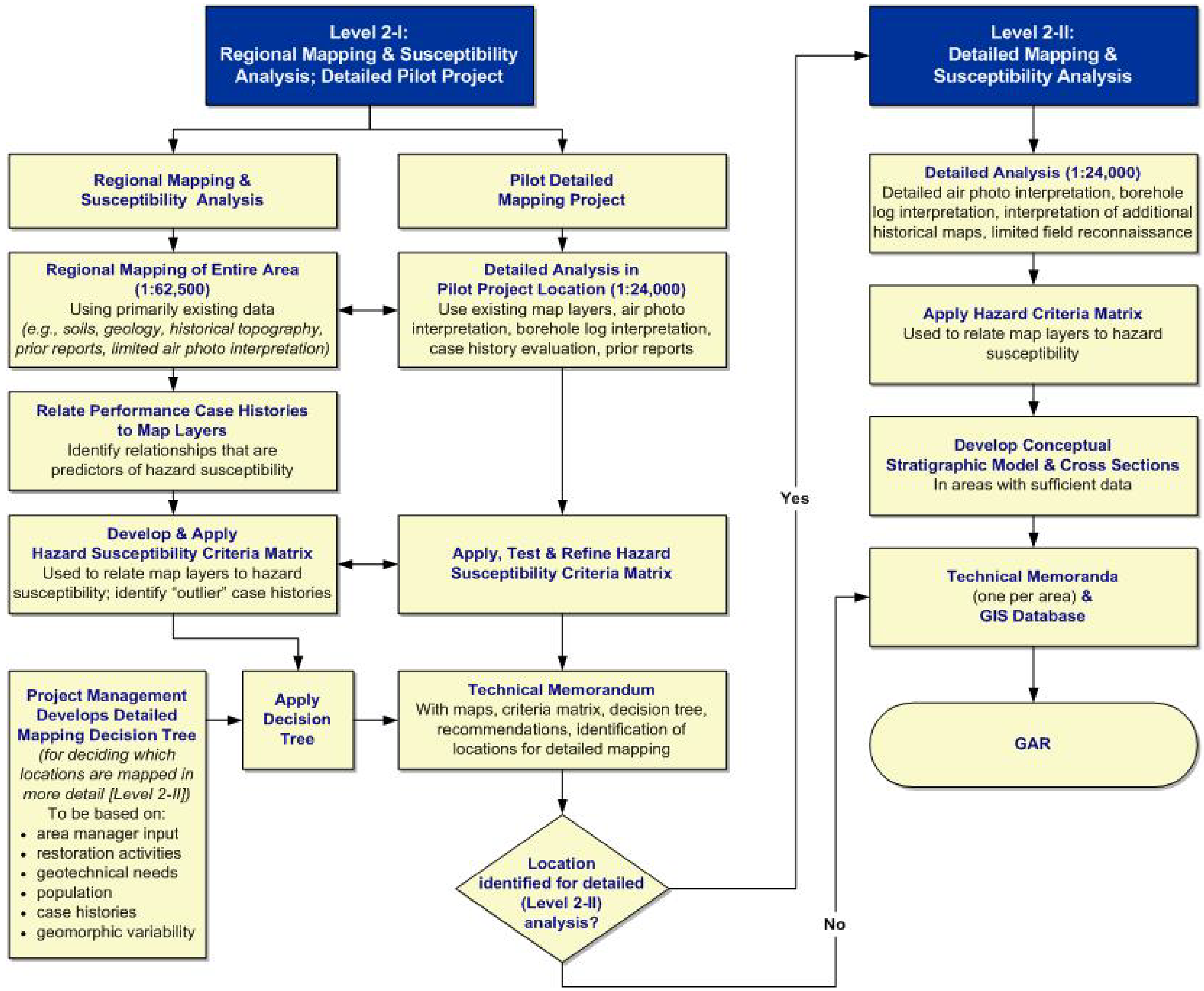
Conceptual Block Diagram

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 4



1965_NULE-workflow_Fig.5.Modified 07.08.09

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Levee Evaluations Branch

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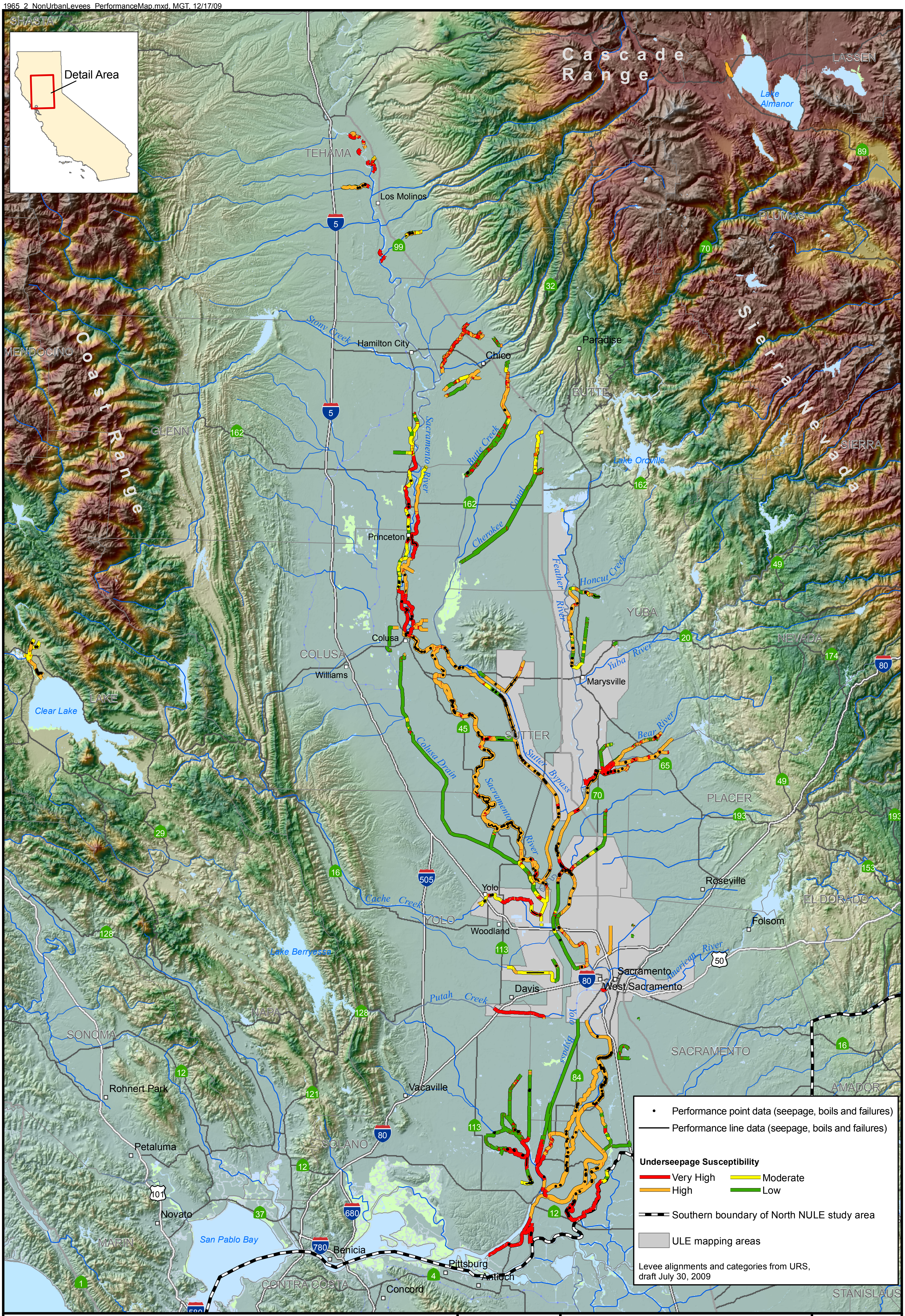
Workflow Diagram

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 5



N
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Miles

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Levee Evaluations Branch

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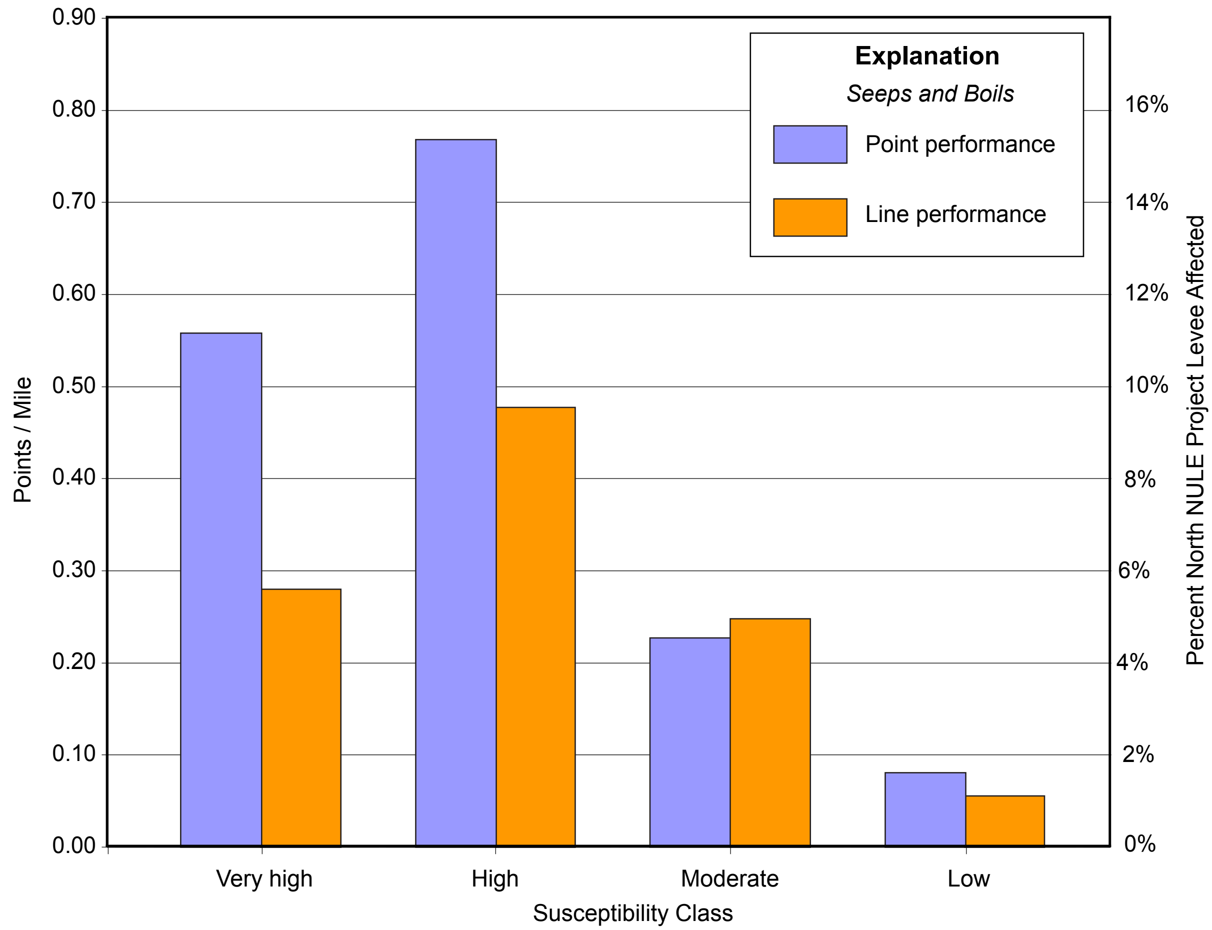
North NULE Performance Map

North Non-Urban Levee Evaluations

Figure 6



1965_NULE_7_Plot Seepage and Boil Frequency_Fig.7.Modified 121709

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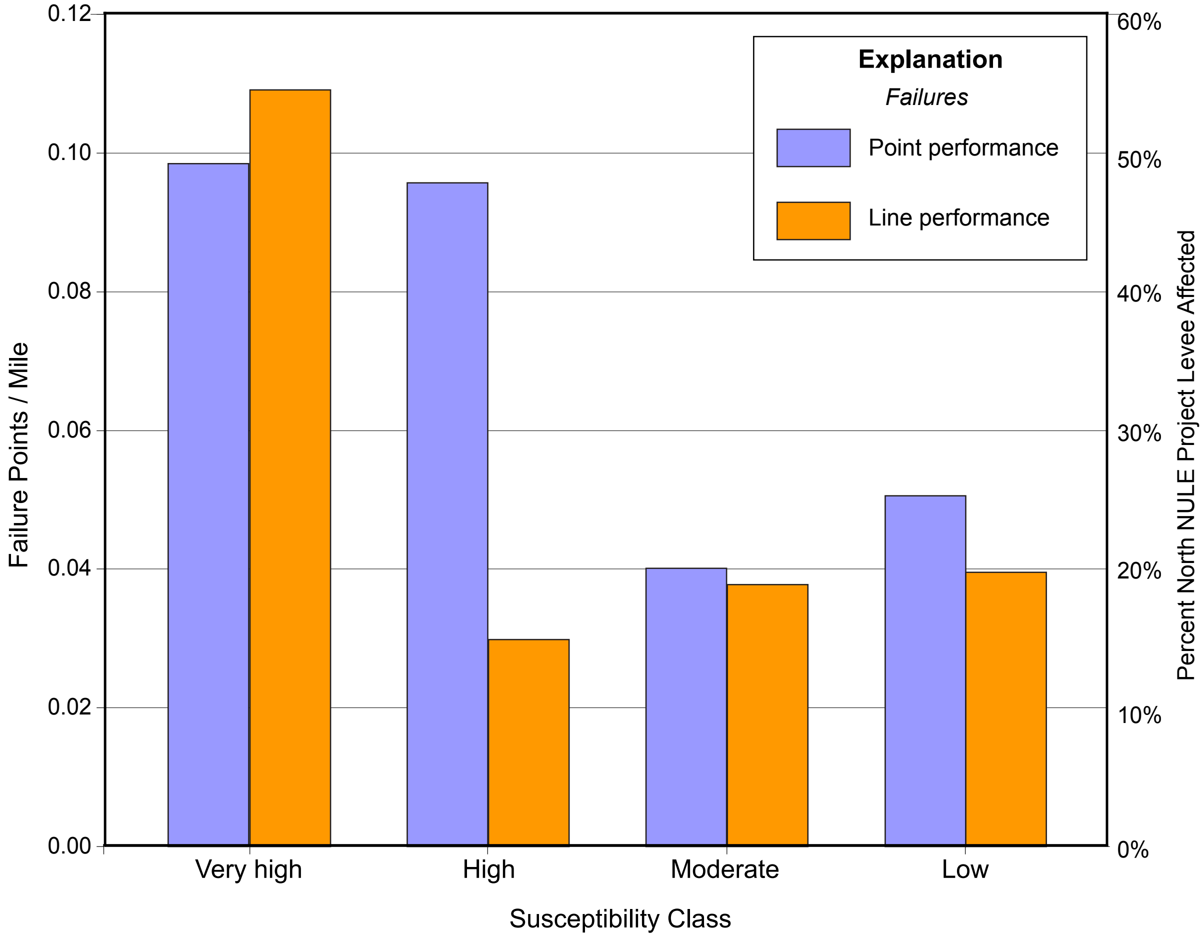
Plot of Seepage and Boil Frequency by Susceptibility Class

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 7



1965_NULE_7_Plot Seepage and Boil Frequency_Fig.8,Modified 121709

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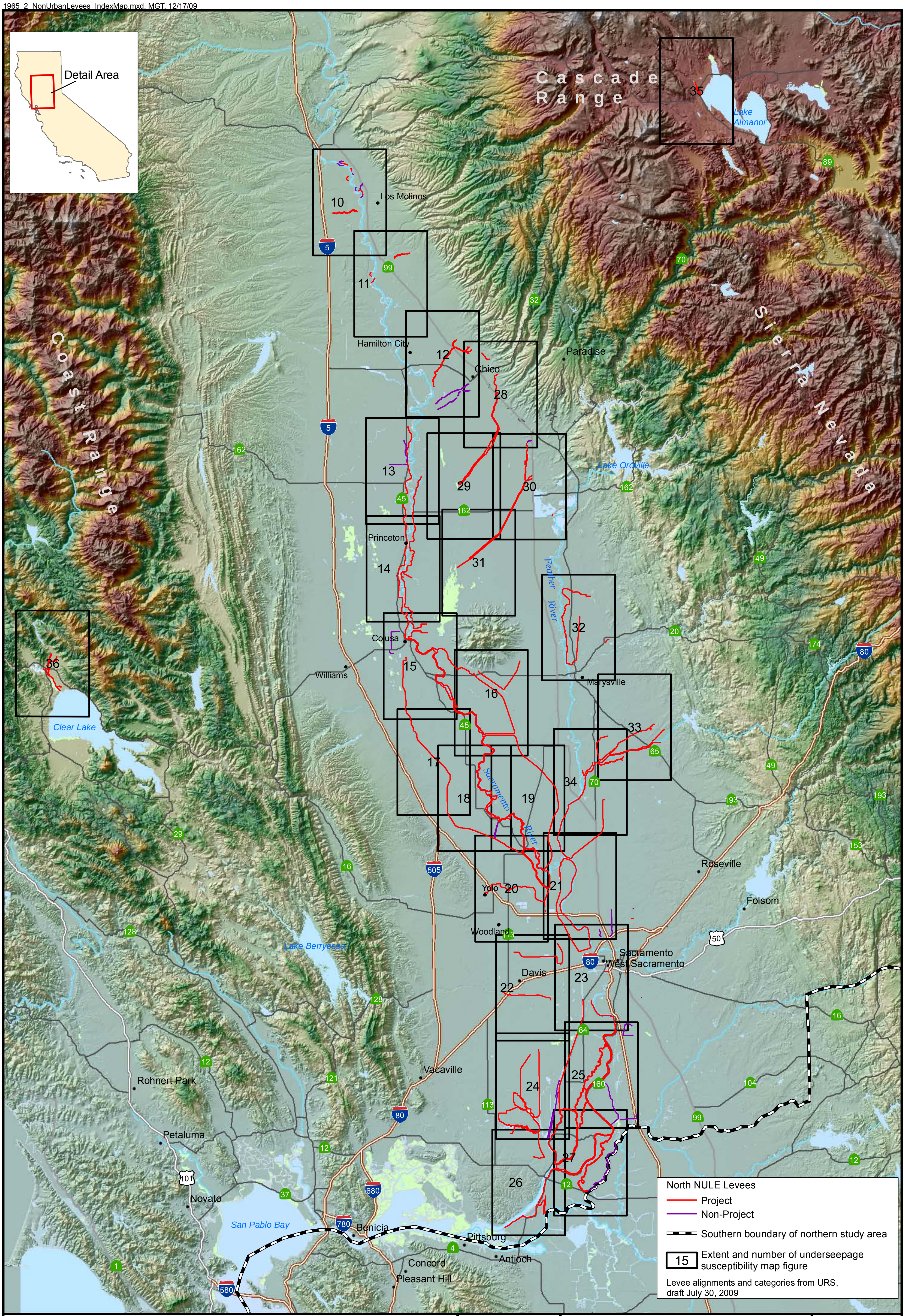
Plot of Failures
by Susceptibility Class

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 8

1965_2_NonUrbanLevees_IndexMap.mxd, MGT, 12/17/09



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Miles

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Division of Flood Management
Levee Evaluations Branch

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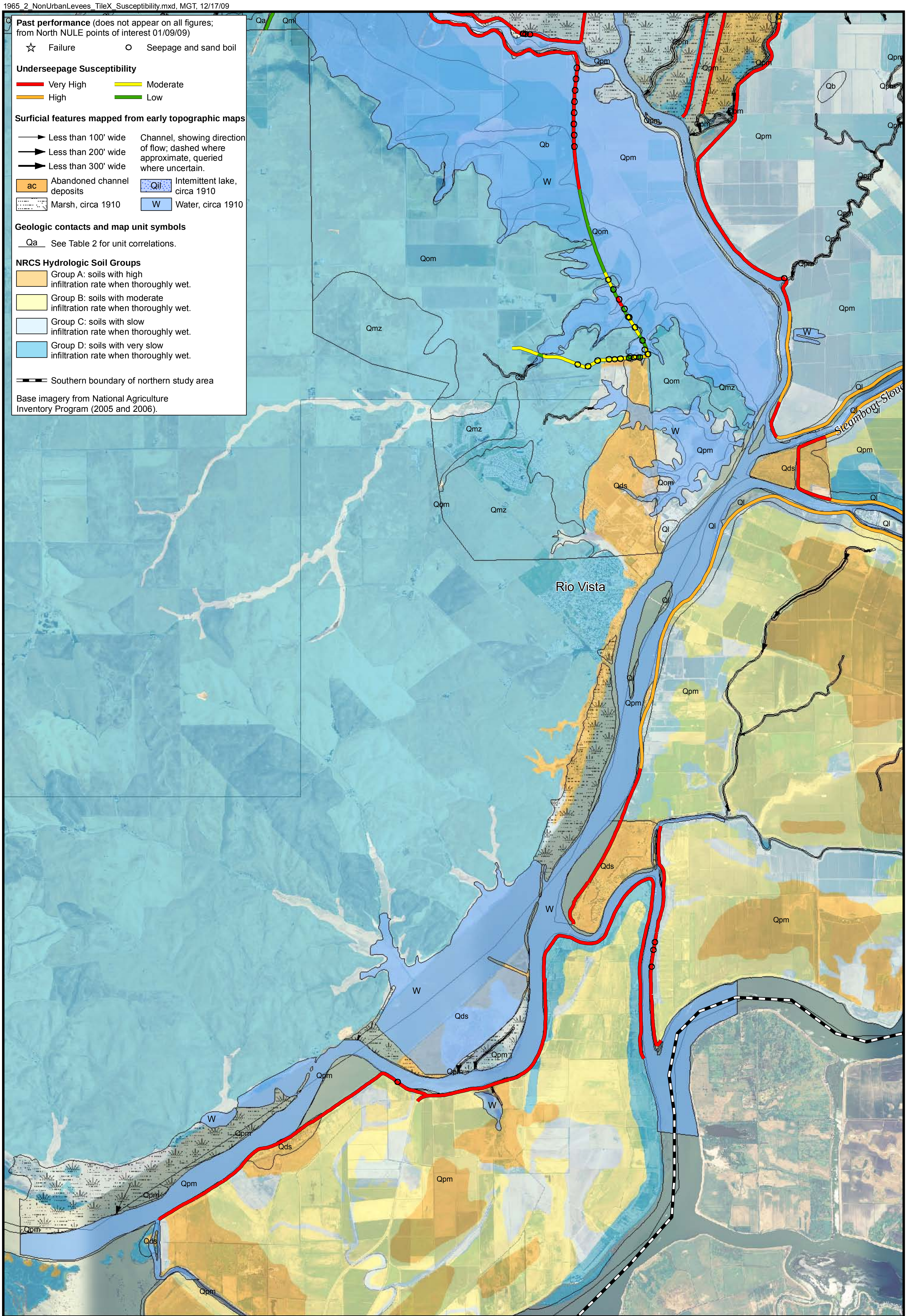
North NULE Index Map

North Non-Urban Levee Evaluations

Figure 9



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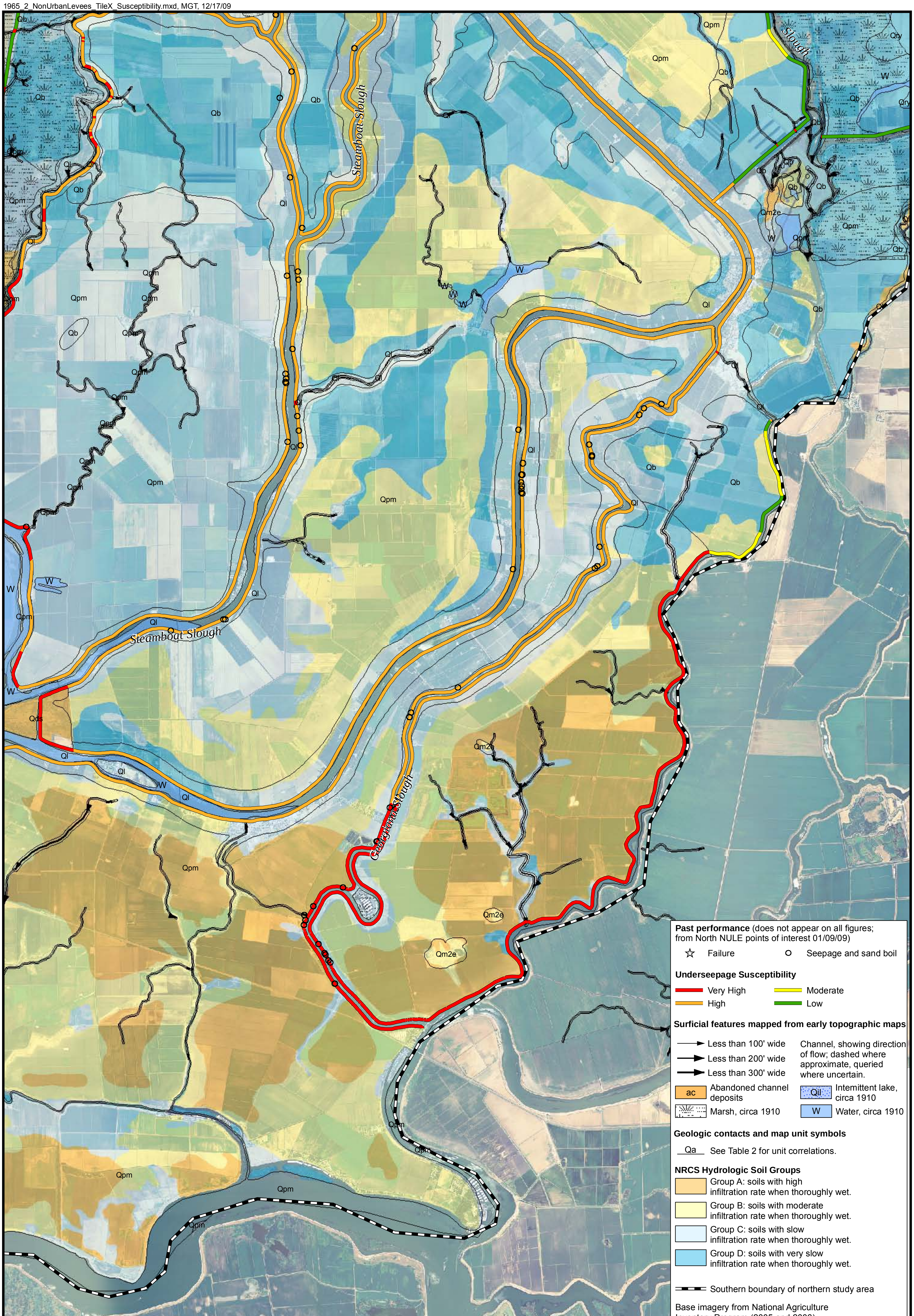
Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 26



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Division of Flood Management
Levee Evaluations Branch

URS
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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 27

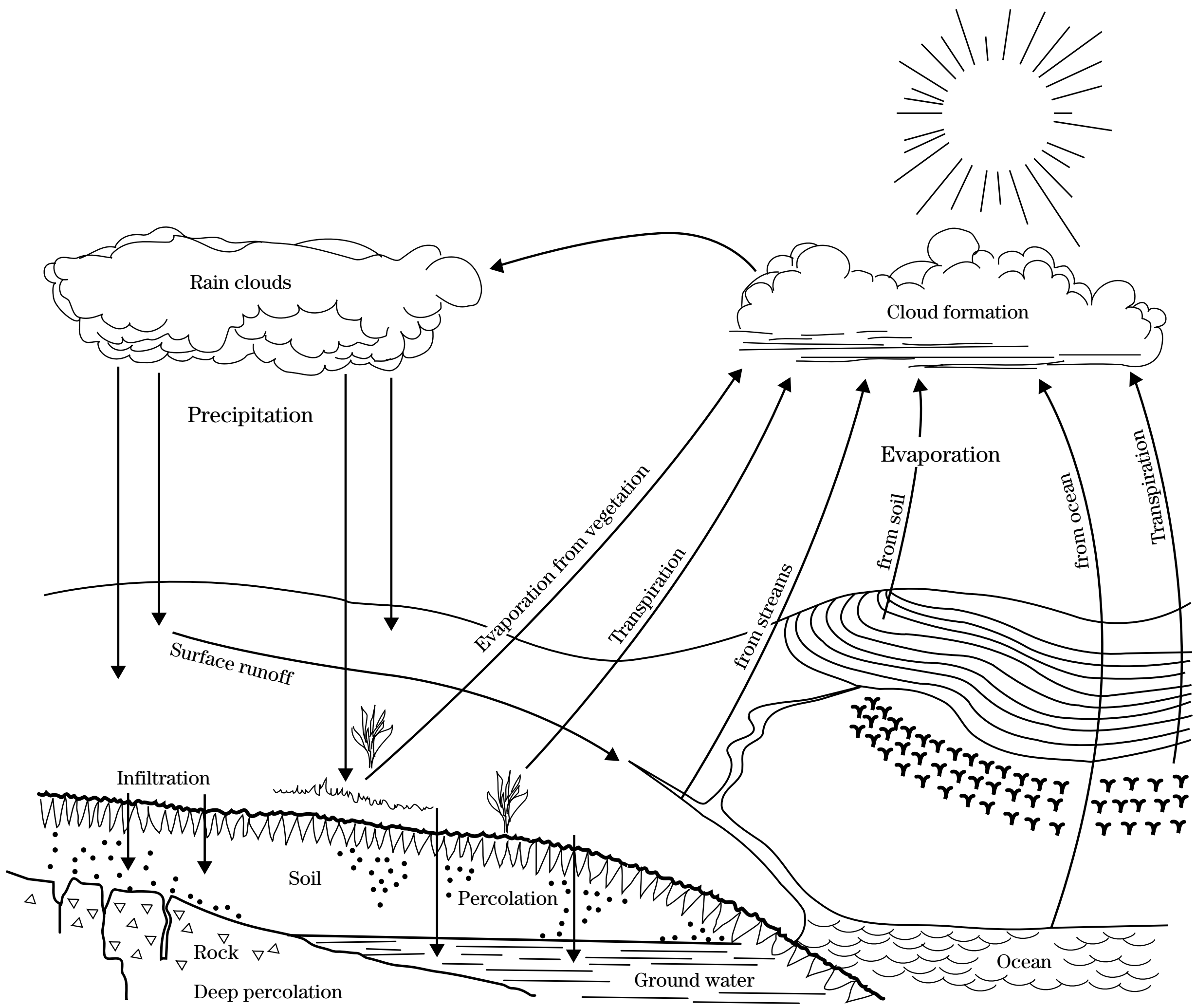
APPENDIX A

United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

Part 630 Hydrology
National Engineering Handbook

Chapter 7 Hydrologic Soil Groups



Issued May 2007

Acknowledgments

Chapter 7 was originally prepared by **Victor Mockus** (retired) and reprinted with minor revisions in 1972. This version was prepared by the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) under guidance of **Jon Werner** (retired), NRCS; with assistance from **Donald E. Woodward** (retired), NRCS; **Robert Nielsen** (retired), NRCS; **Robert Dobos**, soil scientist, NRCS; and **Allen Hjelmfelt** (retired), Agricultural Research Service. It was finalized under the guidance of **Claudia C. Hoeft**, national hydraulic engineer.

Preface

This chapter of the National Engineering Handbook (NEH) Part 630, Hydrology, represents a multi-year collaboration between soil scientists at the National Soil Survey Center (NSSC) and engineers in the Conservation Engineering Division (CED) at National Headquarters to develop an agreed upon model for classifying hydrologic soil groups.

This chapter contains the official definitions of the various hydrologic soil groups. The National Soil Survey Handbook (NSSH) references and refers users to NEH630.07 as the official hydrologic soil group (HSG) reference. Updating the hydrologic soil groups was originally planned and developed based on this perspective.

Listing HSGs by soil map unit component and not by soil series is a new concept for the engineers. Past engineering references contained lists of HSGs by soil series. Soil series are continually being defined and redefined, and the list of soil series names changes so frequently as to make the task of maintaining a single national list virtually impossible. Therefore, no such lists will be maintained. All such references are obsolete and their use should be discontinued.

Instructions for obtaining HSG information can be found in the introduction of this chapter.

Chapter 7 Hydrologic Soil Groups

Contents:

630.0700 Introduction

This chapter defines four hydrologic soil groups, or HSGs, that, along with land use, management practices, and hydrologic conditions, determine a soil's associated runoff curve number (NEH630.09). Runoff curve numbers are used to estimate direct runoff from rainfall (NEH630.10).

A map unit is a collection of areas defined and named the same in terms of their soil components or miscellaneous areas or both (NSSH 627.03). Soil scientists assign map unit components to hydrologic soil groups. Map unit components assigned to a specific hydrologic soil group have similar physical and runoff characteristics. Soils in the United States, its territories, and Puerto Rico have been assigned to hydrologic soil groups. The assigned groups can be found by consulting the Natural Resources Conservation Service's (NRCS) Field Office Technical Guide; published soil survey data bases; the NRCS Soil Data Mart Web site (*http://soildatamart.nrcs.usda.gov/*); and/or the Web Soil Survey Web site (*http://websoilsurvey.nrcs.usda.gov/*).

The state soil scientist should be contacted if a soil survey does not exist for a given area or where the soils within a watershed have not been assigned to hydrologic groups.

630.0701 Hydrologic soil groups

Soils were originally assigned to hydrologic soil groups based on measured rainfall, runoff, and infiltrometer data (Musgrave 1955). Since the initial work was done to establish these groupings, assignment of soils to hydrologic soil groups has been based on the judgment of soil scientists. Assignments are made based on comparison of the characteristics of unclassified soil profiles with profiles of soils already placed into hydrologic soil groups. Most of the groupings are based on the premise that soils found within a climatic region that are similar in depth to a restrictive layer or water table, transmission rate of water, texture, structure, and degree of swelling when saturated, will have similar runoff responses. The classes are based on the following factors:

- intake and transmission of water under the conditions of maximum yearly wetness (thoroughly wet)
- soil not frozen
- bare soil surface
- maximum swelling of expansive clays

The slope of the soil surface is not considered when assigning hydrologic soil groups.

In its simplest form, hydrologic soil group is determined by the water transmitting soil layer with the lowest saturated hydraulic conductivity and depth to any layer that is more or less water impermeable (such as a fragipan or duripan) or depth to a water table (if present). The least transmissive layer can be any soil horizon that transmits water at a slower rate relative to those horizons above or below it. For example, a layer having a saturated hydraulic conductivity of 9.0 micrometers per second (1.3 inches per hour) is the least transmissive layer in a soil if the layers above and below it have a saturated hydraulic conductivity of 23 micrometers per second (3.3 inches per hour).

Water impermeable soil layers are among those types of layers recorded in the component restriction table of the National Soil Information System (NASIS) database. The saturated hydraulic conductivity of an impermeable or nearly impermeable layer may range from essentially 0 micrometers per second (0 inches per hour) to 0.9 micrometers per second (0.1 inches per hour). For simplicity, either case is considered impermeable for hydrologic soil group purposes. In some cases, saturated hydraulic conductivity (a quantitatively measured characteristic) data are not always readily available or obtainable. In these situations, other soil properties such as texture, compaction (bulk density), strength of soil structure, clay mineralogy, and organic matter are used to estimate water movement. Tables 7–1 and 7–2 relate saturated hydraulic conductivity to hydrologic soil group.

The four hydrologic soil groups (HSGs) are described as:

Group A—Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

The limits on the diagnostic physical characteristics of group A are as follows. The saturated hydraulic conductivity of all soil layers exceeds 40.0 micrometers per second (5.67 inches per hour). The depth to any water impermeable layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils that are deeper than 100 centimeters [40 inches] to a water impermeable layer are in group A if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 10 micrometers per second (1.42 inches per hour).

Group B—Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

The limits on the diagnostic physical characteristics of group B are as follows. The saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters [20 inches] ranges from 10.0 micrometers per second (1.42 inches per hour) to 40.0 micrometers per second (5.67 inches per hour). The depth to any water impermeable layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils that are deeper than 100 centimeters [40 inches] to a water impermeable layer or water table are in group B if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 4.0 micrometers per second (0.57 inches per hour) but is less than 10.0 micrometers per second (1.42 inches per hour).

Group C—Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

The limits on the diagnostic physical characteristics of group C are as follows. The saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters [20 inches] is between 1.0 micrometers per second (0.14 inches per hour) and 10.0 micrometers per second (1.42 inches per hour). The depth to any water impermeable layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils that are deeper than 100 centimeters [40 inches] to a restriction or water table are in group C if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 0.40 micrometers per second (0.06 inches per hour) but is less than 4.0 micrometers per second (0.57 inches per hour).

Group D—Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters [20 inches] and all soils with a water table within 60 centimeters [24 inches] of the surface are in this group, although some may have a dual classification, as described in the next section, if they can be adequately drained.

The limits on the physical diagnostic characteristics of group D are as follows. For soils with a water impermeable layer at a depth between 50 centimeters and 100 centimeters [20 and 40 inches], the saturated hydraulic conductivity in the least transmissive soil layer is less than or equal to 1.0 micrometers per second (0.14 inches per hour). For soils that are deeper than 100 centimeters [40 inches] to a restriction or water table, the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface is less than or equal to 0.40 micrometers per second (0.06 inches per hour).

Dual hydrologic soil groups—Certain wet soils are placed in group D based solely on the presence of a water table within 60 centimeters [24 inches] of the surface even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, then they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition. For the purpose of hydrologic soil group, adequately drained means that the seasonal high water table is kept at least 60 centimeters [24 inches] below the surface in a soil where it would be higher in a natural state.

Matrix of hydrologic soil group assignment criteria—The decision matrix in tables 7–1 and 7–2 can be used to determine a soil's hydrologic soil group. Check both tables before making a final decision. If saturated hydraulic conductivity data are available and deemed to be reliable, then these data, along with water table depth information, should be used to place the soil into the appropriate hydrologic soil group. If these data are not available, the hydrologic soil group is determined by observing the properties of the soil in the field. Factors such as texture, compaction (bulk density), strength of soil structure, clay mineralogy, and organic matter are considered in estimating the hydraulic conductivity of each layer in the soil profile. The depth and hydraulic conductivity of any water impermeable layer and the depth to any high water table are used to determine correct hydrologic soil group for the soil. The property that is most limiting to water movement generally determines the soil's hydrologic group. In anomalous situations, when adjustments to hydrologic soil group become necessary, they shall be made by the NRCS state soil scientist in consultation with the state conservation engineer.

Table 7–1 Criteria for assignment of hydrologic soil groups when a water impermeable layer exists at a depth between 50 and 100 centimeters [20 and 40 inches]

Soil property	Hydrologic soil group A	Hydrologic soil group B	Hydrologic soil group C	Hydrologic soil group D
Saturated hydraulic conductivity of the least transmissive layer	>40.0 μm/s (>5.67 in/h)	≤40.0 to >10.0 μm/s (≤5.67 to >1.42 in/h)	≤10.0 to >1.0 μm/s (≤1.42 to >0.14 in/h)	≤1.0 μm/s (≤0.14 in/h)
	and	and	and	and/or
Depth to water impermeable layer	50 to 100 cm [20 to 40 in]	50 to 100 cm [20 to 40 in]	50 to 100 cm [20 to 40 in]	<50 cm [<20 in]
	and	and	and	and/or
Depth to high water table	60 to 100 cm [24 to 40 in]	60 to 100 cm [24 to 40 in]	60 to 100 cm [24 to 40 in]	<60 cm [<24 in]

Table 7–2 Criteria for assignment of hydrologic soil groups when any water impermeable layer exists at a depth greater than 100 centimeters [40 inches]

Soil property	Hydrologic soil group A	Hydrologic soil group B	Hydrologic soil group C	Hydrologic soil group D
Saturated hydraulic conductivity of the least transmissive layer	>10 μm/s (>1.42 in/h)	≤10.0 to >4.0 μm/s (≤1.42 to >57 in/h)	≤4.0 to >0.40 μm/s (≤0.57 to >0.06 in/h)	≤0.40 μm/s (≤0.06 in/h)
	and	and	and	and/or
Depth to water impermeable layer	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]
	and	and	and	and/or
Depth to high water table	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]

630.0702 Disturbed soils

As a result of construction and other disturbances, the soil profile can be altered from its natural state and the listed group assignments generally no longer apply, nor can any supposition based on the natural soil be made that will accurately describe the hydrologic properties of the disturbed soil. In these circumstances, an onsite investigation should be made to determine the hydrologic soil group. A general set of guidelines for estimating saturated hydraulic conductivity from field observable characteristics is presented in the Soil Survey Manual (Soil Survey Staff 1993).

630.0703 References

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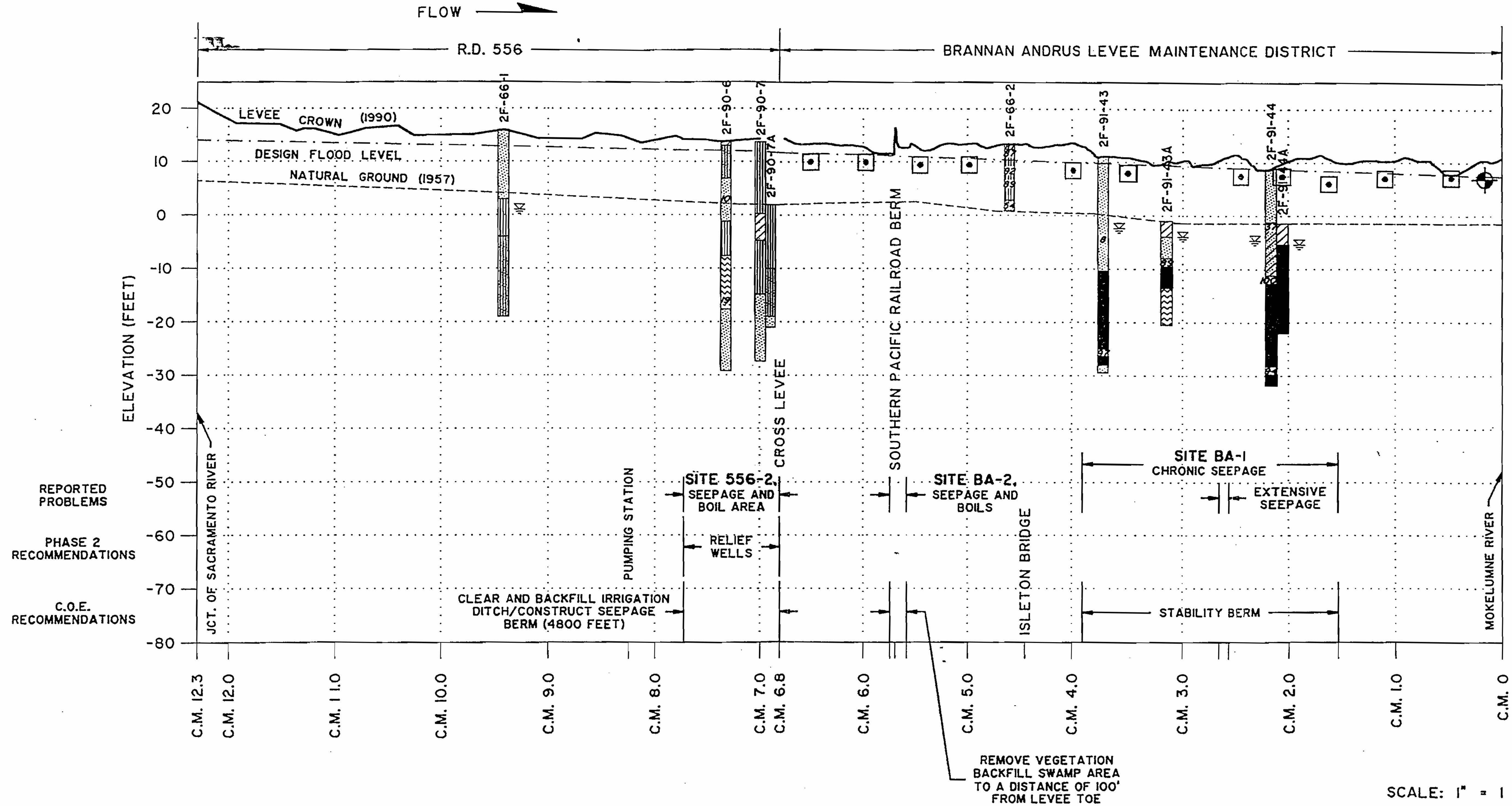
Appendix D

Historic Boring Logs

2868 Prospect Park Drive, Suite 310
Rancho Cordova, CA 95670
916.631.4500 fax 916.631.4501



SCALE: 1" = 1 MILE

NOTES:

1. REFER TO FIGURE 6 FOR NOTES.

LEGEND

- SILT (>70% FINES)
- SILTY SAND OR SANDY SILT (12%-70% FINES)
- CLAY (>70% FINES)
- CLAYEY SAND OR SANDY CLAY (12%-70% FINES)
- SAND (<12% FINES)
- OH
- CLAY (HIGH PLASTICITY, CH)
- PEAT
- PERCENTAGE OF FINES (MINUS 200 SIEVE SIZE) PER LABORATORY TESTING
- FEBRUARY 1986 HIGH WATER MARKS
- SURVEYED
- STAGE RECORDERS

SACRAMENTO RIVER
FLOOD CONTROL SYSTEM EVALUATION
LOWER SACRAMENTO AREA, PHASE IV

LEVEE PROFILES
GEORGIANA SLOUGH
RIGHT BANK LEVEE

SACRAMENTO DISTRICT, CORPS OF ENGINEERS

PREPARED BY: D. RICKETTS
DRAWN BY: R. IWASA FEBRUARY 1993

FIGURE 19

GEO TECH - SOILS\R.IWASA\LSIC-F19.DWG\02-11-93

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 1 of 1
HOLE NO ND-62
ELEV ____ FEET
DEPTH 20.0 FEET

PROJECT 1992 North Delta Seepage Monitoring
FEATURE Andrus Island
LOCATION Levee toe
CONTR. PC Exploration DRILL RIG Mobile Drill B-61

DATE DRILLED 12/4/92-12/4/92
ATTITUDE Vertical
LOGGED BY G. Newmarch
DEPTH TO WATER ∇ Not Determined

AD = Hole drilled with 8" hollow-stem auger

ELEV DEPTH	LOG	WELL CONS	FIELD CLASSIFICATION AND DESCRIPTION	MODE	REMARKS
0	PT		0.0 - 4.0' PEAT: Dusky yellowish brown (10YR 2/2). Short, moderately decayed fibers. Silty and clayey. Saturated.	AD	Soft materials, rapid drilling rate 0 to 7 feet.
4	PT		4.0 - 7.0' PEAT: Olive gray (5Y 4/1). Short, moderately decayed fibers. Silty and clayey. Slight plasticity. Saturated.		
7	PT		7.0 - 16.0' PEAT: Dusky brown (5YR 2/2). Long, fresh* fibers. Saturated.		Very soft material 7 to 16 feet. Local observers would probably call this "Buckskin Peat."
16	OL		16.0 - 20.0' ORGANIC SILT: Dark greenish gray (5G 4/1). No plasticity. Saturated.		Slightly firmer material 16 to 20 feet.
20					Total Depth = 20 feet

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

HOLE NO. ND-63M
ELEV. ______ FEET
DEPTH 100.0 FEET

PROJECT 1992 North Delta Seepage Monitoring
FEATURE Andrus Island
LOCATION East side of island
CONTR. PC Exploration DRILL RIG Mobile Drill, B-61
DATE DRILLED 6/14/93-6/14/93
ATTITUDE Vertical
LOGGED BY G. Newmarch
DEPTH TO WATER ⊻ Not Determined

AD = Hole drilled with 8" hollow-stem auger

ELEV DEPTH	LOG	WELL CONS	FIELD CLASSIFICATION AND DESCRIPTION	MODE	REMARKS
0	PT		0.0 - 19.0' PEAT: Grayish brown (5YR 3/2). Long, fresh fibers. Saturated.	AD	Soft materials, rapid drilling rate 0 to 19 feet.
15			Peat is more decayed at 15 feet. Fibers are short and moderately decayed 15 to 19 feet.		
19	OL		19.0 - 26.0' ORGANIC SILT: Olive gray (5G 3/2). No plasticity. Very soft. Saturated.		Very rapid drilling rate 19 to 25 feet.
26	SM		26.0 - 43.0' SAND: Olive gray (5G 3/2). Silty. Clayey. Medium to fine-grained. Subangular to subrounded grains. More than 50% quartz grains. Poorly graded. Moderately compacted. Saturated.		Firm materials, but rapid drilling rate 26 to 43 feet.

Depth scale: 5, 10, 15, 20, 25, 30, 35

DRILL HOLE LOG

PROJECT & FEATURE 1992 North Delta Seepage Monitoring

ELEV DEPTH	LOG	WELL CONS	FIELD CLASSIFICATION AND DESCRIPTION	MODE	REMARKS
			26.0 - 43.0' SAND: (Continues)	AD	
45	SC		43.0 - 63.0' SAND: Olive gray (5Y 3/2). Medium-grained. Very clayey. Silty. Poorly graded. Subangular to subrounded grains. Quartz grains predominate. Well compacted. Saturated.		Firmer materials 43 to 63 feet.
50					
55					
60					
65	CL		63.0 - 79.0' CLAY: Olive gray (5Y 3/2). Very sandy (medium-size). Low plasticity. Very soft. Saturated		Stiff materials, slower drilling rate 63 to 79 feet.
70					
75					
80	SC		79.0 - 88.0' SAND: Olive gray (5Y 3/2)/ Coarse-grained. Very clayey. Very compacted. Subangular to subrounded grains. Quartz grains predominate. Saturated.		Drilling rate slowed even more 79 to 88 feet. May be called "Blue Sand" by local observers.
85					

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

SHEET 3 of 3
HOLE NO. ND-63M

DRILL HOLE LOG

PROJECT & FEATURE 1992 North Delta Seepage Monitoring

ELEV DEPTH	LOG	WELL CONS	FIELD CLASSIFICATION AND DESCRIPTION	MODE	REMARKS
90, 95	ML		88.0 - 97.5' SILTY SAND to SANDY SILT: Olive gray (5Y 3/2). Fine-grained. Very clayey. Slight plasticity in places. Subangular to subrounded grains. About 50% quartz grains.	AD	Softer materials, moderately rapid drilling rate 88 to 100 feet.
100	CL		97.5 - 100.0' CLAY: Greenish gray (5G 6/1). Silty. Low to medium plasticity. Moderately stiff. Saturated.		Probably called "Blue Clay" by local observers.
					Total Depth = 100 feet

ba-10-dh-1 to dh-10

BORING LOCATION: CROWN OF LEVEE, STA. 45 + 97		APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: NONE		DRILL CONTRACTOR PC DRILLING	TOTAL DEPTH 49.5 ft.
DRILL RIG CME-55	BORING DIA 8" HOLLOW	DATE DRILLED: 6-5-89	LOGGED BY ME

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SM	0.0' - 7.50' SILTY SAND (LEVEE) light brown, dry to damp, Dense, trace of fine sand & gravel.	0	SP-1	13 15 15	6" / 18"	DR	30
		2	SP-2	10 7 6	10" / 18"	DR	13
		4	—	6 4 4	0.0" / 18"	DR	No Recovery ← * 8
	5.0' – Traces of coarse gravel, 1/4" - 1/2".. (Not saturated)		SP-3	6 5 5	8" / 18"	DR	10
	6.5' - Increase in moisture content.	6	SP-4 SP-5	4 3 3	18" / 18"	DR	6
SP-SW	7.5' - 8.75' SAND (LEVEE) loose, light grey, damp to moist.	8	SP-6 SP-7	4 3 3	18" / 18"	DR	6 ✓
ML	8.75' - 13.20' SANDY SILT (LEVEE) brown, moist - very moist, soft		SP-8	3 5 5	6" / 18"	DR	10
		10	—	8 8 8	0.0" / 18"	DR	No Recovery 16
	13' - 13'.2", lense of clean wet sand.	12	SP-9	4 5 6	18" / 18"	DR	11
ML	13.0' - 16.0', CLAYEY SILT (LEVEE) brown, wet, firm to stiff.	14	SP-10	5 5 6	18" / 18"	DR	11
			SP-11	4 6 6	18" / 18"	DR	
CL-CH	16.0' - 18.0', SILTY CLAY (LEVEE) brown, wet, soft to firm. @ 17.0' - becoms dark greyish.	16	SP-12	5 5 5	18" / 18"	DR	
	18.0' - 28.5' ORGANIC SILT (FOUNDATION) dark greyish, wet, soft, traces of organics.	18	SP-13	4 4 4	18" / 18"	DR	
		20	—	4,5,6	18/18	DR	

+10.1

EL +2 to 3 NAVD 88

+2

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet: 1 of 3	DH-1

ba-10-dh-1

BORING LOCATION CROWN of LEVEE, STA. 45+99		APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER : NONE		DRILL CONTRACTOR PC DRILLING	TOTAL DEPTH 49.5'
DRILL RIG CME - 55	BORING DIA. 8" HOLLOW	DATE DRILLED: 6/ 5 / 89	LOGGED BY ME

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT (Cont.) dark greyish, wet, soft to firm, trace of desiccated roots & vegetation.	20				AD	
		22	SP-14	5 5 6	18" / 18"	DR	
	23.0' - Increase in organic content, becomes darker w/ depth, more fibrous.		SP-15	6 8 10	18" / 18"	DR	
	26.25' - two inch lense of sand.	24	SP-16	3 4 5	18" / 18"	DR	
		26	SP-17	6 9 7	10" / 18"	DR	
		28	SP-18	7 7 6	18" / 18"	DR	
OL	28.5' - 39.0' ORGANIC SILT Becomes dark brown, fibrous.		SP-19	5 6 8	18" / 18"	DR	
		30	SP-20	6 8 10	18" / 18"	DR	
	32.0' - Increase in organic content, desiccated wood & vegetation.	32	SP-21	8 10 11	18" / 18"	DR	
		34	SP-27	6 8 11	18" / 18"	DR	
			SP-28	9 11 13	18" / 18"	DR	
		36	SP-29	9 12 13	18" / 18"	DR	
		38	SP-30	5 6 7	18" / 18"	DR	
OH	39.0' - 49.5' BAY MUD black, wet, soft to firm	40	SP-31	6 5 5	18" / 18"	DR	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG Project No. MBK-210D	Sheet 2 of 3	BORING NO. DH-1

BORING LOCATION CROWN OF LEVEE, STA. 45 + 97	APPROVED BY : M.E.	GROUND EL: CROWN
DEPTH TO GROUND NONE	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 49.5'
DRILL RIG CME-55 / BORING DIA 8"HOLLOW	DATE DRILLED: 6 / 5 / 89	LOGGED BY : M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
OH	BAY MUD (Cont.).	40					
	40.5' - Color changes to light greyish.		SP-32	5 5 6	18" / 18"	DR	
		42	SP-33	4 4 5	18" / 18"	DR	
		44	SP-34	6 6 7	18" / 18"	DR	
		46	SP-35	5 6 8	18" / 18"	DR	
			SP-36	10 11 12	18" / 18"	DR	
		48	SP-37	8 9 12	18" / 18"	AD	
	Boring Terminated @ 49.5' No ground water was encountered.	50					
		52					
		54					
		56					
		58					
		60					

DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.

THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION.

THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS.

THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL.

SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet: 3 Of 3	DH-1

Sandy levee

BORING LOCATION CROWN of LEVEE, STA. 82 + 09	APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: 15.5'	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 70.0'
DRILL RIG CME-55 / BORING DIA. 8" HOLLOW	DATE DRILLED: 6 / 5 /89	LOGGED BY: M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SM	0.0'-5.5' SILTY SAND, (LEVEE) very dense, damp, trace of fine gravel.	0	SP-1	11 19 20	8" / 18"	DR	
		2	SP-2	10 11 8	9" / 18"	DR	
	3.0'- 5.5' Interbedded lenses of clean sand (SP-SW), and clayey silt (ML).	4	SP-3	5 6 7	18" / 18"	DR	
			SP-4	4 3 3	18" / 18"	DR	
SP-SW	5.5' - 7.5' SAND, (LEVEE) brown, damp, loose, some trace of silt..	6	SP-5	3 4 4	18" / 18"	DR	
	7.5' - 10.0' coarse sand, dark, brown, loose, trace of fine silt. Liquefy	8	SP-6	3 4 4	18" / 18"	DR	8
		10	SP-7	3 3 3	18" / 18"	DR	+1 NGVD 2.6 or 3.6 NAVD
CL-CH	10.0' - 13.2' SILTY CLAY, (LEVEE) brown, very moist, firm, with traces of desiccated wood, highly weathered.		SP-8	3 3 4	18" / 18"	DR	6.4' depth
		12	SP-9	3 3 3	18" / 18"	DR	
OH	13.25' - 21.0' BAY MUD, (LEVEE) dark greyish, wet, soft, w / fine to coarse sand.	14				AD	10 - 15.5 = - 5.5
							Ground Water @ 15.5'
	15.5' - 21.0' - Interbedded lenses of clean sand.	16	SP-10	11 11 11	18" / 18"	DR	
		18				AD	
		20					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 1 Of 4	DH-2

BORING LOCATION CROWN OF LEVEE, STA. 82 + 09		APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER :15.5'	DRILL CONTRACTOR P.C. DRILLING		TOTAL DEPTH 70.0'
DRILL RIG CME - 55	BORING DIA. 8" HOLLOW	DATE DRILLED: 6 / 4 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
	BAY MUD (Cont.)	20	SP-11	6 5 5	18" / 18"	DR	
OL	21.0' - 40.0' - ORGANIC SILT (FOUNDATION) Becomes fibrous, dark brown, moist, firm, no odor, relatively fibrous w/ desiccated wood & vegetation.	22 24				AD	
	26.0' - Becomes very fibrous w / depth, decreasing soil content, & weight.	26	SP-12	6 7 8	18" / 18"	DR	
		28				AD	
		30	SP-13	5 6 7	18" / 18"	DR	
		32 34				AD	
		36	SP-14	6 8 10	18" / 18"	DR	
		38 40				AD	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG Project No. MBK-201D	Sheet 2 of 4	BORING NO. DH-2

BORING LOCATION CROWN of LEVEE, STA. 82+09		GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL:15.5'	DRILL CONTRACTOR P.C.Drilling	TOTAL DEPTH 70.0'
DRILL RIG CME-55 / BORING DIA.8", hollow	DATE DRILLED: 6 / 5 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
OH	40.0' - 70.0' BAY MUD Dark blue, wet to saturated, soft to firm.	40	SP-15	4 4 6	18" / 18"	DR	
		42					
		44				AD	
		46					
		48					
			SP-16	4 4 4	18" / 18"	DR	
		50					
		52					
		54				AD	
		56					
		58					
		60					

Wahler Associates

ANDRUS ISLAND
SACRAMENTO, CA.

EXPLORATION BORING LOG

Project No. MBK-201D

Sheet 3 Of 4

BORING NO. DH - 2

BORING LOCATION CROWN of LEVEE, STA. 82 + 09		GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL:15.5'	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 70.0'
DRILL RIG CME -55 / BORING DIA 8"HOLLOW	DATE DRILLED: 6 / 5 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
		60					
OH	40.0' - 70.0' BAY MUD (Cont.)						
		62					
						AD	
		64					
		66					
		68					
		70					
	Boring terminated at 70.0' Groundwater encountered at 15.5'.						
		72					
		74					DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES. THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION. THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL. SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.
		76					
		78					
		80					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG Project No. MBK-201D	Sheet 4 Of 4	BORING NO. DH-2

BORING LOCATION CROWN OF LEVEE, Sta. 96 + 50	APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: 8.0'	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 50.0'
DRILL RIG CME-55 / BORING DIA. 8" hollow	DATE DRILLED: 6 / 4 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SM	0.0' - 7'-3" SILTY SAND (LEVEE) brown, dry to damp, medium dense to dense, fine sand w / some gravel, layer of silty clayey.	0	SP-1	4 9 7	6" / 18"	DR	
		2	SP-2	4 6 7	4" / 18"	DR	
		4	SP-3	7 3 4	4" / 18"	DR	
	4' 6" - 7' 3" increase in moisture content, increase in clay content. Becomes loose w / depth.		SP-4	2 2 2	3" / 18"	DR	
		6	SP-5	2 1 1	4" / 18"	DR	
SP	7.25' - 20.75' SAND (LEVEE) dark greyish, wet to saturated, loose, little to no fine.	8	SP-6	2 2 2	18" / 18"	DR	Groundwater Encountered @ 8.0'
		10	SP-7	3 4 5	18" / 18"	DR	
			SP-8	3 3 3	18" / 18"	DR	
		12	SP-9	3 2 2	18" / 18"	DR	
		14	SP-10	2 2 3	18" / 18"	DR	
		16	SP-11	2 3 3	18" / 18"	DR	
			SP-12	3 4 4	18" / 18"	DR	
		18	SP-13	3 4 4	18" / 18"	DR	
		20		—		AD	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 1 Of 3	DH-3

BORING LOCATION CROWN of LEVEE | APPROVED BY: M.E. | GROUND EL: CROWN

DEPTH TO GROUND WATER : 8.0' | DRILL CONTRACTOR P.C. DRILLING | TOTAL DEPTH 50.0'

DRILL RIG CME - 55 | BORING DIA. 8" HOLLOW | DATE DRILLED: 6 / 4 / 89 | LOGGED BY: M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / FREQ	REC.	MODE	REMARKS
SP	SAND (Cont.)	20	SP-14	2 2 3	4" / 18"	DR	
ML	20.75' - 26.0' SANDY SILT (LEVEE) dark greyish, wet, soft. 10 -20 % Fibrous.	22	SP-15	3 3 4	4" / 18"	DR	
			SP-16	4 5 6	18" / 18"	DR	
		24					
OL	26.0' - 30.0' ORGANIC SILT (FOUNDATION) brown, very moist., firm, highly decomposed.	26				AD	
		28					
			SP-17	4 6 9	18" / 18"	AD	
OL	30.0' - 46.0' ORGANIC SILT (FOUNDATION) brown, very moist, firm, fibrous.	30					
		32				AD	
		34					
		36	SP-18	4 7 8	18" / 18"	DR	
		38				AD	
		40					

Wahler Associates

ANDRUS ISLAND
SACRAMENTO, CA.

EXPLORATION BORING LOG

Project No. MBK-201D

Sheet 2 Of 3

BORING NO. DH - 3

BORING LOCATION CROWN OF LEVEE, STA. 96 + 50		GROUND EL:CROWN
DEPTH TO GROUND WATER 8.0'	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 50.0'
DRILL RIG CME - 55 / BORING DIA.8"HOLLOW	DATE DRILLED: 6 / 4 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / FEQ	REC.	MODE	REMARKS
OL	ORGANIC SILT (Cont.) Increase in soil content.	40	SP-19	6 8 10	18" / 18"	DR	
		42					
		44				AD	
OH	46.0' - 50.0' BAY MUD light greyish, saturated, firm.	46					
		48	SP-20	9 5 5	18" / 18"	DR	
	Boring Treminated @ 50.0' Groundwater Encountered @ 8.0'	50					
		52					
		54					
		56					
		58					
		60					

DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.

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SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG Project No. MBK-201D	Sheet 3 Of 3	BORING NO. DH - 3

BORING LOCATION CROWN of LEVEE, STA. 59 + 15	APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: 10.0'	DRILL CONTRACTOR P. C. DRILLING	TOTAL DEPTH 50.0'
DRILL RIG CME-55 / BORING DIA. 8" HOLLOW	DATE DRILLED: 6 /4-5 /89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SM	0.0' - 1.0' SILTY SAND (LEVEE) brown, dry, medium dense.	0	SP-1	9 8 9	18" / 18"	DR	
SP	1.0' - 19.0' SAND (LEVEE) brown, dry, medium dense, fine grained sand.	2	SP-2	6 8 6	18" / 18"	DR	
		4	SP-3	9 9 6	4" / 18"	DR	
						AD	
		6	SP- 4	2 2 2	18" / 18"	DR	
		8	SP-5	3 4 5	18" / 18"	DR	
		10	SP-6	5 6 5	18" / 18"	DR	Groundwater Encountered @ 10.0'
	11.5' - Increase in moisture content, indications of perched water.		SP-7	6 6 5	18" / 18"	DR	Groundwater Encountered @ 11.5' at time of sampling. ✓
	12.0' - 14.25' - alternate lenses of dark greyish & yellow - brown coarse sand.	12	SP-8	3 4 6	18" / 18"	DR	
	14.25' - lense of desiccated wood, approx. 2" in thickness.	14	SP-9	4 4 6	18" / 18"	DR	
		16	SP-10	4 4 4	18" / 18"	DR	✓
			SP-11	4 4 10	18" / 18"	DR	
		18	SP-12	4 4 5	18" / 18"	DR	
OH	19.0' - 19.25' BAY MUD (LEVEE) light greyish, saturated, soft.						
OL	~~19.25' - 38.0'~~ ORGANIC SILT (FOUNDATION)	20				AD	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG — Project No. MBK- 201D — Sheet 1 Of 3	BORING NO. DH-4

BORING LOCATION CROWN of LEVEE, STA. 59+15		APPROVED BY:	GROUND EL: CROWN
DEPTH TO GROUND WATER : 10.0'		DRILL CONTRACTOR P. C.DRILLING	TOTAL DEPTH 50.0'
DRILL RIG CME - 55	BORING DIA.8"HOLLOW	DATE DRILLED:6- 4,5 - 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT (CONT.) dark brown, very moist, firm, highly fibrous.	20					
		22				AD	
		24					
			SP-13	4 6 8	18" / 18"	DR	
		26					
		28				AD	
		30	SP-14	6 6 9	18" / 18"	DR	
		32					
						AD	
		34					
			SP-15	4 5 9	18" / 18"	DR	
		36					
						AD	
		38					
OH	38.0' - 50.0' BAY MUD light greyish, wet to saturated., soft to firm		SP-16	5 5 5	18" / 18"	DR	B.O.H. @ 50.0'
		40.0					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 2 of 3	DH-4

BORING LOCATION CROWN of LEVEE. STA. 59 + 15		GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL: 10.0'	DRILL CONTRACTOR P. C. DRILLING	TOTAL DEPTH 50.0'
DRILL RIG CME - 55	BORING DIA. 8" HOLLOW / DATE DRILLED: 6 - 4,5 - 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
OH	38.0' - 50.0' BAY MUD (Cont.) light greyish, wet to saturated, soft to firm	40–50				AD	
	Boring terminated at 50.0' Groundwater encountered @ 10.0' Groundwater encountered @ 11.5' at time of sampling.	50–60					DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES. THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION. THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS. THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL. SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.

Depth scale: 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG Project No. MBK-201D	Sheet 3 of 3	BORING NO. DH-4

not done Levee

BORING LOCATION TOE of LEVEE, STA. 82 +09		APPROVED BY: M.E.	GROUND EL: TOE
DEPTH TO GROUND WATER LEVEL: 10.5'	DRILL CONTRACTOR P. C. DRILLING		TOTAL DEPTH 26.5'
DRILL RIG CME-55	BORING DIA. 8" HOLLOW	DATE DRILLED: 6 / 7 /89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SP	0.0' - 4.5' SAND (LEVEE) light greyish, dry, medium dense, trace of roots & vegetation.	0	SP-1	1 2 9	18" / 18"	DR	
		2	SP-2	8 8 9	18" / 18"	DR	
	4.0' - Trace of silt & clay in lenses.	4	SP-3	8 7 6	18" / 18"	DR	
SM	4.5' - 7.5' SILTY SAND (LEVEE) brown, very moist, dense, coarse sand w / trace of root.		SP-4	18 10 12	18" / 18"	DR	
		6	SP-5	19 17 17	6" / 18"	DR	
OL	7.5'-23.0' ORGANIC SILT (FOUNDATION) black, wet, soft to firm, increase in desiccated roots w / depth, highly decomposed, no odor.	8	SP-6	6 7 6	18" / 18"	DR	
	10.5' becomes dark brown:	10	SP-7	5 6 10	18" / 18"	DR	Groundwater Encountered @ 10.5'
			SP-8	5 8 3	18" / 18"	DR	
		12	SP-9	2 2 2	18" / 18"	DR	
		14					
		16					
		18				AD	
		20					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG — Project No. MBK- 201D — Sheet 1 of 2	BORING NO. DH-5

BORING LOCATION TOE of LEVEE, STA. 82+09	APPROVED BY: M.E.	GROUND EL: TOE
DEPTH TO GROUND WATER : 10.5'	DRILL CONTRACTOR P. C. Drilling	TOTAL DEPTH 26.5
DRILL RIG CME - 55 / BORING DIA. 8" hollow	DATE DRILLED: 6 / 7 / 89	LOGGED BY M. E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT: (Cont.) dark brown, moist	20	SP-10	3 / 3 / 3	18" / 18"	DR	
		22				AD	
OH	23.0' - 26.5' BAY MUD dark greyish, wet to saturated, soft	24					
		26	SP-11	2 / 3 / 2	18" / 18"	DR	
	Boring terminated @ 26.5' Groundwater encountered @ 10.5' (Perched).	28					
		30					
		32					
		34					DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.
		36					THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION. THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS.
		38					THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL. SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.
		40					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG — Project No. MBK-201D; Sheet 2 of 2	BORING NO. DH-5

BORING LOCATION TOE of LEVEE , STA. 45 + 97	APPROVED BY: M.E.	GROUND EL: Toe
DEPTH TO GROUND WATER LEVEL NONE	DRILL CONTRACTOR P. C. DRILLING	TOTAL DEPTH 25.5'
DRILL RIG CME-55 / BORING DIA.8"HOLLOW	DATE DRILLED: 6 / 7 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SM	0.0' - 1.5' SILTY SAND (LEVEE) light yellow brown, dry, dense	0	SP-1	11 15 11	18" / 18"	DR	
ML	1.5' - 5.9' SANDY SILT (LEVEE) light yellow brown, damp, stiff	2	SP-2	10 9 8	18" / 18"	DR	
	3.0'- Increase in moisture content, becomes very moist.		SP-3	11 9 9	18" / 18"	DR	
		4	SP-4	7 7 9	6" / 18"	DR	
OL	6.0' - 23'.0' ORGANIC SILT (FOUNDATION) Black, moist, firm, highly decomposed.	6	SP-5	4 7 7	18" / 18"	DR	▽
		8					
		10				AD	
		12					
		14	SP-6	2 3 3	18" / 18"	DR	✓
		16				AD	
		18					
		20	SP-7	4 5 5	18" / 18"	DR	

Wahler Associates

ANDRUS ISLAND
SACRAMENTO, CA.

EXPLORATION BORING LOG

Project No. MBK- 201D

Sheet 1 Of 2

BORING NO. DH-6

BORING LOCATION TOE of LEVEE, STA. 45+97		APPROVED BY:M.E.	GROUND EL: TOE
DEPTH TO GROUND WATER :NONE	DRILL CONTRACTOR P.C.DRILLING		TOTAL DEPTH 25.5'
DRILL RIG CME-55	BORING DIA.8"HOLLOW	DATE DRILLED: 6 / 7 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT: (Cont.)	20					
		22				AD	
OH	23.0' - 25.5' BAY MUD light greyish, saturated, soft.	24	SP-8	3 3 3	18" / 18"	DR	
	Boring termined @ 25.5' No groundwater encountered.	26					
		28					
		30					
		32					
		34					DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES. THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION. THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS. THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL. SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.
		36					
		38					
		40					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG Project No. MBK-201D	Sheet 2 Of 2	BORING NO. DH - 6

BORING LOCATION CROWN of LEVEE, STA. 96+50		APPROVED BY: M.E.	GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL: 18.0'		DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 48.0'
DRILL RIG CME-55	BORING DIA: 8"HOLLOW	DATE DRILL 6 / 8 / 89	LOGGED M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
SM	0.0' - 6.0' SILTY SAND (LEVEE) light brown, moist	0				AD	Shelby Sampler
		2	SP-1	—	24"/24"	DR	
		4				AD	
SP	6.0' - 20.0' SAND (LEVEE) light brown, very moist.	6	SP-2	—	10"/24"	DR	
		8				AD	
		10					
		12					
		14					
		16					
		18					Groundwater encountered @ 18.0'
		20	S-3	—	23"/24"	DR	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 1 Of 3	DH-7

BORING LOCATION CROWN of LEVEE, STA. 96 + 50		APPROVED BY: M.E.	GROUND EL:CROWN
DEPTH TO GROUND WATER :18.0'		DRILL CONTRACTOR PC DRILLING	TOTAL DEPTH48.0'
DRILL RIG CME - 55	BORING DIA. 8",hollow	DATE DRILLED:6 / 8 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
ML	20.0' - 26.0' SANDY SILT (LEVEE) dark brown, to dark greyish, very moist to wet.	20	S-3	—	24" / 24"	DR	Shelby Sampling
		22				AD	
		24					
		26	S-4	—	24" / 24"	DR	
OL	26.0' - 45.0' ORGANIC SILT (Foundation) light brown, very moist, highly fibrous dessicated roots and vegetation.	28					
		30					
		32				AD	
		34					
		36					
		38					
		40					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet: 2 Of 3	DH-7

BORING LOCATION CROWN of LEVEE, STA. 96 +50		GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL: 18.0	DRILL CONTRACTOR P C DRILLING	TOTAL DEPTH 48.0'
DRILL RIG CME - 55 / BORING DIA.8", hollow	DATE DRILLED: 6 / 8 / 89	LOGGED BY M. E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT :(CONT.)	40					Shelby Sampling
		42				AD	
		44	S-5	—	24" / 24"	DR	
OH	45.0' - 48.0' BAY MUD light greyish, wet	46	S-6	—	24" / 24"	DR	
	Boring Terminated @ 48.0'. Groundwater Encountered at 18.0'.	48					
		50					
		52					
		54					
		56					
		58					
		60					

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Wahler Associates	ANDRUS HARBOR SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 3 Of 3	DH-7

BORING LOCATION TOE of LEVEE, STA. 82 + 09		APPROVED BY:M.E.	GROUND EL:TOE
DEPTH TO GROUND WATER LEVEL:NONE	DRILL CONTRACTOR PC DRILLING		TOTAL DEPTH 26.0'
DRILL RIG CME - 55	BORING DIA: 8", hollow	DATE DRILL 6/8/89	LOGGED M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SP	0.0' - 7.0' <u>SAND</u> (LEVEE) light brown,dry to damp, fine to coarse gravel.	0		—		AD	
		2	S-1	—	20" / 24"	DR	
	Piece of grey plastic was recovered.	4	S-2	—	8" / 24"	DR	
		6	S-3	—	22" / 24"	DR	
OL	7.0' - 26.0' ORGANIC SILT (FOUNDATION) black, very moist to wet, highly decomposed .	8	S-4	—	12" / 24"	DR	
		10				AD	
		12					
	14.0' - Becomes dark brown, highly fibrous	14	S-5	—	20" / 24"	DR	
		16				AD	
		18					
		20					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 1 Of 2	DH-8

BORING LOCATION TOE of LEVEE, STA.82 + 09		APPROVED BY: M.E.	GROUND EL: TOE
DEPTH TO GROUND WATER : NONE		DRILL CONTRACTOR PC DRILLING	TOTAL DEPTH 26.0'
DRILL RIG CME - 55	BORING DIA. 8"HOLLOW	DATE DRILLED: 6/8/89	LOGGED BY: M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT (Continues)	20				AD	
		22	S-6		12" / 24"	DR	
		24	S-7		0" / 24"	DR	
OH	25.5' - 26.0' BAY MUD greyish, wet.						
	Boring terminated at 26.0' No groundwater encountered.	26					
		28					
		30					
		32					
		34					
		36					
		38					
		40					

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Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 2 Of 2	DH-8

El 10.0

BORING LOCATION CROWN of LEVEE,STA. 30+55	APPROVED BY:M.E.	GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL: NONE	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 43.0'
DRILL RIG CME-55 / BORING DIA: 8"	DATE DRILL 6/19/89	LOGGED M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
SM	0.0' - 2.0' SILTY SAND (LEVEE) light brown, dry, dense, trace of coarse gravel.	0	SP -1	11 14 18	18"/18"	DR	
ML	2.0' - 16.0' SANDY SILT (LEVEE) brown, med. dense, with fine gravel and fine sand.	2	SP-2	13 17 21	18"/18"	DR	
			SP-3	11 7 7	18"/18"	DR	
	4.5' - increase in moisture, increase in silt content.	4	SP-4	3 1 2	18"/18"	DR	
		6	SP-5	3 3 5	18"/18"	DR	▽
		8	SP-6	4 4 6	18"/18"	DR	▽
		10	SP-7	4 6 6	18"/18"	DR	
			SP-8	6 6 6	18"/18"	DR	
		12	SP-9	4 4 6	18"/18"	DR	
		14	SP-10	6 7 8	18"/18"	DR	
			SP-11	4 4 4	18"/18"	DR	
OH	16.0' - 21.5' BAY MUD (LEVEE) dark gray, wet to satrated, soft, reworked Bay Mud.	16	SP-12	4 5 6	18"/18"	DR	
		18	SP-13	5 4 4	18"/18"	DR	▽
		20				AD	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 1 of 3	DH-9

BORING LOCATION CROWN of LEVEE, STA. 30 + 55		APPROVED BY: M.E.	GROUND EL: Crown
DEPTH TO GROUND WATER : NONE		DRILL CONTRACTOR PC DRILLING	TOTAL DEPTH 43.0'
DRILL RIG CME - 55	BORING DIA. 8", hollow	DATE DRILLED: 6/19/89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
		20	SP-14	5 / 5 / 5	24" / 24"	DR	
OL	21.25' - 41.5' ORGANIC SILT (Foundation) dark gray, sat., soft, with desicated wood, highly decomposed peat.	22	S-1	—	30" / 36"	DR	
		24–26				AD	
	28.0' - Becomes Fibrous Increas in organic content, 90-95%	28					
		30	S-2	—	30" / 36"		
		32–34				AD	
	36.0' - Becomes dark brown, decrease in organic content.	36	S-3	—	30" / 36"	DR	
		38–40				AD	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 2 Of 3	DH - 9

BORING LOCATION CROWN of LEVEE, STA. 30 + 55		GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL:NONE	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 43.0'
DRILL RIG CME-55 / BORING DIA.8"HOLLOW	DATE DRILLED: 6 / 19 /89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT (Cont.)	40					
OH	41.5' - 43.0' BAY MUD dark gray, sat., soft.	42	S-4	—	30" / 36"	DR	
	Boring Terminated @ 43.0'. No groundwater encountered.	44					
		46					
		48					
		50					
		52					
		54					
		56					
		58					
		60					

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Wahler Associates	ANDRUS ISLAND SACRAMENTO,CA.	EXPLORATION BORING LOG Project No. MBK- 201D Sheet: 3 Of 3	BORING NO. DH-9

BORING LOCATION CROWN of LEVEE, STA. 111 + 20	APPROVED BY:M.E.	GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL:14.5'	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 41.0'
DRILL RIG CME - 55 / BORING DIA: 8"HOLLOW	DATE DRILL6 19 /89	LOGGED M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SP-SW	0.0' - 8.5' - SAND (LEVEE) light brown, damp, dense, fine to coarse grained sand, lenses of silty sand.	0	SP-1	13 10 14	18" / 18"	DR	
		2	SP-2	10 13 13	18" / 18"	DR	
		4	SP-3	3 4 6	18" / 18"	DR	
			SP-4	4 4 5	18" / 18"	DR	
		6	SP-5	3 3 3	18" / 18"	DR	▽
		8	SP-6	3 4 6	18" / 18"	DR	
ML	8.5' - 14.25' SANDY SILT (LEVEE) brown, very moist, firm, trace of water significant increase in moisture content.	10	SP-7	3 4 5	18" / 18"	DR	
			SP-8	3 5 6	18" / 18"	DR	
	12.0' - Interbedded lenses of sand & silt. 13.0' - Increase in silt content & moisture.	12	SP-9	3 2 2	18" / 18"	DR	
		14	SP-10	3 4 5	18" / 18"	DR	
OH	14.25' - 17.90' - BAY MUD (LEVEE) light to dark greyish, wet to saturated, soft, reworked Bay Mud.	16	SP-11	3 3 3	18" / 18"	DR	Groundwater encountered @ 14.5'
			SP-12	3 5 5	18" / 18"	DR	
OL	17.90' - 37.0' ORGANIC SILT (FOUNDATION) dark greyish, wet, soft, highly decomposed.	18–20				AD	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG — Project No. MBK-201D — Sheet 1 Of 3	BORING NO. DH-10

BORING LOCATION CROWN of LEVEE, STA. 111 + 20 | APPROVED BY:M.E. | GROUND EL:CROWN

DEPTH TO GROUND WATER :14.5' | DRILL CONTRACTOR P.C. Drilling | TOTAL DEPTH 41.0'

DRILL RIG CME - 55 | BORING DIA8"HOLLOW | DATE DRILLED:6 / 19 /89 | LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / BEQ	REC.	MODE	REMARKS
OL	ORGANIC SILT: (Continues) 20.0' - Becomes fibrous	20				AD	
		22					
		24	SP-13	3 4 6	18" / 18"	DR	
		26				AD	
	28.5' - Becomes highly fibrous.	28	SP-14	4 5 6	18" / 18"	DR	
		30				AD	
		32					
		34	SP-15	3 5 6	18" / 18"	DR	
		36				AD	
OH	37.0' - 41.0' BAY MUD dark grey, saturated, soft to firm.	38	SP-16	4 4 5	18" / 18"	DR	
		40				AD	

Wahler Associates

ANDRUS ISLAND
SACRAMENTO, CA.

EXPLORATION BORING LOG

Project No. MBK-201D

Sheet 2 Of 3

BORING NO. DH-10

BORING LOCATION CROWN of LEVEE, STA. 111 + 20			GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: 14.5'	DRILL CONTRACTOR P.C.DRILLING		TOTAL DEPTH 41.0'
DRILL RIG CME - 55	BORING DIA. 8" HOLLOW	DATE DRILLED: 6 / 19 /89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
OH	.37.0'-41.0' BAY MUD (Continues)	40	SP-17	4 5 5	—	DR	
	Boring terminated @ 41.0' Groundwater encountered at 14.5'.	42					
		44					
		46					
		48					
		50					
		52					
		54					
		56					
		58					
		60					

DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.

THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION.

THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS.

THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL.

SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.

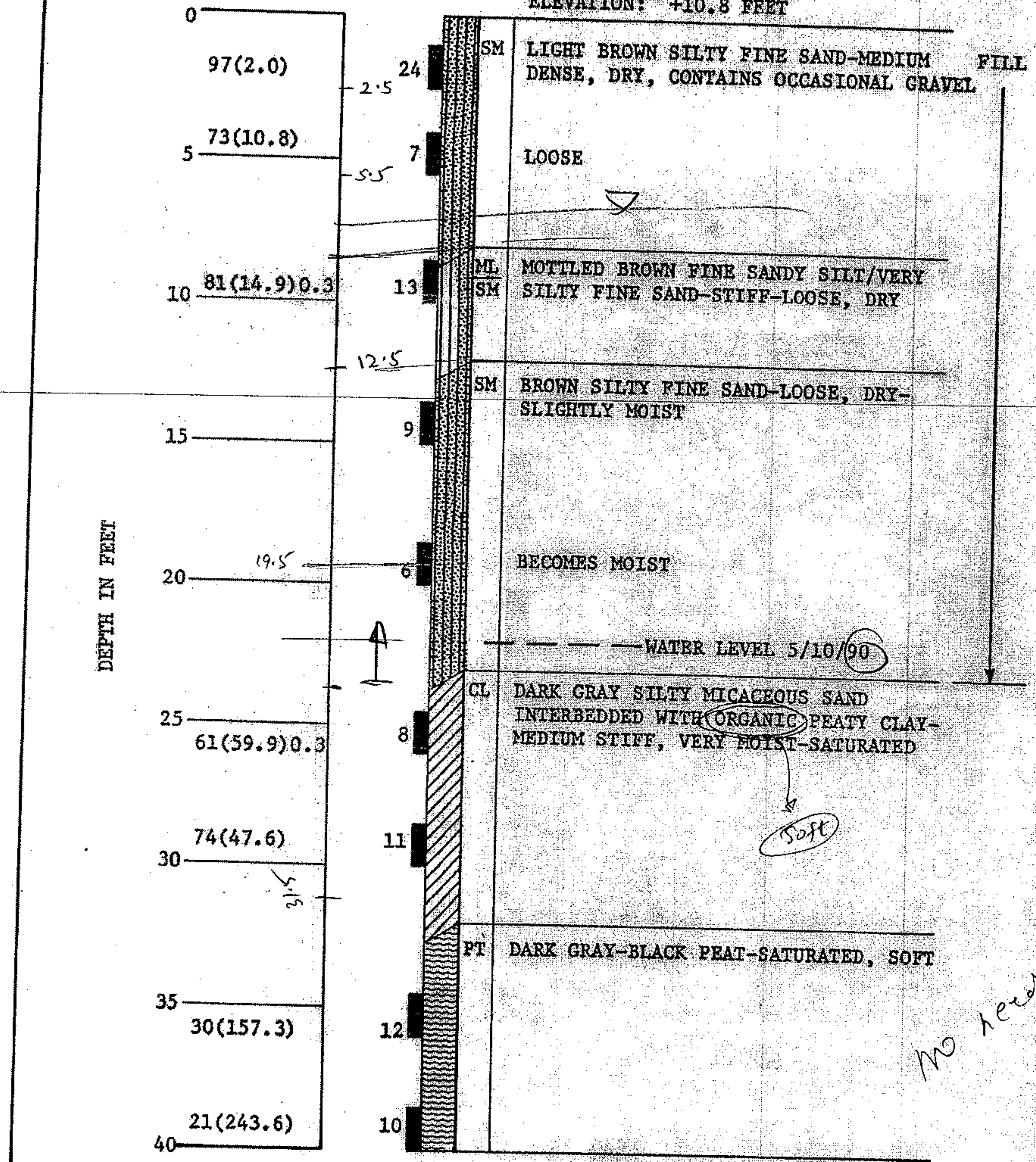
Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG Project No. MBK-201D	Sheet 3 Of 3	BORING NO. DH-10

ba-lp-90-1

(80)

BORING 1

DRILLED: 5/10/90
ELEVATION: +10.8 FEET



PROJECT NUMBER: 569-001
PLATE NUMBER: 2
DRAWN BY: DATE:
CHECKED BY: DATE:

ba-lp-90-B-1 to B-4

NOTES:

1. THE BORING LOG DEPICTS SUBSURFACE CONDITIONS ONLY AT THE BORING LOCATION AND TIME DESIGNATED.
2. SEE NOTES ON PLATE 3.

LOG OF BORING

Raney Geotechnical

PLATE 2

GEOLOGY

DIST.	COUNTY	ROUTE	POST MILE—TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
10	Sac,S.J.	12	5.7/5.8, 0.0/0.1	1	70

INDEX OF SHEETS

Sheet No.	1	Title Sheet
" "	2	Standard Plan List
" "	3	Construction Notes and Details
" "	4-6	Traffic Control System (one way)
" "	7-9	Miscellaneous Details
" "	10-69	Structure Details
" "	70	Cross Sections

STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF TRANSPORTATION

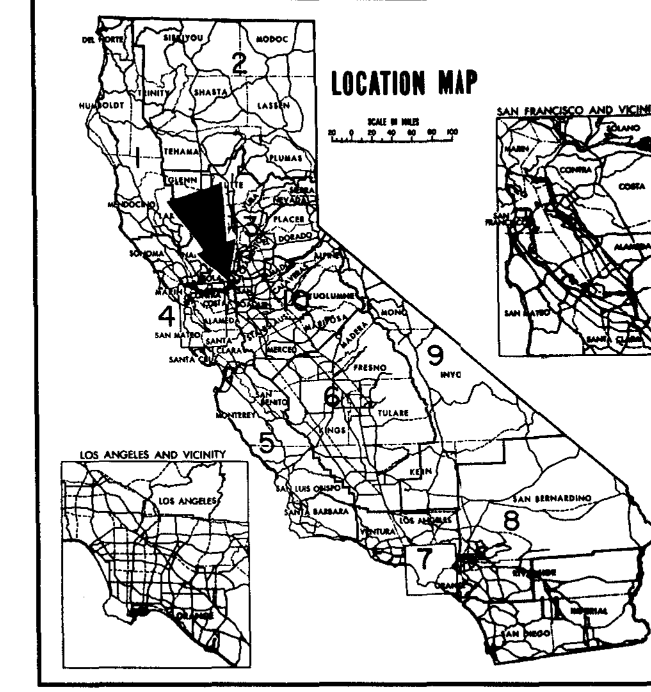
BRF-012(1)

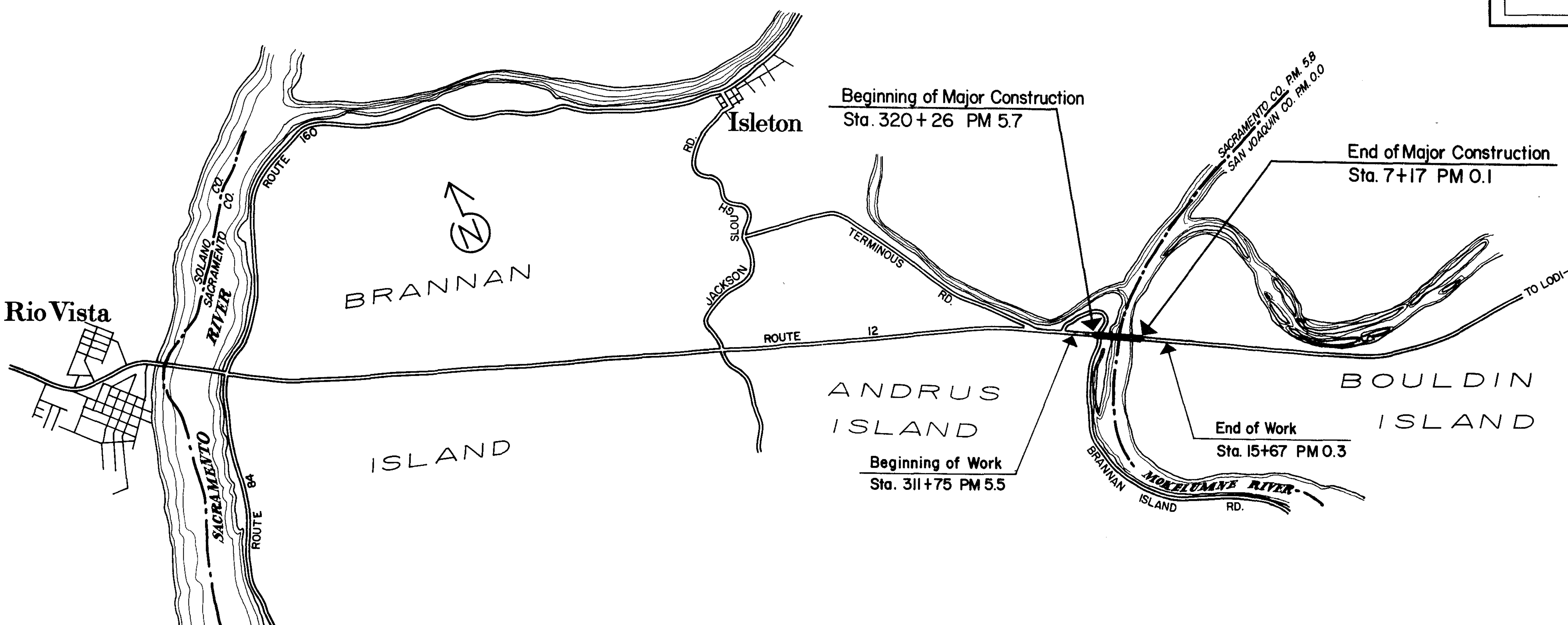
PROJECT PLANS FOR CONSTRUCTION ON

STATE HIGHWAY

IN SACRAMENTO AND SAN JOAQUIN COUNTIES ABOUT 6 MILES EAST OF RIO VISTA AT MOKELUMNE RIVER BRIDGE

To be supplemented by Standard Plans dated January 1975





REDUCED PLAN
USE SCALE BELOW
0 1 2 3
3 INCHES ON ORIGINAL PLAN

SCALE

½ 0 1 Mile

1000 0 1000 2000 3000 4000 5000 6000 7000 Feet

Length of Work = 0.6 mile

Length of Major Construction = 0.3 mile

The detailed plans are a portion of the route for the State Highway

District Engineer
Registered Civil Engineer No. 9109

Approved August 16, 1976

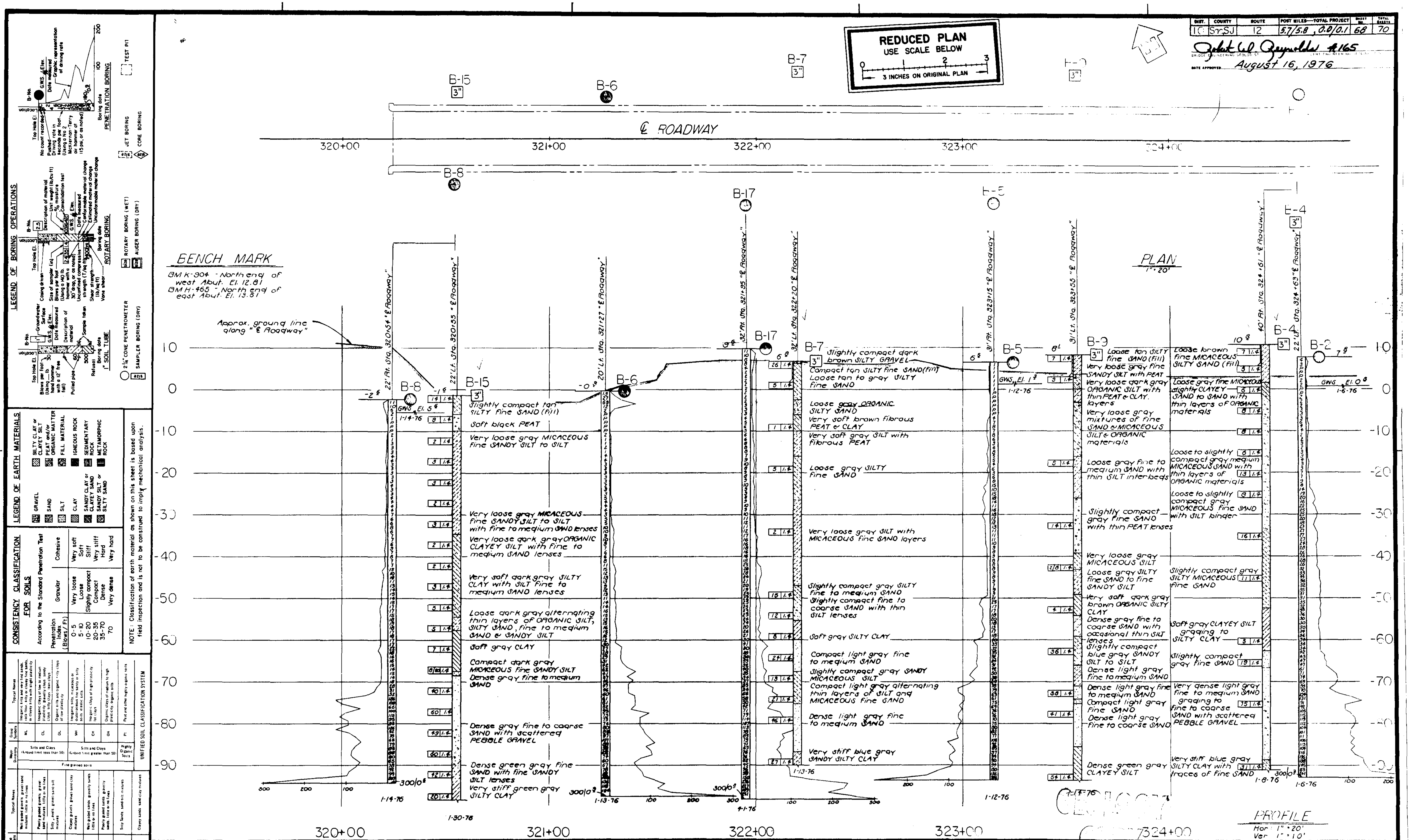
Chief, Project Development Division
Registered Civil Engineer No. 9532

Project Engineer	Date	Design Engineer	Date	Approval Recommended by	Date

Drawn by	Date
Checked by	Date

Contract No. 10-230304

10203-230301



ENGINEERING GEOLOGY SECTION

FIELD STUDY	BY G. G. Miller	1/76	Approval Recommended By
DRAWN	BY ED FONG	2/76	George G. Miller
CHECKED	BY B. Fox	3-29-76	CERTIFIED ENGINEERING GEOLOGIST NUMBER 632

State of CALIFORNIA
DEPARTMENT OF TRANSPORTATION

OFFICE OF STRUCTURES DESIGN GROUP

PROJECT ENGINEER

BRIDGE NO. 29-43

POST MILE 5.8/0.0

MOKELUMNE RIVER

LOG OF TEST BORINGS 1 OF 2

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

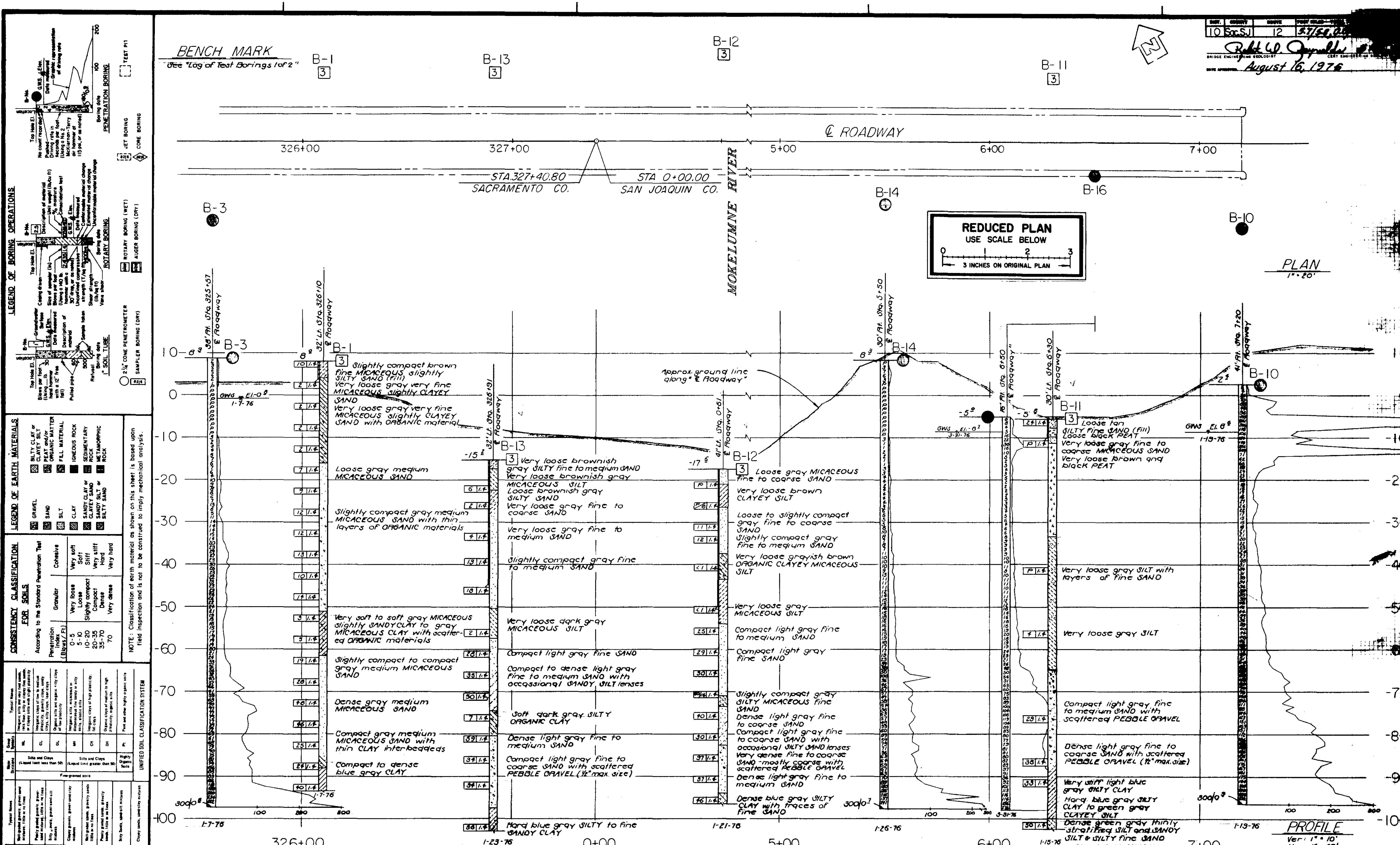
CU 10203
WO 230301

Disregard prints bearing earlier revision dates

REVISION DATES (PRELIMINARY STAGE ONLY) 8/4/76

SHEET 59 OF 60

68



DIST. 10	COUNTY Sac.SJ	ROUTE 12	POST MILES 57/58.0

BRIDGE ENGINEERING GEOLOGIST — CERT. ENGINEERING GEOLOGIST
DATE APPROVED August 16, 1976

ENGINEERING GEOLOGY SECTION

FIELD STUDY	By	1/76	Approval Recommended By
DRAWN	By ED FONG	2/76	
CHECKED	By	3-29-76	CERTIFIED ENGINEERING GEOLOGIST NUMBER 632

State of CALIFORNIA
DEPARTMENT OF TRANSPORTATION

OFFICE OF STRUCTURES
DESIGN GROUP
PROJECT ENGINEER

BRIDGE NO. 29-43
POST MILE 5.8/0.0

MOKELUMNE RIVER
LOG OF TEST BORINGS 2 OF 2

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

CU 10203
WO 230301

Disregard prints bearing earlier revision dates

REVISION DATES (PRELIMINARY STAGE ONLY)

SHEET 60 OF 60

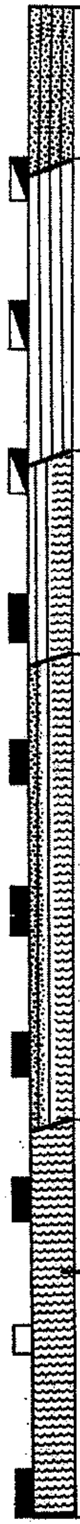
69

BORING 3

2a-lp-87-B3

DRILLED: 10/7/87
ELEVATION: +7.6 ± FEET

DEPTH IN FEET



Depth (ft)	Lab data	Blows	Symbol	Description
0			SM	BROWN SILTY MEDIUM TO COARSE SAND - MEDIUM DENSE
5		2	ML	GRAY SLIGHTLY CLAYEY FINE SANDY SILT - VERY SOFT
10		3		GRADING WITH SOME ORGANIC INCLUSIONS
15		2	ML/PT	GRAY-BROWN CLAYEY FINE SANDY SILT WITH PEAT INCLUSIONS - VERY SOFT
				GRADING WITH MORE SAND
20		2		
			SM/ML/PT	BLUE-GRAY CLAYEY SILTY FINE SAND WITH PEAT INCLUSIONS - LOOSE
25	53(64.1)	6		PEAT (PT) LENSES
30	54(70.8)	3		GRADING WITH MORE SILT AND LESS SAND
35	29(16.1)	6		ODOROUS
			PT	BROWN FIBROUS PEAT - SOFT
40	21(23.2)	6		
				WATER LEVEL 10/7/87
45				
50	64(56.2) 89(31.7)	10		GRADING SANDY
55				

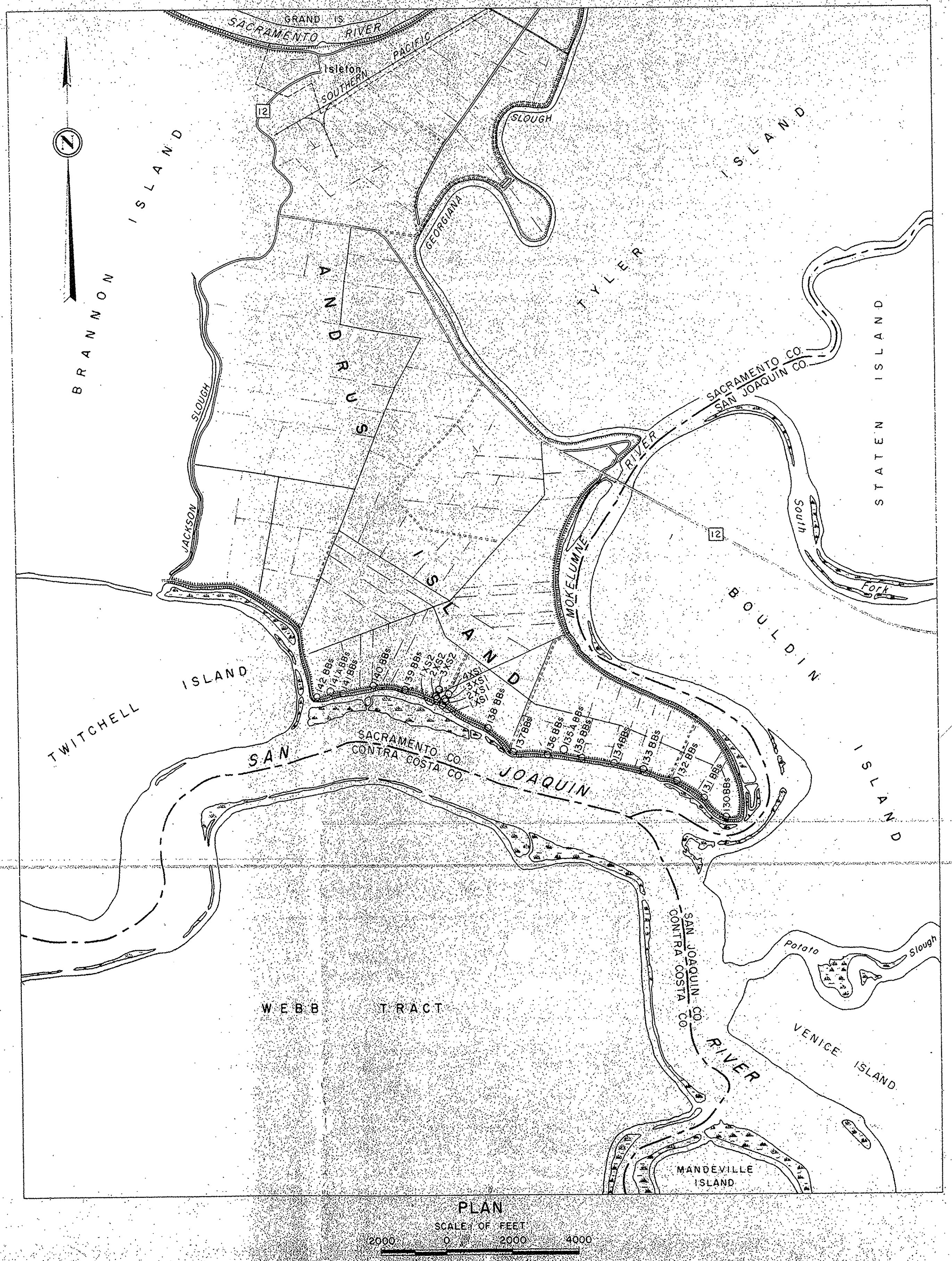
51.5

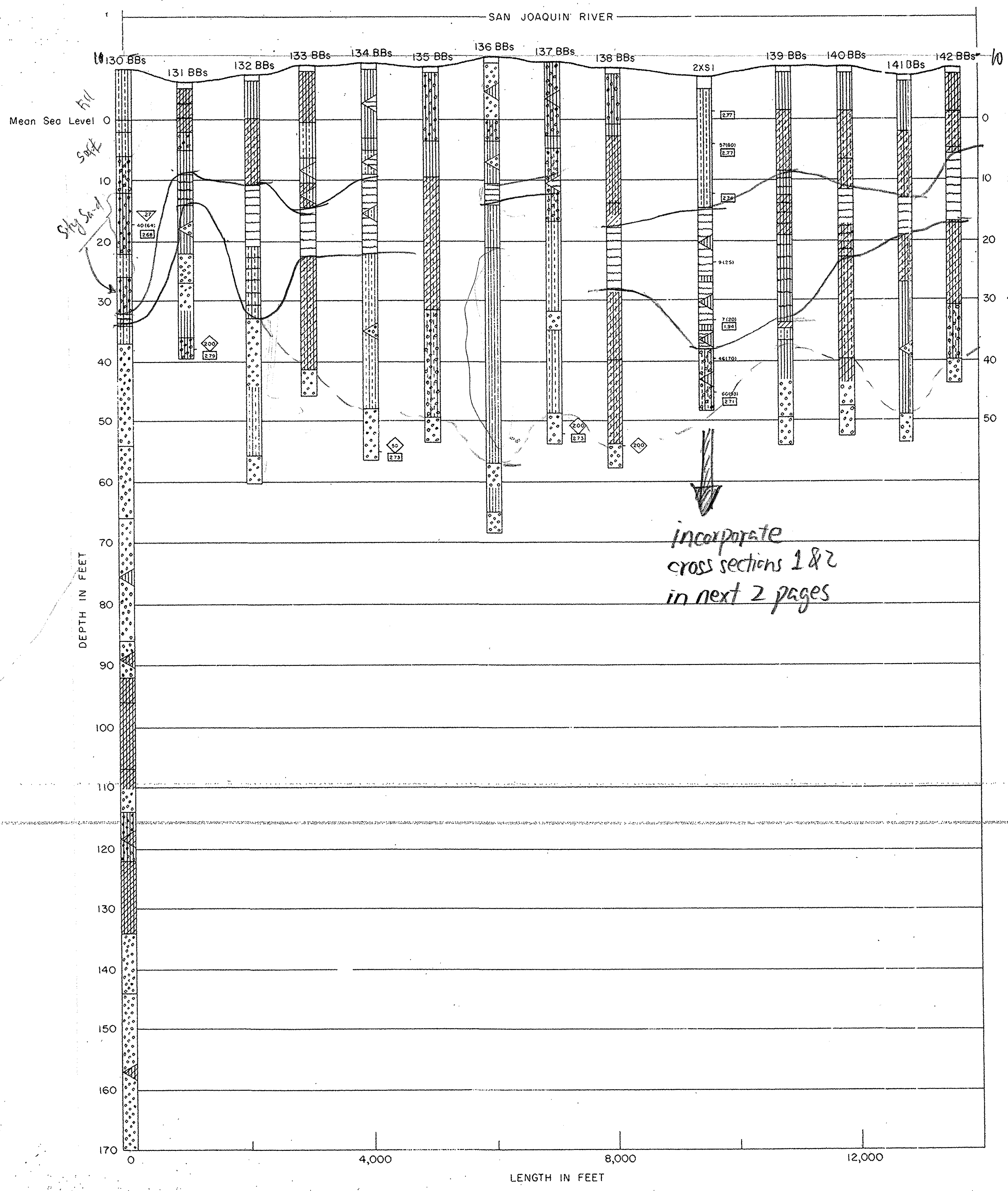
NOTES:
1. THE BORING LOG DEPICTS SUBSURFACE CONDITIONS ONLY AT THE BORING LOCATION AND TIME DESIGNATED.
2. SEE NOTES ON PLATES 3 AND 4.

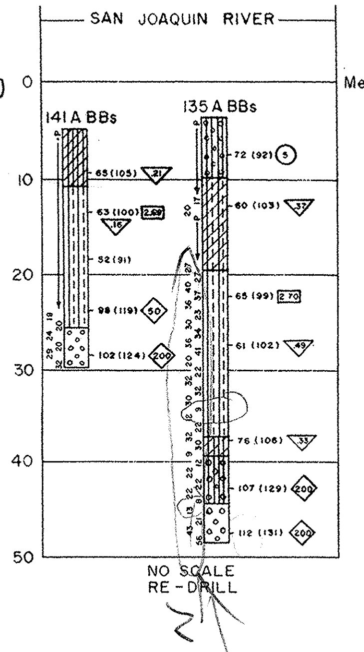
LOG OF BORING

Raney Geotechnical

PLATE NUMBER: 5 CHECKED BY: DATE: 11/3/87







NOTES:

GRAPHIC LOGS ARE BASED ON VISUAL CLASSIFICATION
HOLES 130 TO 142 ARE TWO INCH DIAMETER
HOLES 141 A AND 135 A ARE ONE INCH DIAMETER
HOLES 130 TO 142 ARE LOCATED ON LEVEE CROWN
HOLES 141 A AND 135 A ARE LOCATED ON LEVEE BACKSLOPE
HAMMER WEIGHT:
2" HOLES - 135 LBS
1" HOLES - 100 LBS
DRILLING DATES:
2" HOLES APRIL 9, 1956 TO APRIL 25, 1956
1" HOLES - JULY 23, 1958

LEGEND

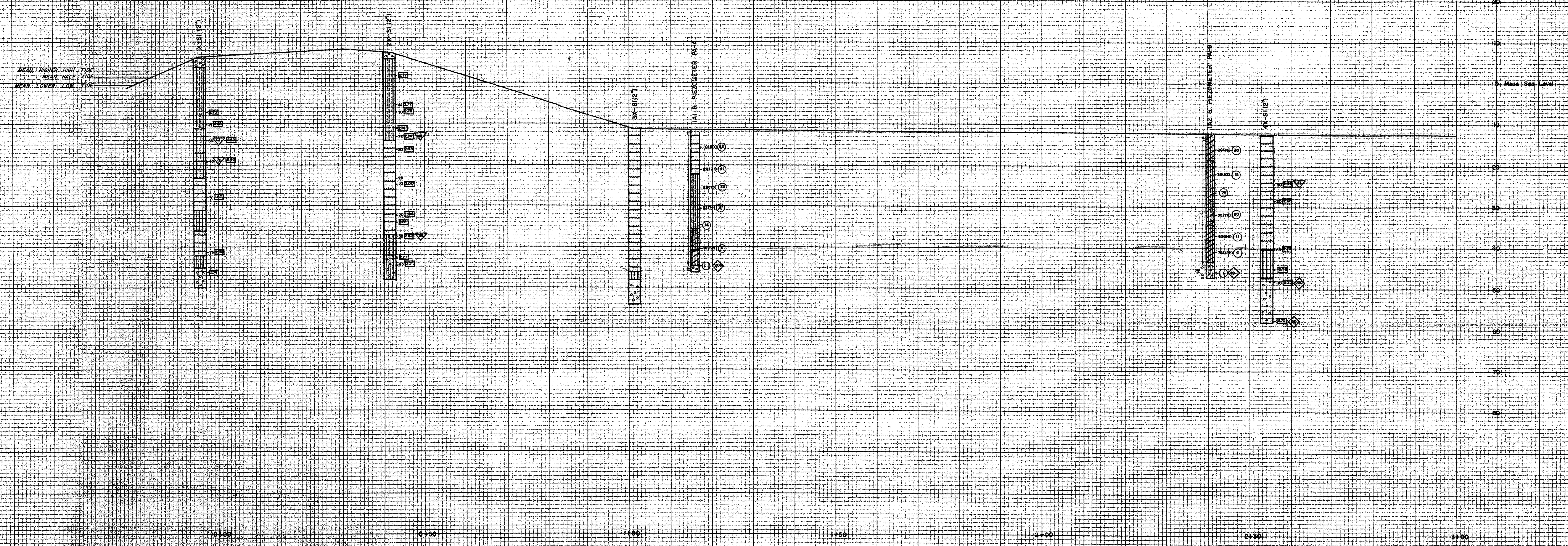
66(106) DRY (WET) DENSITY IN POUNDS PER CUBIC FOOT.
BLOWS PER FOOT (P INDICATES PUSH)
UNCONFINED COMPRESSIVE STRENGTH, K_c Kg/cm^2
UNCONFINED COMPRESSIVE STRESS AT 10% STRAIN, S_{10} Kg/cm^2
LOSS ON IGNITION IN PERCENT.
MAXIMUM SIEVE SIZE RETAINING 50% OF SAMPLE BY WEIGHT D_{50}
SPECIFIC GRAVITY
SAND
SILT
ORGANIC SILT
CLAY
ORGANIC CLAY
PEAT
COMPOSITE OF THE ABOVE MATERIAL - MAJOR CONSTITUENT DESIGNATED BY HEAVIER WEIGHT LINES OR CIRCLES; MINOR CONSTITUENTS BY LIGHTER WEIGHT LINES OR CIRCLES. BLOCK SHOWN IS CLAYEY SILT, ONE OF MANY POSSIBLE COMBINATIONS.
STREAKS OF ONE MATERIAL IN ANOTHER; SAND WITH SILT STREAK.
LAYERS OF MATERIALS; LAYERS OF CLAY AND SILT.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SALINITY CONTROL BARRIER INVESTIGATION

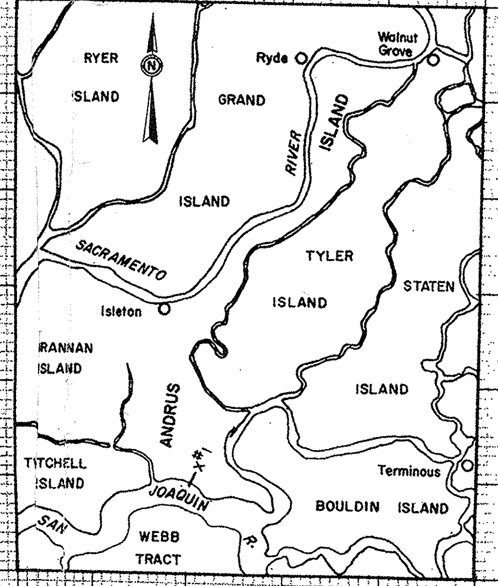
PRIMARY
SUBSURFACE EXPLORATION ON ANDRUS

PLAN AND PROFILE OF BORINGS

SCALE AS SHOWN



NOTES:
GRAPHIC LOGS ARE BASED ON VISUAL CLASSIFICATION
ALL BORINGS ARE ONE INCH DIAMETER EXCEPT WHERE NOTED
HAMMER WEIGHT: 1" HOLES- 140 LBS.
2" HOLES- 350 LBS.
DRILLING DATES: 1" HOLES- APRIL 26, 1957
2" HOLES- APRIL 19, 1957 TO APRIL 24, 1956



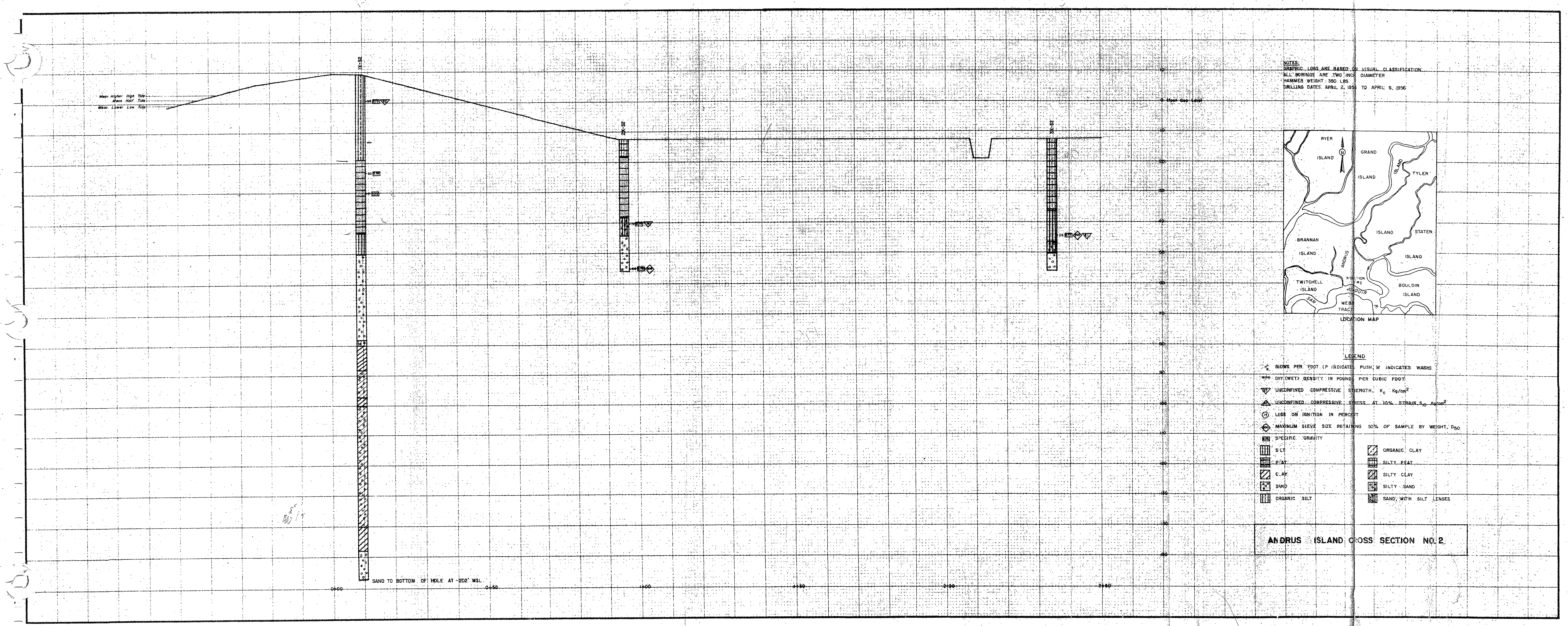
LOCATION MAP

LEGEND

BLOWS PER FOOT (P INDICATES PUSH, W INDICATES WASH)
DRY (W) DENSITY IN POUNDS PER CUBIC FOOT
UNCONFINED COMPRESSIVE STRENGTH, K_c Kg/cm²
UNCONFINED COMPRESSIVE STRESS AT 10% STRAIN S_{10} Kg/cm²
LOSS IGNITION IN PERCENT
MAXIMUM SIEVE SIZE RETAINING 50% OF SAMPLE BY WEIGHT, D_{50}
SPECIFIC GRAVITY

SILT	ORGANIC CLAY
PEAT	SILTY PEAT
CLAY	SILTY CLAY
SAND	SILTY SAND
ORGANIC SILT	SAND, WITH SILT LENSES

ANDRUS ISLAND CROSS SECTION NO. 1


Mean Higher High Tide
Mean Half Tide
Mean Lower Low Tide
SAND TO BOTTOM OF HOLE AT -202' MSL.
0+00
0+50
1+00
1+50
2+00
2+50
NOTES:
GRAPHIC LOGS ARE BASED ON VISUAL CLASSIFICATION
ALL BORINGS ARE TWO INCH DIAMETER
HAMMER WEIGHT : 350 LBS.
DRILLING DATES APRIL 2, 1956 TO APRIL 6, 1956
RYER
ISLAND
GRAND
ISLAND
TYLER
ISLAND
STATEN
ISLAND
BRANNAN
ISLAND
ANDRUS
TWITCHELL
ISLAND
BOULDIN
ISLAND
WEBB
TRACT
LOCATION MAP
LEGEND
BLOWS PER FOOT (P INDICATES PUSH, W INDICATES WASH)
DRY (WET) DENSITY IN POUNDS PER CUBIC FOOT
UNCONFINED COMPRESSIVE STRENGTH, K_c Kg/cm²
UNCONFINED COMPRESSIVE STRESS AT 10% STRAIN, S_{10} Kg/cm²
LOSS ON IGNITION IN PERCENT
MAXIMUM SIEVE SIZE RETAINING 50% OF SAMPLE BY WEIGHT, D_{50}
SPECIFIC GRAVITY
SILT
PEAT
CLAY
SAND
ORGANIC SILT
ORGANIC CLAY
SILTY PEAT
SILTY CLAY
SILTY SAND
SAND, WITH SILT LENSES
ANDRUS ISLAND CROSS SECTION NO. 2

KLEINFELDER

BRA-AND-ISL-B-1

BRANNAN-ANDRUS ISLAND

BORING 1

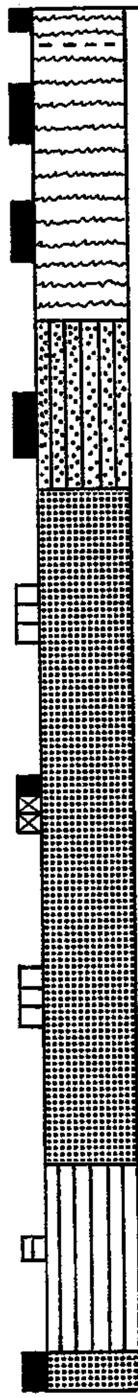
Approximate Surface Elevation +4' U. S. G
Mean Sea Level Datum

Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *	Symbol	Description
0				SM	Brown Silty Fine Sandy Fill. (Moderately Compact) New Fil
				GM	Thin Layer of Sandy Gravel.
	97	12	22	SM / ML	Alternate Layers of Brown and Ta Very Fine Sandy Silt and Silty Very Fine Sand with Lenses of Ta Silty Clay. (Dry and Moderately Compact)
5					
				SP / SM / ML	Grades with Layers of Clean Grey and Tan Fine Sand and Clayey Sil (Soft and Loose)
10	83	22	6	ML	Grades More Silty.
15	76	45	Push	ML	Greenish-Grey Clayey Silt with F Very Thin Lenses of Very Silty Very Fine Sand, Very Fine Sandy Silt and Very Silty Clay with Minor Vegetation. (Soft)
20	76	44	Push		
					(Grades Medium-Stiff)
25	77	42	Push		
				PT	Black Fibrous Clayey Peat. (Sti
30	46	89	Push		
			Push		
			Push		
35					
			Push		
	31	137	Push		
40					

LOG OF BORING

BORING 1
(CONTINUED)

Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *	Description
40				(Grades Medium-Stiff, Color to Dark-Grey)
	46	87	Push	
45	42	102	Push	
			Push	
				SM Bluish-Grey Silty Fine Sand wit[h] Minor Vegetation. (Medium-Dense)
50	103	23	Push	
				SP Bluish-Grey Slightly Silty Fine Sand. (Loose)
55			3/6"	
60			7	
65			8	
70				ML Greenish-Grey Very Fine Sandy Clayey Silt.
			62/8"	
75				SP Greenish-Grey Fine Sand with so[me] Medium Sizes and Silt. (Very De[nse])
80				



BORING TERMINATED AT 76.0-FOOT DEPT[H]

NOTES:

1. Boring Drilled on 9-19-77.
2. No Caving Noted.
3. Ground Water Encountered on 12-21-77, at Approximately 9'4"
4. The Lines Indicating the Transition Between Different Soil Types Represent Approximat[e] Boundaries. The Transition May Be Gradual.

BORING 2

Approximate Surface Elevation +5' U.S.(

Description Mean Sea Level Datum

Depth In Feet

Depth (ft)	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *
0			
	103	8	33
5	84	6	20
	82	6	6
10			
	80	20	5
15	88	20	5
	82	38	Push
20	76	43	Push
	73	48	Push
25			Push
	77	41	Push
30			
	38	112	Push
35			

SM Tan Slightly Silty Fine Sand with Lenses of Clean Fine Sand. (Compact) N F

GM Thin Layer of Sandy Gravel.

SM/SP Alternate Layers Grey-White and Brown and Tan Colored Clean and Silty Fine Sand. (Moderately Compact)
(Grades Poorly Compact)

(Grades with Lenses and Balls of Grey-Tan Clayey Silt)

SM/ML Alternate Layers of Greyish Brov Silty Fine Sand and Grey-Tan Fi Clayey Silt and Silty Clay.

ML Tan Clayey Silt. (Medium-Stiff)

ML Greenish-Grey Silt with Minor Very Fine Sand and Clay with Seams of Sand and Minor Vegetati (Soft to Medium-Stiff)
(Grades Primarily to Clayey Silt

PT Black Fibrous Clayey Peat.

LOG OF BORING

BORING 2
(CONTINUED)

Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *
35			Push
40	29	161	Push
45			Push
50	39	112	7
55			
60			15
65			16
70			18

Description

(Color to Dark-Grey)

OH Dark-Grey Organic Silty Clay. (Medium-Stiff)

SM Greenish-Grey Very Silty Fine Sand.

SP/SM Alternate Layers of Greenish-Grey Slightly Silty and Silty Fine Sand. (Medium-Dense)

CL Greenish-Grey Very Silty Clay. (Very-Stiff)

BORING TERMINATED AT 69.5-FOOT DEPTH

NOTES:
1. Boring Drilled on 9-20-77.
2. No Caving Noted.
3. Ground Water Encountered on 12-21-77, at Approximately 16'.
4. The Lines Indicating the Transition Between Different Soil Types Represent Approximate Boundaries. The Transition May Be Gradual.

Job No. S-2268-1

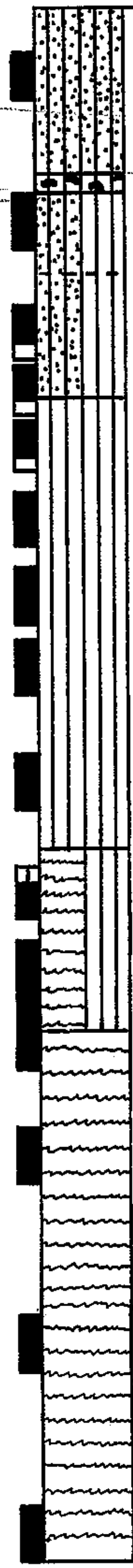
Plate No. V

BORING 3

Approximate Surface Elevation +5' U.S.G.S. Mean Sea Level Datum

Depth In Feet: 0, 5, 10, 15, 20, 25, 30, 35, 40

Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *
101	5	12
81	9	4
86	25	4/18"
80	41	3/18"
		Push
72	47	Push
72	85	Push
42	98	Push
46	88	Push
38	112	Push
41	105	Push
30	148	Push



Description

SM Tan Slightly Silty Fine Sand. (Poorly to Moderately Compact) New Fil

GM Thin Layer of Sandy Gravel.

SM/ML Alternate Layers of Tan and Grey White Very Sandy Silt and Silty Very Fine to Fine Sand with Minor Roots. (Poorly Compact) (Grades with Lenses of Tan Very Silty Clay. (Soft)

ML Greenish-Grey Very Fine Sand and Clayey Silt with Lenses of Silty Fine Sandy Silty Clay and Minor Vegetation. (Soft) F:

PT/ML Grades to Greenish-Grey Very Clayey Silt with Layers of Fibr Peat and Large Tree Roots.

PT Black Fibrous Clayey Peat. (Stiff to Very-Stiff)

BORING TERMINATED AT 41.5-FOOT DEPT

NOTES:

1. Boring Drilled on 9-21-77.
2. No Caving Noted.
3. Ground Water Encountered on 12-21-77, at Approximately 9'.
4. The Lines Indicating the Transition Between Different Soil Types Represent Approximat Boundaries. The Transition May Be Gradual.

LOG OF BORING

BORING 4

Approximate Surface Elevation +5' U.S.G.S Mean Sea Level Datum

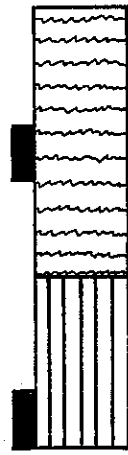
Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count*		Description
0					
			7	ML	Brown Very Fine Sandy and Claye Silt. (Very-Stiff)
					(Grades to Clayey Silt with Minor Vegetation and Lenses of Silty Fine Sand and Silty Clay)
5			5		
					(Color to Grey-Tan) (Grades Medium-Stiff to Stiff)
			5/18"		
10				ML	Greenish-Grey Clayey Silt with Lenses of Silty Fine Sand. (Soft)
			Push		
					(Grades with Many Lenses of Sil Fine Sand Grades Medium-Stiff) Fi
15			Push		
				OL	Greenish-Grey and Dark-Grey Clayey Silt with Decaying Vegetation. (Medium-Stiff to Stiff)
20			Push		
				ML	Greenish-Grey and Dark-Grey Clayey Silt. (Medium-Stiff to Stiff)
			Push		
25					(Grades with Lenses of Silty Clay)
			Push		
30				PT	Black Fibrous Clayey Peat. (Very-Stiff)
35					

LOG OF BORING

BORING 4
(CONTINUED)

Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *
35			
40			
45			
50			

Description



ML Greenish-Grey Clayey Silt with Decaying Vegetation and Lenses of Very Fine Sandy Silt. (Stiff)

BORING TERMINATED AT 46.5-FOOT DEPTH

NOTES:

1. Boring Drilled on 9-21-77.
2. No Caving Noted.
3. Ground Water Encountered on 12-21-77 at 10'.
4. The Lines Indicating the Transition Between Different Soil Types Represent Approximate Boundaries. The Transition May Be Gradual.

LOG OF BORING

Appendix B CPT Report for CPT's, prepared by ConeTec, September 2020

PRESENTATION OF SUPPLEMENTAL II SITE INVESTIGATION RESULTS

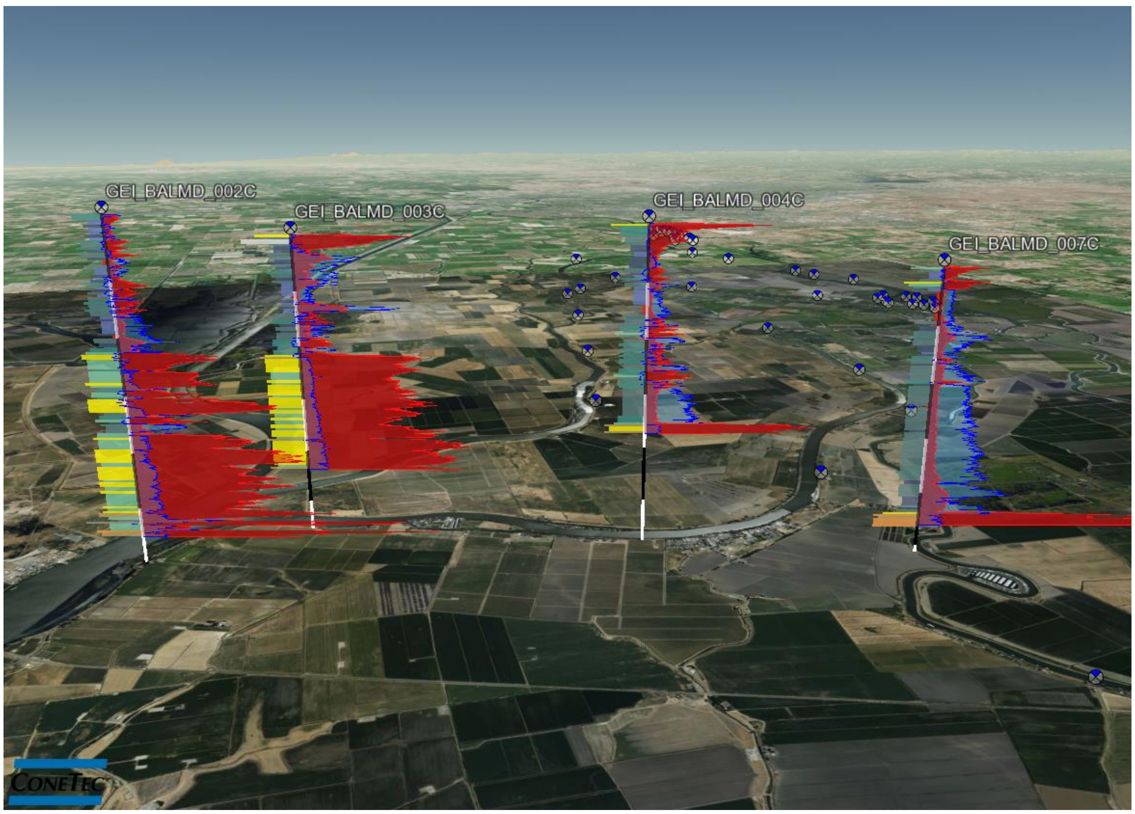
Small Communities - Isleton

Prepared for:

GEI Consultants

ConeTec Job No: 19-56124

Project Start Date: 14-Sep-2020
Project End Date: 16-Sep-2020
Report Date: 18-Sep-2020



Prepared by:

ConeTec Inc.
820 Aladdin Avenue
San Leandro, CA 94577

Tel: (510) 357-3677

ConeTecCA@conetec.com
www.conetec.com
www.conetecdataservices.com

CONETEC

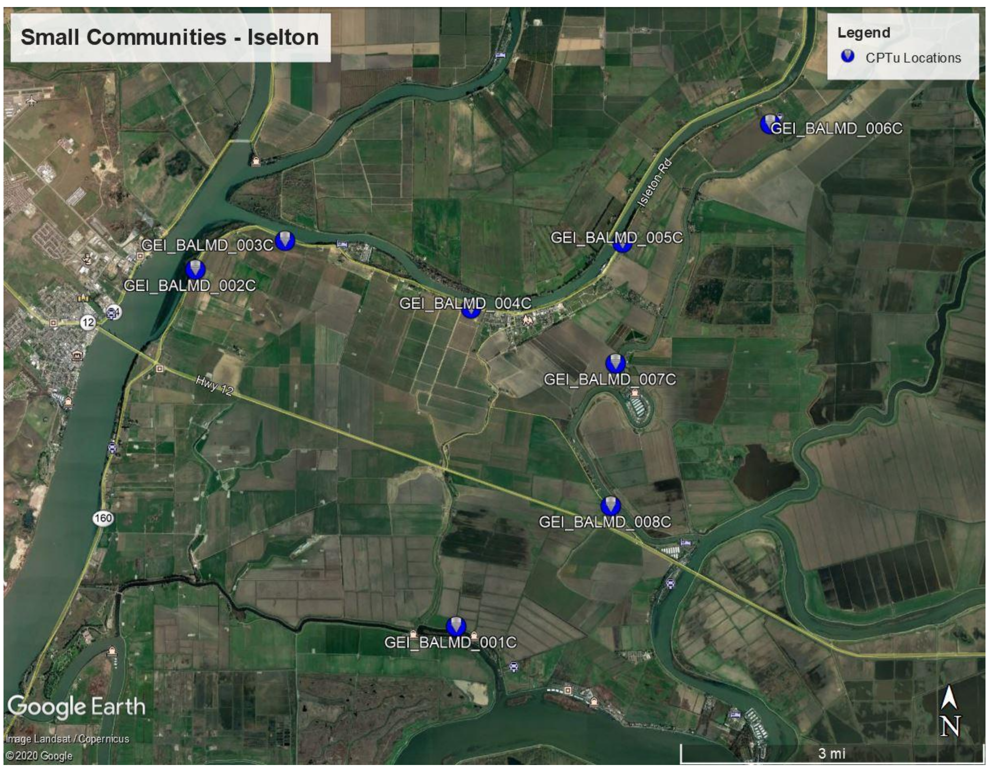
Introduction

The enclosed report presents the results of the supplemental site investigation program conducted by ConeTec Inc. for GEI Consultants of Oakland, CA. The program consisted of cone penetration testing (CPTu) at eight (8) locations. Additionally, several soil samples were collected at all locations. The report supplements the locations completed in August and October 2019.

Project Information

Project	
Client	GEI Consultants
Project	Small Communities - Isleton
ConeTec Project #	19-56124

An aerial overview from Google Earth including the CPT test locations is presented below.



Rig Description	Deployment System	Test Type
CPT truck rig	30-ton truck mounted cylinder	CPTu

Coordinates		
Test Type	Collection Method	EPSG Number
CPTu	Consumer grade GPS	32610

Cone Penetrometers Used for this Project						
Cone Description	Cone Number	Cross Sectional Area (cm^2)	Sleeve Area (cm^2)	Tip Capacity (bar)	Sleeve Capacity (bar)	Pore Pressure Capacity (psi)
448:T1500F15U500	448	15	225	1500	15	500
Cone 448 was used on all soundings.						

Cone Penetration Test	
Depth reference	Depths are referenced to the existing ground surface at the time of test.
Tip and sleeve data offset	0.1 Meter This has been accounted for in the CPT data files.
Additional Comments	Advanced plots with Ic, Phi, Su(Nkt), and N1(60)Ic, as well as Soil Behavior Type (SBT) Scatter plots have been included in the data release package.

Calculated Geotechnical Parameter Tables	
Additional information	The Normalized Soil Behaviour Type Chart based on Q_{tn} (SBT Q_{tn}) (Robertson, 2009) was used to classify the soil for this project. A detailed set of calculated CPTu parameters have been generated and are provided in Excel format files in the release folder. The CPTu parameter calculations are based on values of corrected tip resistance (q_t) sleeve friction (f_s) and pore pressure (u_2). Effective stresses are calculated based on unit weights that have been assigned to the individual soil behaviour type zones and the assumed equilibrium pore pressure profile. Soils were classified as either drained or undrained based on the Q_{tn} Normalized Soil Behaviour Type Chart (Robertson, 2009). Calculations for both drained and undrained parameters were included for materials that classified as silt mixtures (zone 4).

Limitations

This report has been prepared for the exclusive use of GEI Consultants (Client) for the project titled "Small Communities - Isleton". The report's contents may not be relied upon by any other party without the express written permission of ConeTec, Inc. (ConeTec). ConeTec has provided site investigation services, prepared the factual data reporting, and provided geotechnical parameter calculations consistent with current best practices. No other warranty, expressed or implied, is made.

The information presented in the report document and the accompanying data set pertain to the specific project, site conditions and objectives described to ConeTec by the Client. In order to properly understand the factual data, assumptions and calculations, reference must be made to the documents provided and their accompanying data sets, in their entirety.

Cone penetration tests (CPTu) are conducted using an integrated electronic piezocone penetrometer and data acquisition system manufactured by Adara Systems Ltd., a subsidiary of ConeTec.

ConeTec's piezocone penetrometers are compression type designs in which the tip and friction sleeve load cells are independent and have separate load capacities. The piezocones use strain gauged load cells for tip and sleeve friction and a strain gauged diaphragm type transducer for recording pore pressure. The piezocones also have a platinum resistive temperature device (RTD) for monitoring the temperature of the sensors, an accelerometer type dual axis inclinometer and a geophone sensor for recording seismic signals. All signals are amplified down hole within the cone body and the analog signals are sent to the surface through a shielded cable.

ConeTec penetrometers are manufactured with various tip, friction and pore pressure capacities in 5 cm^2, 10 cm^2 and 15 cm^2 tip base area configurations in order to maximize signal resolution for various soil conditions. The specific piezocone used for each test is described in the CPT summary table presented in the first appendix. The 15 cm^2 penetrometers do not require friction reducers as they have a diameter larger than the deployment rods. The 10 cm^2 piezocones use a friction reducer consisting of a rod adapter extension behind the main cone body with an enlarged cross-sectional area (typically forty-four millimeter diameter over a length of thirty-two millimeter with tapered leading and trailing edges) located at a distance of 585 millimeters above the cone tip.

The penetrometers are designed with equal end area friction sleeves, a net end area ratio of 0.8 and cone tips with a sixty-degree apex angle.

All ConeTec piezocones can record pore pressure at various locations. Unless otherwise noted, the pore pressure filter is located directly behind the cone tip in the "u_2" position (ASTM Type 2). The filter is six millimeters thick, made of porous plastic (polyethylene) having an average pore size of 125 microns (90-160 microns). The function of the filter is to allow rapid movements of extremely small volumes of water needed to activate the pressure transducer while preventing soil ingress or blockage.

The piezocone penetrometers are manufactured with dimensions, tolerances and sensor characteristics that are in general accordance with the current ASTM D5778 standard. ConeTec's calibration criteria also meets or exceeds those of the current ASTM D5778 standard. An illustration of the piezocone penetrometer is presented in Figure CPTu.

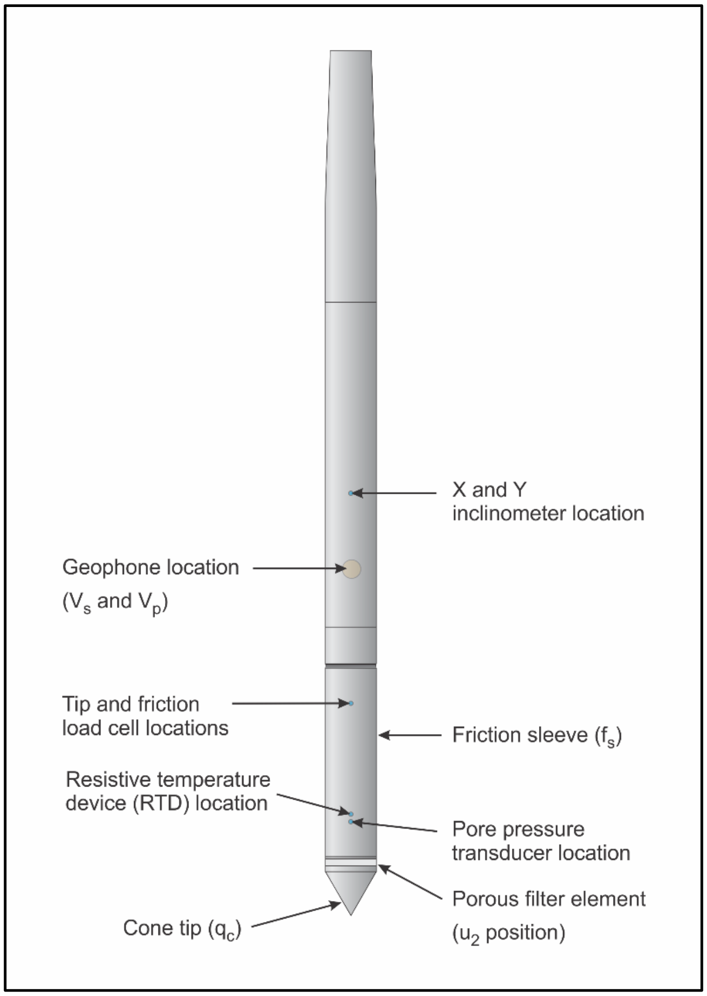


Figure CPTu. Piezocone Penetrometer (15 cm^2)

The ConeTec data acquisition systems consist of a Windows based computer and a signal conditioner and power supply interface box with a sixteen bit (or greater) analog to digital (A/D) converter. The data is recorded at fixed depth increments using a depth wheel attached to the push cylinders or by using a spring loaded rubber depth wheel that is held against the cone rods. The typical recording interval is 2.5 centimeters; custom recording intervals are possible. The system displays the CPTu data in real time and records the following parameters to a storage media during penetration:

- Depth
- Uncorrected tip resistance (q_c)
- Sleeve friction (f_s)
- Dynamic pore pressure (u)
- Additional sensors such as resistivity, passive gamma, ultra violet induced fluorescence, if applicable

All testing is performed in accordance to ConeTec's CPT operating procedures which are in general accordance with the current ASTM D5778 standard.

Prior to the start of a CPTu sounding a suitable cone is selected, the cone and data acquisition system are powered on, the pore pressure system is saturated with silicone oil and the baseline readings are recorded with the cone hanging freely in a vertical position.

The CPTu is conducted at a steady rate of two centimeters per second, within acceptable tolerances. Typically, one-meter length rods with an outer diameter of 1.5 inches (38.1 millimeters) are added to advance the cone to the sounding termination depth. After cone retraction final baselines are recorded.

Additional information pertaining to ConeTec's cone penetration testing procedures:

- Each filter is saturated in silicone oil under vacuum pressure prior to use
- Recorded baselines are checked with an independent multi-meter
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards

The interpretation of piezocone data for this report is based on the corrected tip resistance (q_t), sleeve friction (f_s) and pore water pressure (u). The interpretation of soil type is based on the correlations developed by Robertson et al. (1986) and Robertson (1990, 2009). It should be noted that it is not always possible to accurately identify a soil behavior type based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behavior type.

The recorded tip resistance (q_c) is the total force acting on the piezocone tip divided by its base area. The tip resistance is corrected for pore pressure effects and termed corrected tip resistance (q_t) according to the following expression presented in Robertson et al. (1986):

$$q_t = q_c + (1-a) \bullet u_2$$

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the piezocone (0.8 for ConeTec probes)

The sleeve friction (f_s) is the frictional force on the sleeve divided by its surface area. As all ConeTec piezocones have equal end area friction sleeves, pore pressure corrections to the sleeve data are not required.

The dynamic pore pressure (u) is a measure of the pore pressures generated during cone penetration. To record equilibrium pore pressure, the penetration must be stopped to allow the dynamic pore pressures to stabilize. The rate at which this occurs is predominantly a function of the permeability of the soil and the diameter of the cone.

The friction ratio (Rf) is a calculated parameter. It is defined as the ratio of sleeve friction to the tip resistance expressed as a percentage. Generally, saturated cohesive soils have low tip resistance, high friction ratios and generate large excess pore water pressures. Cohesionless soils have higher tip resistances, lower friction ratios and do not generate significant excess pore water pressure.

A summary of the CPTu soundings along with test details and individual plots are provided in the appendices. A set of files with calculated geotechnical parameters were generated for each sounding based on published correlations and are provided in Excel format in the data release folder. Information regarding the methods used is also included in the data release folder.

For additional information on CPTu interpretations and calculated geotechnical parameters, refer to Robertson et al. (1986), Lunne et al. (1997), Robertson (2009), Mayne (2013, 2014) and Mayne and Peuchen (2012).

The cone penetration test is halted at specific depths to carry out pore pressure dissipation (PPD) tests, shown in Figure PPD-1. For each dissipation test the cone and rods are decoupled from the rig and the data acquisition system measures and records the variation of the pore pressure (u) with time (t).

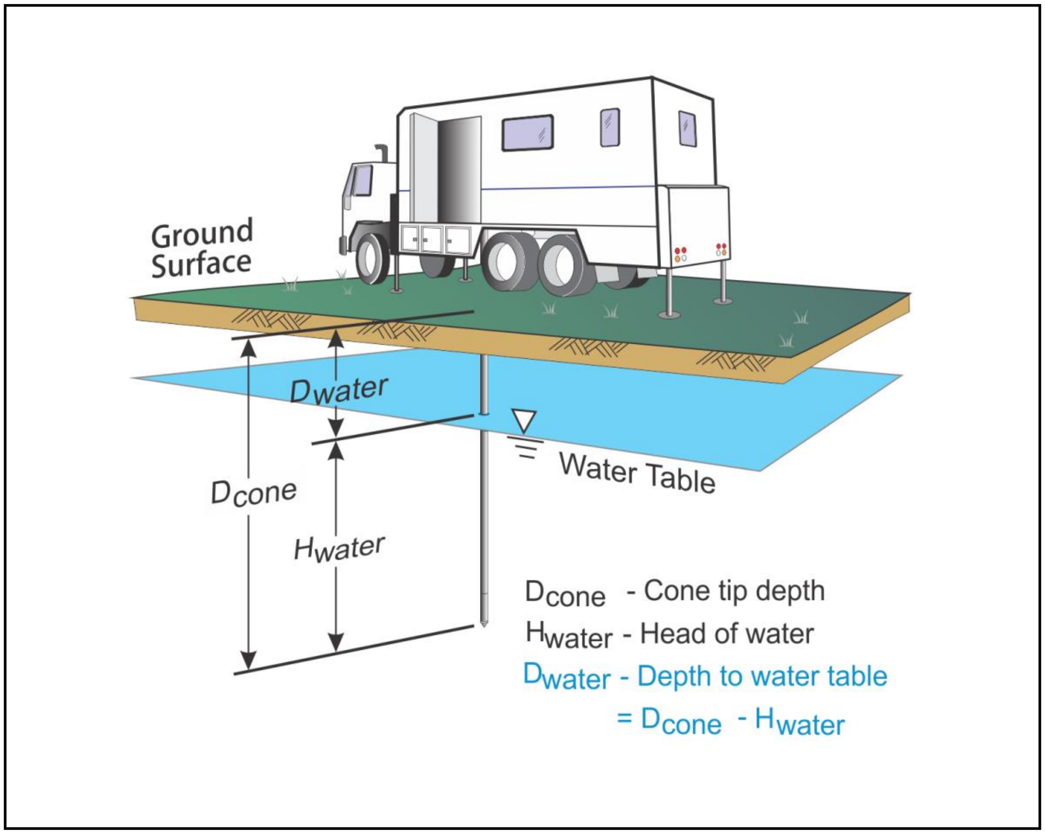


Figure PPD-1. Pore pressure dissipation test setup

Pore pressure dissipation data can be interpreted to provide estimates of ground water conditions, permeability, consolidation characteristics and soil behavior.

The typical shapes of dissipation curves shown in Figure PPD-2 are very useful in assessing soil type, drainage, in situ pore pressure and soil properties. A flat curve that stabilizes quickly is typical of a freely draining sand. Undrained soils such as clays will typically show positive excess pore pressure and have long dissipation times. Dilative soils will often exhibit dynamic pore pressures below equilibrium that then rise over time. Overconsolidated fine-grained soils will often exhibit an initial dilatory response where there is an initial rise in pore pressure before reaching a peak and dissipating.

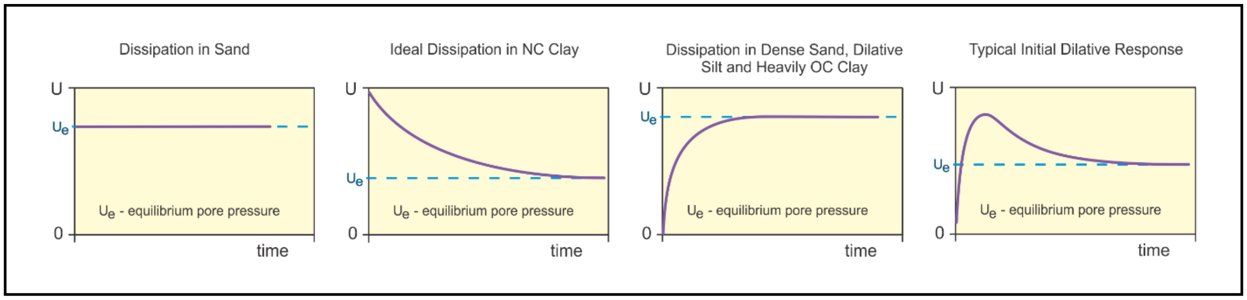


Figure PPD-2. Pore pressure dissipation curve examples

In order to interpret the equilibrium pore pressure (u_{eq}) and the apparent phreatic surface, the pore pressure should be monitored until such time as there is no variation in pore pressure with time as shown for each curve in Figure PPD-2.

In fine grained deposits the point at which 100% of the excess pore pressure has dissipated is known as t_{100}. In some cases this can take an excessive amount of time and it may be impractical to take the dissipation to t_{100}. A theoretical analysis of pore pressure dissipations by Teh and Houlsby (1991) showed that a single curve relating degree of dissipation versus theoretical time factor (T*) may be used to calculate the coefficient of consolidation (c_h) at various degrees of dissipation resulting in the expression for c_h shown below.

$$c_h = \frac{T^* \cdot a^2 \cdot \sqrt{I_r}}{t}$$

Where:

T* is the dimensionless time factor (Table Time Factor)
a is the radius of the cone
I_r is the rigidity index
t is the time at the degree of consolidation

Table Time Factor. T* versus degree of dissipation (Teh and Houlsby (1991))

Degree of Dissipation (%)	20	30	40	50	60	70	80
T* (u_2)	0.038	0.078	0.142	0.245	0.439	0.804	1.60

The coefficient of consolidation is typically analyzed using the time (t_{50}) corresponding to a degree of dissipation of 50% (u_{50}). In order to determine t_{50}, dissipation tests must be taken to a pressure less than u_{50}. The u_{50} value is half way between the initial maximum pore pressure and the equilibrium pore pressure value, known as u_{100}. To estimate u_{50}, both the initial maximum pore pressure and u_{100} must be known or estimated. Other degrees of dissipations may be considered, particularly for extremely long dissipations.

At any specific degree of dissipation the equilibrium pore pressure (u at t_{100}) must be estimated at the depth of interest. The equilibrium value may be determined from one or more sources such as measuring the value directly (u_{100}), estimating it from other dissipations in the same profile, estimating the phreatic surface and assuming hydrostatic conditions, from nearby soundings, from client provided information, from site observations and/or past experience, or from other site instrumentation.

For calculations of c_h (Teh and Houlsby (1991)), t_{50} values are estimated from the corresponding pore pressure dissipation curve and a rigidity index (I_r) is assumed. For curves having an initial dilatory response in which an initial rise in pore pressure occurs before reaching a peak, the relative time from the peak value is used in determining t_{50}. In cases where the time to peak is excessive, t_{50} values are not calculated.

Due to possible inherent uncertainties in estimating I_r, the equilibrium pore pressure and the effect of an initial dilatory response on calculating t_{50}, other methods should be applied to confirm the results for c_h.

Additional published methods for estimating the coefficient of consolidation from a piezocone test are described in Burns and Mayne (1998, 2002), Jones and Van Zyl (1981), Robertson et al. (1992) and Sully et al. (1999).

A summary of the pore pressure dissipation tests and dissipation plots are presented in the relevant appendix.

ASTM D5778-12, 2012, "Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils", ASTM International, West Conshohocken, PA. DOI: 10.1520/D5778-12.

Burns, S.E. and Mayne, P.W., 1998, "Monotonic and dilatory pore pressure decay during piezocone tests", Canadian Geotechnical Journal 26 (4): 1063-1073. DOI: 1063-1073/T98-062.

Burns, S.E. and Mayne, P.W., 2002, "Analytical cavity expansion-critical state model cone dissipation in fine-grained soils", Soils & Foundations, Vol. 42(2): 131-137.

Jones, G.A. and Van Zyl, D.J.A., 1981, "The piezometer probe: a useful investigation tool", Proceedings, 10th International Conference on Soil Mechanics and Foundation Engineering, Vol. 3, Stockholm: 489-495.

Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, "Cone Penetration Testing in Geotechnical Practice", Blackie Academic and Professional.

Mayne, P.W., 2013, "Evaluating yield stress of soils from laboratory consolidation and in-situ cone penetration tests", Sound Geotechnical Research to Practice (Holtz Volume) GSP 230, ASCE, Reston/VA: 406-420. DOI: 10.1061/9780784412770.027.

Mayne, P.W. and Peuchen, J., 2012, "Unit weight trends with cone resistance in soft to firm clays", Geotechnical and Geophysical Site Characterization *4,* Vol. 1 (Proc. ISC-4, Pernambuco), CRC Press, London: 903-910.

Mayne, P.W., 2014, "Interpretation of geotechnical parameters from seismic piezocone tests", CPT'14 Keynote Address, Las Vegas, NV, May 2014.

Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.

Robertson, P.K., 1990, "Soil Classification Using the Cone Penetration Test", Canadian Geotechnical Journal, Volume 27: 151-158. DOI: 10.1139/T90-014.

Robertson, P.K., Sully, J.P., Woeller, D.J., Lunne, T., Powell, J.J.M. and Gillespie, D.G., 1992, "Estimating coefficient of consolidation from piezocone tests", Canadian Geotechnical Journal, 29(4): 539-550. DOI: 10.1139/T92-061.

Robertson, P.K., 2009, "Interpretation of cone penetration tests – a unified approach", Canadian Geotechnical Journal, Volume 46: 1337-1355. DOI: 10.1139/T09-065.

Sully, J.P., Robertson, P.K., Campanella, R.G. and Woeller, D.J., 1999, "An approach to evaluation of field CPTU dissipation data in overconsolidated fine-grained soils", Canadian Geotechnical Journal, 36(2): 369-381. DOI: 10.1139/T98-105.

Teh, C.I., and Houlsby, G.T., 1991, "An analytical study of the cone penetration test in clay", Geotechnique, 41(1): 17-34. DOI: 10.1680/geot.1991.41.1.17.

A direct push piston-type soil sampler is used to collect soil samples at specific depths as directed by the field program coordinator. Figure DPSS illustrates the procedure for collecting a sample.

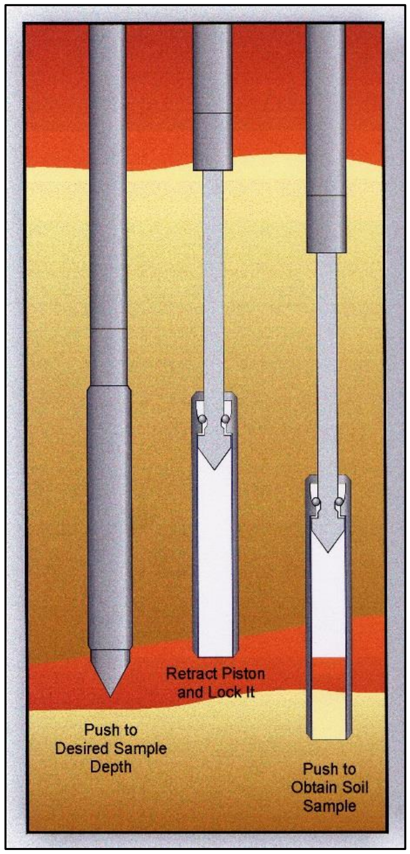


Figure DPSS. Direct push soil sampler procedure

The soil sampler is initially pushed in a “closed” position to the desired sampling interval. The inner cone tip portion of the sampler is then retracted (approximately twelve inches) leaving a hollow soil sampler with two inner soil sample tubes, 1 ¼ inch diameter by six inches long. The hollow sampler is then pushed in a locked “open” position to collect a soil sample. The filled sampler and push rods are then retrieved to the ground surface. For environmental analyses, the soil sample tube ends are sealed with Teflon and plastic caps.

A representative photograph is taken of each sample, including a label with the location name, sample depth range, date and sample number. The samples are placed into sample containers or plastic bags and logged in an Excel spreadsheet. The sample log provides information pertaining to the sample location, as well as each sample that was collected.

The sample logs are presented in the relevant appendix and the sample photos are provided in the data release folder.

The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Advanced Cone Penetration Test Plots with Ic, Phi, Su(Nkt), and N1(60)Ic
- Soil Behavior Type (SBT) Zone Scatter Plots
- Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots
- Soil Sample Summary

Cone Penetration Test Summary and Standard Cone Penetration Test Plots

ConeTec

Job No: 19-56124
Client: GEI Consultants
Project: Small Communities - Isleton
Start Date: 14-Sep-2020
End Date: 16-Sep-2020

CONE PENETRATION TEST SUMMARY

Sounding ID	File Name	Date	Cone	Assumed Phreatic Surface[1] (ft)	Final Depth (ft)	Northing[2] (m)	Easting[2] (m)	Elevation[3] (ft)	Refer to Notation Number
GEI_BALMD_001C	19-56124_CP-BALMD-001C	15-Sep-2020	448:T1500F15U500	8.5	95.55	4219767	620788	-14	
GEI_BALMD_002C	19-56124_CP-BALMD-002C	15-Sep-2020	448:T1500F15U500	1.4	90.55	4225340	616567	10	
GEI_BALMD_003C	19-56124_CP-BALMD-003C	14-Sep-2020	448:T1500F15U500	2.6	71.52	4225816	617982	2	
GEI_BALMD_004C	19-56124_CP-BALMD-004C	14-Sep-2020	448:T1500F15U500	7.1	61.02	4224793	620949	6	
GEI_BALMD_005C	19-56124_CP-BALMD-005C	15-Sep-2020	448:T1500F15U500	3.1	75.54	4225867	623336	12	
GEI_BALMD_006C	19-56124_CP-BALMD-006C	16-Sep-2020	448:T1500F15U500	16.3	72.59	4227775	625653	1	
GEI_BALMD_007C	19-56124_CP-BALMD-007C	16-Sep-2020	448:T1500F15U500	2.1	75.54	4223958	623256	-5	
GEI_BALMD_008C	19-56124_CP-BALMD-008C	16-Sep-2020	448:T1500F15U500	9.5	60.53	4221706	623212	1	

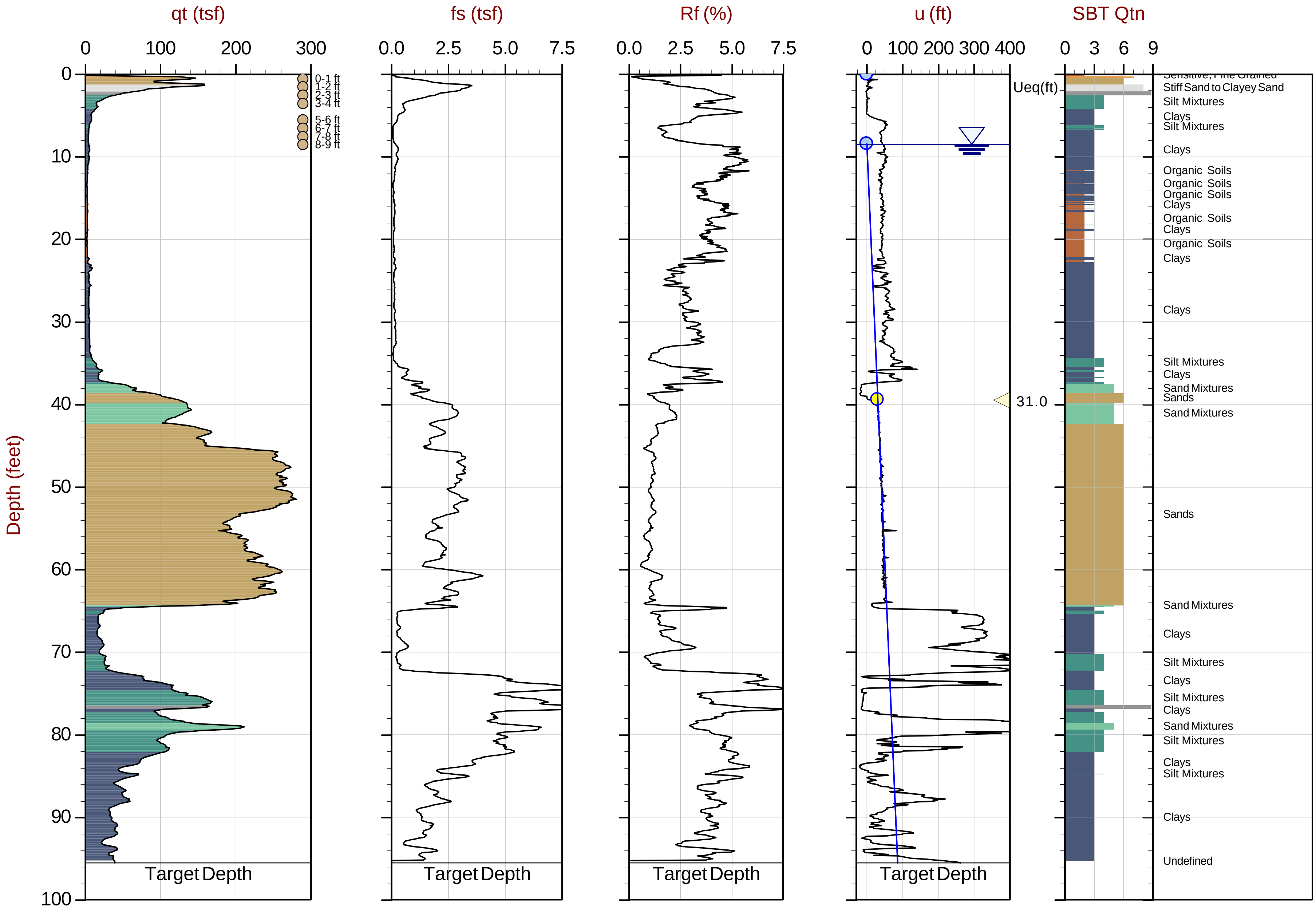
1. The assumed phreatic surface was based on the results of the shallowest pore pressure dissipation test performed within the sounding. Hydrostatic conditions were assumed for the calculated parameters.
2. The coordinates were acquired using consumer grade GPS equipment, datum: WGS 1984 / UTM Zone 10 North.
3. Elevations are refrenced to the ground surface and are derived from Google Earth Elevation for the recorded coordinates.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-15 07:38
Site: Small Communities - Isleton

Sounding: GEI_BALMD_001C
Cone: 448:T1500F15U500



Max Depth: 29.125 m / 95.55 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-001C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4219767m E: 620788m

Overplot Item: Ueq | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line | Soil Sample

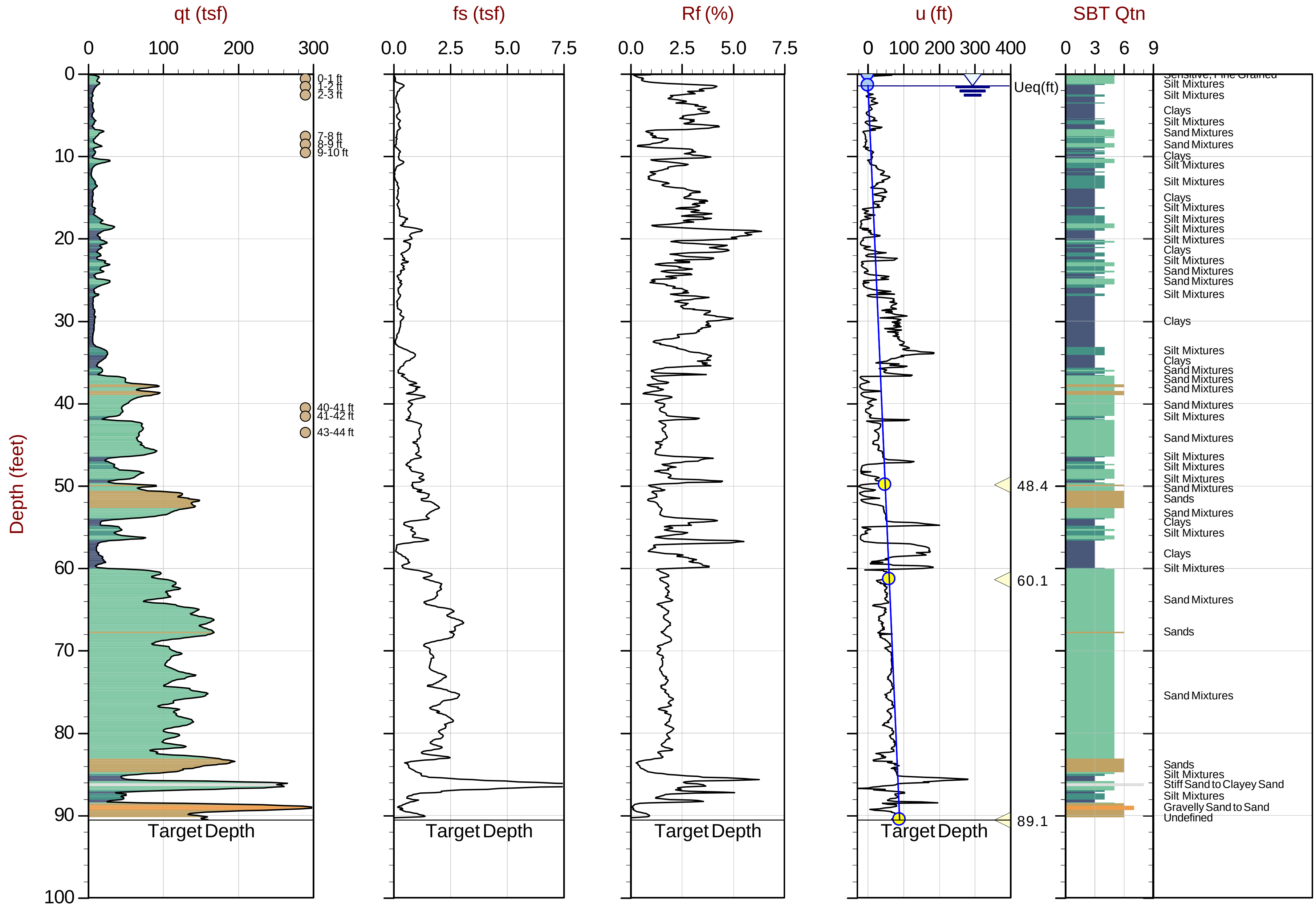
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-15 10:39
Site: Small Communities - Isleton

Sounding: GEI_BALMD_002C
Cone: 448:T1500F15U500



Max Depth: 27.600 m / 90.55 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-002C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225340m E: 616567m

Overplot Item: Ueq Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line Soil Sample

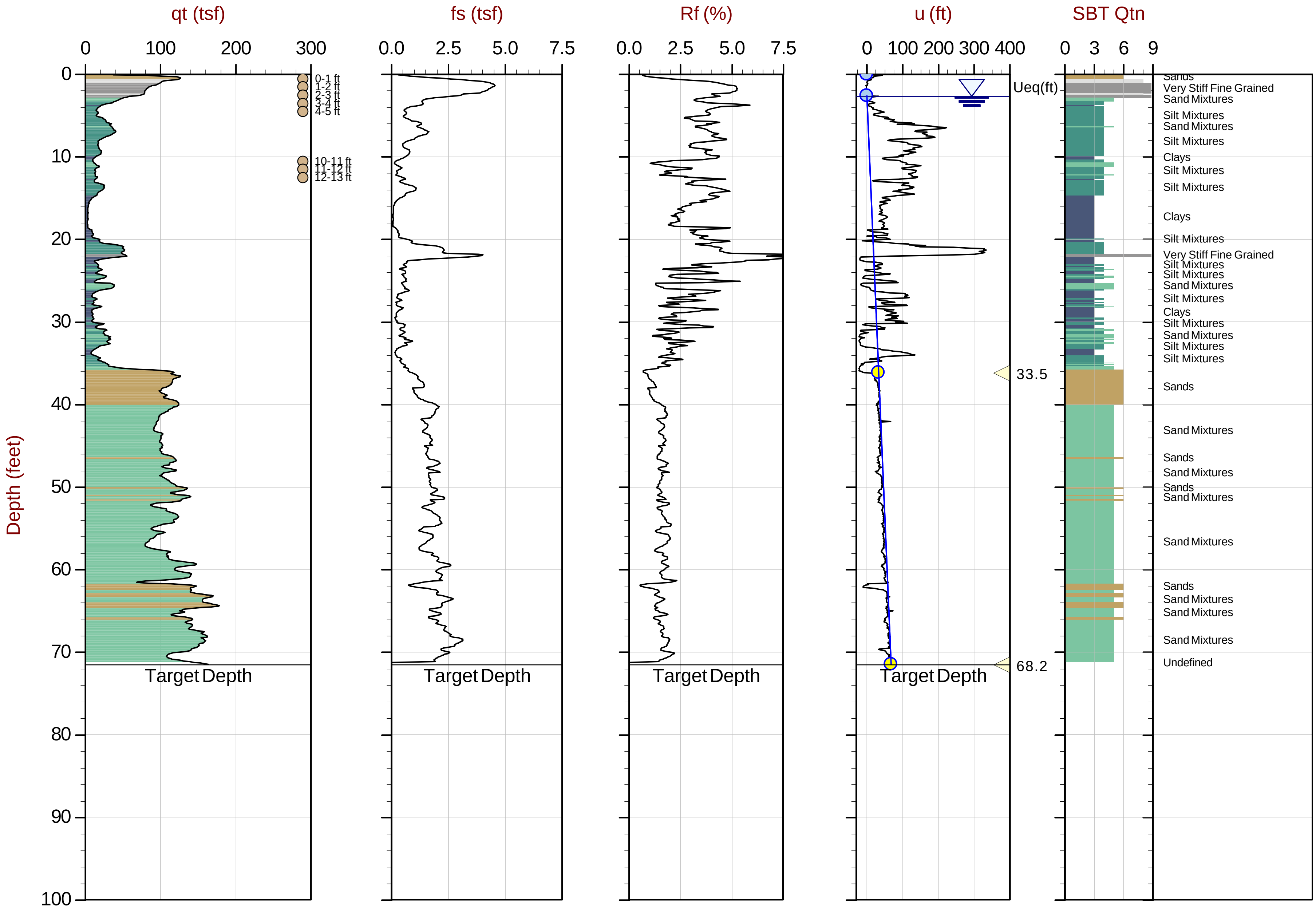
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-14 12:30
Site: Small Communities - Isleton

Sounding: GEI_BALMD_003C
Cone: 448:T1500F15U500



Max Depth: 21.800 m / 71.52 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-003C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225816m E: 617982m

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line, Soil Sample

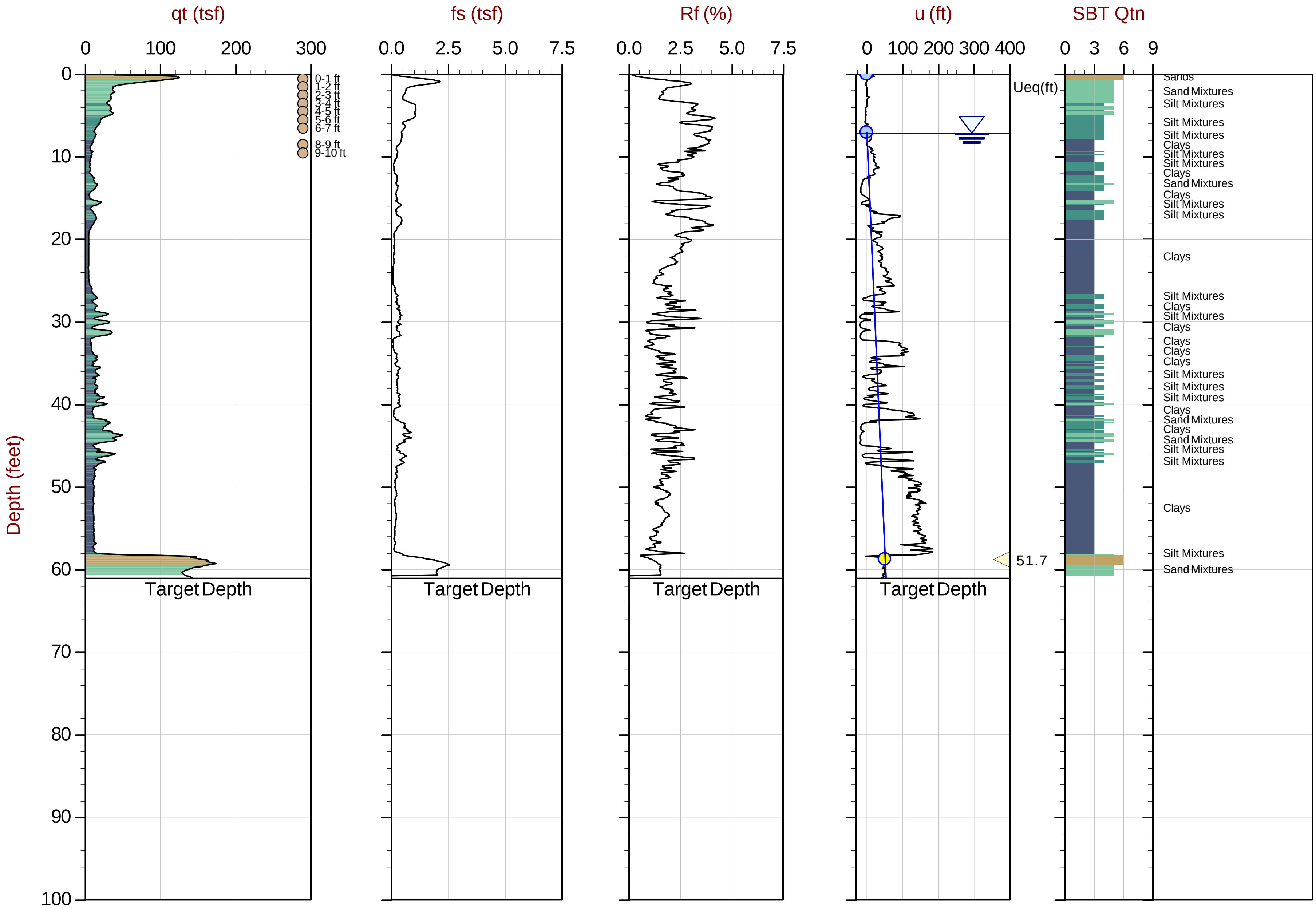
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-14 08:36
Site: Small Communities - Isleton

Sounding: GEI_BALMD_004C
Cone: 448:T1500F15U500



Max Depth: 18.600 m / 61.02 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-004C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4224793m E: 620949m

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line, Soil Sample

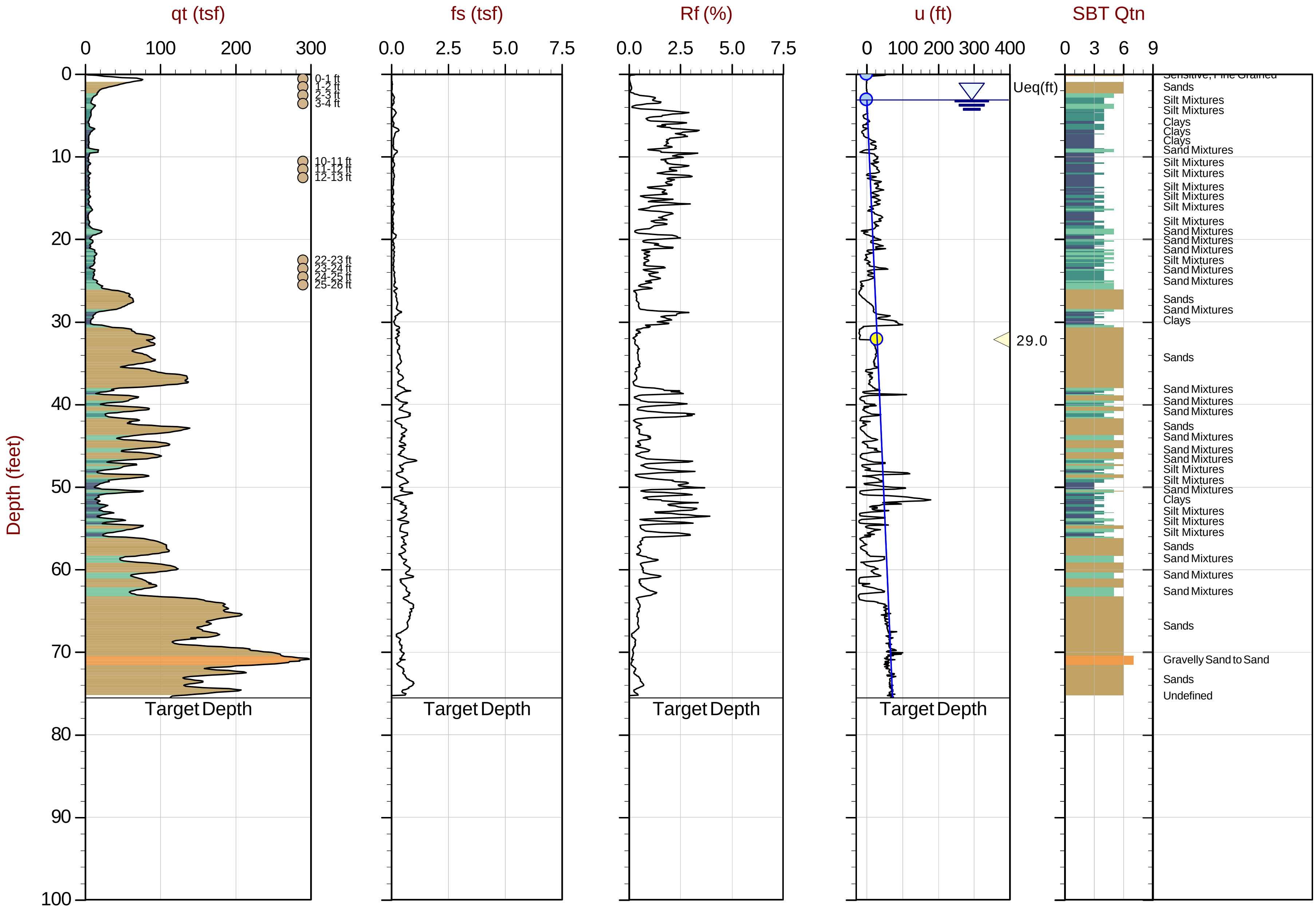
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-15 14:08
Site: Small Communities - Isleton

Sounding: GEI_BALMD_005C
Cone: 448:T1500F15U500



Max Depth: 23.025 m / 75.54 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-005C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225867m E: 623336m

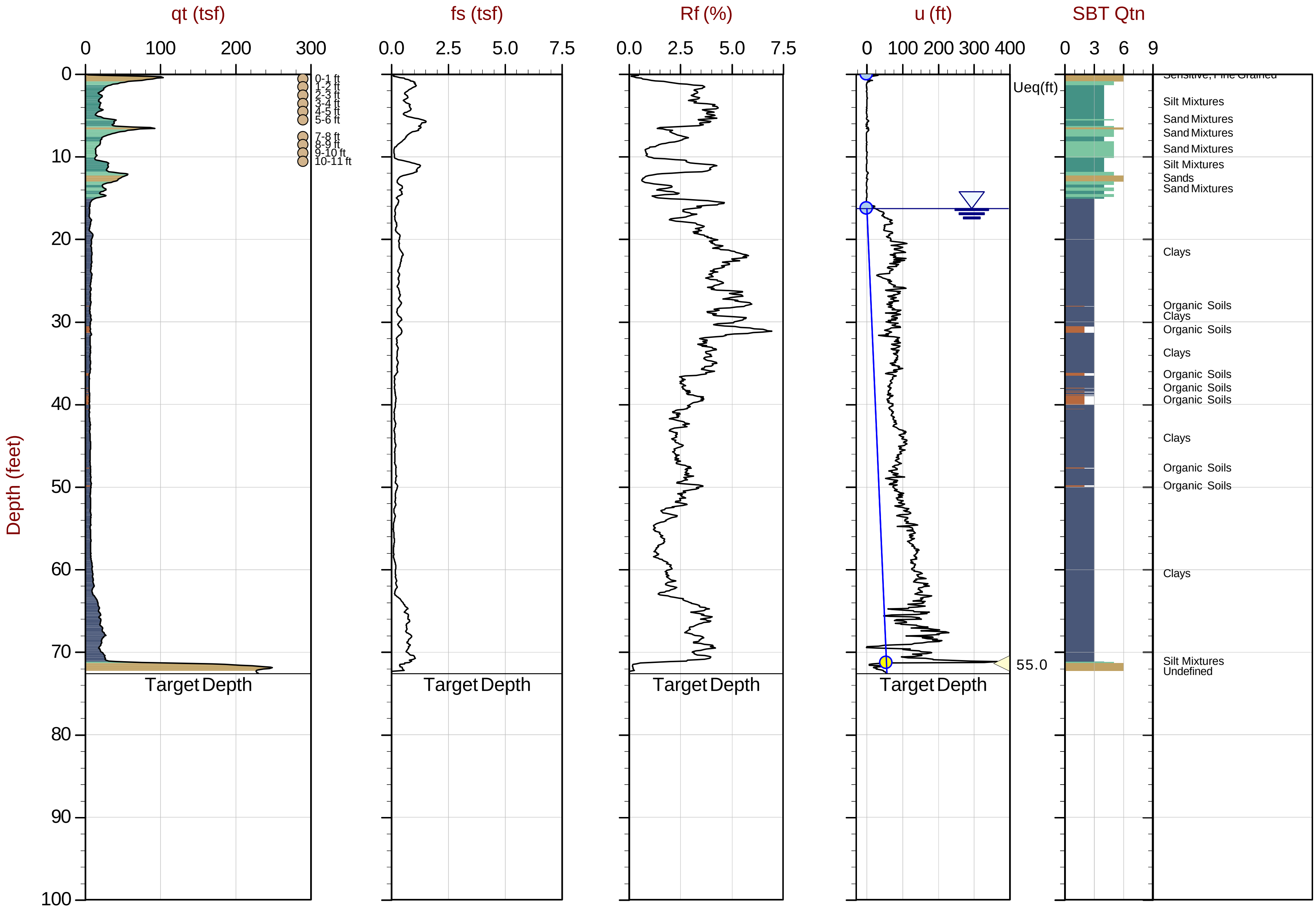
Overplot Item: Ueq; Assumed Ueq; Dissipation, Ueq achieved; Dissipation, Ueq not achieved; Hydrostatic Line; Soil Sample

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-16 13:46
Site: Small Communities - Isleton
Sounding: GEI_BALMD_006C
Cone: 448:T1500F15U500



Max Depth: 22.125 m / 72.59 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-006C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4227775m E: 625653m

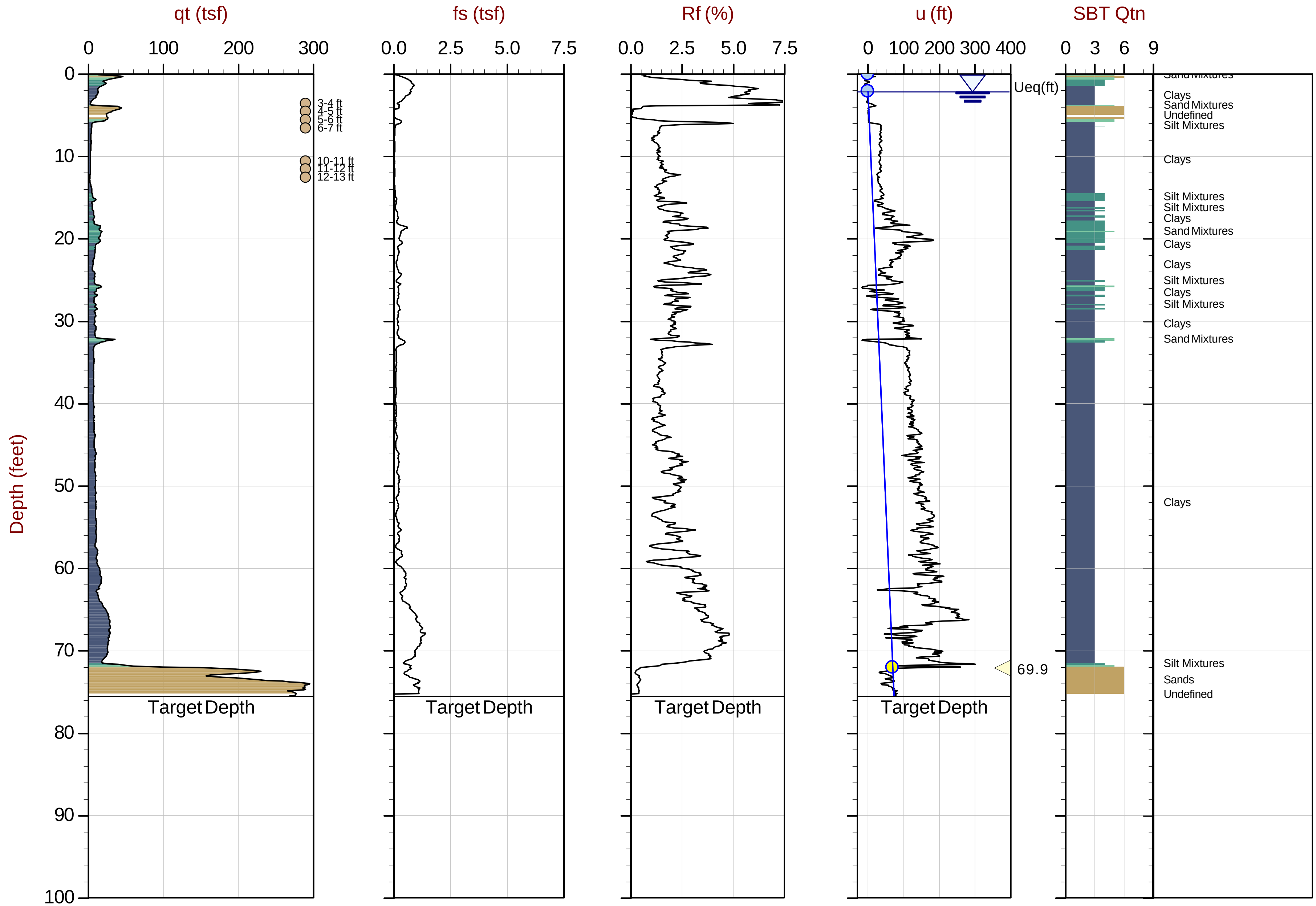
Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line, Soil Sample

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-16 11:19
Site: Small Communities - Isleton

Sounding: GEI_BALMD_007C
Cone: 448:T1500F15U500



Max Depth: 23.025 m / 75.54 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-007C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4223958m E: 623256m

Overplot Item: Ueq Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line Soil Sample

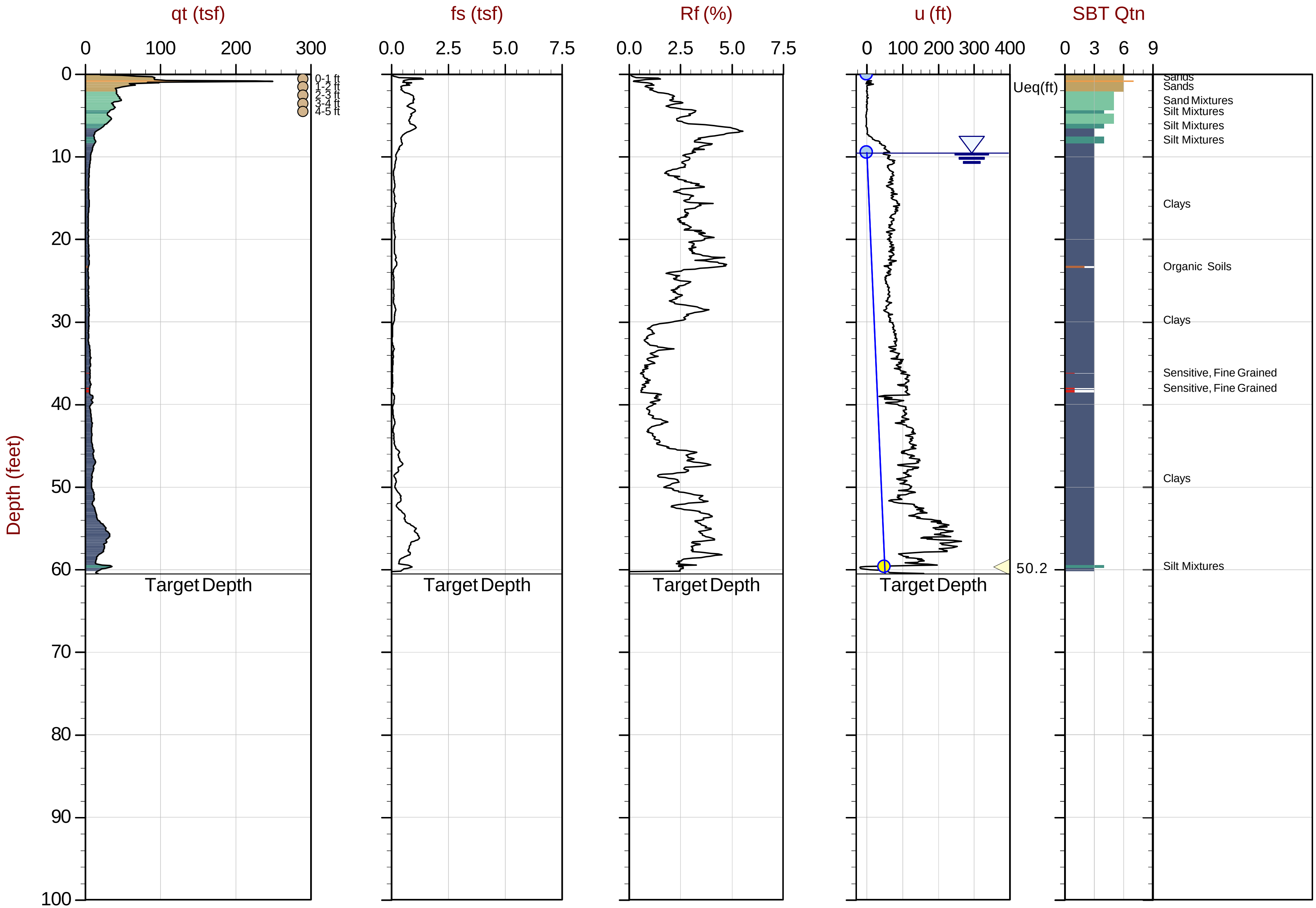
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-16 08:22
Site: Small Communities - Isleton

Sounding: GEI_BALMD_008C
Cone: 448:T1500F15U500



Max Depth: 18.450 m / 60.53 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-008C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4221706m E: 623212m

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line, Soil Sample

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

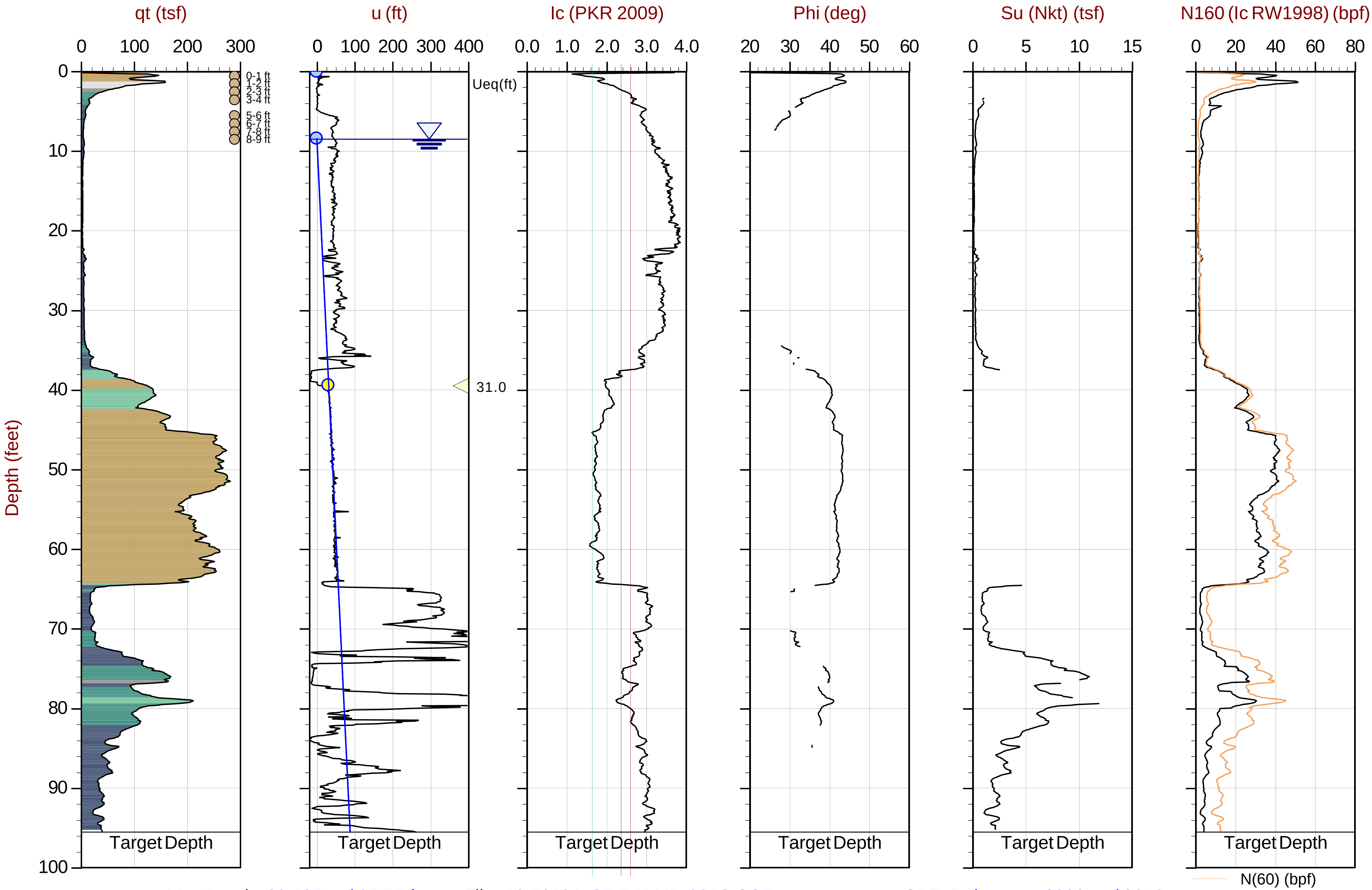
Advanced Cone Penetration Test Plots with Ic, Phi, Su(Nkt), and N1(60)Ic

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-15 07:38
Site: Small Communities - Isleton

Sounding: GEI_BALMD_001C
Cone: 448:T1500F15U500



Max Depth: 29.125 m / 95.55 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-001C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4219767m E: 620788m

Overplot Item: Ueq · Assumed Ueq · Dissipation, Ueq achieved · Dissipation, Ueq not achieved · Hydrostatic Line · Soil Sample

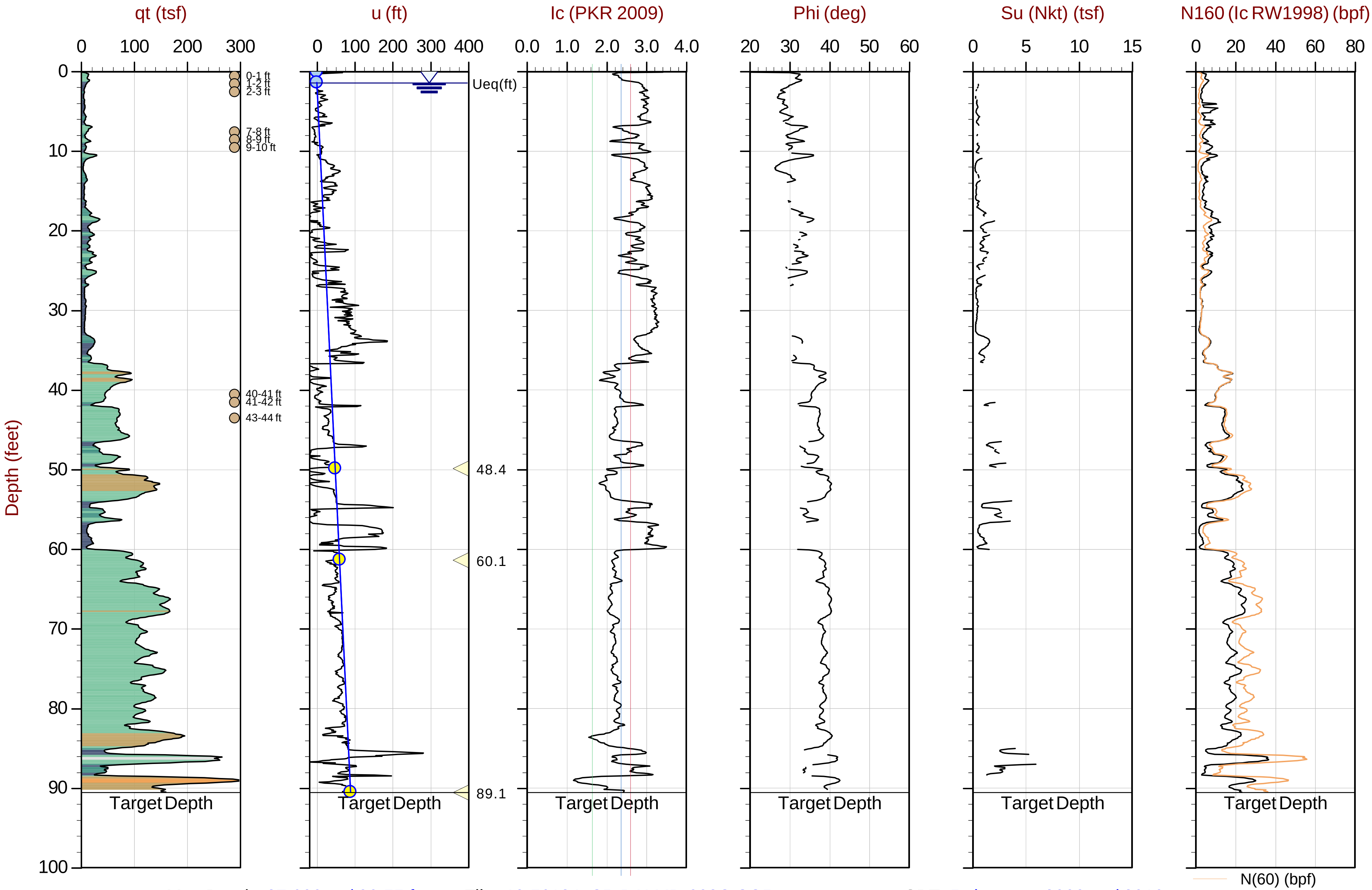
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-15 10:39
Site: Small Communities - Isleton

Sounding: GEI_BALMD_002C
Cone: 448:T1500F15U500



Max Depth: 27.600 m / 90.55 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-002C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225340m E: 616567m

Overplot Item: Ueq | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line | Soil Sample

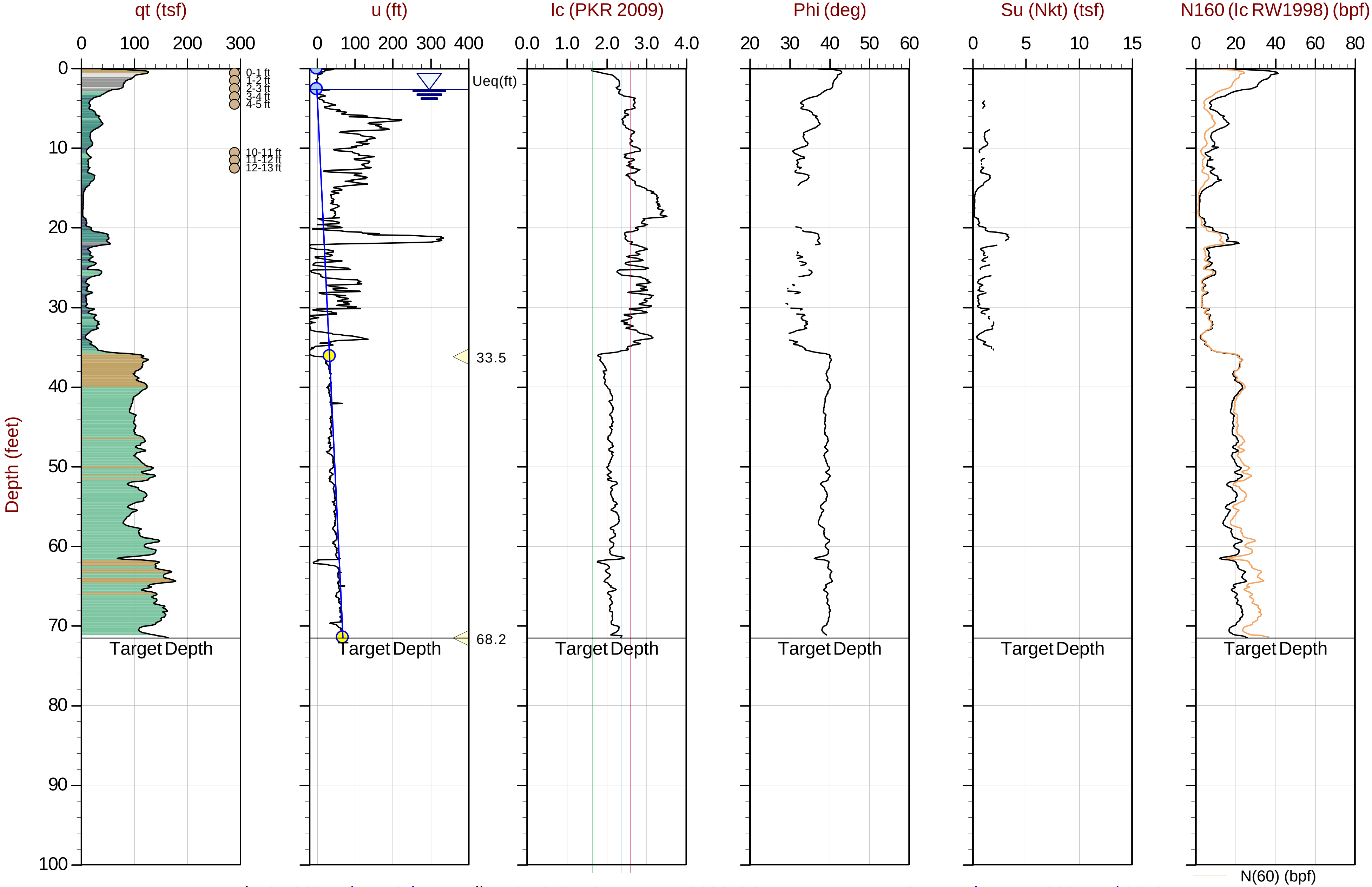
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

ConeTec

GEI

Job No: 19-56124
Date: 2020-09-14 12:30
Site: Small Communities - Isleton

Sounding: GEI_BALMD_003C
Cone: 448:T1500F15U500



Max Depth: 21.800 m / 71.52 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-003C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225816m E: 617982m

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line, Soil Sample

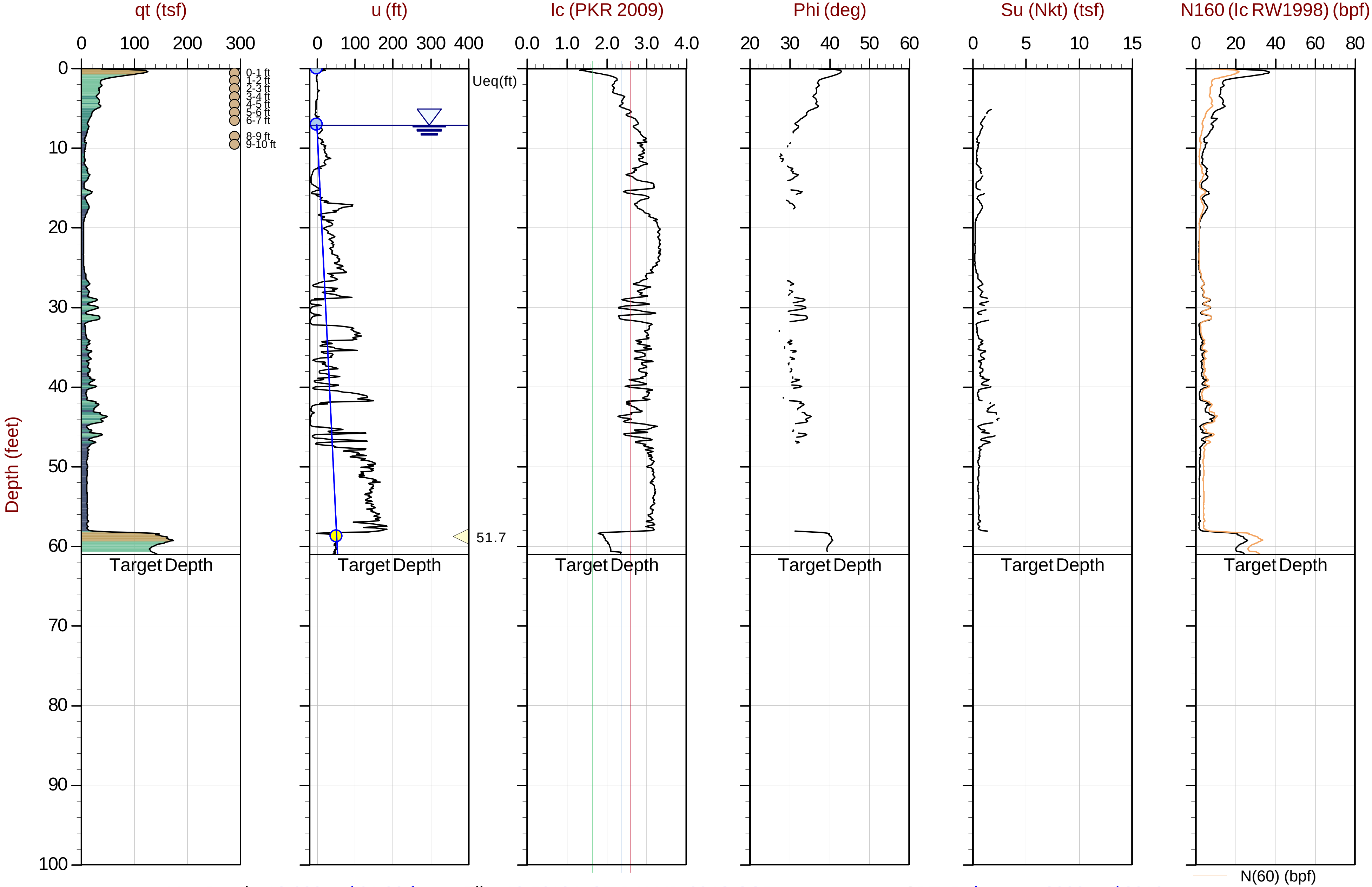
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-14 08:36
Site: Small Communities - Isleton

Sounding: GEI_BALMD_004C
Cone: 448:T1500F15U500



Max Depth: 18.600 m / 61.02 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

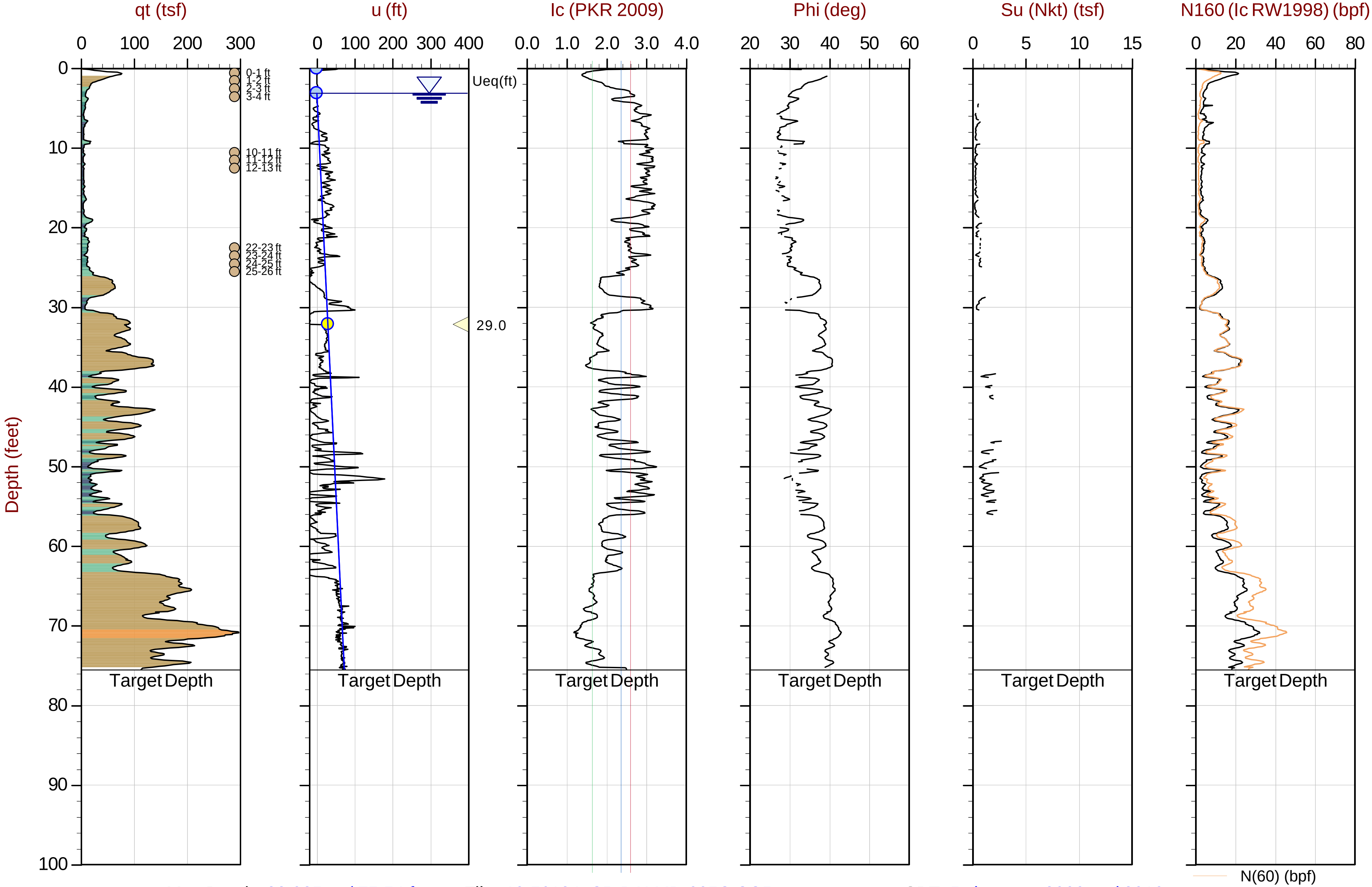
File: 19-56124_CP-BALMD-004C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4224793m E: 620949m

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line, Soil Sample

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC GEI	Job No: 19-56124	Sounding: GEI_BALMD_005C
	Date: 2020-09-15 14:08	Cone: 448:T1500F15U500
	Site: Small Communities - Isleton	



Max Depth: 23.025 m / 75.54 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-005C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225867m E: 623336m

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line, Soil Sample

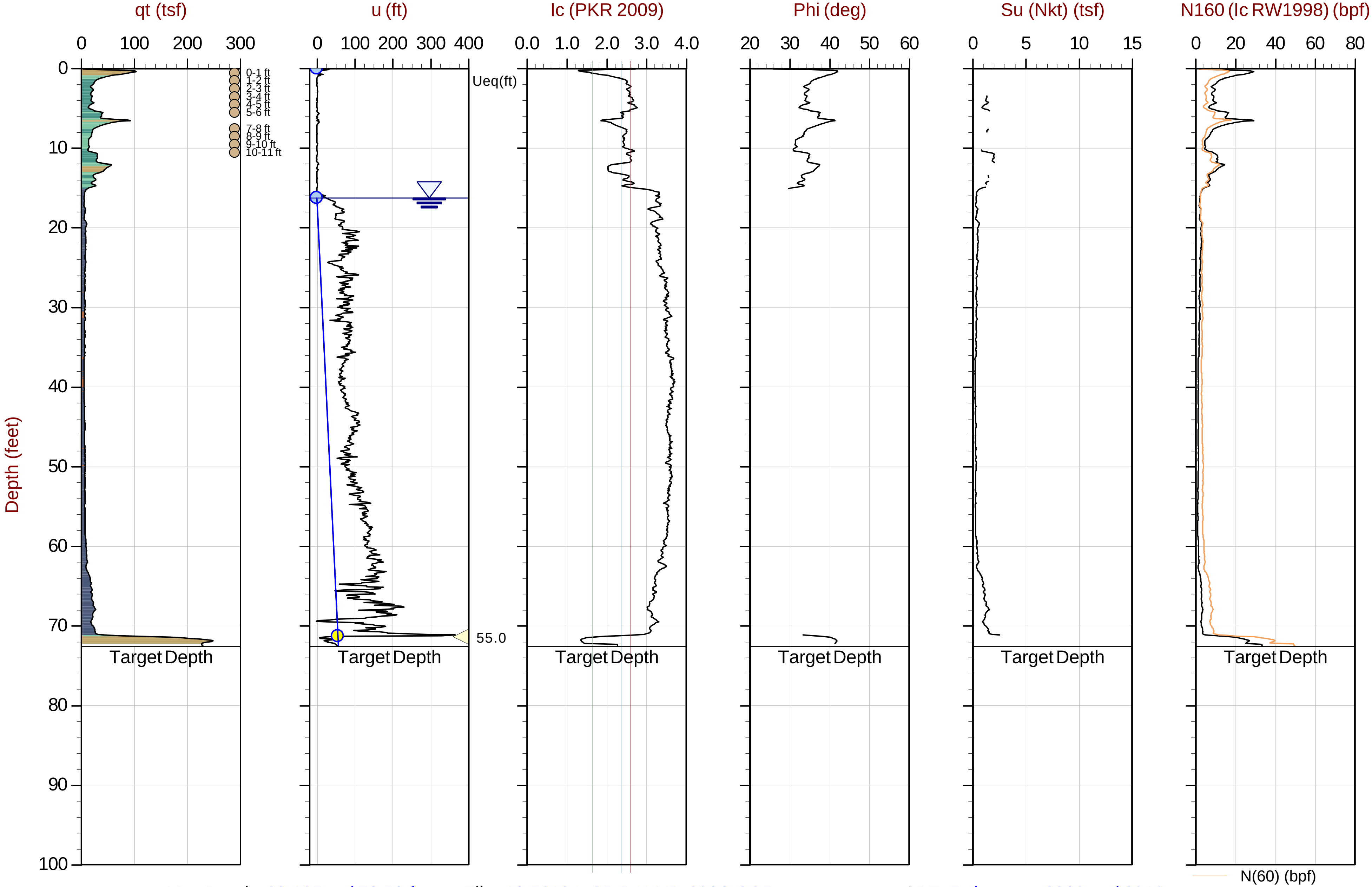
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-16 13:46
Site: Small Communities - Isleton

Sounding: GEI_BALMD_006C
Cone: 448:T1500F15U500



Max Depth: 22.125 m / 72.59 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-006C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4227775m E: 625653m

Overplot Item: Ueq, Assumed Ueq, Dissipation, Ueq achieved, Dissipation, Ueq not achieved, Hydrostatic Line, Soil Sample

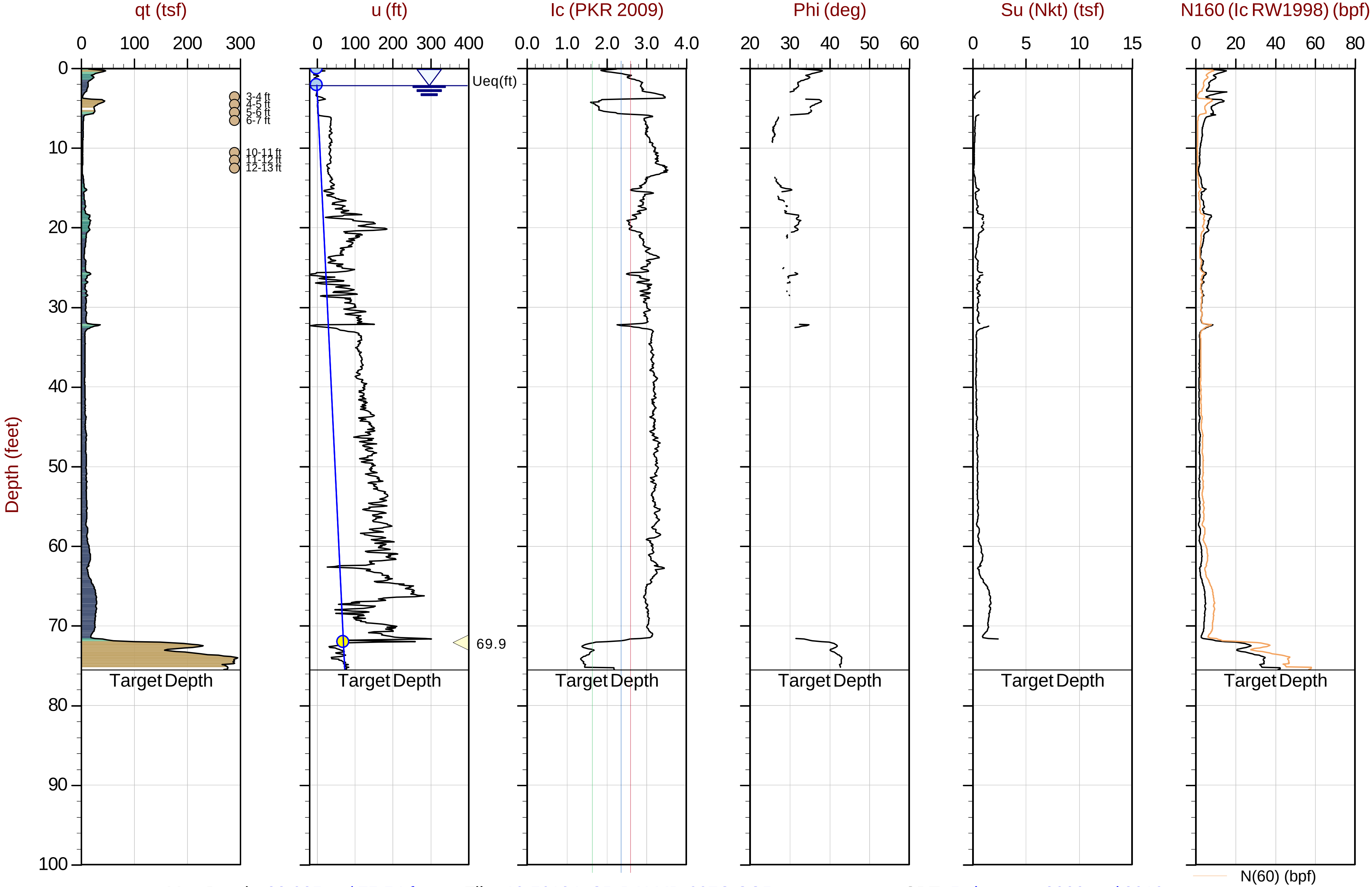
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-16 11:19
Site: Small Communities - Isleton

Sounding: GEI_BALMD_007C
Cone: 448:T1500F15U500



Max Depth: 23.025 m / 75.54 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-007C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4223958m E: 623256m

Overplot Item: Ueq | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line | Soil Sample

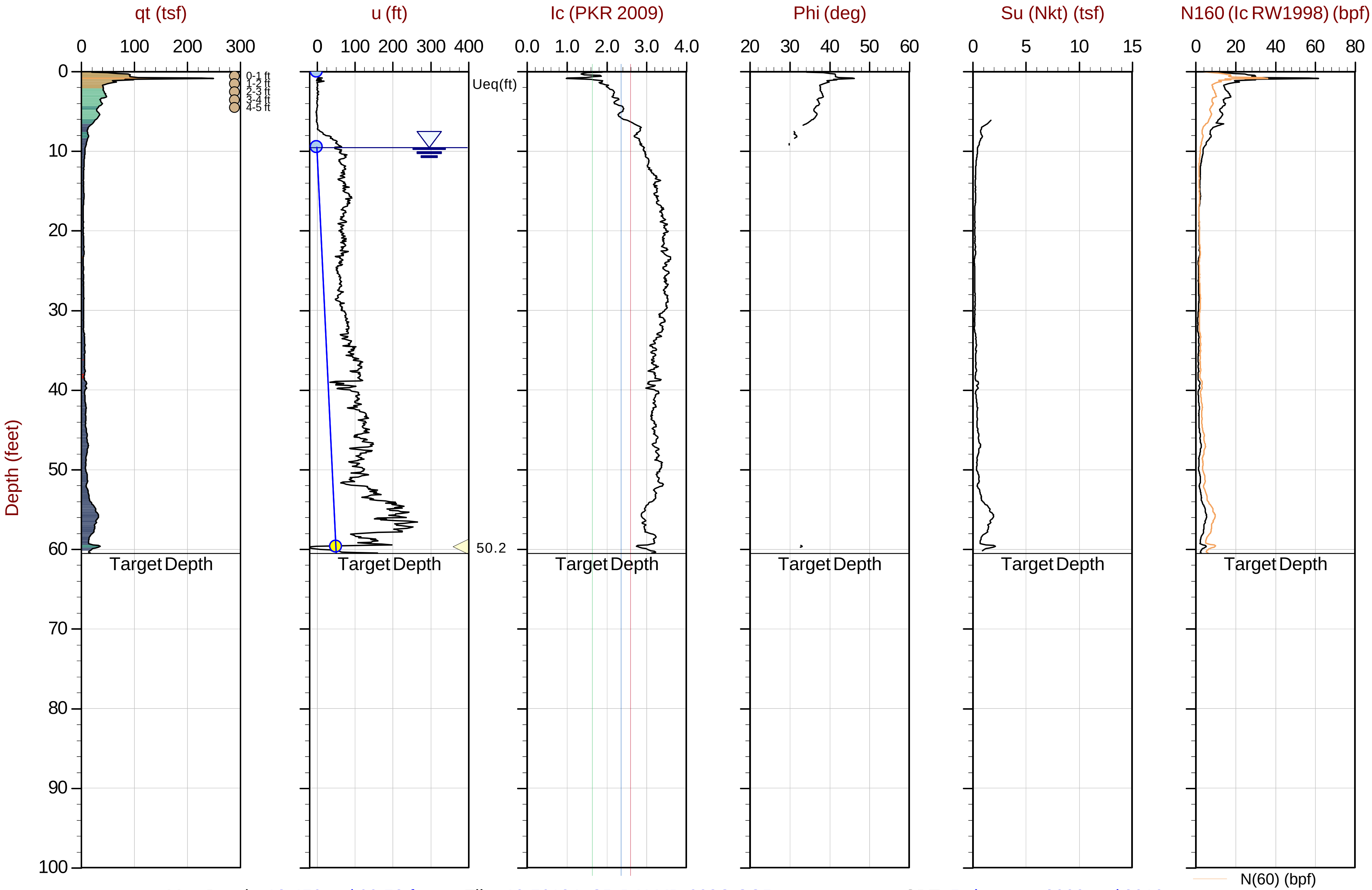
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-16 08:22
Site: Small Communities - Isleton

Sounding: GEI_BALMD_008C
Cone: 448:T1500F15U500



Max Depth: 18.450 m / 60.53 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-BALMD-008C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4221706m E: 623212m

Overplot Item: Ueq Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line Soil Sample

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

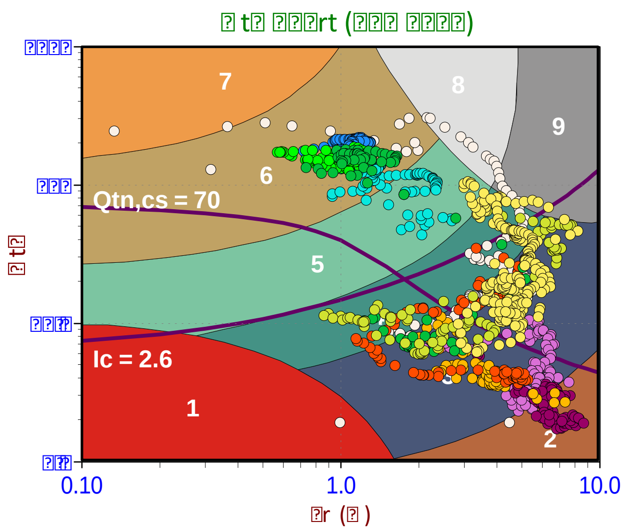
Soil Behavior Type (SBT) Scatter Plots

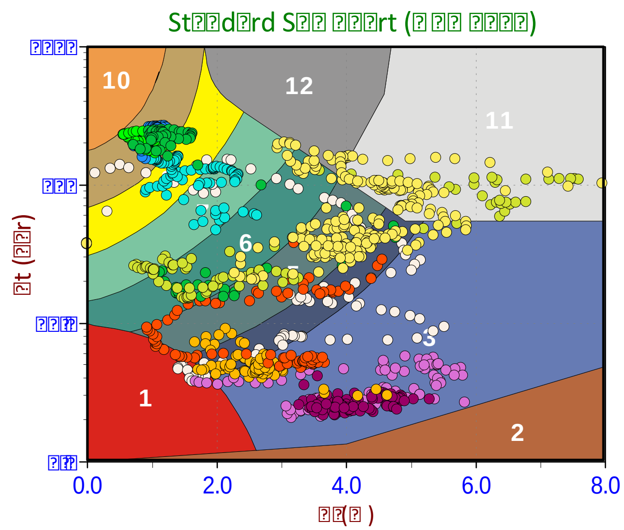
ConeTec

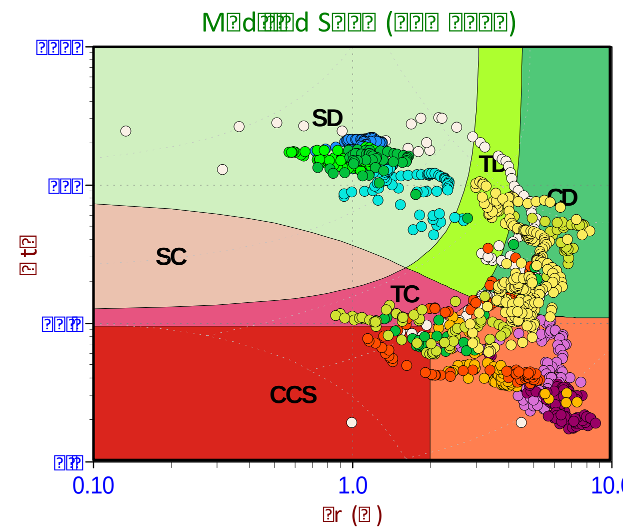
ConeTec

GEI

Job No: 19-56124
Date: 2020-09-15 07:38
Site: Small Communities - Isleton
Sounding: GEI_BALMD_001C
Cone: 448:T1500F15U500







Depth Ranges

- >0.0 to 7.5 ft
- >7.5 to 15.0 ft
- >15.0 to 22.5 ft
- >22.5 to 30.0 ft
- >30.0 to 37.5 ft
- >37.5 to 45.0 ft
- >45.0 to 52.5 ft
- >52.5 to 60.0 ft
- >60.0 to 67.5 ft
- >67.5 to 75.0 ft
- >75.0 ft

Legend

- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained

Legend

- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

Legend

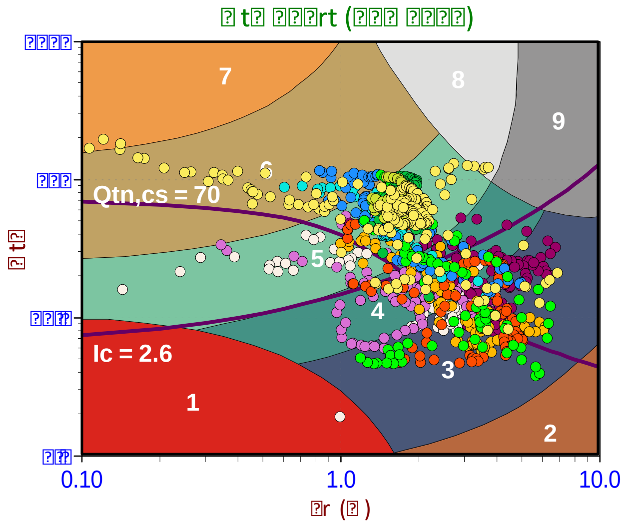
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

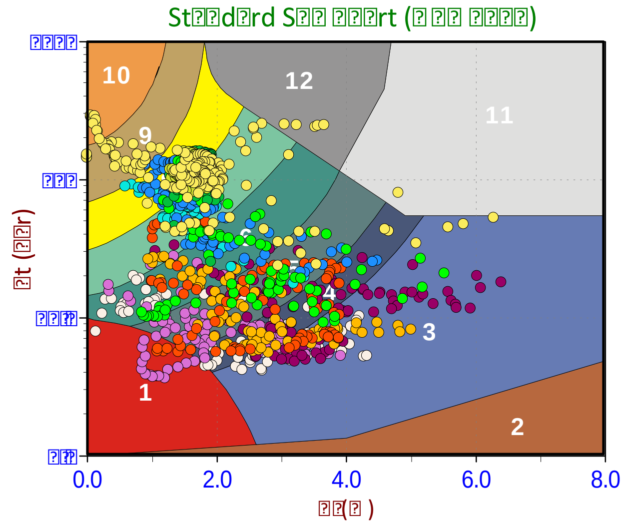
CONETEC

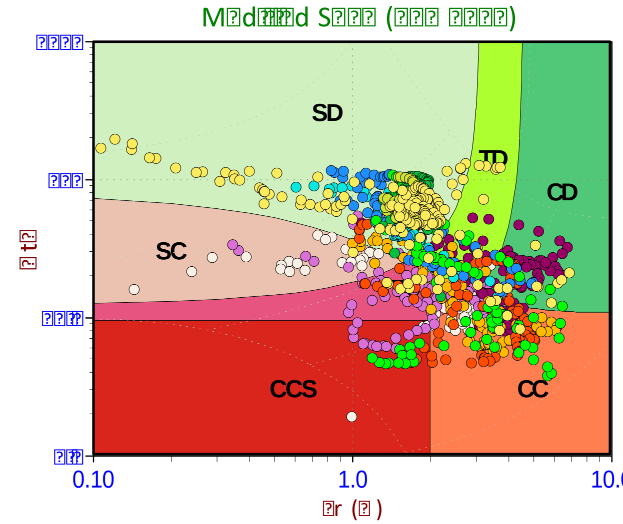
GEI

Job No: 19-56124
Date: 2020-09-15 10:39
Site: Small Communities - Isleton

Sounding: GEI_BALMD_002C
Cone: 448:T1500F15U500







Depth Ranges

- >0.0 to 7.5 ft
- >7.5 to 15.0 ft
- >15.0 to 22.5 ft
- >22.5 to 30.0 ft
- >30.0 to 37.5 ft
- >37.5 to 45.0 ft
- >45.0 to 52.5 ft
- >52.5 to 60.0 ft
- >60.0 to 67.5 ft
- >67.5 to 75.0 ft
- >75.0 ft

Legend

- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained

Legend

- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

Legend

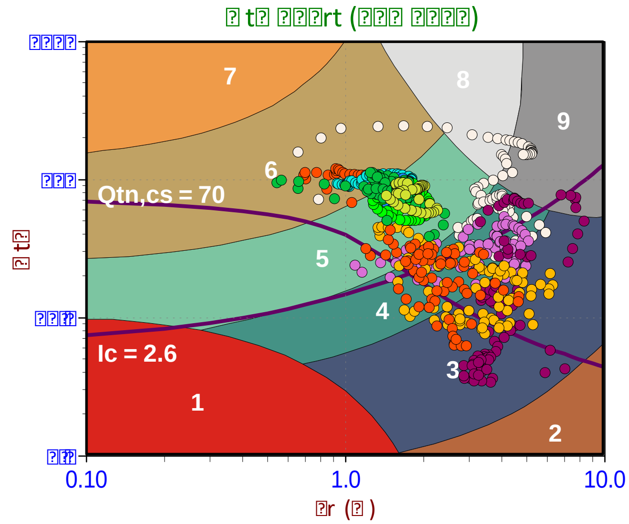
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

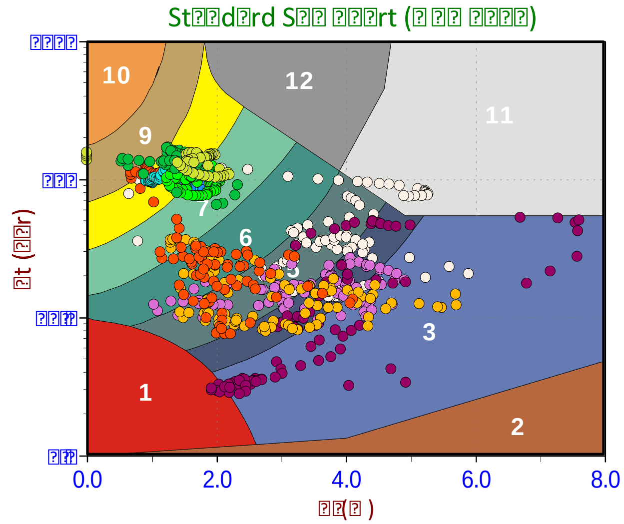
CONETEC

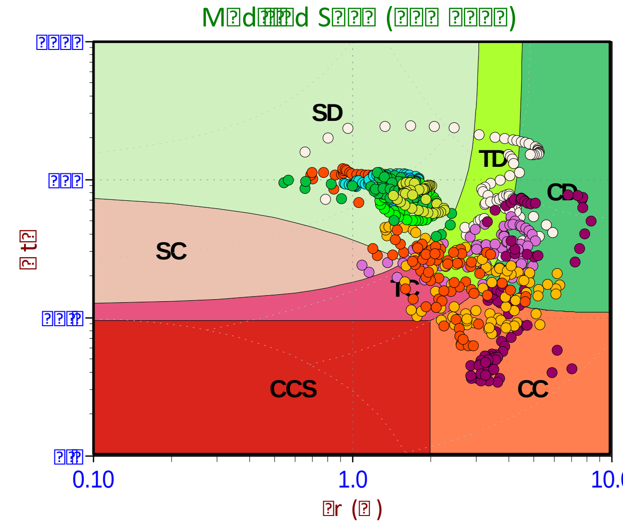
GEI

Job No: 19-56124
Date: 2020-09-14 12:30
Site: Small Communities - Isleton

Sounding: GEI_BALMD_003C
Cone: 448:T1500F15U500







Depth Ranges
- >0.0 to 7.5 ft
- >7.5 to 15.0 ft
- >15.0 to 22.5 ft
- >22.5 to 30.0 ft
- >30.0 to 37.5 ft
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- >45.0 to 52.5 ft
- >52.5 to 60.0 ft
- >60.0 to 67.5 ft
- >67.5 to 75.0 ft
- >75.0 ft

Legend
- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained

Legend
- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

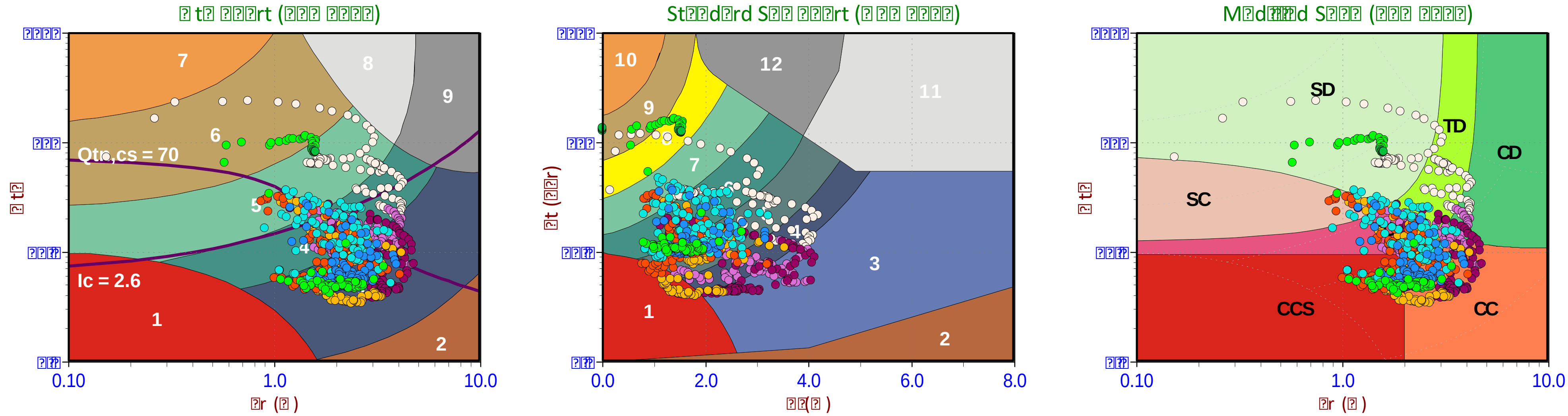
Legend
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-14 08:36
Site: Small Communities - Isleton

Sounding: GEI_BALMD_004C
Cone: 448:T1500F15U500



Depth Ranges

- >0.0 to 7.5 ft
- >7.5 to 15.0 ft
- >15.0 to 22.5 ft
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- >30.0 to 37.5 ft
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- >60.0 to 67.5 ft
- >67.5 to 75.0 ft
- >75.0 ft

Legend

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- Gravelly Sand to Sand
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- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

Legend

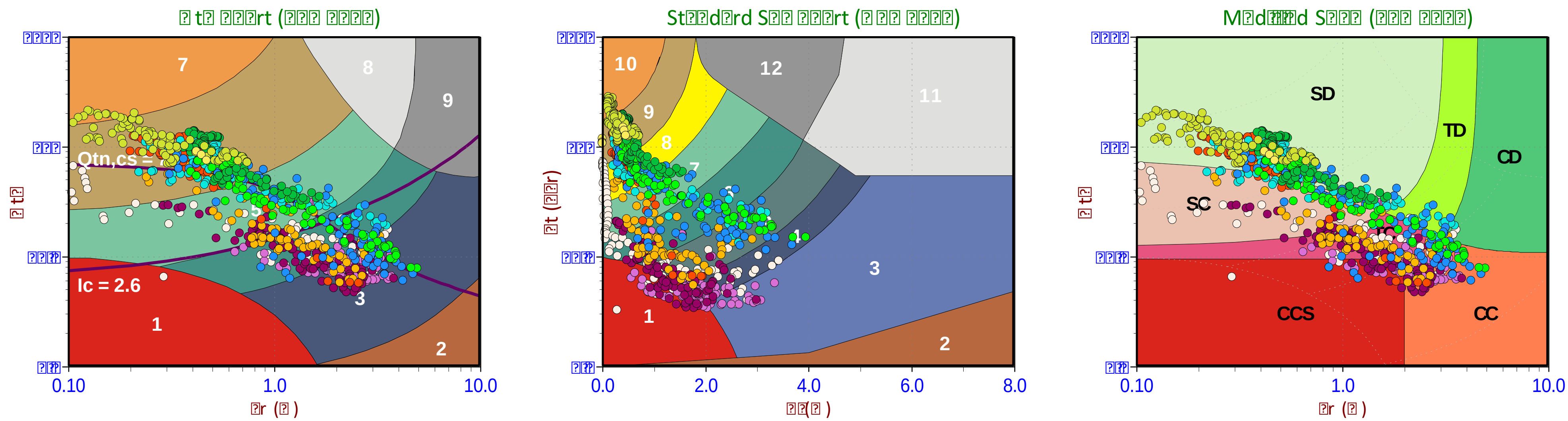
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

CONETEC

GEI

Job No: 19-56124
Date: 2020-09-15 14:08
Site: Small Communities - Isleton

Sounding: GEI_BALMD_005C
Cone: 448:T1500F15U500



Depth Ranges
- >0.0 to 7.5 ft
- >7.5 to 15.0 ft
- >15.0 to 22.5 ft
- >22.5 to 30.0 ft
- >30.0 to 37.5 ft
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- >52.5 to 60.0 ft
- >60.0 to 67.5 ft
- >67.5 to 75.0 ft
- >75.0 ft

Legend
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- Stiff Fine Grained
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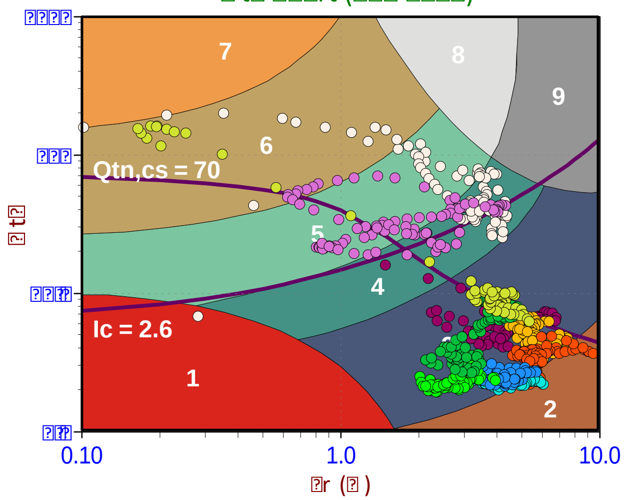
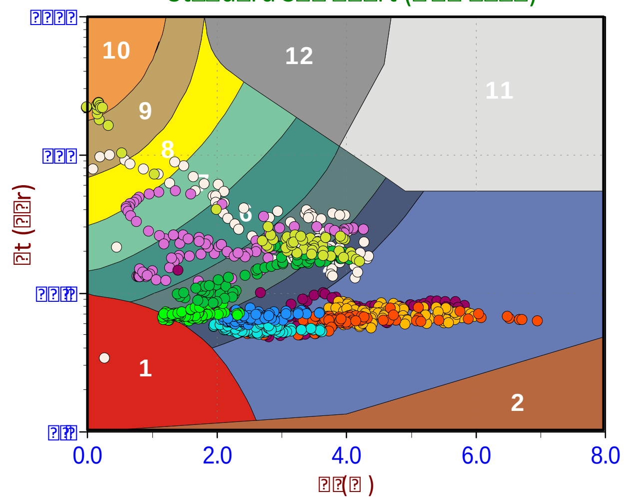
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

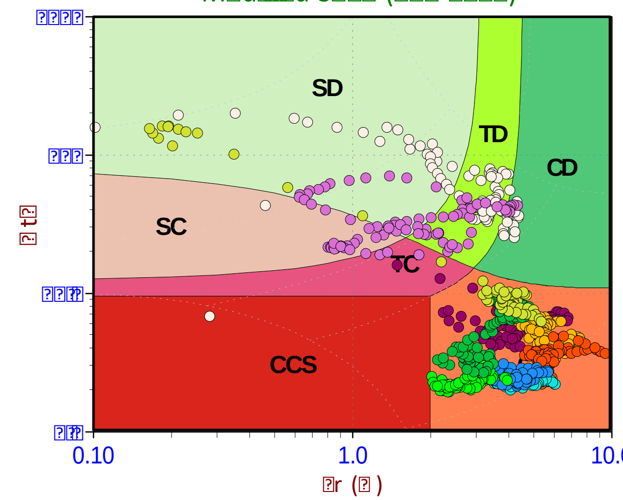
GEI

Job No: 19-56124
Date: 2020-09-16 13:46
Site: Small Communities - Isleton

Sounding: GEI_BALMD_006C
Cone: 448:T1500F15U500







Depth Ranges

- >0.0 to 7.5 ft
- >7.5 to 15.0 ft
- >15.0 to 22.5 ft
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- >30.0 to 37.5 ft
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- >52.5 to 60.0 ft
- >60.0 to 67.5 ft
- >67.5 to 75.0 ft
- >75.0 ft

Legend

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Legend

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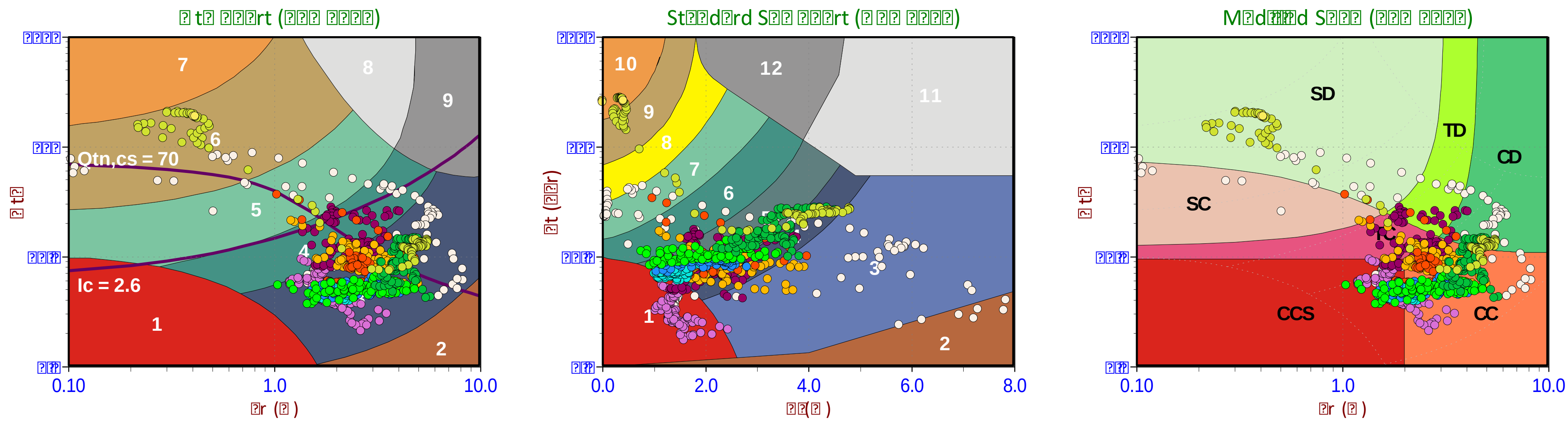
- TD (Dil. transitional)
- SD (Dil. sand like)

ConeTec

GEI

Job No: 19-56124
Date: 2020-09-16 11:19
Site: Small Communities - Isleton

Sounding: GEI_BALMD_007C
Cone: 448:T1500F15U500



Depth Ranges
- >0.0 to 7.5 ft
- >7.5 to 15.0 ft
- >15.0 to 22.5 ft
- >22.5 to 30.0 ft
- >30.0 to 37.5 ft
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- >52.5 to 60.0 ft
- >60.0 to 67.5 ft
- >67.5 to 75.0 ft
- >75.0 ft

Legend
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Legend
- Sensitive Fines
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Legend
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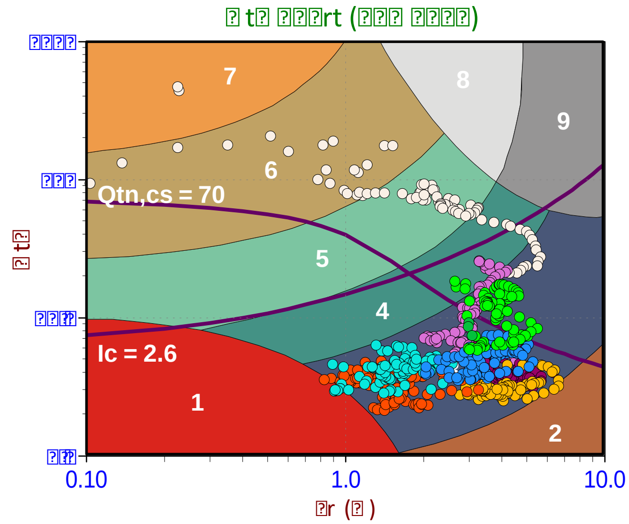
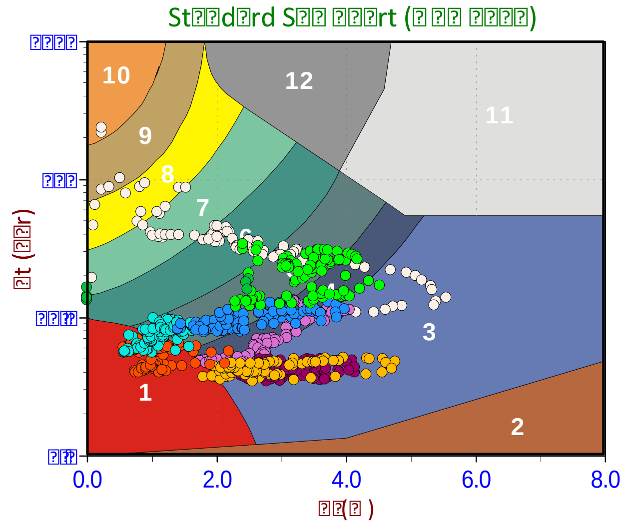
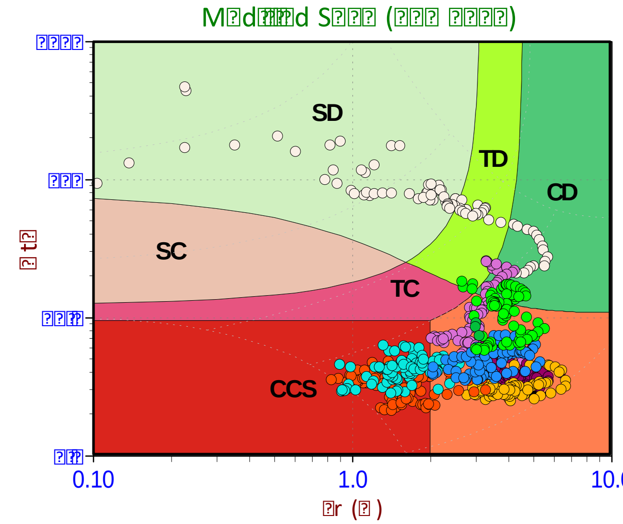
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

CONETEC

GEI	Job No: 19-56124	Sounding: GEI_BALMD_008C
	Date: 2020-09-16 08:22	Cone: 448:T1500F15U500
	Site: Small Communities - Isleton	







Depth Ranges

- >0.0 to 7.5 ft
- >7.5 to 15.0 ft
- >15.0 to 22.5 ft
- >22.5 to 30.0 ft
- >30.0 to 37.5 ft
- >37.5 to 45.0 ft
- >45.0 to 52.5 ft
- >52.5 to 60.0 ft
- >60.0 to 67.5 ft
- >67.5 to 75.0 ft
- >75.0 ft

Legend

- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained

Legend

- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

Legend

- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

CONETEC

Job No:	19-56124
Client:	GEI Consultants
Project:	Small Communities - Isleton
Start Date:	14-Sep-2020
End Date:	16-Sep-2020

CPTu PORE PRESSURE DISSIPATION SUMMARY

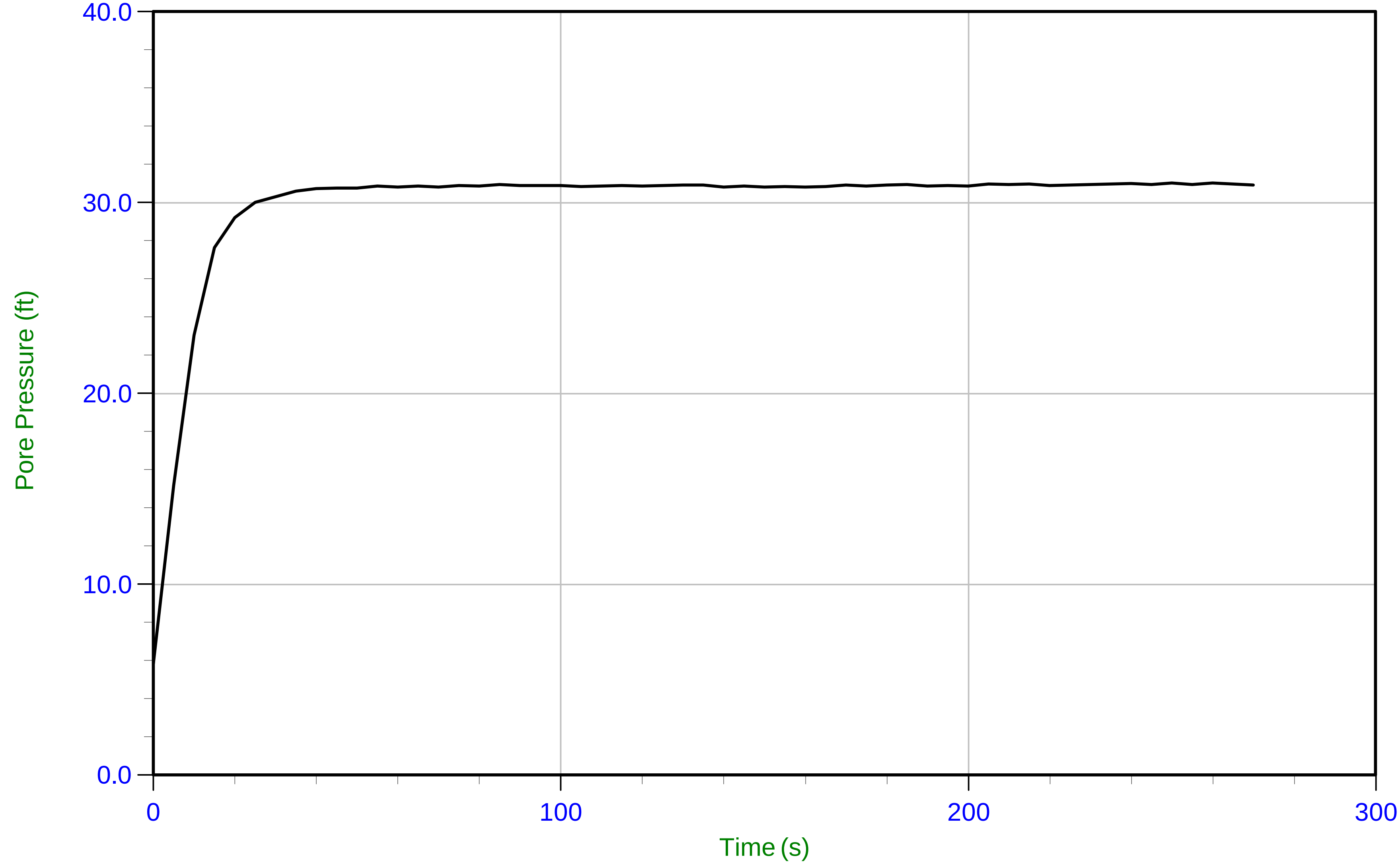
Sounding ID	File Name	Cone Area (cm^2)	Duration (s)	Test Depth (ft)	Estimated Equilibrium Pore Pressure U_{eq} (ft)	Calculated Phreatic Surface (ft)
GEI_BALMD_001C	19-56124_CP-BALMD-001C	15	270	39.45	31.0	8.5
GEI_BALMD_002C	19-56124_CP-BALMD-002C	15	180	49.87	48.5	1.4
GEI_BALMD_002C	19-56124_CP-BALMD-002C	15	180	61.35	60.1	1.2
GEI_BALMD_002C	19-56124_CP-BALMD-002C	15	175	90.55	89.1	1.4
GEI_BALMD_003C	19-56124_CP-BALMD-003C	15	365	36.17	33.5	2.6
GEI_BALMD_003C	19-56124_CP-BALMD-003C	15	220	71.52	68.3	3.2
GEI_BALMD_004C	19-56124_CP-BALMD-004C	15	305	58.81	51.7	7.1
GEI_BALMD_005C	19-56124_CP-BALMD-005C	15	300	32.15	29.0	3.1
GEI_BALMD_006C	19-56124_CP-BALMD-006C	15	240	71.36	55.1	16.3
GEI_BALMD_007C	19-56124_CP-BALMD-007C	15	300	72.10	70.0	2.1
GEI_BALMD_008C	19-56124_CP-BALMD-008C	15	210	59.71	50.2	9.5

CONETEC

GEI

Job No: 19-56124
Date: 09/15/2020 07:38
Site: Small Communities - Isleton

Sounding: GEI_BALMD_001C
Cone: 448:T1500F15U500 Area=15 cm²



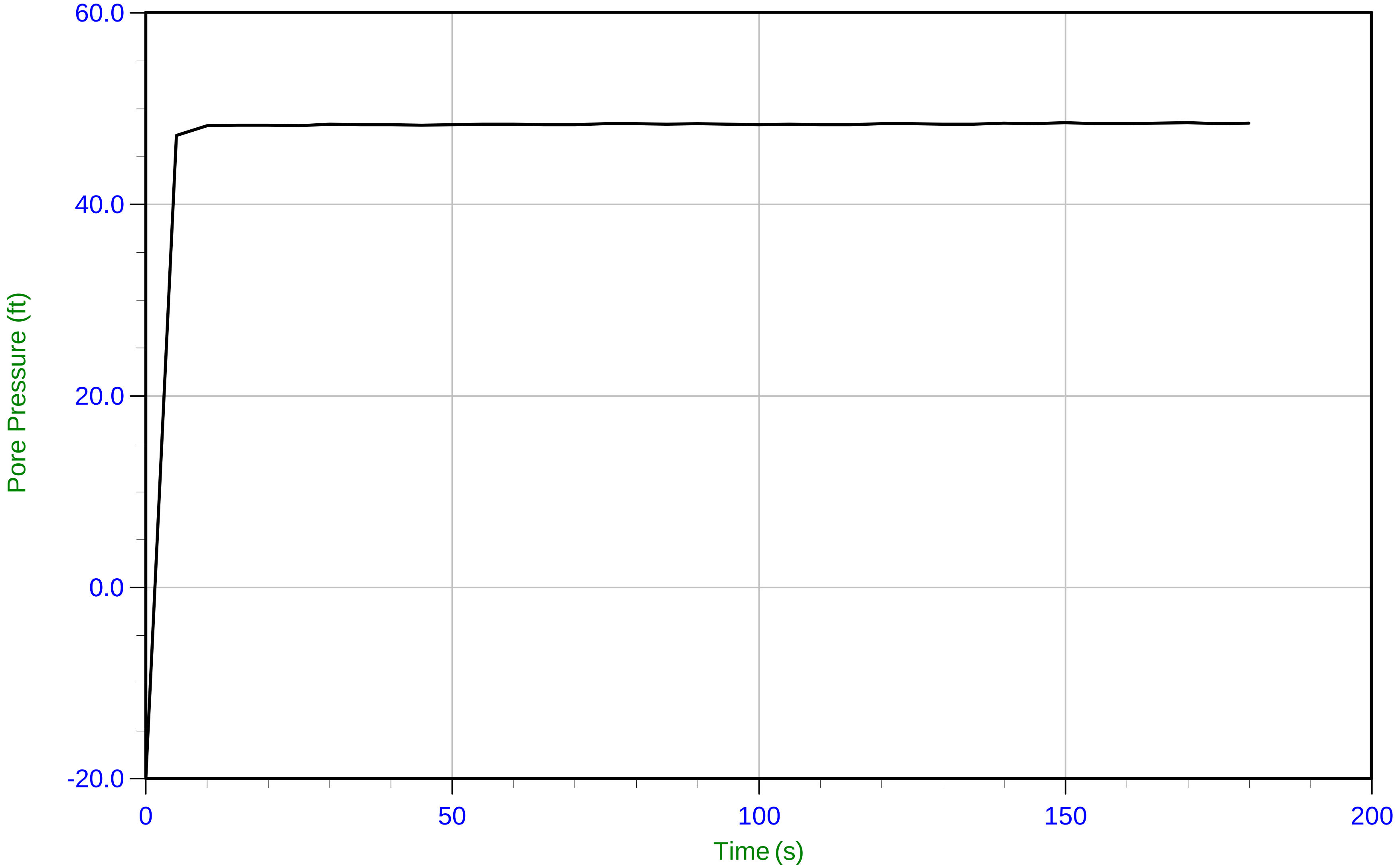
Trace Summary:

Filename: 19-56124_CP-BALMD-001C.PPF
Depth: 12.025 m / 39.452 ft
Duration: 270.0 s

u Min: 5.8 ft
u Max: 31.0 ft
u Final: 30.9 ft

WT: 2.577 m / 8.455 ft
Ueq: 31.0 ft

CONETEC GEI	Job No: 19-56124 Date: 09/15/2020 10:39 Site: Small Communities - Isleton	Sounding: GEI_BALMD_002C Cone: 448:T1500F15U500 Area=15 cm²



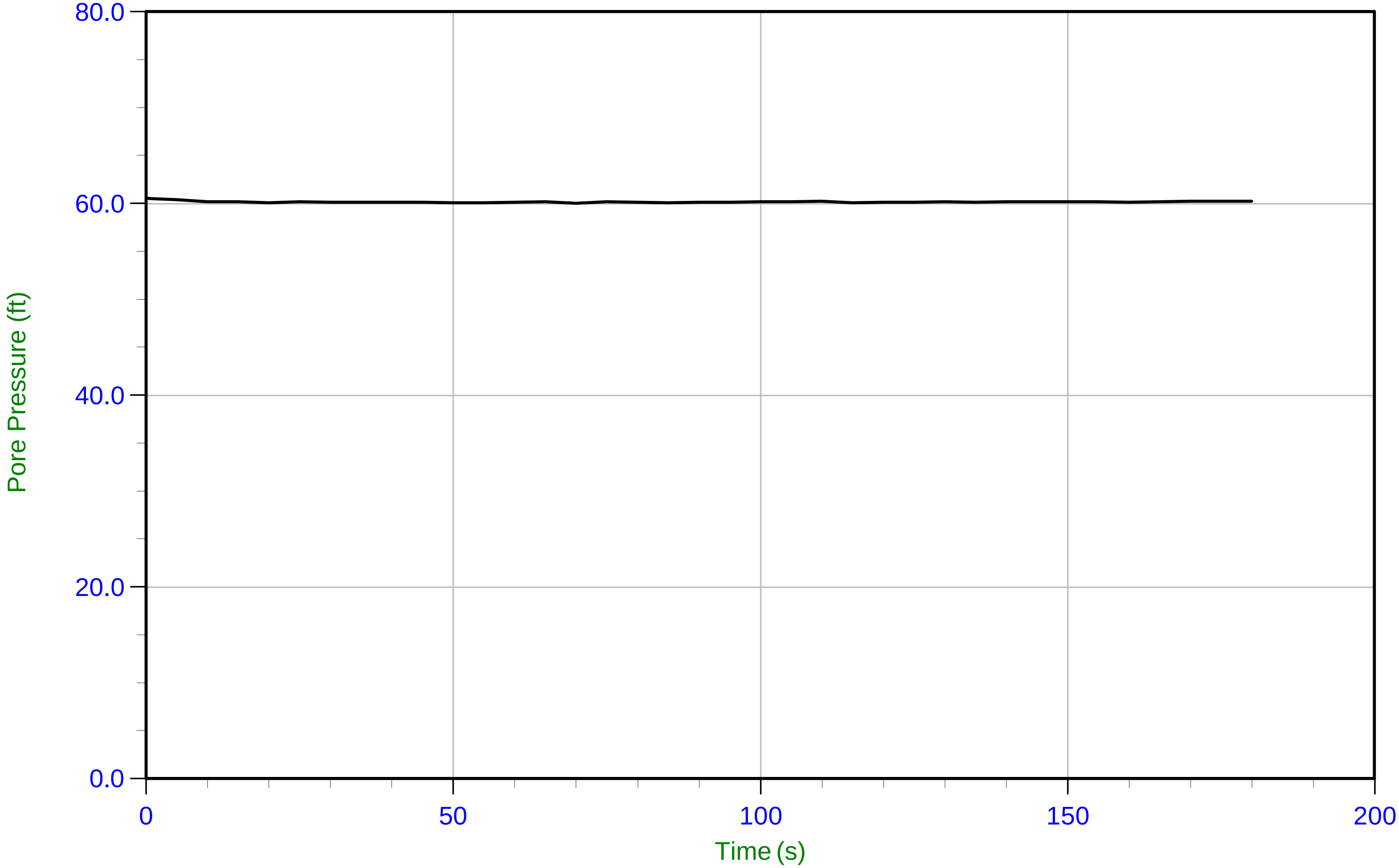
Trace Summary:

Filename: 19-56124_CP-BALMD-002C.PPF
Depth: 15.200 m / 49.868 ft
Duration: 180.0 s

u Min: -20.1 ft
u Max: 48.5 ft
u Final: 48.4 ft

WT: 0.426 m / 1.398 ft
Ueq: 48.5 ft

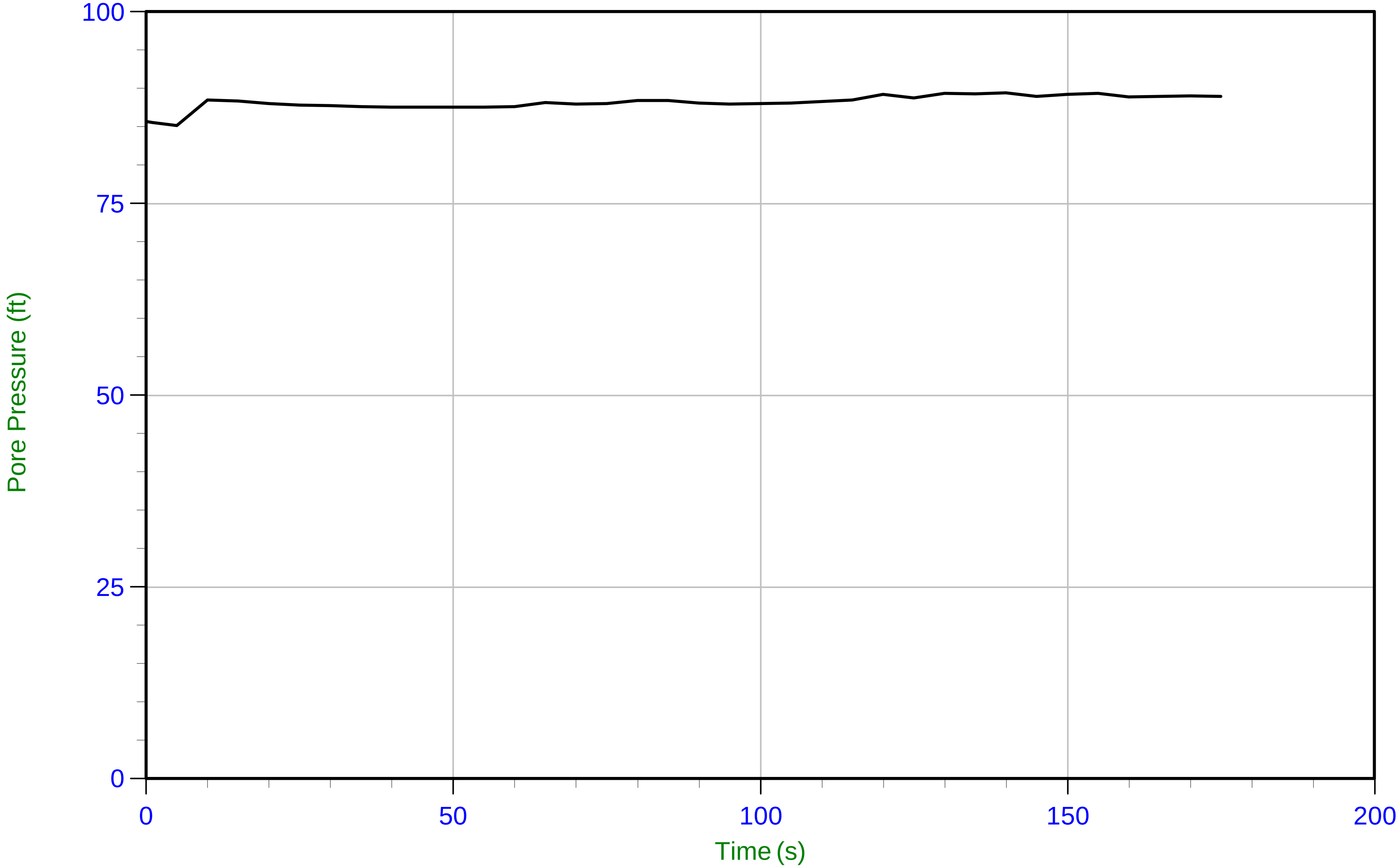
GEI	Job No: 19-56124 Date: 09/15/2020 10:39 Site: Small Communities - Isleton	Sounding: GEI_BALMD_002C Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-BALMD-002C.PPF	u Min: 60.0 ft	WT: 0.373 m / 1.224 ft
Depth: 18.700 m / 61.351 ft	u Max: 60.6 ft	Ueq: 60.1 ft
Duration: 180.0 s	u Final: 60.2 ft	

GEI	Job No: 19-56124 Date: 09/15/2020 10:39 Site: Small Communities - Isleton	Sounding: GEI_BALMD_002C Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-BALMD-002C.PPF
Depth: 27.600 m / 90.550 ft
Duration: 175.0 s

u Min: 85.2 ft
u Max: 89.4 ft
u Final: 89.0 ft

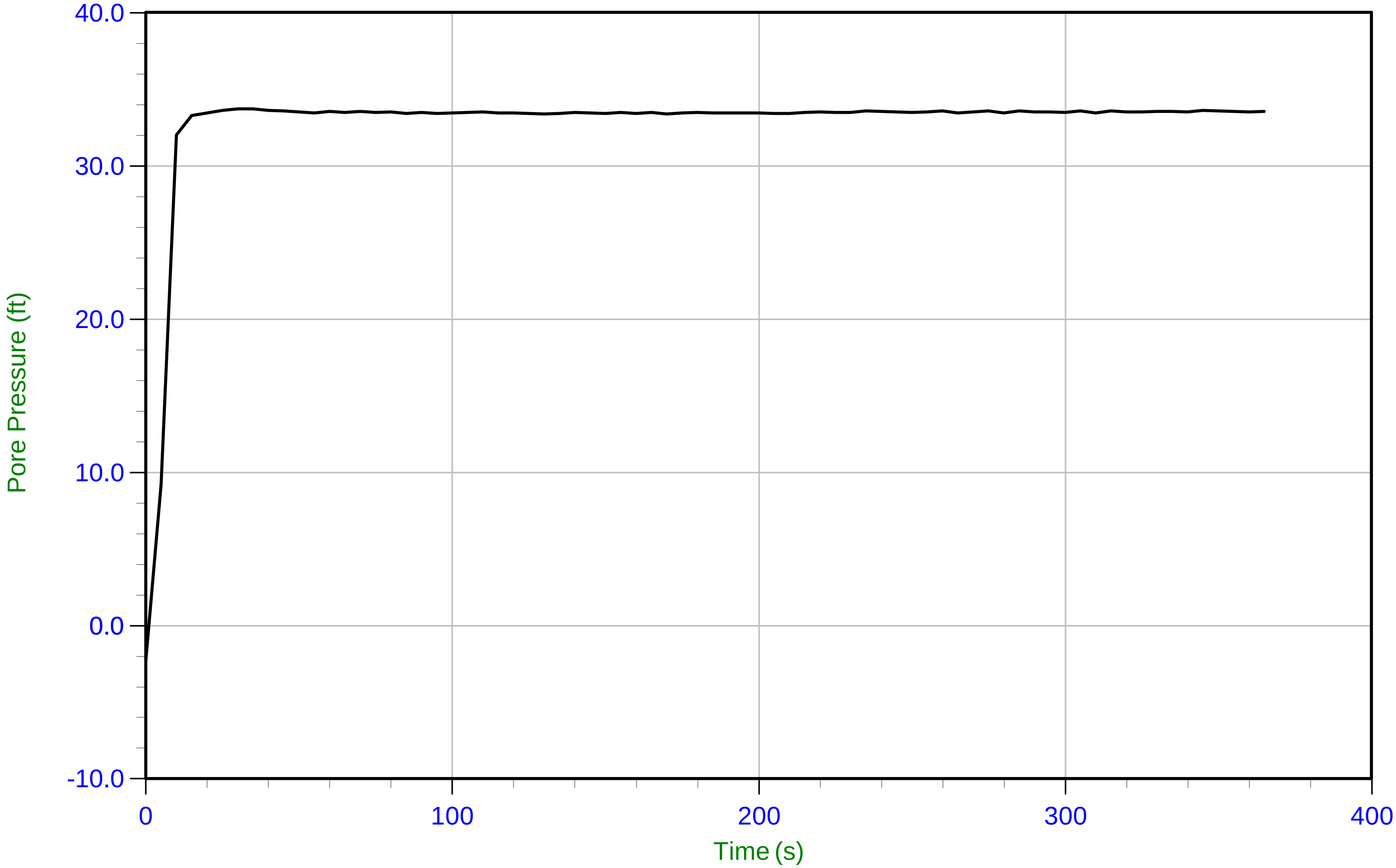
WT: 0.437 m / 1.434 ft
Ueq: 89.1 ft

CONETEC

GEI

Job No: 19-56124
Date: 09/14/2020 12:30
Site: Small Communities - Isleton

Sounding: GEI_BALMD_003C
Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-BALMD-003C.PPF
Depth: 11.025 m / 36.171 ft
Duration: 365.0 s

u Min: -2.3 ft
u Max: 33.7 ft
u Final: 33.5 ft

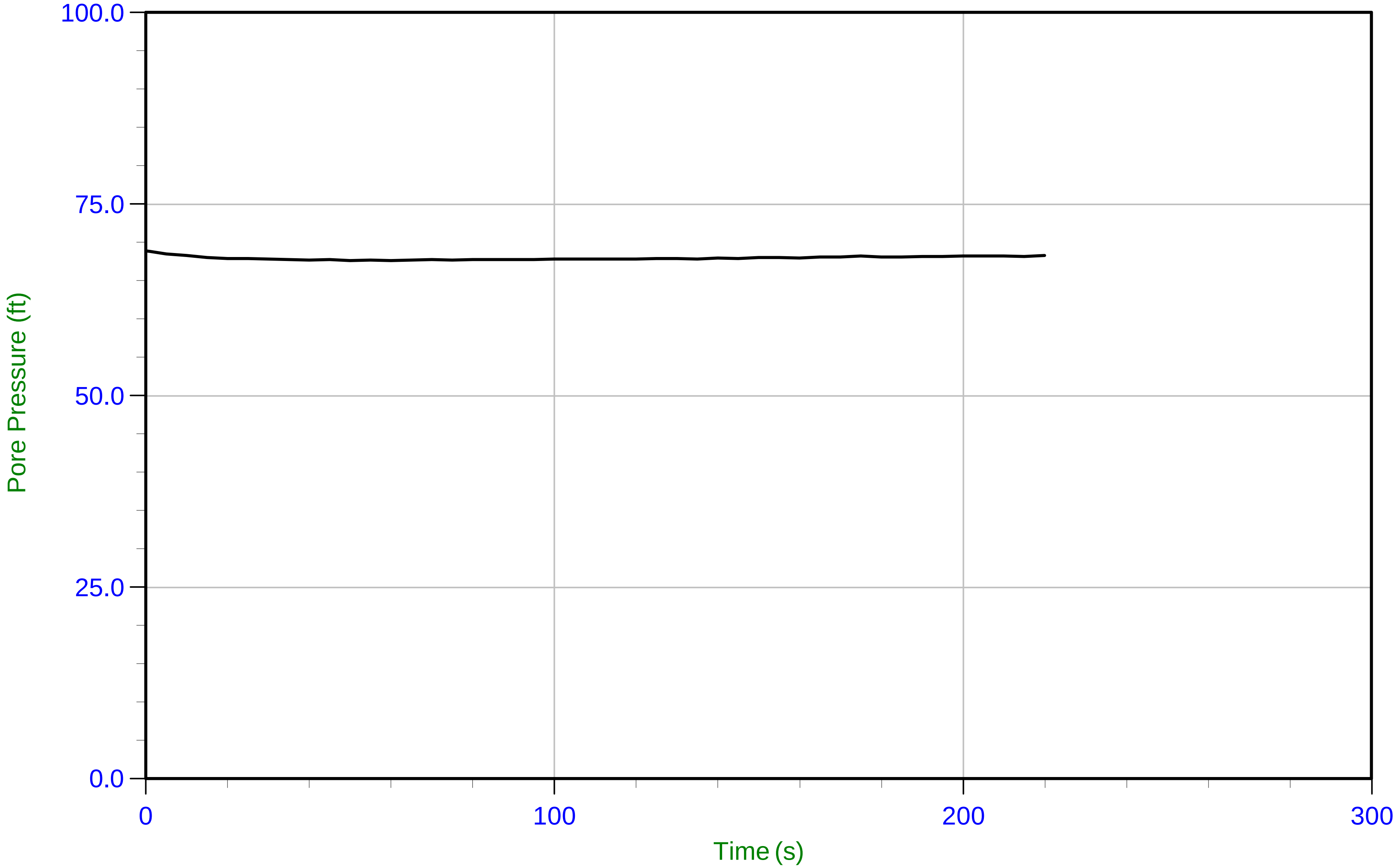
WT: 0.807 m / 2.648 ft
Ueq: 33.5 ft

CONETEC

GEI

Job No: 19-56124
Date: 09/14/2020 12:30
Site: Small Communities - Isleton

Sounding: GEI_BALMD_003C
Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-BALMD-003C.PPF
Depth: 21.800 m / 71.521 ft
Duration: 220.0 s

u Min: 67.6 ft
u Max: 68.9 ft
u Final: 68.3 ft

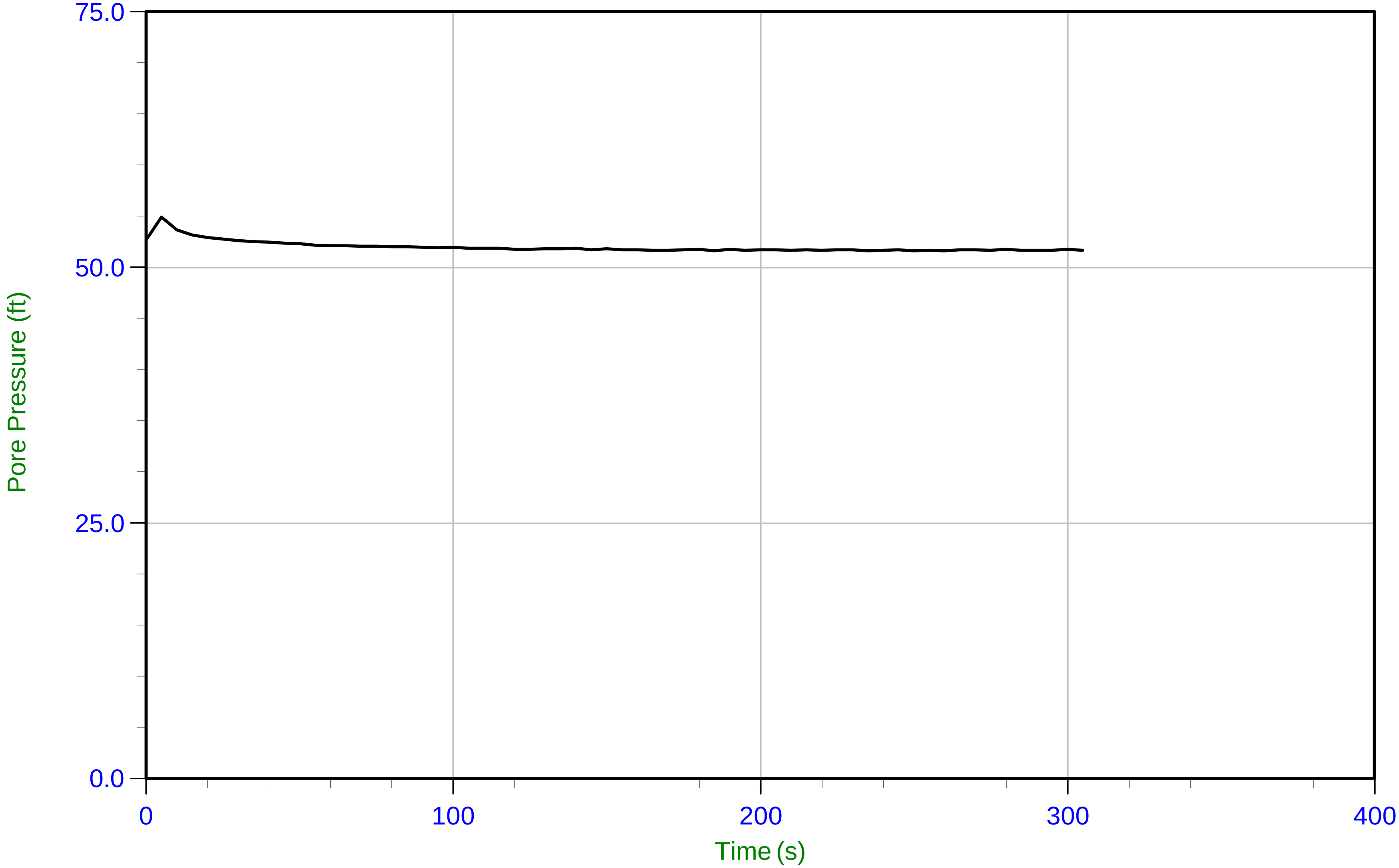
WT: 0.988 m / 3.241 ft
Ueq: 68.3 ft

CONETEC

GEI

Job No: 19-56124
Date: 09/14/2020 08:36
Site: Small Communities - Isleton

Sounding: GEI_BALMD_004C
Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-BALMD-004C.PPF
Depth: 17.925 m / 58.808 ft
Duration: 305.0 s

u Min: 51.6 ft
u Max: 54.9 ft
u Final: 51.7 ft

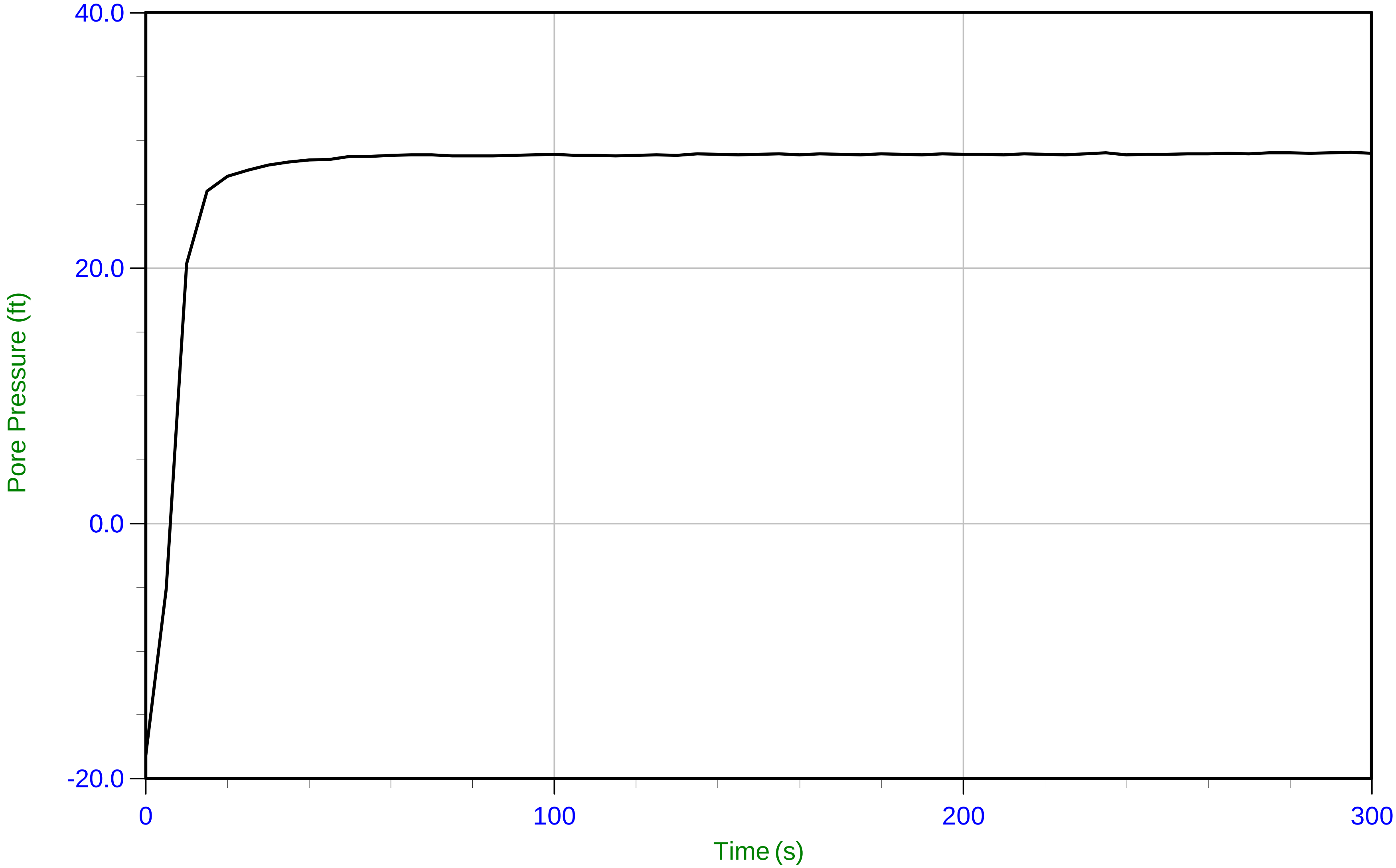
WT: 2.161 m / 7.090 ft
Ueq: 51.7 ft

CONETEC

GEI

Job No: 19-56124
Date: 09/15/2020 14:08
Site: Small Communities - Isleton

Sounding: GEI_BALMD_005C
Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-BALMD-005C.PPF
Depth: 9.800 m / 32.152 ft
Duration: 300.0 s

u Min: -18.1 ft
u Max: 29.1 ft
u Final: 29.0 ft

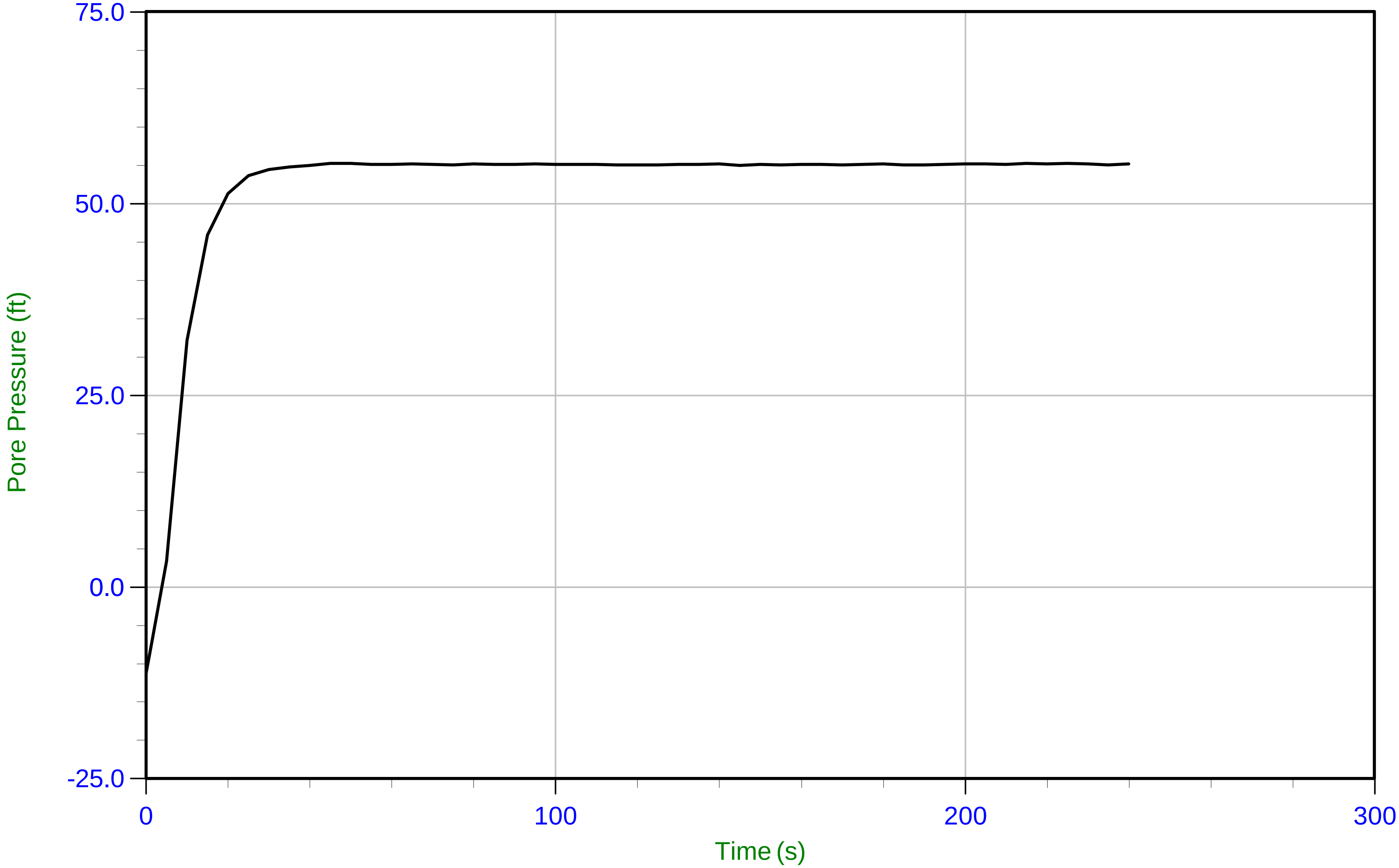
WT: 0.947 m / 3.107 ft
Ueq: 29.0 ft

CONETEC

GEI

Job No: 19-56124
Date: 09/16/2020 13:46
Site: Small Communities - Isleton

Sounding: GEI_BALMD_006C
Cone: 448:T1500F15U500 Area=15 cm²



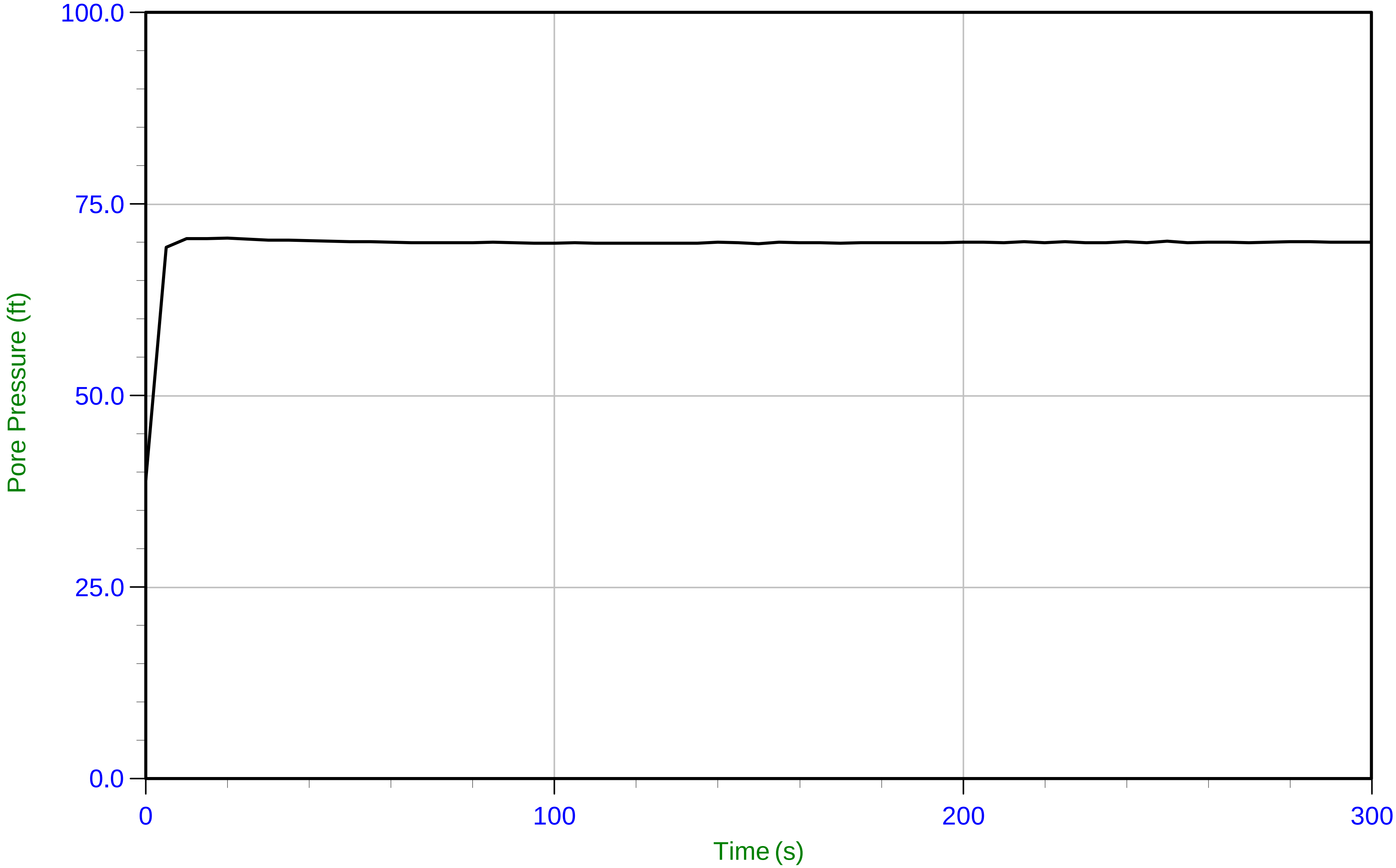
Trace Summary:

Filename: 19-56124_CP-BALMD-006C.PPF
Depth: 21.750 m / 71.357 ft
Duration: 240.0 s

u Min: -11.3 ft
u Max: 55.2 ft
u Final: 55.2 ft

WT: 4.963 m / 16.283 ft
Ueq: 55.1 ft

GEI	Job No: 19-56124 Date: 09/16/2020 11:19 Site: Small Communities - Isleton	Sounding: GEI_BALMD_007C Cone: 448:T1500F15U500 Area=15 cm²

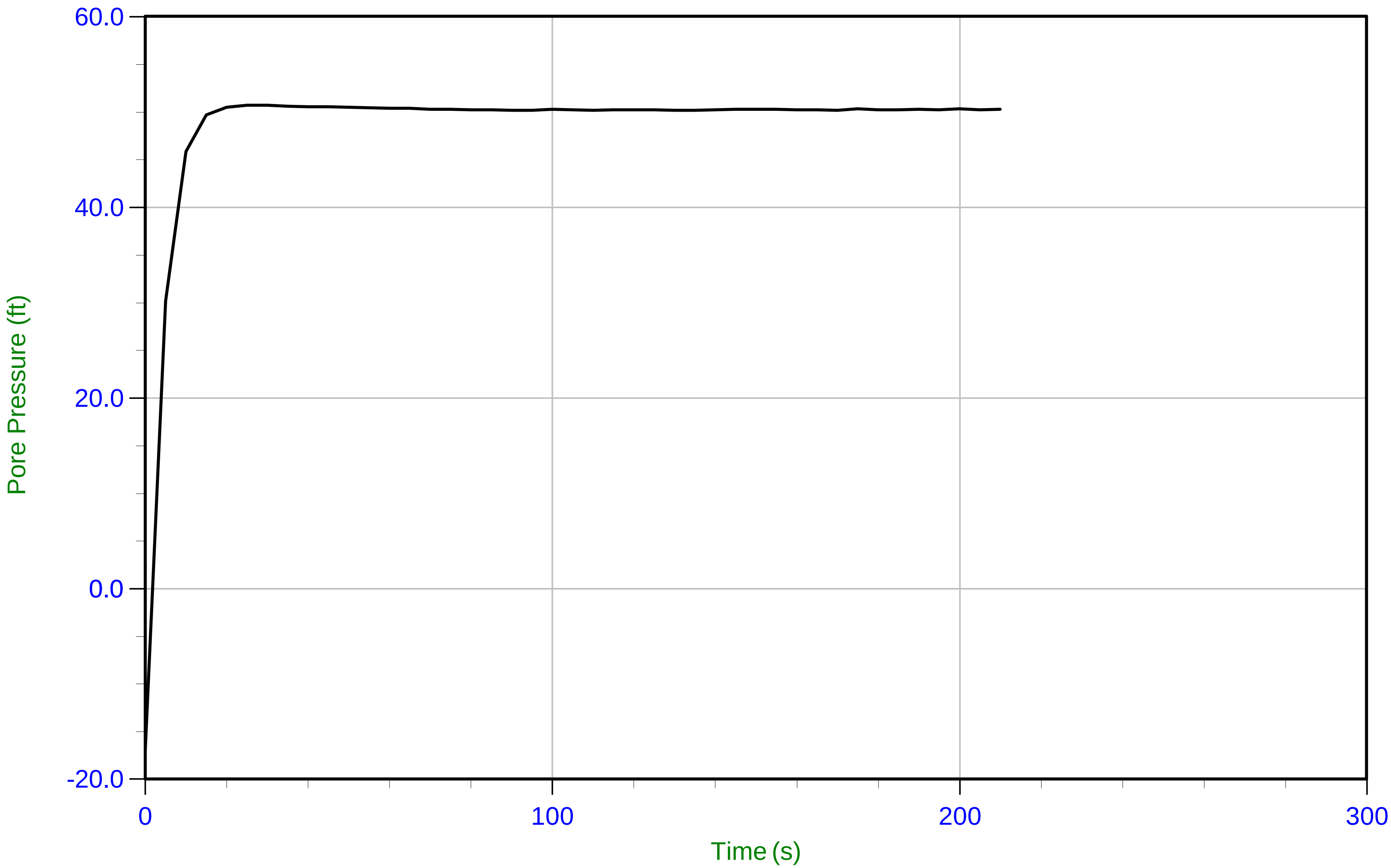


Trace Summary:

Filename: 19-56124_CP-BALMD-007C.PPF	u Min: 39.0 ft	WT: 0.645 m / 2.116 ft
Depth: 21.975 m / 72.096 ft	u Max: 70.5 ft	Ueq: 70.0 ft
Duration: 300.0 s	u Final: 70.0 ft	

CONETEC

GEI	Job No: 19-56124 Date: 09/16/2020 08:22 Site: Small Communities - Isleton	Sounding: GEI_BALMD_008C Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-BALMD-008C.PPF
Depth: 18.200 m / 59.711 ft
Duration: 210.0 s

u Min: -17.0 ft
u Max: 50.7 ft
u Final: 50.2 ft

WT: 2.902 m / 9.520 ft
Ueq: 50.2 ft

Soil Sample Summary

Job No: 19-56124
Client: GEI Consultants
Project: Small Communities - Isleton
Start Date: 14-Sep-2020
End Date: 16-Sep-2020

SOIL SAMPLE SUMMARY

Sounding ID	Sample Intervals (ft)	Sampling Date	Northing[1] (m)	Easting[1] (m)	Elevation[2] (ft)	Refer to Notation Number
GEI_BALMD_001C	0.0 - 1.0	15-Sep-2020	4219767	620788	-14	
GEI_BALMD_001C	1.0 - 2.0	15-Sep-2020	4219767	620788	-14	
GEI_BALMD_001C	2.0 - 3.0	15-Sep-2020	4219767	620788	-14	
GEI_BALMD_001C	3.0 - 4.0	15-Sep-2020	4219767	620788	-14	
GEI_BALMD_001C	5.0 - 6.0	15-Sep-2020	4219767	620788	-14	
GEI_BALMD_001C	6.0 - 7.0	15-Sep-2020	4219767	620788	-14	
GEI_BALMD_001C	7.0 - 8.0	15-Sep-2020	4219767	620788	-14	
GEI_BALMD_001C	8.0 - 9.0	15-Sep-2020	4219767	620788	-14	
GEI_BALMD_002C	0.0 - 1.0	15-Sep-2020	4225340	616567	10	
GEI_BALMD_002C	1.0 - 2.0	15-Sep-2020	4225340	616567	10	
GEI_BALMD_002C	2.0 - 3.0	15-Sep-2020	4225340	616567	10	
GEI_BALMD_002C	7.0 - 8.0	15-Sep-2020	4225340	616567	10	
GEI_BALMD_002C	8.0 - 9.0	15-Sep-2020	4225340	616567	10	
GEI_BALMD_002C	9.0 - 10.0	15-Sep-2020	4225340	616567	10	
GEI_BALMD_002C	40.0 - 41.0	15-Sep-2020	4225340	616567	10	
GEI_BALMD_002C	41.0 - 42.0	15-Sep-2020	4225340	616567	10	
GEI_BALMD_002C	43.0 - 44.0	15-Sep-2020	4225340	616567	10	
GEI_BALMD_003C	0.0 - 1.0	14-Sep-2020	4225816	617982	2	
GEI_BALMD_003C	1.0 - 2.0	14-Sep-2020	4225816	617982	2	
GEI_BALMD_003C	2.0 - 3.0	14-Sep-2020	4225816	617982	2	
GEI_BALMD_003C	3.0 - 4.0	14-Sep-2020	4225816	617982	2	
GEI_BALMD_003C	4.0 - 5.0	14-Sep-2020	4225816	617982	2	
GEI_BALMD_003C	10.0 - 11.0	14-Sep-2020	4225816	617982	2	
GEI_BALMD_003C	11.0 - 12.0	14-Sep-2020	4225816	617982	2	
GEI_BALMD_003C	12.0 - 13.0	14-Sep-2020	4225816	617982	2	
GEI_BALMD_004C	0.0 - 1.0	14-Sep-2020	4224793	620949	6	
GEI_BALMD_004C	1.0 - 2.0	14-Sep-2020	4224793	620949	6	
GEI_BALMD_004C	2.0 - 3.0	14-Sep-2020	4224793	620949	6	3
GEI_BALMD_004C	3.0 - 4.0	14-Sep-2020	4224793	620949	6	3
GEI_BALMD_004C	4.0 - 5.0	14-Sep-2020	4224793	620949	6	3

Job No: 19-56124
Client: GEI Consultants
Project: Small Communities - Isleton
Start Date: 14-Sep-2020
End Date: 16-Sep-2020

SOIL SAMPLE SUMMARY

Sounding ID	Sample Intervals (ft)	Sampling Date	Northing[1] (m)	Easting[1] (m)	Elevation[2] (ft)	Refer to Notation Number
GEI_BALMD_004C	5.0 - 6.0	14-Sep-2020	4224793	620949	6	
GEI_BALMD_004C	6.0 - 7.0	14-Sep-2020	4224793	620949	6	
GEI_BALMD_004C	8.0 - 9.0	14-Sep-2020	4224793	620949	6	
GEI_BALMD_004C	9.0 - 10.0	14-Sep-2020	4224793	620949	6	
GEI_BALMD_005C	0.0 - 1.0	15-Sep-2020	4225867	623336	12	
GEI_BALMD_005C	1.0 - 2.0	15-Sep-2020	4225867	623336	12	
GEI_BALMD_005C	2.0 - 3.0	15-Sep-2020	4225867	623336	12	
GEI_BALMD_005C	3.0 - 4.0	15-Sep-2020	4225867	623336	12	
GEI_BALMD_005C	10.0 - 11.0	15-Sep-2020	4225867	623336	12	
GEI_BALMD_005C	11.0 - 12.0	15-Sep-2020	4225867	623336	12	
GEI_BALMD_005C	12.0 - 13.0	15-Sep-2020	4225867	623336	12	
GEI_BALMD_005C	22.0 - 23.0	15-Sep-2020	4225867	623336	12	
GEI_BALMD_005C	23.0 - 24.0	15-Sep-2020	4225867	623336	12	
GEI_BALMD_005C	24.0 - 25.0	15-Sep-2020	4225867	623336	12	3
GEI_BALMD_005C	25.0 - 26.0	15-Sep-2020	4225867	623336	12	
GEI_BALMD_006C	0.0 - 1.0	16-Sep-2020	4227775	625653	1	
GEI_BALMD_006C	1.0 - 2.0	16-Sep-2020	4227775	625653	1	
GEI_BALMD_006C	2.0 - 3.0	16-Sep-2020	4227775	625653	1	
GEI_BALMD_006C	3.0 - 4.0	16-Sep-2020	4227775	625653	1	
GEI_BALMD_006C	4.0 - 5.0	16-Sep-2020	4227775	625653	1	
GEI_BALMD_006C	5.0 - 6.0	16-Sep-2020	4227775	625653	1	
GEI_BALMD_006C	7.0 - 8.0	16-Sep-2020	4227775	625653	1	
GEI_BALMD_006C	8.0 - 9.0	16-Sep-2020	4227775	625653	1	
GEI_BALMD_006C	9.0 - 10.0	16-Sep-2020	4227775	625653	1	3
GEI_BALMD_006C	10.0 - 11.0	16-Sep-2020	4227775	625653	1	
GEI_BALMD_007C	3.0 - 4.0	16-Sep-2020	4223958	623256	-5	
GEI_BALMD_007C	4.0 - 5.0	16-Sep-2020	4223958	623256	-5	
GEI_BALMD_007C	5.0 - 6.0	16-Sep-2020	4223958	623256	-5	
GEI_BALMD_007C	6.0 - 7.0	16-Sep-2020	4223958	623256	-5	
GEI_BALMD_007C	10.0 - 11.0	16-Sep-2020	4223958	623256	-5	

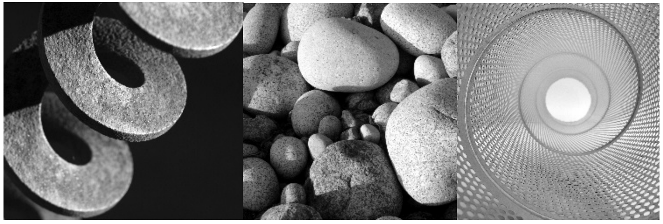
Job No: 19-56124
Client: GEI Consultants
Project: Small Communities - Isleton
Start Date: 14-Sep-2020
End Date: 16-Sep-2020

SOIL SAMPLE SUMMARY

Sounding ID	Sample Intervals (ft)	Sampling Date	Northing[1] (m)	Easting[1] (m)	Elevation[2] (ft)	Refer to Notation Number
GEI_BALMD_007C	11.0 - 12.0	16-Sep-2020	4223958	623256	-5	
GEI_BALMD_007C	12.0 - 13.0	16-Sep-2020	4223958	623256	-5	
GEI_BALMD_008C	0.0 - 1.0	16-Sep-2020	4221706	623212	1	
GEI_BALMD_008C	1.0 - 2.0	16-Sep-2020	4221706	623212	1	
GEI_BALMD_008C	2.0 - 3.0	16-Sep-2020	4221706	623212	1	
GEI_BALMD_008C	3.0 - 4.0	16-Sep-2020	4221706	623212	1	
GEI_BALMD_008C	4.0 - 5.0	16-Sep-2020	4221706	623212	1	

1. The coordinates were acquired using consumer grade GPS equipment, datum: WGS 1984 / UTM Zone 10 North.
2. Elevations were acquired from the Google Earth Elevation for the recorded coordinates.

Appendix C Geotechnical Exploration Work Plan, September 2020



Consulting
Engineers and
Scientists

Geotechnical Exploration Work Plan

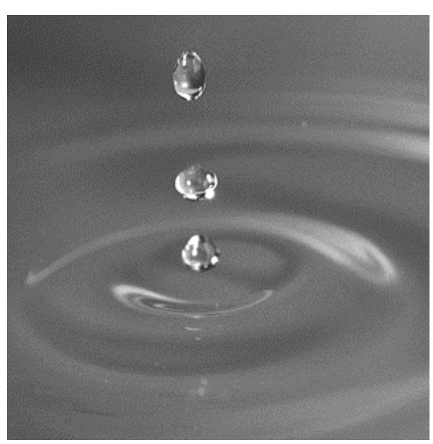
Sacramento County Small Community of Isleton

Sacramento County, California

Submitted to:
Sacramento County Department of Water Resources
827 Seventh Street, Room 301
Sacramento CA 95814

Submitted by:
GEI Consultants, Inc.
2868 Prospect Park Drive, Suite 310
Rancho Cordova, CA 95670

Date: September 2020
Project No. 1800488



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Abbreviations and Acronyms

ASTM	American Society for Testing and Materials
CAL	Standard California Sampler
CPT	Cone Penetration Testing
DWR	California Department of Water Resources
FEMA	Federal Emergency Management Agency
GEI	GEI Consultants, Inc.
GPS	Global Positioning Satellite
HASP	Health and Safety Plan
District	Marin County Flood Control and Water Conservation District
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
QA/QC	Quality Assurance/Quality Control
SMART	Sonoma Marin Area Rail Transit
SPT	Standard Penetration Test
USA	Underground Service Alert
USACE	United States Army Corps of Engineers

1 Introduction and Background

1.1 Project Overview

1.1.1 Background

GEI Consultants, Inc. (GEI) is assisting the California Department of Water Resources (DWR) for the city of Isleton. Isleton is located approximately 40 miles south of Sacramento (Figure 1). The Brannan-Andrus Levee Maintenance District (BALMD) levees protect the City of Isleton and are constructed along the left bank of the Sacramento River (California Department of Water Resources [DWR] Non-Urban Levee Evaluation [NULE] Segment 378), the right bank of Georgiana Slough (NULE Segment 40), the right bank the North Mokelumne River (NULE Segment 1050), the right bank of the San Joaquin River (NULE Segment 1049), and the left bank of Seven Mile Slough (NULE Segment 1048), as shown on Figure 1 and discussed in more detailed below. The ring levee system (Brannan-Andrus Island) protecting the City of Isleton is completed by a cross-levee common with Reclamation District (RD) 556 at the northeastern end and high ground at the southwestern extent between Sacramento River and Three Mile Slough.

Exploratory borings were previously performed along Sacramento River levee left bank and Georgiana Slough levee right bank, Mokelumne River right bank, and Sevenmile Slough right bank, but are widely spaced and were drilled in the 1990's. Existing subsurface data is limited and previous assessments are based primarily on non-intrusive studies. Geotechnical exploration and evaluations are needed to further understand and characterize the levee and foundation composition and conditions, including the depth of the aquiclude layer.

This work plan describes the objectives of the geotechnical exploration and laboratory testing program and the methods and equipment that will be used. This project includes collection of soil samples and in-situ data, detailed descriptions of embankment and foundation conditions, and laboratory testing to support geotechnical evaluation and development of feasibility-level repair recommendations.

1.1.2 Purpose and Scope

The purpose of the geotechnical exploration and laboratory testing project is to collect additional site-specific subsurface information regarding soil properties and geotechnical conditions of the levee embankment and underlying foundation. The results of the exploration program will be used to help fill in the data gaps where no past explorations have been performed. GEI and its subcontractors have planned to complete 10 cone penetration tests (CPT's) approximately 15 feet or more from the landside toe for the State Plan Flood Control (SPFC) levees and through the levee crown on Non-SPFC levees protecting the community of Locke (Figure 2).

The field explorations will be performed using ConeTec, Inc. from San Leandro, California. Explorations are expected to begin the week of September 14, 2019 and be completed by September 16, 2019.

This work plan describes the relevant information associated with the current exploration program and includes the proposed exploration locations (Figure 2), exploration methods, depths, types of samples, and a general plan for laboratory testing of collected samples. A site-specific Health and Safety Plan (HASP) has been prepared for this exploration program (Appendix E).

This Plan's scope is limited to:

- Reviewing existing data and planning/layout of proposed subsurface explorations;
- Performing the following geotechnical explorations:
    - 4 CPTs landward of the landside toe of the Sacramento River left bank;
    - 2 CPTs landward of the landside toe of Georgiana Slough right bank;
    - 1 CPT landward of the landside toe of Sevenmile Slough right bank;
    - 1 CPT on the crown of the cross-levee
- Documenting final CPT locations;
- Geotechnical laboratory testing;
- Providing final CPT logs and report.

Information collected during the subsurface exploration program will be documented in a Geotechnical Evaluation Report.

1.2 Site Description

The project area is in Sacramento County and includes 6 levee segments encompassing the city of Isleton. The Sacramento River left bank levee near Isleton (NULE Segment 378) extends approximately 11.5 miles along the northwest side of Brannan-Andrus Island from the confluence of the Sacramento River and Three Mile Slough, northeast to the cross-levee common between BALMD and RD 556. NULE Segment 378 is a SPFC levee that is a part of the BALMD levee system. The Georgiana Slough right bank levee

(NULE Segment 40) is an SPFC levee that is part of the RD BALMD levee system. The cross-levee borders BALMD and RD 556. The right bank levees of the North Mokelumne River (NULE Segment 1050) and San Joaquin River (NULE Segment 1049) are non-SPFC levees that are a part of BALMD. This levee system protects an area of approximately 13,000 acres, which includes numerous farms and agricultural-related businesses.

1.3 Existing Data Summary

Based on review of existing subsurface data, there are total of five known explorations along the approximately 17.5 miles of SPFC levees in the Brannan-Andrus Levee Maintenance District. Exploration locations are shown in Figure 3. All five investigations are along the right bank of Georgiana Slough (NULE Segment 40), no existing explorations were identified along the levee near the City of Isleton or elsewhere on the BALMD extent of the left bank of the Sacramento River (NULE Segment 378). The identified explorations along Georgian Slough were completed by USACE, four in 1991 composed of two pairs of crown and toe borings completed near Oxbow Marina and one boring completed in 1966 near Isleton Bridge that was only through the embankment. The 1991 crown borings were 40-feet deep, approximately 30 feet below the natural ground surface, and the toe borings were about 20-feet deep. These borings show a sandy levee and sandy shallow foundation with some clay to about 10 feet below the natural ground surface. The sandy shallow foundation is shown to be underlain by primarily organic clay (OH) and peat material. One of the borings terminated in sand, at about 30 feet below the natural ground surface. The 1966 boring identified a silty embankment with 54-87% fines based on laboratory sieve testing. Available log or profile information for the existing investigations is included in Appendix D.

Along the approximately 10 miles of non-SPFC levee that complete the ring levee system protecting the City of Isleton, review of existing subsurface data identified appreciably more existing explorations which are described below. Exploration locations are shown in Figure 2 and available log or profile information for the existing investigations is included in Appendix D.

Along the right bank of the North Mokelumne River BALMD levee (NULE Segment 1050) 18 explorations have been completed. Ten borings were complete by Whaler Associates in 1989, including seven through the levee crown to depths of 41 to 70 feet below the crown and three at the landside levee toe to depths around 26 feet below the ground surface. One boring was drilled through the levee by Raney Geotechnical in 1990 to a depth of 40 feet. Two landsides borings were completed by DWR as part of the 1992 North Delta Seepage Monitoring project, one at the landside toe to a depth of 20 feet and one further landward to a depth of 100 feet. Based on these explorations, the levee is primary composed of silty sand, sand, silt, and organic soil and the foundation consists primarily of peat and organic soil (organic silt and organic clay). The thickness of organic soil found in the foundation ranges from about 10 to 55 feet. Caltrans bridge exploration data from 1976 for the Highway 12 bridge across the Mokelumne River, connecting Brannan-Andrus Island to Bouldin, included five borings on the right bank, on the waterside of the levee. These borings show a waterside foundation composed of silt, sand, and silty clay.

Along the right bank San Joaquin River BALMD levee (NULE Segment 1049) 26 borings have been completed along the 2.6-mile long segment. Twenty-two of the borings were performed between 1956 and 1958 by DWR as part of the Salinity Control Barrier Investigation. Most of the borings were drilled through the levee crown with a couple each on the levee slope, landside levee toe, and landward of the landside toe. Borings generally range in depth from 20 feet to 80 feet deep with two deeper explorations going to depths of about 170 and 210 feet below the levee crown. Profiles of these explorations are available and show a levee embankment generally composed of silt, silty sand, sand, and organic silt and a foundation consisting of organic soil (peat, organic silt, and organic clay), sand, and silt. Organic soil in the foundation ranges from 2 to 40 feet in thickness.

Four additional borings were drilled by Rainey Geotechnical in 1987. No log or profile information was found for three of the four borings. The log available is approximately 51.5 feet deep and shows materials consistent with those encountered by the Salinity Control Barrier Investigation described above. Five other explorations were drilled in 1987 by Raney Geotechnical along the landside of the levee, for private development, logs are not available.

Along the left bank Seven Mile Slough BALMD levee (NULE Segment 1048) 4 borings were drilled by J.H. Kleinfelder & Associates in September of 1977. As shown in Figure 3, three of the boring were closely spaced near the western end of the segment. The borings ranged in depth from 41.5 feet to 76 feet below the levee crown. Based on the available logs, the levee consists of primarily silt and sand, and the foundation consists of organic soil (peat, organic clay, and organic silt), sand, and some silt. The thickness of organic soil in the foundation ranged from about 15 to 20 feet.

2 Health and Safety Plan, Permitting, and Clearances

2.1 Site Specific and Drilling Contractor Health and Safety Plans (HASPs)

A site-specific Health and Safety Plan (Site HASP), included in Appendix E, was prepared by GEI prior to commencing field work, to cover work performed by GEI field personnel. All work performed by GEI personnel will comply with the HASP. The drilling contractor will be required to prepare a Health and Safety Plan for their specific operations (Driller HASP) and the protection of their employees. Copies of the Driller HASPs must be provided to GEI prior to the initiation of any Project field exploration activities. If GEI personnel observe the drilling crew not following the Driller's health and safety policies, we will remind the crew of the need to comply. If they fail to do so, we will contact and inform Driller's management of the situation. If GEI personnel observe an obvious and serious failure to comply with the Driller's HASP requirements, and if the drilling crew continues to be non-compliant, operations will be shut down until the safety issue is resolved.

The drilling contractor has the sole Health and Safety responsibility for their operation. However, GEI will be vigilant in our assessment of conditions related to our work and the driller's work with respect to maintain a safe work environment. Safety tailgate meetings accompanied with sign-in sheets (Appendix D) will be conducted prior to beginning work each day and a copy of the Site HASP (Appendix E) will be kept on-site. GEI does not intend to complete an inspection checklist for ConeTec's equipment.

2.2 Permits

At the direction of the District, drilling permits and an Environmental Health Services permit were obtained for the work included in this Plan.

Copies of these permits, included in Appendix B, required to perform field work will be kept on-site during the exploration.

2.3 Utility Clearance

Before exploration activities begin, Underground Service Alert (USA) requires a visual inspection at each exploration location. GEI has completed the visual inspection, and outlined each location with stakes and white paint. USA was contacted prior to any subsurface exploration with a minimum of 48 hours prior to the start of drilling. A USA ticket number, as well as clearance date, expiration date and call-back-to-extend date, was obtained for each work area and documented for the project file. Table 1 includes the USA ticket number for each exploration.

Exploration locations may be hand cleared (hand augered) for the upper five feet as directed by the field engineer/geologist. Hand auger borings will be monitored and logged by the GEI representative on site.

Proximity to overhead utilities will be evaluated at each exploration location. In general, a clearance of at least 15 feet will be maintained between a drill rig mast and any overhead utilities (i.e., power lines), including during mobilization when traversing the access roads leading to the exploration locations.

2.4 Organization and Communication

The key point of contact for all communication related to the exploration activities is the GEI Project Manager. The GEI Project Manager will be a licensed Professional Geologist and Certified Engineering Geologist in the State of California. The GEI Project Manager will communicate with the District regarding progress updates or any issues that warrant input. Contact information is provided in Table 2.

During field activities, the GEI Field Engineer/Geologist (point-of-contact on site) will prepare daily field reports summarizing work performed, footage drilled/explored, personnel and equipment on-site, and other related project information. Sample field forms are included in Appendix D. Daily field reports will be complied and provided to GEI's Project Manager.

Geotechnical data, including CPT logs and laboratory test results will be provided to the District in the Geotechnical Data Report.

Field exploration roles and responsibilities are as follows:

2.4.1 GEI Field Engineer/Geologist

- Reports daily to the GEI Project Manager
- Facilitates daily safety meetings
- Coordinates field logistics
- Supervises CPT activities
- Analyzes CPT report and identifies sampling depths

- Prepares field logs
- Labels and stores all recovered samples
- Communicates with the Project Manager, CPT subcontractor, utility locator, and site visitors

2.4.2 GEI Project Manager

- Coordinates program with personnel responsible for clearances (county and city)
- Monitors and supervises ongoing field activities
- Monitors exploration progress
- Coordinates and reviews daily reports compiled by field personnel
- Reviews and approves field logs
- Reviews field staff labor costs and driller invoices
- Communicates with field engineer(s)/geologist(s), Project Management team, and the District

3 Subsurface Exploration Plan

3.1 Overview

Prior to drilling, field personnel will review the field exploration program with the GEI Project Manager. Required permits and sub-consultants license are included in Appendix B and C, respectively.

This review provides the basis for field work completion and offers field personnel the opportunity to raise any questions regarding project scope, procedures, schedule, or any issue that may not be clearly understood. Items discussed during this pre-drilling meeting include:

- Health and safety
- Goals, objectives, and scope of the field explorations
- Project schedule
- Sampling procedures and sample requirements for laboratory testing
- Criteria for the final depth of explorations
- Site access and client contacts
- Utility clearance
- Permits and security
- Potential of encountering hazardous materials
- Backfill requirements
- Disposal of cuttings and drill fluids
- Erosion control requirements, if necessary
- Site restoration requirements
- Applicable standards (ASTM, etc.) to be implemented

All fieldwork will be summarized daily using a Daily Field Report (Appendix D).

3.2 Objectives

The purpose of the exploration program is to define (or refine) site-specific information regarding soil properties and geotechnical conditions of the levee embankment and underlying foundational strata for engineering analyses required for the feasibility level analysis and evaluation. The focus of the geotechnical explorations will be on refining subsurface conditions of the study area, investigating the presence, thickness, extent(s), engineering properties, and depth of the fine-grained compressible layers. In addition, where appropriate, data will be obtained to either confirm or refine assumptions made in previous analyses.

3.3 Exploration Locations and Techniques

Geotechnical CPT explorations will be conducted at locations shown on Figure 2. A total of 8 CPTs are planned along the Sacramento River left bank landside toe (western and southern banks as appropriate), Georgiana Slough right (eastern) bank landside toe, Sevenmile Slough right (northern) bank landside toe, and the cross-levee crown. A summary of the exploration locations and types is below:

Planned Explorations:

- Sacramento River left bank, NULE Segment 378 - 4 CPTs
- Georgiana Slough right bank, NULE Segment 40 - 2 CPTs
- Sevenmile Slough right bank, NULE Segment 1048 - 1 CPT
- Cross-levee crown, BALMD/RD 556 – 1 CPT

Exploration locations, types, and targeted depths are summarized on Table 1.

3.3.1 CPT Explorations

Continuous CPT soundings will be performed to log foundation sediments using a truck-mounted 20- to 30-ton capacity cone apparatus in general accordance with ASTM D5778. The conventional instrumented cone assembly includes a cone tip with a 60-degree apex and a cross-sectional area of 10 or 15 square centimeters (cm^2), a sleeve segment with a surface area of 200 cm^2, and a pore pressure transducer near the base (shoulder) of the cone tip. The CPT hole diameter is approximately 2 inches.

Prior to the start of testing, the rig is jacked up and leveled on four pads to provide a stable and level reaction for the cone thrust. During the test, the instrumented cone is hydraulically pushed into the ground at a rate of about 2 centimeters per second (cm/s), and readings of cone tip resistance, sleeve friction, and pore pressure are digitally recorded every second. As the cone tip advances, additional cone rods are added such that a "string" of rods continuously advances through the soil. As the test progresses, the CPT operator monitors the cone resistance and its deviation from vertical alignment.

Interpretation of the cone parameters are performed by on-board computers. Soils are classified based on the soil behavior type, which is an interpretation based on cone tip resistance and friction ratio. Cone resistance is typically high in sands and low in clays. Sampling and testing will help confirm the soil behavior type identified by the CPT. A continuous log of the soil is produced on a real-time basis.

Pore-pressure dissipation tests will be conducted in predominantly granular materials below the water table to determine approximate water levels and provide estimates of hydraulic conductivity. In a dissipation test, the CPT sounding is advanced to the test depth, or as directed by the field engineer/geologist, and then halted. In clays, pore pressure data is then recorded until approximately 50 to 75 percent of the induced excess pore pressure is dissipated, or to a maximum duration of approximately 30 minutes. In sands, pore pressure dissipation tests are generally conducted until 100 percent of the excess pore pressure is dissipated. All pore pressure data during the test are digitally recorded for subsequent analyses. After the dissipation test data are recorded, cone advancement is resumed. At the conclusion of each test, the electronic data are stored for further processing in the office. The direct push samples will be labeled in accordance with the naming convention described below.

3.3.1.1 Soil Sample Naming Convention

Soil samples will be clearly labeled with the following:

- GEI project number
- CPT exploration number
- sample identification number
- depth of sample
- date collected

The sample identification number consists of four primary identifiers. The first identifier will be the Sample Number and will be used to represent the sequence of sampling within the hole. The Sample Number will be numbered consecutively from the top of the hole to the bottom. For example, the sampling interval number for the first sample to be pushed in a given hole will be “1”, the sampling interval number for the second sample will be “2”, the sampling interval number for the third sample will be “3”, etc. Sample Numbers will be assigned for each sampling interval, even in situations where there is no sample recovery.

3.3.1.2 Soil Sampling and Frequency

Soil sampling will consist of advancing a second CPT probe adjacent to the first CPT and sampling at depths selected by the field engineer/ geologist on site. Samples will be bagged, and selected samples will be laboratory tested to confirm the soil behavior type shown on the CPT output.

3.4 Exploration Depths

The anticipated boring depths are included in Table 1. All proposed explorations are planned to reach a minimum of 60 feet or four times the levee height below ground surface to obtain a better understanding of the extents of the fine-grained layers encountered in previous explorations and determine the extents of these materials throughout the study area. The exploration depth ranges between 60-95 feet, with final termination depth determined by the field engineer/ geologist.

3.5 Hours of Operation

Normal exploration activities will be between about 7 AM and 5 PM. Drill rig maintenance activities will be performed during normal working hours.

3.6 CPT Reports

A field summary will be completed for every exploration. The field engineer/geologist should record the following information on the CPT field stratigraphy print out:

- Project name
- Project number
- Exploration number
- Start/ completion date
- CPT hole diameter
- Type of CPT rig
- Rig driller's name and helpers
- Exploration location (crown, landside toe, etc.)

As the exploration progresses and is completed, the field engineer/geologist should complete the following information on the log:

- The depth of encountered groundwater
- Method of backfilling

3.7 Access, Traffic Control, and Staging

Traffic control measures, including the placement of caution tape, cones, and signs around the drilling operation, will be used during drilling at some locations where pedestrian, bicycle, or vehicle traffic occurs, or limited property access exists. A staging area will be arranged for the overnight storage of equipment and supplies.

Levee toe areas are unpaved. Rainfall should not impact CPT operations unless the ground at a given exploration location becomes too soft to mobilize a CPT truck, high water impounds against the levee, or lightning is present. Investigations will be terminated if lightning appears likely or if, in the opinion of the project team, water against the riverbank is too high. The GEI HASP states that work can resume 30-minutes after the last clap of thunder or flash of lightning. CPTs will be suspended if the river level is forecast to rise above the levee foundation.

3.8 Exploration Completion and Site Restoration

In accordance with county requirements, all CPTs will be backfilled with cement-bentonite grout (up to 5 percent bentonite) at the completion of drilling. The grout proportions and quantities will be recorded on the field CPT print out.

Grout will be placed into the hole by tremie method through a pipe placed at the bottom of the borehole. The end of the tremie pipe will be kept submerged in the grout as it fills the borehole and rises. The hole is to be grouted to 5 feet of the ground surface with the cement-bentonite grout mix. The remaining 5 feet will be backfilled with hydrated bentonite chips. Explorations will be backfilled the day that the hole is completed. At the end of the day, the holes are revisited and topped off with additional grout mix if needed.

Drill sites will be cleaned and restored as closely as practicable to pre-exploration conditions. At completion, all equipment, materials, tools, and unused materials will be removed, and trash will be disposed offsite.

3.9 Documentation of Exploration Locations

The locations of explorations will be documented using hand-held GPS unit. After completion of the exploration program, the exploration location will be confirmed or refined using physical features on the ground and aerial imagery. The elevations will be estimated from available topographic surveys using a horizontal datum of NAD83 and vertical datum in NAVD88.

4 Geotechnical Laboratory Testing

4.1 Material Sampling and Testing Protocols

Geotechnical laboratory tests will be performed on selected samples obtained from the borings to assist with characterization of the geotechnical engineering properties of the subsurface materials. The geotechnical laboratory testing will be performed by Blackburn Consulting in their West Sacramento, CA laboratory. This program is subject to modification based on actual conditions encountered, and on the judgments of the GEI Project Manager.

4.2 Geotechnical Laboratory Testing Program

Geotechnical laboratory testing will be performed on selected soil samples collected in the field to aid in soil classification and development of engineering parameters for geotechnical evaluations. Laboratory testing will be performed in general accordance with ASTM standards and will be focused on characterization of the composition of the levee embankment and foundation materials.

Soil sample laboratory testing may include Atterberg limits, grain-size distribution, in-situ moisture content and density (unit weight), shear/compressive strength, and consolidation tests, as appropriate. The number and type of geotechnical laboratory tests will be determined based on the subsurface conditions and stratigraphic units encountered in the CPTs and determined by the GEI Project Manager.

The list below summarizes possible laboratory testing, but is not limited to the following:

- Sieve Analysis, ASTM D422
- #200 Sieve Wash, ASTM D1140
- Moisture Content and Density of Soils, ASTM D2937
- Atterberg Limits, ASTM D4318
- Organic Content, ASTM D2974

5 Quality Assurance/ Quality Control (QA/QC)

5.1 Field Log and Data QC

Field quality control measures will be provided through senior engineering geologist oversight of the field activities throughout the duration of the geotechnical investigations.

GEI personnel are responsible for collecting and transporting soil samples to the soil testing laboratory, processing laboratory test results, and adjusting field logs based on laboratory test data.

Creating logs for this project includes:

- Field sampling and CPT reports.
- Quality check of field observations.
- If laboratory tests are performed on samples recovered from explorations, soil classifications and descriptions will be refined as appropriate based on test results.
- CPT data will be compared with laboratory data and nearby explorations.
- Final draft CPT logs will be prepared based on adjustments for laboratory tests and subsequent quality checks.

6 Public Awareness

All field personnel will be trained and informed to not provide opinions when approached by members of the general public or press who are seeking information regarding the Isleton Flood Risk Reduction Feasibility Study. Rather, field personnel will explain that DWR consultants are inspecting and documenting the subsurface conditions along the Sacramento River, Georgiana Slough, and Sevenmile Slough levees. Field personnel will log the date and time of contact with members of the public, name of the person making the inquiry, and subject of the inquiry.

7 References and Documentation of Previous Explorations

AASHTO (1988). *Manual on Subsurface Investigations, Revision 1*. American Association of State Highway and Transportation Officials (AASHTO).

ASTM D422. *Standard Test Method for Particle-Size Analysis of Soils.*

ASTM D1140. *Standard Test Method for Amount of Material in Soils Finer than No. 200 (75µm) Sieve.*

ASTM D1587. *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*.

ASTM D2487. *Standard Practice for Classification of Soils for Engineering Purposes (United Soil Classification System)*.

ASTM D2488. *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*.

ASTM D2937. *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method*.

ASTM D2974. *Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*.

ASTM D4318. *Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.*

ASTM D4633. *Standard Test Method for Energy Measurement for Dynamic Penetrometers.*

ASTM D5778. *Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils.*

Terzaghi and Peck (1967). *Soil Mechanics in Engineering Practice*. Karl Terzaghi and Ralph Peck, Wiley, 1967.

Tables

GEI Consultants

Table 1. Summary of Subsurface Explorations - Isleton

CPT ID	River	Location	Latitude	Longitude	USA Ticket Number	Approxiomate Levee Height (ft)	Proposed Depth of CPT (feet)
GEI_BALMD_001C	Sevenmile Slough	Landside Toe	38.117644	-121.622111	X023302940-00X	24.0	95
GEI_BALMD_002C	Sacramento River	Landside Toe	38.16843	-121.66927	X023302963-00X	22.5	90
GEI_BALMD_003C	Sacramento River	Landside Toe	38.17258	-121.65298	X023302967-00X	15.0	60
GEI_BALMD_004C	Sacramento River	Landside Toe	38.16292	-121.61935	X023302969-00X	15.0	60
GEI_BALMD_005C	Sacramento River	Landside Toe	38.17228	-121.59191	X023302971-00X	14.0	60
GEI_BALMD_006C	Cross Levee	Crown	38.1892	-121.56515	X023302976-00X	17.0	70
GEI_BALMD_007C	Georgiana Slough	Landside Toe	38.15508	-121.59316	X023302978-00X	19.0	75
GEI_BALMD_008C	Georgiana Slough	Landside Toe	38.134794	-121.59408	X023302980-00X	14.5	60

Table 2. List of Contacts

Name	Role	Organization	Mailing Address	Email Address	Telephone Number	Cell Number
Sonia Klingensmith	Regional Health & Safety Officer	GEI	2868 Prospect Park Dr, Suite 400, Rancho Cordova, CA 95670	sklingensmith@ geiconsultants.com	(916) 341-9139	(916) 350-0558
Jeff Twitchell	Project Manager	GEI	2868 Prospect Park Dr, Suite 400, Rancho Cordova, CA 95670	jtwitchell@ geiconsultants.com	(916) 631-4555	(916) 990-2569
Nichole Tollefson	Project Engineer	GEI	2868 Prospect Park Dr, Suite 400, Rancho Cordova, CA 95670	ntollefson@ geiconsultants.com	(916) 631-4590	(916) 580-7030
Ben Neely	District Representative	DCC Engineering	Post Office Box 929 Walnut Grove, CA 95690	BNeely@ dccengineering.net	--	(916) 776-9123
Robert Montanez Jr	District Representative	DCC Engineering	Post Office Box 929 Walnut Grove, CA 95690	RMontanez@ dccengineering.net	(916) 776-9128	--
Nicole Cholewinski	Field Geologist	GEI	2868 Prospect Park Dr, Suite 400, Rancho Cordova, CA 95670	ncholewinski@ geiconsultants.com	(916) 631-4584	(803) 524-1060
John Rogie	CPT Manager	ConeTec	820 Aladdin Ave, San Leandro, CA 94577	jrogie@conetec.com	(510) 357-3677	(650) 346-1490
Clayton Bartholomew	CPT Manager	ConeTec	820 Aladdin Ave, San Leandro, CA 94577	cbartholomew@ contec.com	(510) 357-3677	(925) 849-2989
Terry Kociemba	Grout Inspector	County of Sacramento	10590 Armstrong Ave. Suite A, Mather, CA 95655	To Schedule: (916) 875-8524	(916) 875-8899	(916) 202-3902

Figures

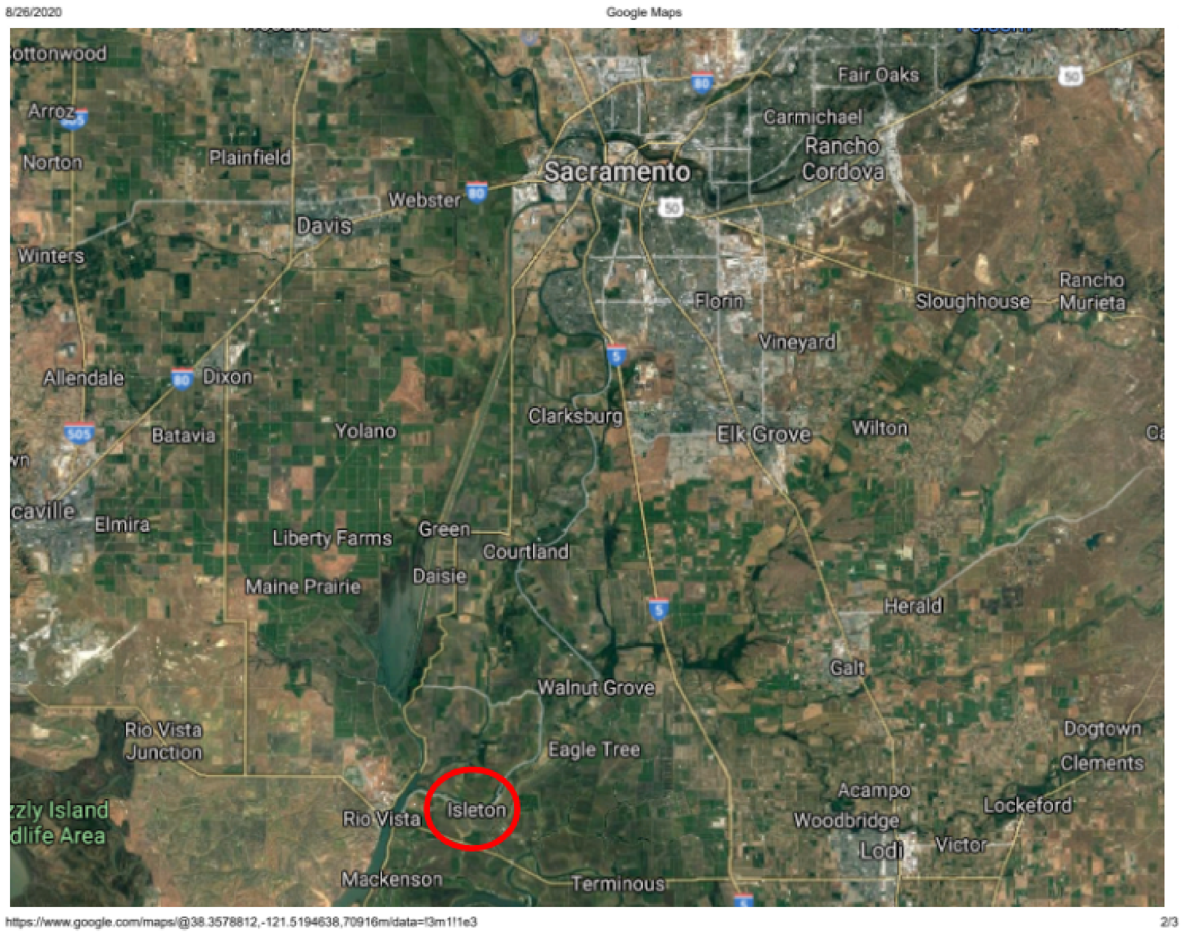


Figure 1. Site Vicinity

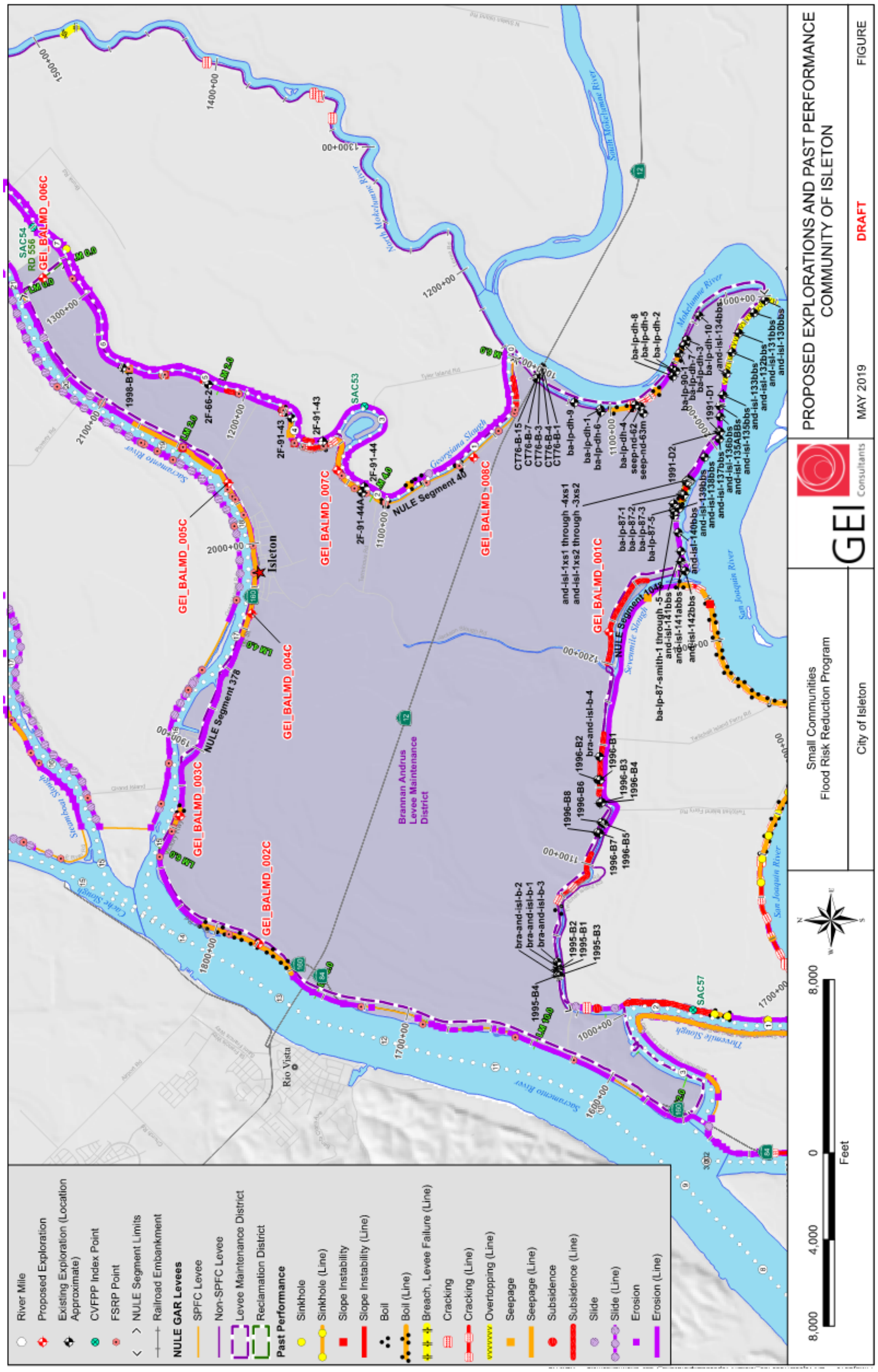
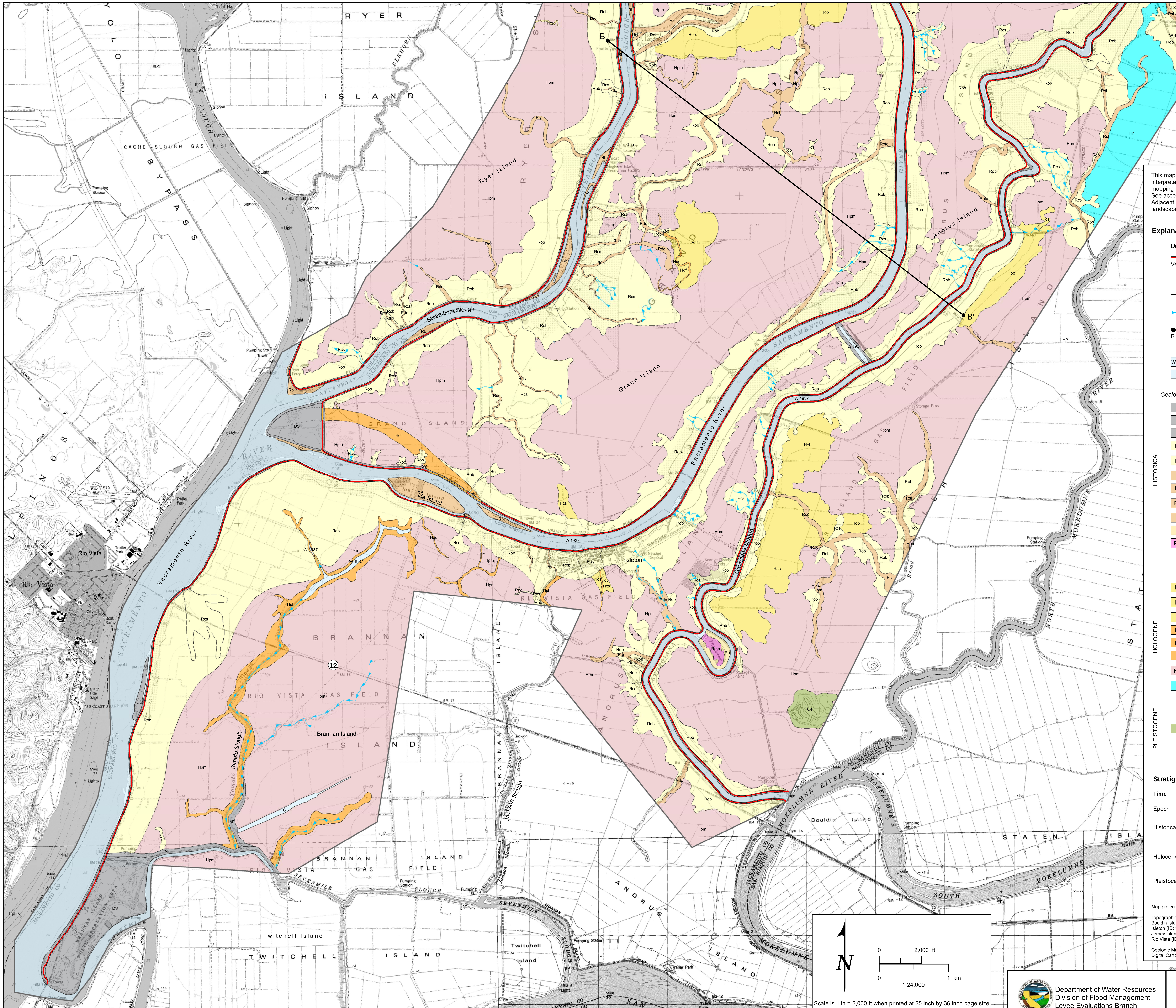


Figure 2. Proposed and Existing Geotechnical Explorations



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). 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 (not present in Plate 2) — Low (not present in this Study Area)

Geologic contact; dashed where approximate, dotted where concealed, queried where uncertain; solid contacts accurate to within about 100' on either side of line shown on map. Dashed contacts accurate to within about 250', and are generally gradational.

Narrow channel, generally <100 ft in width; dashed where approximate.

B — B' Cross section location

W 1937 — Water; date indicates year of historical dataset.

C — Canal, circa 1937.

Geologic Units

AF — Artificial fill, circa 1937.

L — Levee (made of artificial fill), circa 1937.

DS — Dredge spoils; material from channel dredging and typically hydraulically emplaced.

HISTORICAL

Rob — Overbank deposits; silt, clay, and lesser sand; 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.

Rb — Channel bar deposits; fine gravel, sand, and silt deposited in or along channel lateral margins.

Rdc — Distributary channel deposits, sand, silt, and clay; channelized flow conducting sediment to floodplain.

Rofc — Overflow channel deposits; sand, silt, and clay deposited in floodplain channels occupied primarily when high-stage water overtops channel banks and returns to river.

Rsl — Slough deposits; silt, clay, and sand, fining upward facies, low-energy channel deposits.

Ra — Alluvial deposits undifferentiated; sand, silt, and minor lenses of fine gravel.

Rpm — Tidal marsh deposits; peat and muck, interbedded peat and organic-rich silt and clay.

HOLOCENE

Hob — Overbank deposits; silt, clay, and lesser sand; 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.

Hdf — Distributary fan deposits; sand, silt and clay.

Hch — Channel deposits; poorly graded sand and trace fine gravel.

Hdc — Distributary channel deposits, sand, silt, and clay; channelized flow conducting sediment to floodplain.

Hsl — Slough deposits; silt, clay, and trace fine sand, fining upward facies, low-energy tidally or formerly tidally influenced channel deposits.

Hpm — Peat and muck; interbedded peat and organic-rich silt and clay, former tidal marsh deposits, now drained and farmed.

Hn — Basin deposits; fine sand, silt and clay.

PLEISTOCENE

Qe — Eolian deposits; poorly to moderately cemented sand and silt.

Stratigraphic Correlation Chart

Time: Epoch	Channel deposits	Floodplain and alluvial-fan deposits	Flood basin deposits	Cultural deposits
Historical	Rch, Rb, Rdc, Rofc, Rsl	Ra, Rob, Rcs	Hn, Rpm	L, AF, DS
Holocene	Hch, Hsl, Hdc	Ha, Hob, Hcs, Hdf	Hn, Hpm	
Pleistocene		Qe		

Map projection: UTM NAD83 Zone 10N

Topographic base USGS 7.5' quadrangles:
Bouldin Island (ID: 38121-A5), published 1997; map scale 1:24,000, five foot contour interval.
Isleton (ID: 38121-B5), published 1978, revised 1993; map scale 1:24,000, five foot contour interval.
Jersey Island (ID: 38121-A6), published 1978; map scale 1:24,000, five foot contour interval.
Rio Vista (ID: 38121-B6), published 1978, revised 1993; map scale 1:24,000, five foot contour interval.

Geologic Mapping by S. Dee, G. Van Etten, A. Wade
Digital Cartography by M. Ticci and J. Finley

N

0 — 2,000 ft
0 — 1 km
1:24,000

Scale is 1 in = 2,000 ft when printed at 25 inch by 36 inch page size

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS
in association with:
Fugro William Lettis & Associates, Inc.

Surficial Geologic Map of South of Courtland Study Area

NORTH NON-URBAN LEVEE EVALUATIONS

Plate 1

Sheet 2

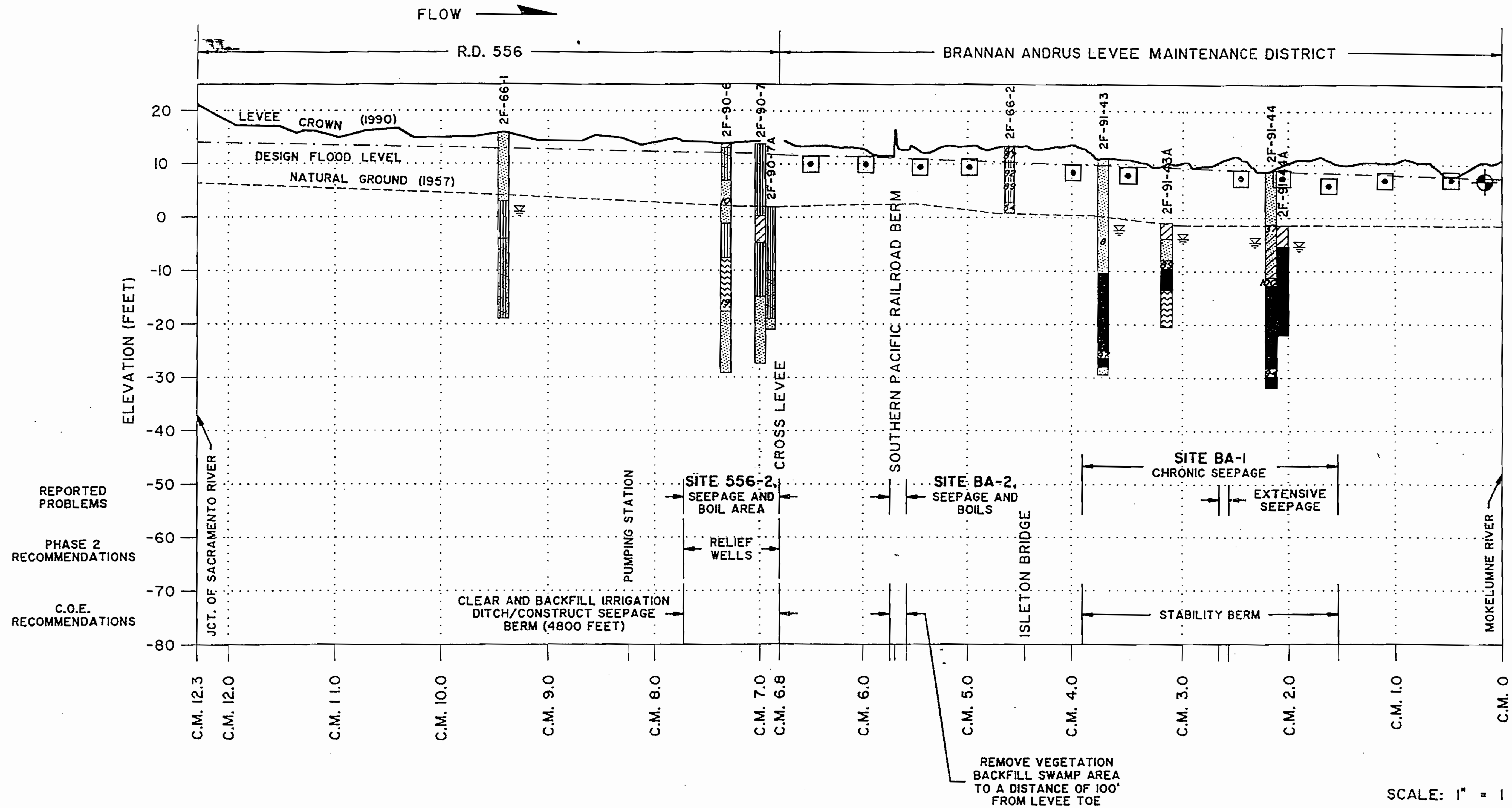
NULE Level 2-II: Group B Levees Geomorphic Assessment

1965_2_NULE_GroupB_Plate_South.mxd MGT 12/21/10

Appendix A

Historic Boring Logs

GEI Consultants



SCALE: 1" = 1 MILE

NOTES:

1. REFER TO FIGURE 6 FOR NOTES.

LEGEND

- SILT (>70% FINES)
- SILTY SAND OR SANDY SILT (12%-70% FINES)
- CLAY (>70% FINES)
- CLAYEY SAND OR SANDY CLAY (12%-70% FINES)
- SAND (<12% FINES)
- OH
- CLAY (HIGH PLASTICITY, CH)
- PEAT
- PERCENTAGE OF FINES (MINUS 200 SIEVE SIZE) PER LABORATORY TESTING

FEBRUARY 1986 HIGH WATER MARKS

- SURVEYED
- STAGE RECORDERS

SACRAMENTO RIVER
FLOOD CONTROL SYSTEM EVALUATION
LOWER SACRAMENTO AREA, PHASE IV

**LEVEE PROFILES
GEORGIANA SLOUGH
RIGHT BANK LEVEE**

SACRAMENTO DISTRICT, CORPS OF ENGINEERS

PREPARED BY: D. RICKETTS
DRAWN BY: R. IWASA
FEBRUARY 1993

GEO TECH - SOILS\R.IWASA\LSAC-F19.DWG\02-11-93

FIGURE 19

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 1 of 1
HOLE NO ND-62
ELEV ______ FEET
DEPTH 20.0 FEET

PROJECT 1992 North Delta Seepage Monitoring
FEATURE Andrus Island
LOCATION Levee toe
CONTR. PC Exploration DRILL RIG Mobile Drill B-61

DATE DRILLED 12/4/92-12/4/92
ATTITUDE Vertical
LOGGED BY G. Newmarch
DEPTH TO WATER ∇ Not Determined

AD = Hole drilled with 8" hollow-stem auger

ELEV DEPTH	LOG	WELL CONS	FIELD CLASSIFICATION AND DESCRIPTION	MODE	REMARKS
0	PT		0.0 - 4.0' PEAT: Dusky yellowish brown (10YR 2/2). Short, moderately decayed fibers. Silty and clayey. Saturated.	AD	Soft materials, rapid drilling rate 0 to 7 feet.
5	PT		4.0 - 7.0' PEAT: Olive gray (5Y 4/1). Short, moderately decayed fibers. Silty and clayey. Slight plasticity. Saturated.		
10	PT		7.0 - 16.0' PEAT: Dusky brown (5YR 2/2). Long, fresh* fibers. Saturated.		Very soft material 7 to 16 feet. Local observers would probably call this "Buckskin Peat."
15	OL		16.0 - 20.0' ORGANIC SILT: Dark greenish gray (5G 4/1). No plasticity. Saturated.		Slightly firmer material 16 to 20 feet.
20					Total Depth = 20 feet

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 1 of 3
HOLE NO. ND-63M
ELEV. ______ FEET
DEPTH 100.0 FEET

PROJECT 1992 North Delta Seepage Monitoring
FEATURE Andrus Island
LOCATION East side of island
CONTR. PC Exploration DRILL RIG Mobile Drill, B-61
DATE DRILLED 6/14/93-6/14/93
ATTITUDE Vertical
LOGGED BY G. Newmarch
DEPTH TO WATER ∇ Not Determined

AD = Hole drilled with 8" hollow-stem auger

ELEV DEPTH	LOG	WELL CONS	FIELD CLASSIFICATION AND DESCRIPTION	MODE	REMARKS
0	PT		0.0 - 19.0' PEAT: Grayish brown (5YR 3/2). Long, fresh fibers. Saturated.	AD	Soft materials, rapid drilling rate 0 to 19 feet.
15			Peat is more decayed at 15 feet. Fibers are short and moderately decayed 15 to 19 feet.		
19	OL		19.0 - 26.0' ORGANIC SILT: Olive gray (5G 3/2). No plasticity. Very soft. Saturated.		Very rapid drilling rate 19 to 25 feet.
26	SM		26.0 - 43.0' SAND: Olive gray (5G 3/2). Silty. Clayey. Medium to fine-grained. Subangular to subrounded grains. More than 50% quartz grains. Poorly graded. Moderately compacted. Saturated.		Firm materials, but rapid drilling rate 26 to 43 feet.

Depth scale: 5, 10, 15, 20, 25, 30, 35

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

SHEET 2 of 3
HOLE NO. ND-63M

DRILL HOLE LOG

PROJECT & FEATURE 1992 North Delta Seepage Monitoring

ELEV DEPTH	LOG	WELL CONS	FIELD CLASSIFICATION AND DESCRIPTION	MODE	REMARKS
			26.0 - 43.0' SAND: (Continues)	AD	
	SC		43.0 - 63.0' SAND: Olive gray (5Y 3/2). Medium-grained. Very clayey. Silty. Poorly graded. Subangular to subrounded grains. Quartz grains predominate. Well compacted. Saturated.		Firmer materials 43 to 63 feet
45					
50					
55					
60					
	CL		63.0 - 79.0' CLAY: Olive gray (5Y 3/2). Very sandy (medium-size). Low plasticity. Very soft. Saturated		Stiff materials, slower drilling rate 63 to 79 feet.
65					
70					
75					
	SC		79.0 - 88.0' SAND: Olive gray (5Y 3/2)/ Coarse-grained. Very clayey. Very compacted. Subangular to subrounded grains. Quartz grains predominate. Saturated.		Drilling rate slowed even more 79 to 88 feet. May be called "Blue Sand" by local observers.
80					
85					

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

SHEET 3 of 3

HOLE NO. ND-63M

DRILL HOLE LOG

PROJECT & FEATURE 1992 North Delta Seepage Monitoring

ELEV DEPTH	LOG	WELL CONS	FIELD CLASSIFICATION AND DESCRIPTION	MODE	REMARKS
90, 95	ML		88.0 - 97.5' SILTY SAND to SANDY SILT: Olive gray (5Y 3/2). Fine-grained. Very clayey. Slight plasticity in places. Subangular to subrounded grains. About 50% quartz grains.	AD	Softer materials, moderately rapid drilling rate 88 to 100 feet.
	CL		97.5 - 100.0' CLAY: Greenish gray (5G 6/1). Silty. Low to medium plasticity. Moderately stiff. Saturated.		Probably called "Blue Clay" by local observers
100					Total Depth = 100 feet

ba-10-dh-1 to dh-10

BORING LOCATION CROWN OF LEVEE, STA. 45 + 97			APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: NONE		DRILL CONTRACTOR PC DRILLING		TOTAL DEPTH 49.5 ft.
DRILL RIG CME-55	BORING DIA 8" HOLLOW	DATE DRILLED: 6-5-89		LOGGED BY ME

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
SM	0.0' - 7.50' SILTY SAND (LEVEE) light brown, dry to damp, Dense, trace of fine sand & gravel.	0	SP-1	13 15 15	6" / 18"	DR	30
		2	SP-2	10 7 6	10" / 18"	DR	13
			—	6 4 4	0.0" / 18"	DR	No Recovery 8
	5.0' – Traces of coarse gravel, 1/4" - 1/2"..		SP-3	6 5 5	8" / 18"	DR	10
	6.5' - Increase in moisture content.	6	SP-4 SP-5	4 3 3	18" / 18"	DR	6
SP-SW	7.5' - 8.75' SAND (LEVEE) loose, light grey, damp to moist.	8	SP-6 SP-7	4 3 3	18" / 18"	DR	6
ML	8.75' - 13.20' SANDY SILT (LEVEE) brown, moist - very moist, soft		SP-8	3 5 5	6" / 18"	DR	10
		10	—	8 8 8	0.0" / 18"	DR	No Recovery 16
	13' - 13'.2", lense of clean wet sand.	12	SP-9	4 5 6	18" / 18"	DR	11
ML	13.0' - 16.0', CLAYEY SILT (LEVEE) brown, wet, firm to stiff.	14	SP-10	5 5 6	18" / 18'	DR	11
			SP-11	4 6 6	18" / 18"	DR	
CL-CH	16.0' - 18.0', SILTY CLAY (LEVEE) brown, wet, soft to firm. @ 17.0' - becoms dark greyish.	16	SP-12	5 5 5	18" / 18"	DR	
	18.0' - 28.5' ORGANIC SILT (FOUNDATION) dark greyish, wet, soft, traces of organics.	18	SP-13	4 4 4	18" / 18"	DR	
		20	—	4,5,6	18/18	DR	

Handwritten annotations: +10.1; Not saturated; EL +2 to 3 NAVD 88; +2

Wahler Associates

ANDRUS ISLAND
SACRAMENTO, CA.

EXPLORATION BORING LOG

Project No. MBK-201D

Sheet: 1 of 3

BORING NO. DH-1

ba-10-dh-1

BORING LOCATION CROWN of LEVEE, STA. 45+99	APPROVED BY:M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER : NONE	DRILL CONTRACTOR PC DRILLING	TOTAL DEPTH 49.5'
DRILL RIG CME - 55 / BORING DIA.8"HOLLOW	DATE DRILLED:6/ 5 / 89	LOGGED BY ME

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT (Cont.) dark greyish, wet, soft to firm, trace of desiccated roots & vegetation.	20				AD	
		22	SP-14	5 5 6	18"/18"	DR	
	23.0' - Increase in organic content, becomes darker w/ depth, more fibrous.		SP-15	6 8 10	18"/18"	DR	
	26.25' - two inch lense of sand.	24	SP-16	3 4 5	18"/18"	DR	
		26	SP-17	6 9 7	10"/18"	DR	
		28	SP-18	7 7 6	18"/18"	DR	
OL	28.5' - 39.0' ORGANIC SILT Becomes dark brown, fibrous.		SP-19	5 6 8	18"/18"	DR	
		30	SP-20	6 8 10	18"/18"	DR	
	32.0' - Increase in organic content, desiccated wood & vegetation.	32	SP-21	8 10 11	18"/18"	DR	
		34	SP-27	6 8 11	18"/18"	DR	
			SP-28	9 11 13	18"/18"	DR	
		36	SP-29	9 12 13	18"/18"	DR	
		38	SP-30	5 6 7	18"/18"	DR	
OH	39.0' - 49.5' BAY MUD black,wet,soft to firm	40	SP-31	6 5 5	18"/18"	DR	

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ANDRUS ISLAND
SACRAMENTO, CA.

EXPLORATION BORING LOG		BORING NO.
Project No. MBK-210D	Sheet 2 of 3	DH-1

BORING LOCATION CROWN OF LEVEE, STA. 45 + 97	APPROVED BY : M.E.		GROUND EL: CROWN
DEPTH TO GROUND NONE	DRILL CONTRACTOR P.C. DRILLING		TOTAL DEPTH 49.5'
DRILL RIG CME-55	BORING DIA 8"HOLLOW	DATE DRILLED: 6 / 5 / 89	LOGGED BY : M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
	BAY MUD (Cont.).	40					
OH	40.5' - Color changes to light greyish.		SP-32	5 5 6	18" / 18"	DR	
		42	SP-33	4 4 5	18" / 18"	DR	
		44	SP-34	6 6 7	18" / 18"	DR	
		46	SP-35	5 6 8	18" / 18"	DR	
			SP-36	10 11 12	18" / 18"	DR	
		48	SP-37	8 9 12	18" / 18"	AD	
	Boring Terminated @ 49.5' No ground water was encountered.	50					
		52					
		54					DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.
		56					THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION. THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS.
		58					THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL. SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.
		60					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet: 3 Of 3	DH-1

Sandy levee

BORING LOCATION CROWN of LEVEE, STA. 82 + 09	APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: 15.5'	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 70.0'
DRILL RIG CME-55 / BORING DIA. 8" HOLLOW	DATE DRILLED: 6 / 5 /89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SM	0.0'-5.5' SILTY SAND, (LEVEE) very dense, damp, trace of fine gravel.	0	SP-1	11 19 20	8" / 18"	DR	
		2	SP-2	10 11 8	9" / 18"	DR	
	3.0'- 5.5' Interbedded lenses of clean sand (SP-SW), and clayey silt (ML).	4	SP-3	5 6 7	18" / 18"	DR	
			SP-4	4 3 3	18" / 18"	DR	
SP-SW	5.5' - 7.5' SAND, (LEVEE) brown, damp, loose, some trace of silt..	6	SP-5	3 4 4	18" / 18"	DR	
	7.5' - 10.0' coarse sand, dark, brown, loose, trace of fine silt. Liquefy	8	SP-6	3 4 4	18" / 18"	DR	8
			SP-7	3 3 3	18" / 18"	DR	+1 NGVD 2.6 or 3.6 NAVD (6.4') depth
CL-CH	10.0' - 13.2' SILTY CLAY, (LEVEE) brown, very moist, firm, with traces of desiccated wood, highly weathered.	10	SP-8	3 3 4	18" / 18"	DR	
		12	SP-9	3 3 3	18" / 18"	DR	10 - 15.5 = -5.5
OH	13.25' - 21.0' BAY MUD, (LEVEE) dark greyish, wet, soft, w / fine to coarse sand.	14				AD	Ground Water @ 15.5'
	15.5' - 21.0' - Interbedded lenses of clean sand.	16	SP-10	11 11 11	18" / 18"	DR	
		18				AD	
		20					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG — Project No. MBK-201D	Sheet 1 Of 4	BORING NO. DH-2

BORING LOCATION CROWN OF LEVEE, STA. 82 + 09		APPROVED BY: M.E.	GROUND EL:CROWN
DEPTH TO GROUND WATER :15.5'	DRILL CONTRACTOR P.C. DRILLING		TOTAL DEPTH 70.0'
DRILL RIG CME - 55	BORING DIA.8"HOLLOW	DATE DRILLED:6 / 4 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
	BAY MUD (Cont.)	20	SP-11	6 5 5	18" / 18"	DR	
OL	21.0' - 40.0' - ORGANIC SILT (FOUNDATION) Becomes fibrous, dark brown, moist, firm, no odor, relatively fibrous w/ desiccated wood & vegetation.	22				AD	
		24					
	26.0' - Becomes very fibrous w / depth, decreasing soil content, & weight.	26	SP-12	6 7 8	18" / 18"	DR	
		28				AD	
		30	SP-13	5 6 7	18" / 18"	DR	
		32				AD	
		34					
		36	SP-14	6 8 10	18" / 18"	DR	
		38				AD	
		40					

BORING LOCATION CROWN of LEVEE, STA. 82+09			GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL:15.5'	DRILL CONTRACTOR P.C.Drilling		TOTAL DEPTH 70.0'
DRILL RIG CME-55	BORING DIA.8", hollow	DATE DRILLED: 6 / 5 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
OH	40.0' - 70.0' BAY MUD Dark blue, wet to saturated, soft to firm.	40	SP-15	4 4 6	18" / 18"	DR	
		42					
		44				AD	
		46					
		48					
			SP-16	4 4 4	18" / 18"	DR	
		50					
		52					
		54				AD	
		56					
		58					
		60					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG Project No. MBK-201D	Sheet 3 Of 4	BORING NO. DH - 2

BORING LOCATION CROWN of LEVEE, STA. 82 + 09		GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL:15.5'	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 70.0'
DRILL RIG CME -55 / BORING DIA 8"HOLLOW	DATE DRILLED: 6 / 5 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
		60					
OH	40.0' - 70.0' BAY MUD (Cont.)						
		62					
						AD	
		64					
		66					
		68					
	Boring terminated at 70.0' Groundwater encountered at 15.5'.	70					
		72					
		74					DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.
		76					THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION.
							THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS
		78					THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL.
							SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.
		80					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 4 Of 4	DH-2

BORING LOCATION CROWN OF LEVEE, Sta. 96 + 50		APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: 8.0'		DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 50.0'
DRILL RIG CME-55	BORING DIA. 8" hollow	DATE DRILLED: 6 / 4 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
SM	0.0' - 7'-3" SILTY SAND (LEVEE) brown, dry to damp, medium dense to dense, fine sand w / some gravel, layer of silty clayey.	0	SP-1	4 9 7	6" / 18"	DR	
		2	SP-2	4 6 7	4" / 18"	DR	Sandy levee
		4	SP-3	7 3 4	4" / 18"	DR	
	4' 6" - 7' 3" increase in moisture content, increase in clay content. Becomes loose w / depth.		SP-4	2 2 2	3" / 18"	DR	
		6	SP-5	2 1 1	4" / 18"	DR	
SP	7.25' - 20.75' SAND (LEVEE) dark greyish, wet to saturated, loose, little to no fine.	8	SP-6	2 2 2	18" / 18"	DR	Groundwater Encountered @ 8.0'
		10	SP-7	3 4 5	18" / 18"	DR	
			SP-8	3 3 3	18" / 18"	DR	
		12	SP-9	3 2 2	18" / 18"	DR	
		14	SP-10	2 2 3	18" / 18"	DR	
		16	SP-11	2 3 3	18" / 18"	DR	
			SP-12	3 4 4	18" / 18"	DR	
		18	SP-13	3 4 4	18" / 18"	DR	
		20		—		AD	

Wahler Associates

ANDRUS ISLAND
SACRAMENTO, CA.

EXPLORATION BORING LOG

Project No. MBK-201D

Sheet 1 Of 3

BORING NO. DH-3

BORING LOCATION CROWN of LEVEE	APPROVED BY:M.E.	GROUND EL:CROWN
DEPTH TO GROUND WATER :8.0'	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 50.0'
DRILL RIG CME - 55 / BORING DIA.8" HOLLOW	DATE DRILLED:6 / 4 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / BEQ	REC.	MODE	REMARKS
SP	SAND (Cont.)	20	SP-14	2, 2, 3	4" / 18"	DR	
ML	20.75' - 26.0' SANDY SILT (LEVEE) dark greyish, wet, soft. 10 -20 % Fibrous.	21–22	SP-15	3, 3, 4	4" / 18"	DR	
		23	SP-16	4, 5, 6	18" / 18"	DR	
		24–26				AD	
OL	26.0' - 30.0' ORGANIC SILT (FOUNDATION) brown, very moist., firm, highly decomposed.	26–29				AD	
		29–30	SP-17	4, 6, 9	18" / 18"	AD	
OL	30.0' - 46.0' ORGANIC SILT (FOUNDATION) brown, very moist, firm, fibrous.	30–35				AD	
		35–36	SP-18	4, 7, 8	18" / 18"	DR	
		36–40				AD	

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ANDRUS ISLAND
SACRAMENTO, CA.

EXPLORATION BORING LOG

Project No. MBK-201D

Sheet 2 Of 3

BORING NO. DH - 3

BORING LOCATION CROWN OF LEVEE, STA. 96 + 50		GROUND EL:CROWN
DEPTH TO GROUND WATER 8.0'	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 50.0'
DRILL RIG CME - 55 / BORING DIA.8"HOLLOW	DATE DRILLED: 6 / 4 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/FREQ	REC.	MODE	REMARKS
OL	ORGANIC SILT (Cont.) Increase in soil content.	40	SP-19	6 8 10	18"/18"	DR	
		42					
		44				AD	
OH	46.0' - 50.0' BAY MUD light greyish, saturated, firm.	46					
		48	SP-20	9 5 5	18"/18"	DR	
	Boring Treminated @ 50.0' Groundwater Encountered @ 8.0'	50					
		52					
		54					
		56					
		58					
		60					

DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.

THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION.

THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS.

THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL.

SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG Project No. MBK-201D	Sheet 3 Of 3	BORING NO. DH - 3

BORING LOCATION CROWN of LEVEE, STA. 59 + 15		APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: 10.0'	DRILL CONTRACTOR P. C. DRILLING		TOTAL DEPTH 50.0'
DRILL RIG CME-55	BORING DIA. 8" HOLLOW	DATE DRILLED: 6 /4-5 /89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SM	0.0' - 1.0' SILTY SAND (LEVEE) brown, dry, medium dense.	0	SP-1	9 8 9	18" / 18"	DR	
SP	1.0' - 19.0' SAND (LEVEE) brown, dry, medium dense, fine grained sand.	2	SP-2	6 8 6	18" / 18"	DR	
		4	SP-3	9 9 6	4" / 18"	DR	
						AD	
		6	SP- 4	2 2 2	18" / 18"	DR	
		8	SP-5	3 4 5	18" / 18"	DR	
		10	SP-6	5 6 5	18" / 18"	DR	Groundwater Encountered @ 10.0'
	11.5' - Increase in moisture content, indications of perched water.		SP-7	6 6 5	18" / 18"	DR	Groundwater Encountered @ 11.5' at time of sampling. ✓
	12.0' - 14.25' - alternate lenses of dark greyish & yellow - brown coarse sand.	12	SP-8	3 4 6	18" / 18"	DR	
	14.25' - lense of desiccated wood, approx. 2" in thickness.	14	SP-9	4 4 6	18" / 18"	DR	
		16	SP-10	4 4 4	18" / 18"	DR	✓
			SP-11	4 4 10	18" / 18"	DR	
		18	SP-12	4 4 5	18" / 18"	DR	
OH	19.0' - 19.25' BAY MUD (LEVEE) light greyish, saturated, soft.						
OL	19.25' - ~~38.0'~~ ORGANIC SILT (FOUNDATION)	20				AD	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO. DH-4
		Project No. MBK- 201D	Sheet 1 Of 3	

BORING LOCATION CROWN of LEVEE, STA. 59+15		APPROVED BY:	GROUND EL: CROWN
DEPTH TO GROUND WATER : 10.0'		DRILL CONTRACTOR P. C.DRILLING	TOTAL DEPTH 50.0'
DRILL RIG CME - 55	BORING DIA.8"HOLLOW	DATE DRILLED:6- 4,5 - 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT (CONT.) dark brown, very moist, firm, highly fibrous.	20					
		22				AD	
		24					
			SP-13	4 6 8	18" / 18"	DR	
		26					
		28				AD	
		30	SP-14	6 6 9	18" / 18"	DR	
		32				AD	
		34					
		36	SP-15	4 5 9	18" / 18"	DR	
						AD	
		38					
OH	38.0' - 50.0' BAY MUD light greyish, wet to saturated., soft to firm		SP-16	5 5 5	18" / 18"	DR	B.O.H. @ 50.0'
		40.0					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 2 of 3	DH-4

BORING LOCATION CROWN of LEVEE. STA. 59 + 15				GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL: 10.0'	DRILL CONTRACTOR P. C. DRILLING			TOTAL DEPTH 50.0'
DRILL RIG CME - 55	BORING DIA. 8" HOLLOW	DATE DRILLED: 6 - 4,5 - 89		LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
OH	38.0' - 50.0' <u>BAY MUD</u> (Cont.) light greyish, wet to saturated, soft to firm	40					
		42					
		44				AD	
		46					
		48					
	Boring terminated at 50.0' Groundwater encountered @ 10.0' Groundwater encountered @ 11.5' at time of sampling.	50					
		52					
		54					DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.
		56					THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION. THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS.
		58					THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL. SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.
		60					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 3 of 3	DH-4

not done — 3 — Levee

BORING LOCATION TOE of LEVEE, STA. 82 +09	APPROVED BY: M.E.	GROUND EL: TOE
DEPTH TO GROUND WATER LEVEL: 10.5'	DRILL CONTRACTOR P. C. DRILLING	TOTAL DEPTH 26.5'
DRILL RIG CME-55 / BORING DIA. 8" HOLLOW	DATE DRILLED: 6 / 7 /89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SP	0.0' - 4.5' SAND (LEVEE) light greyish, dry, medium dense, trace of roots & vegetation.	0	SP-1	1 2 9	18" / 18"	DR	
		2	SP-2	8 8 9	18" / 18"	DR	
	4.0' - Trace of silt & clay in lenses.	4	SP-3	8 7 6	18" / 18"	DR	
SM	4.5' - 7.5' SILTY SAND (LEVEE) brown, very moist, dense, coarse sand w / trace of root.		SP-4	18 10 12	18" / 18"	DR	
		6	SP-5	19 17 17	6" / 18"	DR	
OL	7.5'-23.0' ORGANIC SILT (FOUNDATION) black, wet, soft to firm, increase in desiccated roots w / depth, highly decomposed, no odor.	8	SP-6	6 7 6	18" / 18"	DR	
	10.5' becomes dark brown:	10	SP-7	5 6 10	18" / 18"	DR	
			SP-8	5 8 3	18" / 18"	DR	Groundwater Encountered @ 10.5'
		12	SP-9	2 2 2	18" / 18"	DR	
		14					
		16					
		18				AD	
		20					

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ANDRUS ISLAND
SACRAMENTO, CA.

EXPLORATION BORING LOG		BORING NO.
Project No. MBK- 201D	Sheet 1 of 2	DH-5

BORING LOCATION TOE of LEVEE, STA. 82+09		APPROVED BY:M.E.	GROUND EL: TOE
DEPTH TO GROUND WATER : 10.5'	DRILL CONTRACTOR P. C. Drilling		TOTAL DEPTH 26.5
DRILL RIG CME - 55	BORING DIA. 8" hollow	DATE DRILLED:6 / 7 / 89	LOGGED BY M. E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT: (Cont.) dark brown, moist	20	SP-10	3 / 3 / 3	18" / 18"	DR	
		22				AD	
OH	23.0' - 26.5' BAY MUD dark greyish, wet to saturated,soft	24					
		26	SP-11	2 / 3 / 2	18" / 18"	DR	
	Boring terminated @ 26.5' Groundwater encountered @ 10.5' (Perched).	28					
		30					
		32					
		34					DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.
		36					THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION. THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS.
		38					THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL. SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.
		40					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO. DH-5
		Project No. MBK-201D	Sheet 2 of 2	

BORING LOCATION TOE of LEVEE , STA. 45 + 97	APPROVED BY: M.E.	GROUND EL: Toe
DEPTH TO GROUND WATER LEVEL NONE	DRILL CONTRACTOR P. C. DRILLING	TOTAL DEPTH 25.5'
DRILL RIG CME-55 / BORING DIA.8"HOLLOW	DATE DRILLED: 6 / 7 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
SM	0.0' - 1.5' SILTY SAND (LEVEE) light yellow brown, dry, dense	0	SP-1	11 15 11	18"/18"	DR	
ML	1.5' - 5.9' SANDY SILT (LEVEE) light yellow brown, damp, stiff	2	SP-2	10 9 8	18"/18"	DR	
	3.0'- Increase in moisture content, becomes very moist.	4	SP-3	11 9 9	18"/18"	DR	
			SP-4	7 7 9	6"/18"	DR	
OL	6.0' - 23'.0' ORGANIC SILT (FOUNDATION) Black, moist, firm, highly decomposed.	6	SP-5	4 7 7	18"/18"	DR	▽
		8–14				AD	
		14	SP-6	2 3 3	18"/18"	DR	✓
		16–18				AD	
		20	SP-7	4 5 5	18"/18"	DR	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG — Project No. MBK- 201D — Sheet 1 Of 2	BORING NO. DH-6

BORING LOCATION TOE of LEVEE, STA. 45+97	APPROVED BY: M.E.	GROUND EL: TOE
DEPTH TO GROUND WATER: NONE	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 25.5'
DRILL RIG CME-55 / BORING DIA. 8" HOLLOW	DATE DRILLED: 6 / 7 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT: (Cont.)	20					
		22				AD	
OH	23.0' - 25.5' BAY MUD light greyish, saturated, soft.	24	SP-8	3 3 3	18" / 18"	DR	
	Boring termined @ 25.5' No groundwater encountered.	26					
		28					
		30					
		32					
		34					
		36					
		38					
		40					

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SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG Project No. MBK-201D Sheet 2 Of 2	BORING NO. DH - 6

BORING LOCATION CROWN of LEVEE, STA. 96+50		APPROVED BY: M.E.	GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL: 18.0'		DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 48.0'
DRILL RIG CME-55	BORING DIA: 8"HOLLOW	DATE DRILL 6 / 8 / 89	LOGGED M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
SM	0.0' - 6.0' SILTY SAND (LEVEE) light brown, moist	0				AD	Shelby Sampler
		2	SP-1	—	24"/24"	DR	
		4				AD	
SP	6.0' - 20.0' SAND (LEVEE) light brown, very moist.	6	SP-2	—	10"/24"	DR	
		8–18				AD	Groundwater encountered @ 18.0'
		20	S-3	—	23"/24"	DR	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 1 Of 3	DH-7

BORING LOCATION CROWN of LEVEE, STA. 96 + 50	APPROVED BY: M.E.	GROUND EL:CROWN
DEPTH TO GROUND WATER :18.0'	DRILL CONTRACTOR PC DRILLING	TOTAL DEPTH48.0'
DRILL RIG CME - 55 / BORING DIA. 8",hollow	DATE DRILLED:6 / 8 / 89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
ML	20.0' - 26.0' SANDY SILT (LEVEE) dark brown, to dark greyish, very moist to wet.	20	S-3	—	24" / 24"	DR	Shelby Sampling
		22				AD	
		24					
		26	S-4	—	24" / 24"	DR	
OL	26.0' - 45.0' ORGANIC SILT (Foundation) light brown, very moist, highly fibrous dessicated roots and vegetation.	28					
		30					
		32				AD	
		34					
		36					
		38					
		40					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet: 2 Of 3	DH-7

BORING LOCATION CROWN of LEVEE, STA. 96 +50		GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL: 18.0	DRILL CONTRACTOR P C DRILLING	TOTAL DEPTH 48.0'
DRILL RIG CME - 55 / BORING DIA.8",hollow	DATE DRILLED: 6 / 8 / 89	LOGGED BY M. E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT :(CONT.)	40					Shelby Sampling
		42				AD	
		44					
			S-5	—	24" / 24"	DR	
OH	45.0' - 48.0' BAY MUD light greyish, wet	46					
			S-6	—	24" / 24"	DR	
	Boring Terminated @ 48.0'. Groundwater Encountered at 18.0'.	48					
		50					
		52					
		54					
		56					
		58					
		60					

DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.

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SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.

Wahler Associates	ANDRUS HARBOR SACRAMENTO,CA.	EXPLORATION BORING LOG Project No. MBK-201D	Sheet 3 Of 3	BORING NO. DH-7

BORING LOCATION TOE of LEVEE, STA. 82 + 09			APPROVED BY:M.E.				GROUND EL:TOE
DEPTH TO GROUND WATER LEVEL:NONE		DRILL CONTRACTOR PC DRILLING					TOTAL DEPTH 26.0'
DRILL RIG CME - 55	BORING DIA: 8", hollow	DATE DRILL 6/8/89					LOGGED M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
SP	0.0' - 7.0' SAND (LEVEE) light brown,dry to damp, fine to coarse gravel.	0		—		AD	
		2	S-1	—	20"/24"	DR	
	Piece of grey plastic was recovered.	4	S-2	—	8"/24"	DR	
		6	S-3	—	22"/24"	DR	
OL	7.0' - 26.0' ORGANIC SILT (FOUNDATION) black, very moist to wet, highly decomposed .						
		8	S-4	—	12"/24"	DR	
		10				AD	
		12					
	14.0' - Becomes dark brown, highly fibrous	14	S-5	—	20"/24"	DR	
		16				AD	
		18					
		20					

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 1 Of 2	DH-8

BORING LOCATION TOE of LEVEE, STA.82 + 09	APPROVED BY:M.E.	GROUND EL: TOE
DEPTH TO GROUND WATER : NONE	DRILL CONTRACTOR PC DRILLING	TOTAL DEPTH 26.0'
DRILL RIG CME - 55 / BORING DIA. 8"HOLLOW	DATE DRILLED: 6/8/89	LOGGED BY:M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT (Continues)	20				AD	
		22	S-6		12" / 24"	DR	
		24	S-7		0" / 24"	DR	
OH	25.5' - 26.0' BAY MUD greyish, wet.						
	Boring terminated at 26.0' No groundwater encountered.	26					
		28					
		30					
		32					
		34					
		36					
		38					
		40					

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Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 2 Of 2	DH-8

BORING LOCATION CROWN of LEVEE, STA. 30+55	APPROVED BY: M.E.	GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: NONE	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 43.0'
DRILL RIG CME-55 / BORING DIA: 8"	DATE DRILL 6/19/89	LOGGED M.E.

Elev 10.0

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SM	0.0' - 2.0' SILTY SAND (LEVEE) light brown, dry, dense, trace of coarse gravel.	0	SP-1	11 14 18	18"/18"	DR	
ML	2.0' - 16.0' SANDY SILT (LEVEE) brown, med. dense, with fine gravel and fine sand.	2	SP-2	13 17 21	18"/18"	DR	
		4	SP-3	11 7 7	18"/18"	DR	
	4.5' - increase in moisture, increase in silt content.		SP-4	3 1 2	18"/18"	DR	
		6	SP-5	3 3 5	18"/18"	DR	∇
		8	SP-6	4 4 6	18"/18"	DR	∇
		10	SP-7	4 6 6	18"/18"	DR	
			SP-8	6 6 6	18"/18"	DR	
		12	SP-9	4 4 6	18"/18"	DR	
		14	SP-10	6 7 8	18"/18"	DR	
			SP-11	4 4 4	18"/18"	DR	
OH	16.0' - 21.5' BAY MUD (LEVEE) dark gray, wet to satrated, soft, reworked Bay Mud.	16	SP-12	4 5 6	18"/18"	DR	∇
		18	SP-13	5 4 4	18"/18"	DR	
		20				AD	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG — Project No. MBK-201D	Sheet 1 of 3	BORING NO. DH-9

BORING LOCATION CROWN of LEVEE, STA. 30 + 55	APPROVED BY:M.E.	GROUND EL: Crown
DEPTH TO GROUND WATER : NONE	DRILL CONTRACTOR PC DRILLING	TOTAL DEPTH 43.0'
DRILL RIG CME - 55 / BORING DIA. 8", hollow	DATE DRILLED:6/19/89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
		20	SP-14	5 / 5 / 5	24" / 24"	DR	
OL	21.25' - 41.5' ORGANIC SILT (Foundation) dark gray, sat., soft, with desicated wood, highly decomposed peat.	22	S-1	—	30" / 36"	DR	
		24–28				AD	
	28.0' - Becomes Fibrous Increas in organic content, 90-95%	28					
		30	S-2	—	30" / 36"		
		32–34				AD	
	36.0' - Becomes dark brown, decrease in organic content.	36	S-3	—	30" / 36"	DR	
		38–40				AD	

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EXPLORATION BORING LOG		BORING NO.
Project No. MBK-201D	Sheet 2 Of 3	DH - 9

BORING LOCATION CROWN of LEVEE, STA. 30 + 55		GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL:NONE	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 43.0'
DRILL RIG CME-55 / BORING DIA.8"HOLLOW	DATE DRILLED: 6 / 19 /89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT (Cont.)	40					
OH	41.5' - 43.0' BAY MUD dark gray, sat., soft.	42	S-4	—	30"/36"	DR	
	Boring Terminated @ 43.0'. No groundwater encountered.	44					
		46					
		48					
		50					
		52					
		54					
		56					
		58					
		60					

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Wahler Associates	ANDRUS ISLAND SACRAMENTO,CA.	EXPLORATION BORING LOG Project No. MBK- 201D Sheet: 3 Of 3	BORING NO. DH-9

BORING LOCATION CROWN of LEVEE, STA. 111 + 20	APPROVED BY:M.E.	GROUND EL:CROWN
DEPTH TO GROUND WATER LEVEL:14.5'	DRILL CONTRACTOR P.C. DRILLING	TOTAL DEPTH 41.0'
DRILL RIG CME - 55 / BORING DIA: 8"HOLLOW	DATE DRILL6 19 /89	LOGGED M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
SP-SW	0.0' - 8.5' - SAND (LEVEE) light brown, damp, dense, fine to coarse grained sand, lenses of silty sand.	0	SP-1	13 10 14	18" / 18"	DR	
		2	SP-2	10 13 13	18" / 18"	DR	
		4	SP-3	3 4 6	18" / 18"	DR	
			SP-4	4 4 5	18" / 18"	DR	
		6	SP-5	3 3 3	18" / 18"	DR	▽
		8	SP-6	3 4 6	18" / 18"	DR	
ML	8.5' - 14.25' SANDY SILT (LEVEE) brown, very moist, firm, trace of water significant increase in moisture content.	10	SP-7	3 4 5	18" / 18"	DR	
			SP-8	3 5 6	18" / 18"	DR	
	12.0' - Interbedded lenses of sand & silt. 13.0' - Increase in silt content & moisture.	12	SP-9	3 2 2	18" / 18"	DR	
		14	SP-10	3 4 5	18" / 18"	DR	
OH	14.25' - 17.90' - BAY MUD (LEVEE) light to dark greyish, wet to saturated, soft, reworked Bay Mud.	16	SP-11	3 3 3	18" / 18"	DR	Groundwater encountered @ 14.5'
			SP-12	3 5 5	18" / 18"	DR	
OL	17.90' - 37.0' ORGANIC SILT (FOUNDATION) dark greyish, wet, soft, highly decomposed.	18 – 20				AD	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 1 Of 3	DH-10

BORING LOCATION CROWN of LEVEE, STA. 111 + 20		APPROVED BY:M.E.	GROUND EL:CROWN
DEPTH TO GROUND WATER :14.5'	DRILL CONTRACTOR P.C. Drilling		TOTAL DEPTH 41.0'
DRILL RIG CME - 55	BORING DIA8"HOLLOW	DATE DRILLED:6 / 19 /89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR/REQ	REC.	MODE	REMARKS
OL	ORGANIC SILT: (Continues) 20.0' - Becomes fibrous	20				AD	
		22					
		24	SP-13	3 4 6	18" / 18"	DR	
		26				AD	
	28.5' - Becomes highly fibrous.	28	SP-14	4 5 6	18" / 18"	DR	
		30				AD	
		32					
		34	SP-15	3 5 6	18" / 18"	DR	
		36				AD	
OH	37.0' - 41.0' BAY MUD dark grey, saturated, soft to firm.	38	SP-16	4 4 5	18" / 18"	DR	
		40				AD	

Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 2 Of 3	DH-10

BORING LOCATION CROWN of LEVEE, STA. 111 + 20		GROUND EL: CROWN
DEPTH TO GROUND WATER LEVEL: 14.5'	DRILL CONTRACTOR P.C.DRILLING	TOTAL DEPTH 41.0'
DRILL RIG CME - 55	BORING DIA. 8" HOLLOW / DATE DRILLED: 6 / 19 /89	LOGGED BY M.E.

SOIL CLASS	DESCRIPTION	DEPTH	SAMPLE NO.	PR / REQ	REC.	MODE	REMARKS
OH	37.0'-41.0' BAY MUD (Continues)	40	SP-17	4 5 5	—	DR	
	Boring terminated @ 41.0' Groundwater encountered at 14.5'.	42					
		44					
		46					
		48					
		50					
		52					
		54					
		56					
		58					
		60					

DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.

THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION.

THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS.

THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL.

SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.

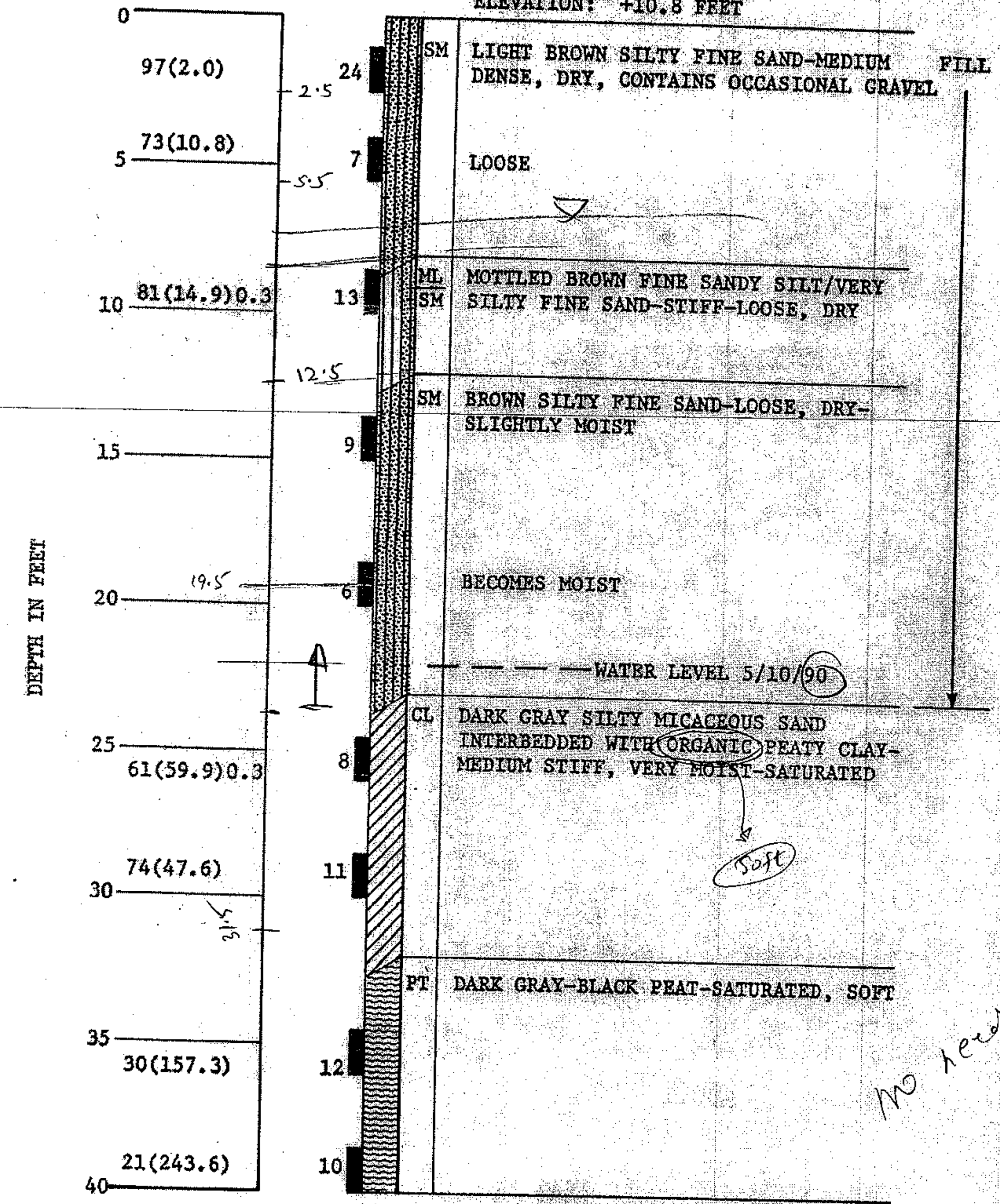
Wahler Associates	ANDRUS ISLAND SACRAMENTO, CA.	EXPLORATION BORING LOG		BORING NO.
		Project No. MBK-201D	Sheet 3 Of 3	DH-10

ba-lp-90-1

(80)

BORING 1

DRILLED: 5/10/90
ELEVATION: +10.8 FEET



ba-lP-90-B-1 to B-4

NOTES:
1. THE BORING LOG DEPICTS SUBSURFACE CONDITIONS ONLY AT THE BORING LOCATION AND TIME DESIGNATED.
2. SEE NOTES ON PLATE 3.

PROJECT NUMBER: 569-001
PLATE NUMBER: 2
[illegible] BY: DATE:
CHECKED BY: DATE:

LOG OF BORING

Raney Geotechnical

PLATE 2

GEOLOGY

DIST.	COUNTY	ROUTE	POST MILE—TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
10	Sac,S.J.	12	5.7/5.8, 0.0/0.1	1	70

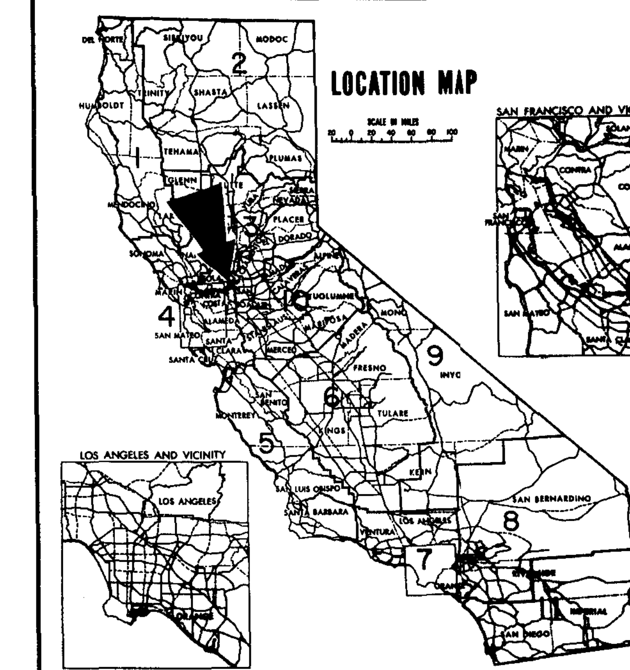
BRF-012(1)

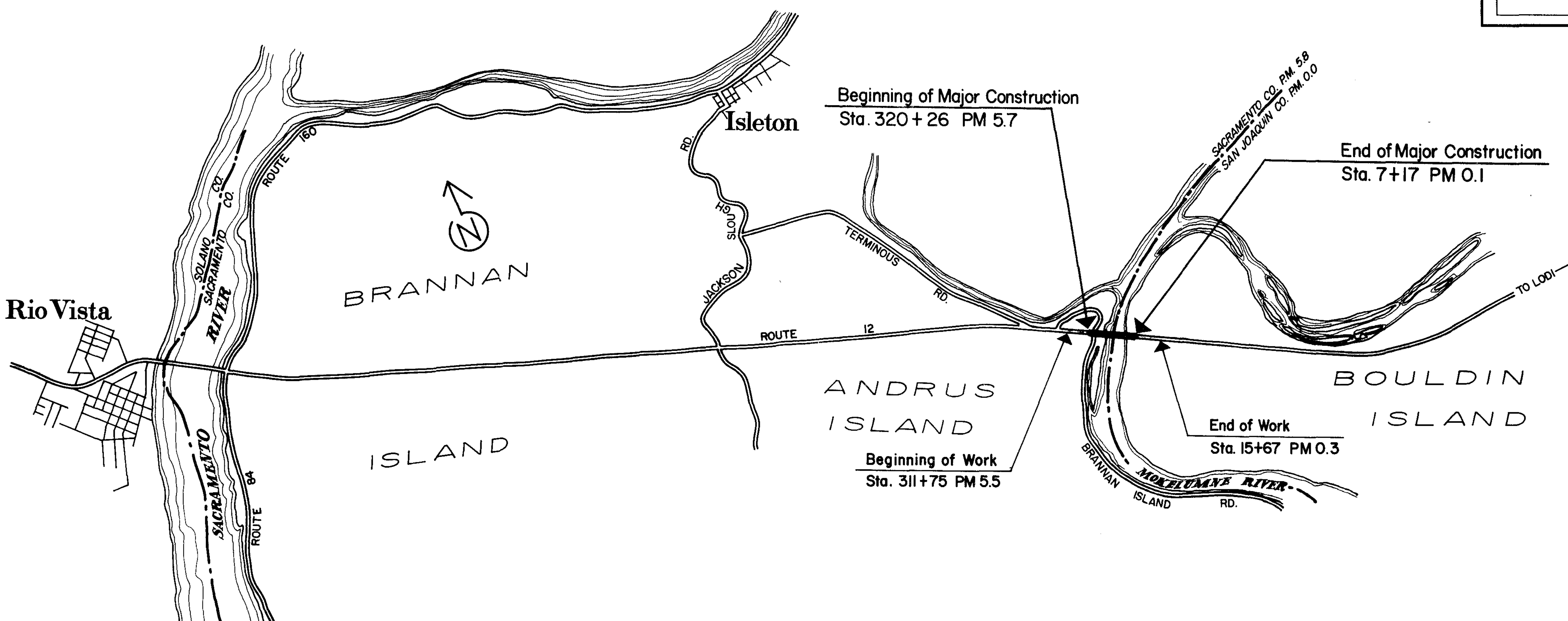
STATE OF CALIFORNIA
BUSINESS AND TRANSPORTATION AGENCY
DEPARTMENT OF TRANSPORTATION

PROJECT PLANS FOR CONSTRUCTION ON
STATE HIGHWAY

IN SACRAMENTO AND SAN JOAQUIN COUNTIES ABOUT 6 MILES
EAST OF RIO VISTA AT MOKELUMNE RIVER BRIDGE

To be supplemented by Standard Plans dated January 1975





REDUCED PLAN
USE SCALE BELOW
0 1 2 3
3 INCHES ON ORIGINAL PLAN

SCALE
1/2 0 1 Mile
1000 0 1000 2000 3000 4000 5000 6000 7000 Feet

Length of Work = 0.6 mile
Length of Major Construction = 0.3 mile

The detailed plans are a portion of the route for the State Highway

District Engineer
Registered Civil Engineer No. 9109

Approved August 16, 1976

Chief, Project Development Division
Registered Civil Engineer No. 9532

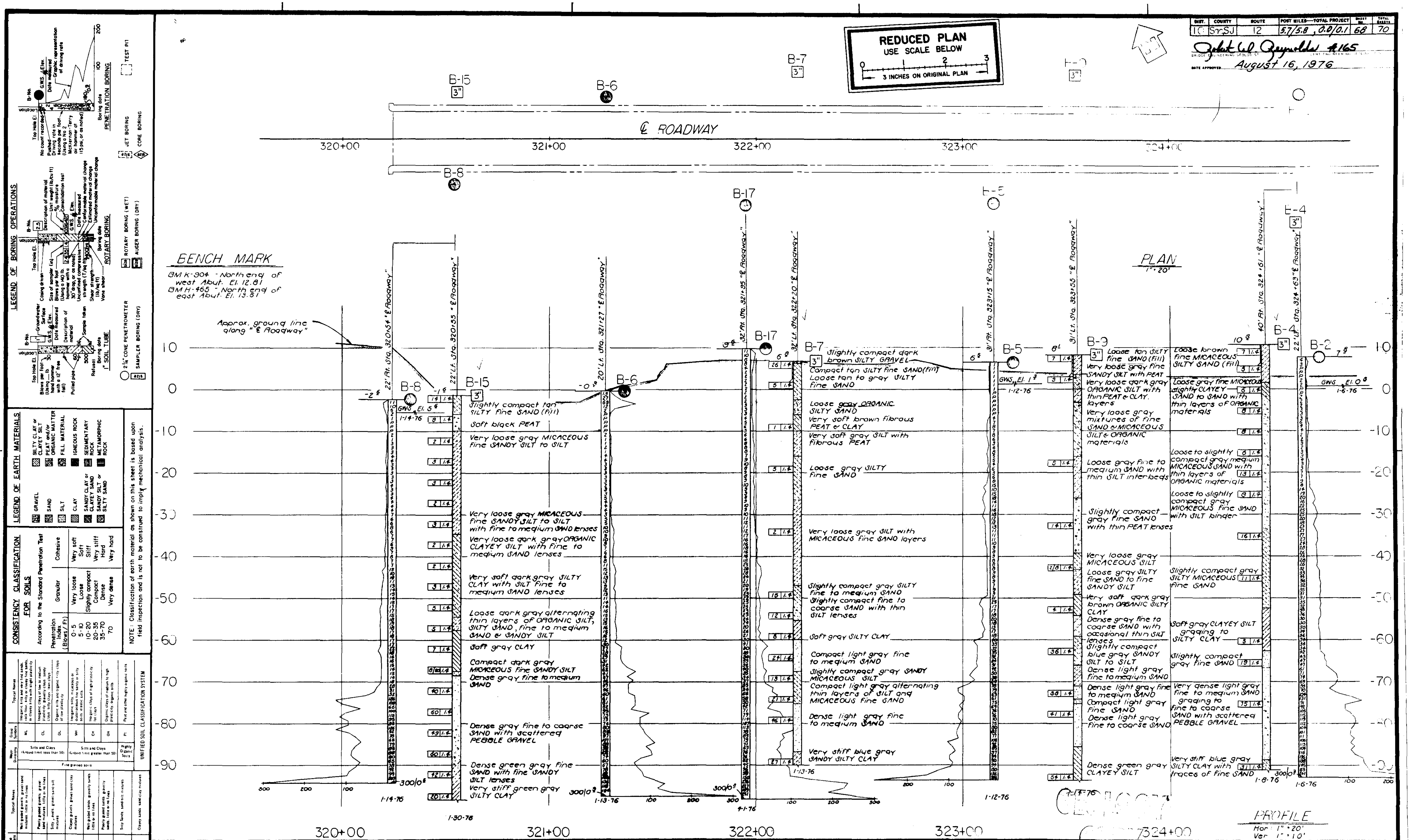
Project Engineer	Date	Design Engineer	Date	Approval Recommended by	Date
			7/14/76		7/14/76

Drawn by	Date
Checked by	Date

Contract No. 10-230304

10203-230301

Form No. HD-33-PP



ENGINEERING GEOLOGY SECTION		
FIELD STUDY	G.G. Miller	1/76
DRAWN	ED FONG	2/76
CHECKED	B. Fox	3-29-76

Approval Recommended By: George G. Miller
CERTIFIED ENGINEERING GEOLOGIST NUMBER 632

State of CALIFORNIA
DEPARTMENT OF TRANSPORTATION

OFFICE OF STRUCTURES DESIGN GROUP
PROJECT ENGINEER: C. E. Pearson 7/27/76

BRIDGE NO. 29-43
POST MILE 5.8/0.0

MOKELUMNE RIVER
LOG OF TEST BORINGS 1 OF 2

DIST.	COUNTY	ROUTE	POST MILES—TOTAL PROJECT	SHEET No.	TOTAL SHEETS
10	Sac, SJ	12	5.7/5.8, 0.0/0.1	68	70

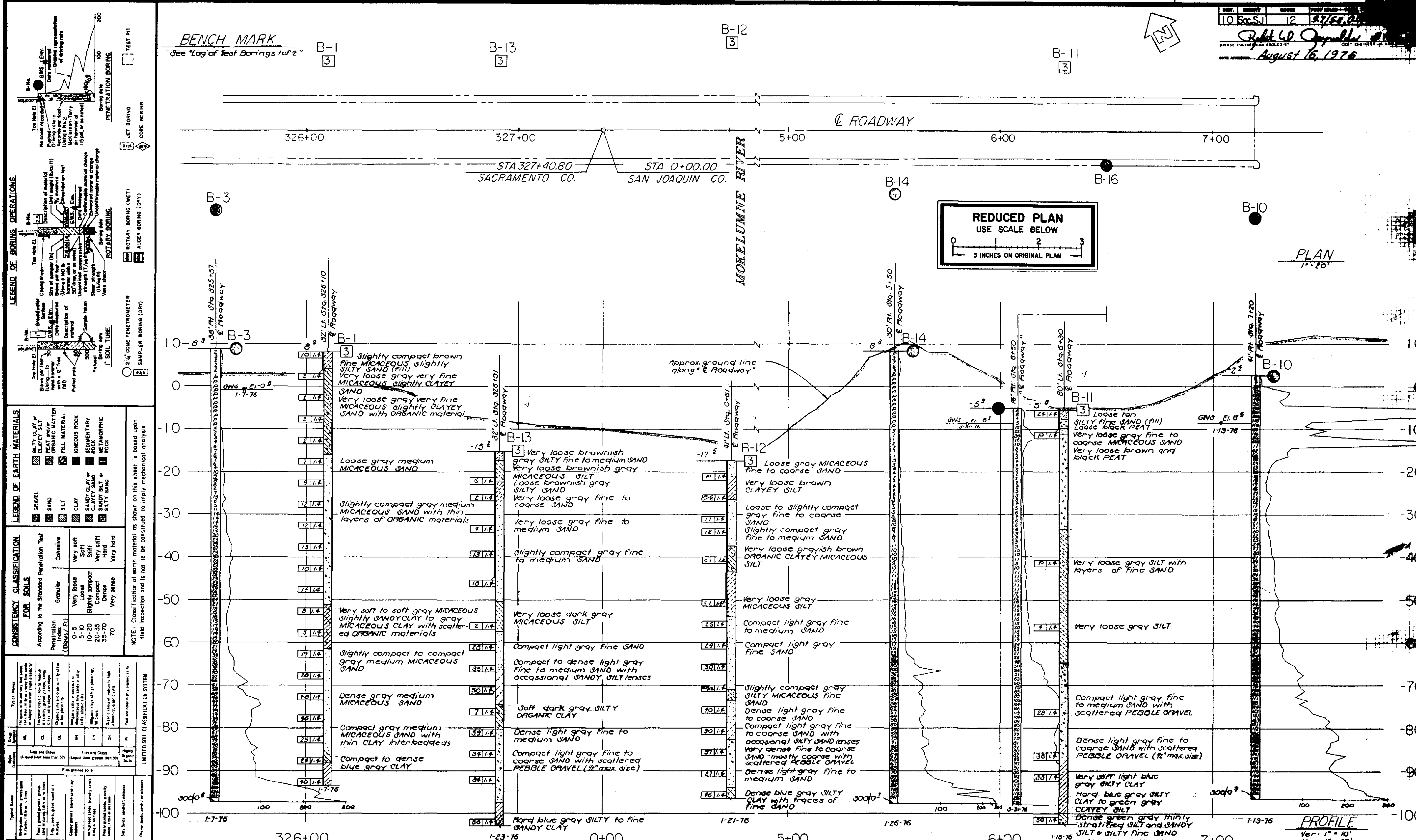
ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

CU 10203
WO 230301

Disregard prints bearing earlier revision dates
REVISION DATES (PRELIMINARY STAGE ONLY) 9/9/76

SHEET 59 OF 60

68



69

ENGINEERING GEOLOGY SECTION		State of CALIFORNIA DEPARTMENT OF TRANSPORTATION	OFFICE OF STRUCTURES DESIGN GROUP
FIELD STUDY	1/76		BRIDGE NO. 29-43
DRAWN	ED FONG 2/76		POST MILE 5.8/0.0
CHECKED	3-29-76	CERTIFIED ENGINEERING GEOLOGIST NUMBER 632	PROJECT ENGINEER

MOKELUMNE RIVER

LOG OF TEST BORINGS 2 OF 2

CU 10203
WO 230301

10 Sac.SJ 12

August 16, 1976

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS

Disregard prints bearing earlier revision dates

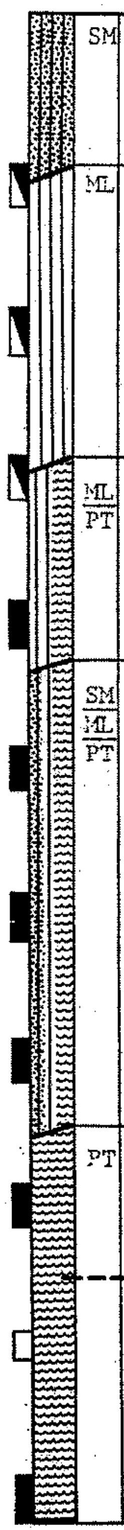
60 60

Ja-IP-87-B3

BORING 3

DRILLED: 10/7/87
ELEVATION: +7.6 ± FEET

DEPTH IN FEET



Depth (ft)	Lab data	Blows	Symbol	Description
0			SM	BROWN SILTY MEDIUM TO COARSE SAND - MEDIUM DENSE
5		2	ML	GRAY SLIGHTLY CLAYEY FINE SANDY SILT - VERY SOFT
10		3		GRADING WITH SOME ORGANIC INCLUSIONS
15		2	ML/PT	GRAY-BROWN CLAYEY FINE SANDY SILT WITH PEAT INCLUSIONS - VERY SOFT
				GRADING WITH MORE SAND
20		2		
			SM/ML/PT	BLUE-GRAY CLAYEY SILTY FINE SAND WITH PEAT INCLUSIONS - LOOSE
25	53(64.1)	6		PEAT (PT) LENSES
30	54(70.8)	3		GRADING WITH MORE SILT AND LESS SAND
35	29(16.1)	6		ODOROUS
			PT	BROWN FIBROUS PEAT - SOFT
40	21(23.2)	6		
				WATER LEVEL 10/7/87
45				
50	64(56.2) 89(31.7)	10		GRADING SANDY
55				

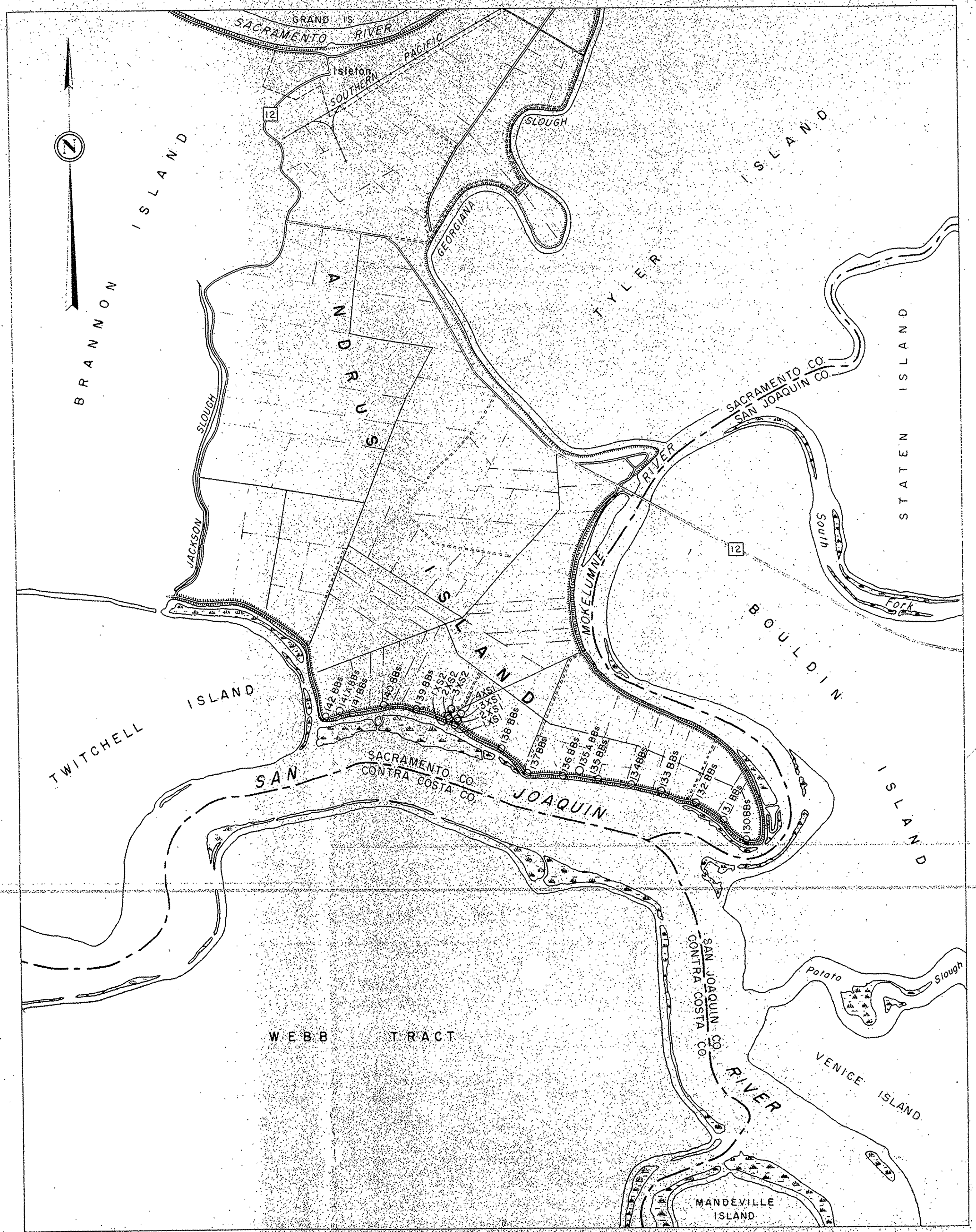
NOTES:
1. THE BORING LOG DEPICTS SUBSURFACE CONDITIONS ONLY AT THE BORING LOCATION AND TIME DESIGNATED.
2. SEE NOTES ON PLATES 3 AND 4.

LOG OF BORING

Raney Geotechnical

PLATE NUMBER: 5 CHECKED BY: DATE: 11/3/87

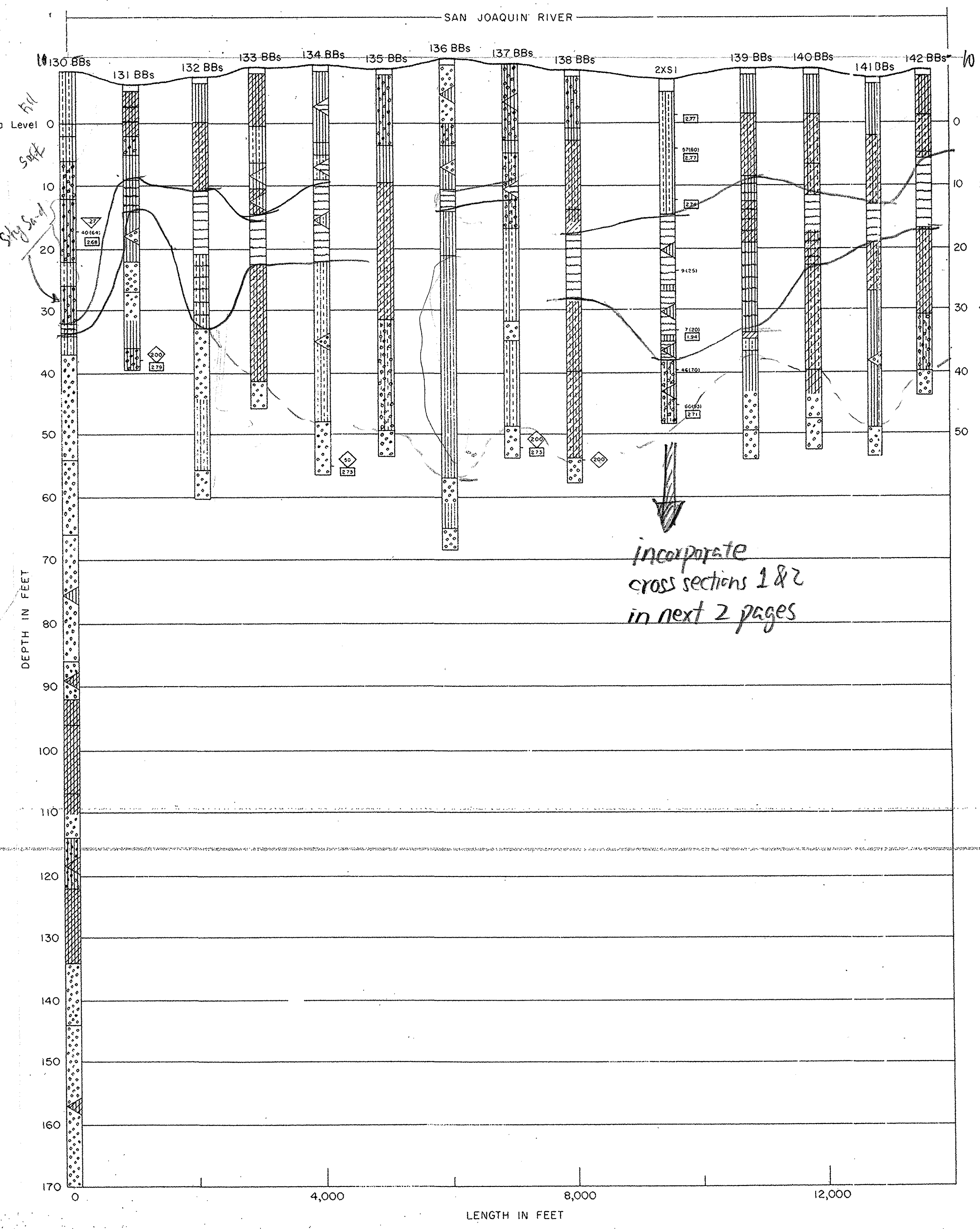
683

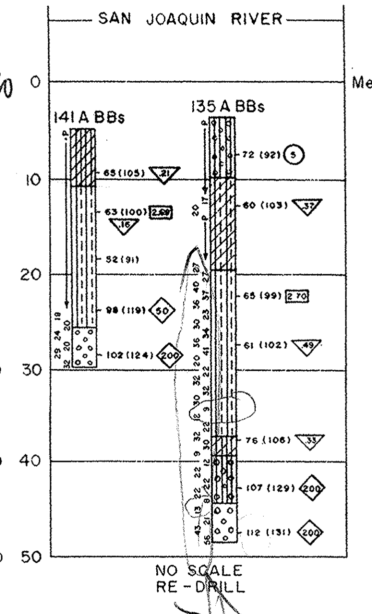


PLAN

SCALE OF FEET

2000 0 2000 4000





NOTES:

GRAPHIC LOGS ARE BASED ON VISUAL CLASSIFICATION
HOLES 130 TO 142 ARE TWO INCH DIAMETER
HOLES 141 A AND 135 A ARE ONE INCH DIAMETER
HOLES 130 TO 142 ARE LOCATED ON LEVEE CROWN
HOLES 141 A AND 135 A ARE LOCATED ON LEVEE BACKSLOPE
HAMMER WEIGHT:
2" HOLES - 135 LBS
1" HOLES - 100 LBS
DRILLING DATES:
2" HOLES APRIL 9, 1956 TO APRIL 25, 1956
1" HOLES - JULY 23, 1958

LEGEND

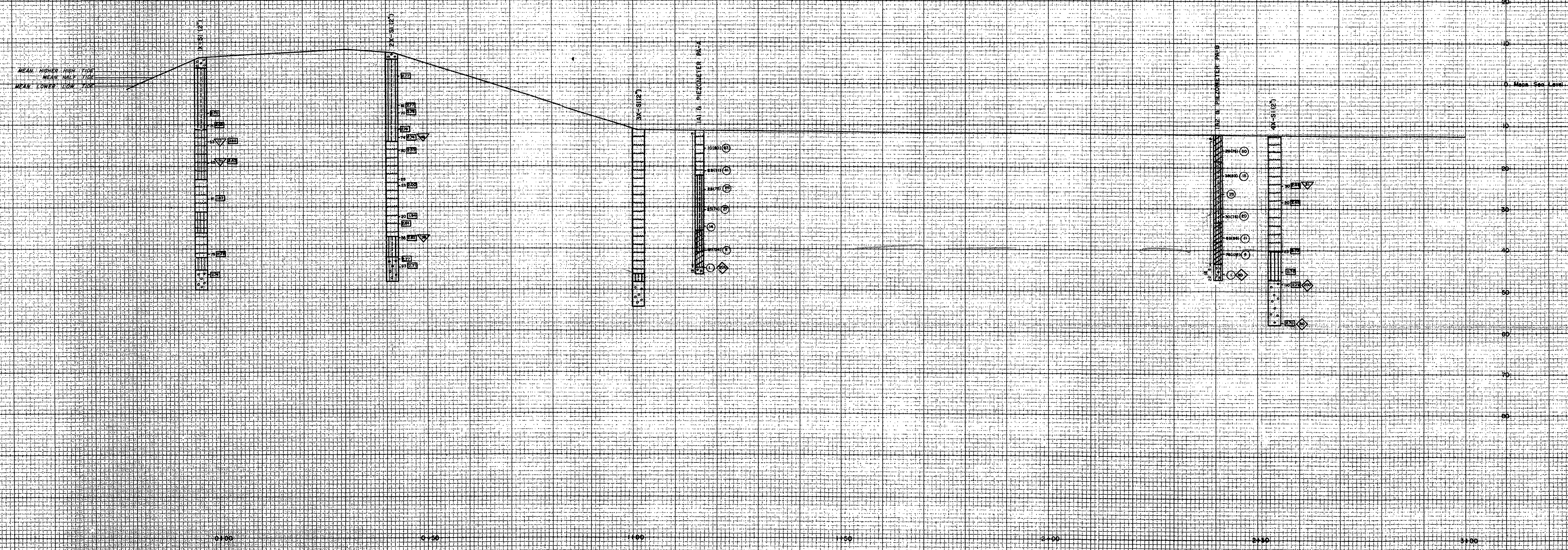
- 66(105) DRY (WET) DENSITY IN POUNDS PER CUBIC FOOT.
- BLOWS PER FOOT (P INDICATES PUSH)
- UNCONFINED COMPRESSIVE STRENGTH, K_c Kg/cm^2
- UNCONFINED COMPRESSIVE STRESS AT 10% STRAIN, S_{10} Kg/cm^2
- LOSS ON IGNITION IN PERCENT.
- MAXIMUM SIEVE SIZE RETAINING 50% OF SAMPLE BY WEIGHT D_{50}
- 2.68 SPECIFIC GRAVITY
- SAND
- SILT
- ORGANIC SILT
- CLAY
- ORGANIC CLAY
- PEAT
- COMPOSITE OF THE ABOVE MATERIAL - MAJOR CONSTITUENT DESIGNATED BY HEAVIER WEIGHT LINES OR CIRCLES; MINOR CONSTITUENTS BY LIGHTER WEIGHT LINES OR CIRCLES. BLOCK SHOWN IS CLAYEY SILT, ONE OF MANY POSSIBLE COMBINATIONS
- STREAKS OF ONE MATERIAL IN ANOTHER; SAND WITH SILT STREAK.
- LAYERS OF MATERIALS; LAYERS OF CLAY AND SILT.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SALINITY CONTROL BARRIER INVESTIGATION

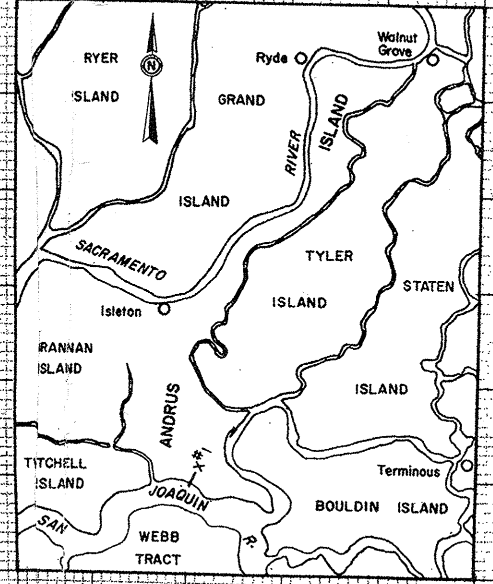
PRIMARY SUBSURFACE EXPLORATION ON ANDRUS ISLAND

PLAN AND PROFILE OF BORINGS

SCALE AS SHOWN



NOTES:
GRAPHIC LOGS ARE BASED ON VISUAL CLASSIFICATION
ALL BORINGS ARE ONE INCH DIAMETER EXCEPT WHERE NOTED
HAMMER WEIGHT: 1" HOLES- 140 LBS.
2" HOLES- 350 LBS.
DRILLING DATES: 1" HOLES- APRIL 26, 1957
2" HOLES- APRIL 19, 1957 TO APRIL 24, 1956



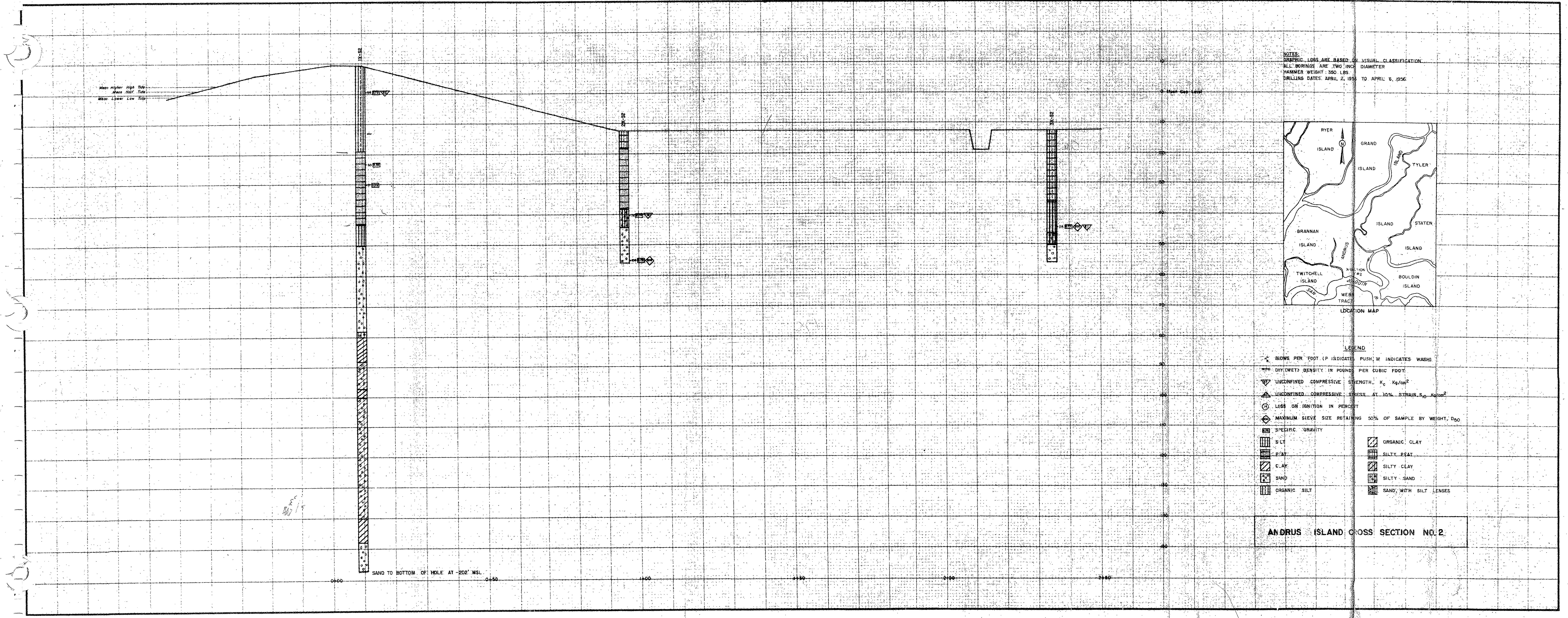
LOCATION MAP

LEGEND

BLOWS PER FOOT (P INDICATES PUSH, W INDICATES WASH)
DRY (W) DENSITY IN POUNDS PER CUBIC FOOT
UNCONFINED COMPRESSIVE STRENGTH, K_c Kg/cm^2
UNCONFINED COMPRESSIVE STRESS AT 10% STRAIN S_{10} Kg/cm^2
LOSS IGNITION IN PERCENT
MAXIMUM SIEVE SIZE RETAINING 50% OF SAMPLE BY WEIGHT, D_{50}
SPECIFIC GRAVITY

SILT	ORGANIC CLAY
PEAT	SILTY PEAT
CLAY	SILTY CLAY
SAND	SILTY SAND
ORGANIC SILT	SAND, WITH SILT LENSES

ANDRUS ISLAND CROSS SECTION NO. 1



ANDRUS ISLAND CROSS SECTION NO. 2

KLEINFELDER

BRA-AND-ISL-B-1

BRANNAN-ANDRUS ISLAND

BORING 1

Approximate Surface Elevation +4' U. S. G
Mean Sea Level Datum

Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *
0			
5	97	12	22
10	83	22	6
15	76	45	Push
20	76	44	Push
25	77	42	Push
30	46	89	Push
			Push
35			Push
			Push
40	31	137	Push

Description

SM Brown Silty Fine Sandy Fill. (Moderately Compact) New Fil

GM Thin Layer of Sandy Gravel.

SM/ML Alternate Layers of Brown and Ta Very Fine Sandy Silt and Silty Very Fine Sand with Lenses of Ta Silty Clay. (Dry and Moderately Compact)

SP/SM/ML Grades with Layers of Clean Grey and Tan Fine Sand and Clayey Sil (Soft and Loose)

ML Grades More Silty.

ML Greenish-Grey Clayey Silt with F Very Thin Lenses of Very Silty Very Fine Sand, Very Fine Sandy Silt and Very Silty Clay with Minor Vegetation. (Soft)

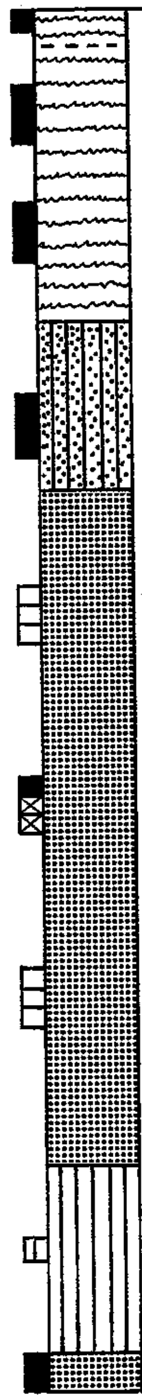
(Grades Medium-Stiff)

PT Black Fibrous Clayey Peat. (Sti

LOG OF BORING

BORING 1
(CONTINUED)

Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *
40			
	46	87	Push
45	42	102	Push
			Push
50	103	23	Push
			—
55			
			3/6"
60			7
65			8
70			
			62/8"
75			
80			



Description

(Grades Medium-Stiff, Color to Dark-Grey)

SM Bluish-Grey Silty Fine Sand wit Minor Vegetation. (Medium-Dense)

SP Bluish-Grey Slightly Silty Fine Sand. (Loose)

ML Greenish-Grey Very Fine Sandy Clayey Silt.

SP Greenish-Grey Fine Sand with so Medium Sizes and Silt. (Very De

BORING TERMINATED AT 76.0-FOOT DEPT

NOTES:

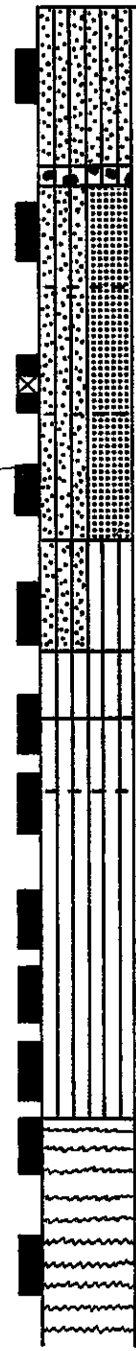
1. Boring Drilled on 9-19-77.
2. No Caving Noted.
3. Ground Water Encountered on 12-21-77, at Approximately 9'4"
4. The Lines Indicating the Transition Between Different Soil Types Represent Approximat Boundaries. The Transition May Be Gradual.

BORING 2

Approximate Surface Elevation +5' U.S.(
Description Mean Sea Level Datum

Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *
103	8	33
84	6	20
82	6	6
80	20	5
88	20	5
82	38	Push
76	43	Push
73	48	Push
		Push
77	41	Push
38	112	Push

Depth In Feet: 0, 5, 10, 15, 20, 25, 30, 35



SM Tan Slightly Silty Fine Sand with Lenses of Clean Fine Sand. (Compact) N F

GM Thin Layer of Sandy Gravel.

SM SP Alternate Layers Grey-White and Brown and Tan Colored Clean and Silty Fine Sand. (Moderately Compact)
(Grades Poorly Compact)

(Grades with Lenses and Balls of Grey-Tan Clayey Silt)

SM ML Alternate Layers of Greyish Brov Silty Fine Sand and Grey-Tan Fi Clayey Silt and Silty Clay.

ML Tan Clayey Silt. (Medium-Stiff)

ML Greenish-Grey Silt with Minor Very Fine Sand and Clay with Seams of Sand and Minor Vegetati (Soft to Medium-Stiff)
(Grades Primarily to Clayey Silt

PT Black Fibrous Clayey Peat.

LOG OF BORING

BORING 2
(CONTINUED)

Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *		Description
35			Push		
					(Color to Dark-Grey)
40	29	161	Push		
45			Push		
50	39	112	7		
				OH	Dark-Grey Organic Silty Clay. (Medium-Stiff)
55				SM	Greenish-Grey Very Silty Fine Sand.
				SP/SM	Alternate Layers of Greenish-Grey Slightly Silty and Silty Fine Sand. (Medium-Dense)
			15		
60					
			16		
65					
			18	CL	Greenish-Grey Very Silty Clay. (Very-Stiff)
70					

BORING TERMINATED AT 69.5-FOOT DEPTH

NOTES:

1. Boring Drilled on 9-20-77.
2. No Caving Noted.
3. Ground Water Encountered on 12-21-77, at Approximately 16'.
4. The Lines Indicating the Transition Between Different Soil Types Represent Approximate Boundaries. The Transition May Be Gradual.

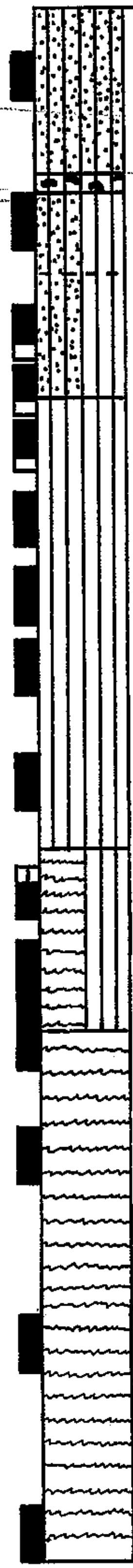
Job No. S-2268-1

Plate No. V

BORING 3

Approximate Surface Elevation +5' U.S.G.: Mean Sea Level Datum

Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *
0–5	101	5	12
5	81	9	4
5–10	86	25	4/18"
10	80	41	3/18"
10–15			Push
15–20	72	47	Push
20	72	85	Push
20–25	42	98	Push
25	46	88	Push
30	38	112	Push
35	41	105	Push
40	30	148	Push



Description

SM — Tan Slightly Silty Fine Sand. (Poorly to Moderately Compact)

New Fil

GM — Thin Layer of Sandy Gravel.

SM / ML — Alternate Layers of Tan and Grey White Very Sandy Silt and Silty Very Fine to Fine Sand with Minor Roots. (Poorly Compact) (Grades with Lenses of Tan Very Silty Clay. (Soft)

ML — Greenish-Grey Very Fine Sand and Clayey Silt with Lenses of Silty Fine Sandy Silty Clay and Minor Vegetation. (Soft)

F:

PT / ML — Grades to Greenish-Grey Very Clayey Silt with Layers of Fibr Peat and Large Tree Roots.

PT — Black Fibrous Clayey Peat. (Stiff to Very-Stiff)

BORING TERMINATED AT 41.5-FOOT DEPT

NOTES:

1. Boring Drilled on 9-21-77.
2. No Caving Noted.
3. Ground Water Encountered on 12-21-77, at Approximately 9'.
4. The Lines Indicating the Transition Between Different Soil Types Represent Approximat Boundaries. The Transition May Be Gradual.

LOG OF BORING

BORING 4

Approximate Surface Elevation +5' U.S.G.S Mean Sea Level Datum

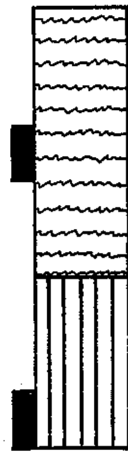
Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count*		Description
0					
			7	ML	Brown Very Fine Sandy and Claye Silt. (Very-Stiff)
					(Grades to Clayey Silt with Minor Vegetation and Lenses of Silty Fine Sand and Silty Clay)
5			5		
					(Color to Grey-Tan) (Grades Medium-Stiff to Stiff)
			5/18"		
10				ML	Greenish-Grey Clayey Silt with Lenses of Silty Fine Sand. (Soft)
			Push		
					(Grades with Many Lenses of Sil Fine Sand Grades Medium-Stiff) Fi
15			Push		
				OL	Greenish-Grey and Dark-Grey Clayey Silt with Decaying Vegetation. (Medium-Stiff to Stiff)
20			Push		
				ML	Greenish-Grey and Dark-Grey Clayey Silt. (Medium-Stiff to Stiff)
			Push		
25					(Grades with Lenses of Silty Clay)
			Push		
30				PT	Black Fibrous Clayey Peat. (Very-Stiff)
35					

LOG OF BORING

BORING 4
(CONTINUED)

Depth In Feet	Dry Density Lbs./Cu. Ft.	Moisture Content % Dry Weight	Blow Count *
35			
40			
45			
50			

Description



ML Greenish-Grey Clayey Silt with Decaying Vegetation and Lenses of Very Fine Sandy Silt. (Stiff)

BORING TERMINATED AT 46.5-FOOT DEPTH

NOTES:

1. Boring Drilled on 9-21-77.
2. No Caving Noted.
3. Ground Water Encountered on 12-21-77 at 10'.
4. The Lines Indicating the Transition Between Different Soil Types Represent Approximate Boundaries. The Transition May Be Gradual.

LOG OF BORING

Appendix B

Permits

GEI Consultants

WELL APPLICATION AND PERMIT FORM

ENVIRONMENTAL MANAGEMENT DEPARTMENT – ENVIRONMENTAL COMPLIANCE DIVISION
10590 ARMSTRONG AVENUE • SUITE A • MATHER, CA 95655
TELEPHONE (916) 875-8400 FAX: (916) 875-8513

WELL INSPECTION LINE: (916) 875-8524 AR57769

IS THIS PERMIT FOR A HAZARDOUS SUBSTANCE INVESTIGATION? YES X NO

FOR OFFICE USE ONLY

EXPEDITED PROCESSING? YES NO

✓ APPROVED APPROVED W/CONDITIONS (ATTACHED)

PERMIT NUMBER(S): 61090 A-H

BY: C. [signature] DATE: 9/23/19
INITIAL GROUT BY: DATE:
FINAL INSPECTION BY: DATE:
DESTRUCTION BY: DATE:

DATE RECEIVED: 9/19/19 TOTAL FEE: $426
RECEIPT NO: 496277 DEPTH TO WATER:
WELL DEPTH: GROUT DEPTH:
GPS: N: 38 W: -121

COMMENTS: Delta Levee CPTs - Isleton

SITE ADDRESS: See Attached Tables	
Job Address: River Rd, Isleton 95641	Nearest Major Cross Street: Hwy 160
Property Owner: See attached	Parcel Number(s): Multiple Parcels (see table)
Well Contractor: ConeTec	CA License No.: C57 1049248 Exp 1/31/2021 OK TBC
Contractor's Address: 820 Aladdin Ave., San Leandro, CA 94577 (510-357-3677)	
Well/Boring Identification Number(s): See Attached Tables GEI_BAHMD_001C thru -008C	

98 DS U

TYPE OF WORK: (California C-57 License required unless noted otherwise)

Well construction
Pump replacement (or C-61)
Well inactivation (Owner only)
Vault box repair (General A or B)
Well repair
Pump repair (or C-61)
Well destruction **(SUPPLEMENT REQUIRED)**
X Exploratory boring (C-57 if water present)
X Other: CPT (Cone Penetration Testing)

INTENDED USE:

Domestic/private
Irrigation/agricultural
Water/vapor monitoring/extraction
Dewatering
Cathodic protection
Heat exchange
Geotechnical ~~boring~~ exploration using CPT
Environmental boring
Other:
Public water system:
(NAME OF WATER PURVEYOR WITH CONTACT NAME AND TELEPHONE NUMBER)

DRILLING METHOD:

Mud rotary Air Rotary Cable tool Auger Driven X Other: CPT

SETBACKS: (Wells only)

Is the well located within 50 feet of a: sewer line, stream, ditch, drainage course, pond, or lake? No
Is the well located within 100 feet of a: septic tank, leach line, deep trench, or animal enclosure? No

SPECIFICATIONS:

BOREHOLE: Diameter: 2 in. Depth: 80 ft.
Diameter: Depth:
CONDUCTOR: Diameter: Depth:
ANNULAR SEAL: Depth: Material: Bentonite (5%) cement
TRANSITION SEAL: Material:
COMMENTS:

CASING: Diameter: Depth:
CASING: Diameter: Depth:
IF STEEL: Gauge: or Thickness:
IF PLASTIC: Type: (Must meet ASTM F-480)
MULTIPLE COMPLETION? Yes **(DIAGRAM REQUIRED)**

PUMP INSTALLATION/REPAIR:

Contractor:
License Number: Type of Pump: Horsepower:

I will comply with all Codes, Rules and Regulations of the State and County pertaining to or regulating wells and pumps, **call (916) 875-8524 for a grout inspection at least 24 hours prior to the requested appointment time**, submit a "Well Completion Report" (if required) within 60 days of the completion of my work so a final inspection can be made, and obtain WPD approval before placing a well in service.

SIGNATURE: [signature]
PRINTED NAME: Nichole Tollefson
COMPANY: GEI Consultants
MAILING ADDRESS: 2868 Prospect Park Dr. Suite 310, Rancho Cordova, CA 95670
PHONE NUMBER: (916) 631-4590

Property Owner
Well Contractor
X Agent **(REQUIRES AUTHORIZATION FORM)** OK TBC
FIELD PHONE: (831) 540-7620

A SITE PLAN MUST BE SUBMITTED WITH EACH APPLICATION.
PERMIT EXPIRES ONE (1) YEAR AFTER DATE APPROVED (UNLESS EXTENDED)

8/19/2012 gfb W:\Data\FORMSARCHIVE\WP\WELLS\07 WELL APPLICATION AND PERMIT FORM.doc

SACRAMENTO COUNTY Environmental Management

Sacramento County
Environmental Management

Confirmation 85967941144

Department: Environmental Management
Location: Internet ARU
Account Holder: Nichole Tollefson
12775 Thornberg Way
Rancho Cordova, CA 95742
United States
916-761-5334
ntollefson@geiconsultants.com

Posted Date: 08/22/2019 4:30 PM PDT
Received Via: Online
# of Items: 1
Cart Amount: $ 426.00
Fee: $ 9.76
Total: $ 435.76

Receipt

Shopping Cart

#	Description	Amount	Fee
	Well Construction/Destruction/Repair AR0000012 GEI Levee Explorations	$ 426.00	$ 9.76

Payments

Action	Status	Via	Account Information	Amount	Fee
Charge	Complete	Credit Card	Visa CC# ***9133	$ 426.00	$ 9.76
Subtotal:				**$ 426.00**	**$ 9.76**
Total (Payment + Fee):				**$ 435.76**	

VISA MasterCard AMERICAN EXPRESS Cards DISCOVER NETWORK e-check

PaymentExpress

Environmental Management Department
Marie Woodin, Director

WELL DRILLER'S AUTHORIZATION LETTER

Site Address	See Attached Tables
Well Driller	ConeTec
Driller's Address	820 Aladdin Ave, San Leandro, CA 94577
Driller's Phone No.	510-357-3677

C-57 License No.	1049248	Exp. Date	01/31/2021

For the sole purpose of procuring permits for the construction, modification, repair, or destruction of wells or soil borings and the installation, repair, or replacement of well pumps at the aforementioned site, I hereby designate the following entity(ies) to act as my authorized representative:

Name(s)	Nichole Tollefson
Company	GEI Consultants
Address	2868 Prospect Park Dr. Suite 310
City, State, Zip	Rancho Cordova, CA 95670

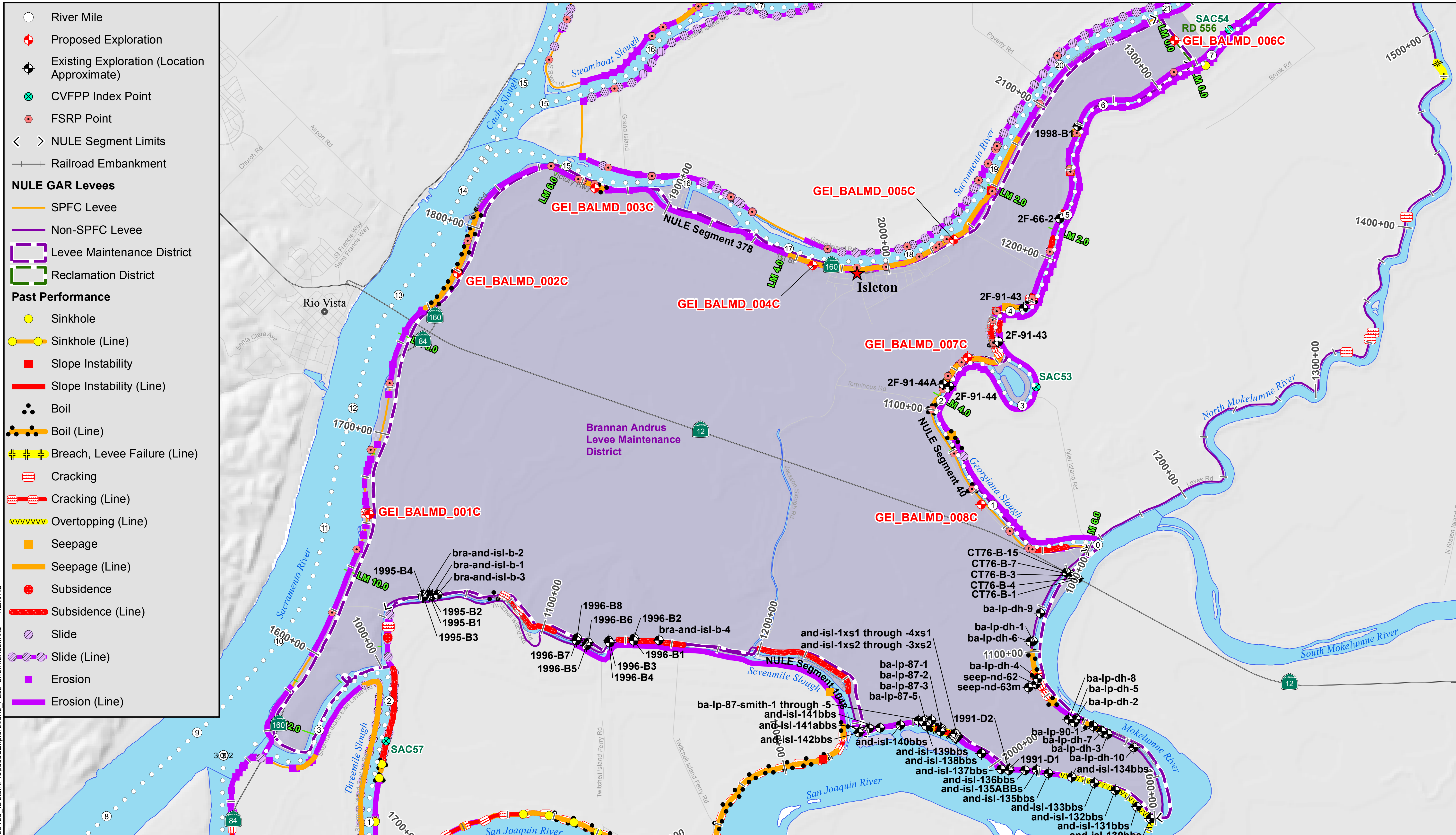
I understand that as the applicant for permits for activities regulated under Chapter 6.28 of the Sacramento County Code, I am responsible for compliance with all provisions of that Chapter. I further understand that upon written notification to the EMD, I may rescind this authorization.

Signature	John D Rogie
Printed	John Rogie
Title: RMO, RME, Officer	RME
Date:	08/05/2019

8/9/2013 gfb W:\Data\FORMSARCHIVE\WP\WELLS\11 WELL DRILLER'S AUTHORIZATION LETTER .DOC

ISLETON PROPOSED LOCATIONS

Exp_ID	Latitude	Longitude	Pacel APN	Site Address	Landowner Name
GEI_BALMD_001C	38.1337824	-121.685563	157-0120-030	BRANNAN, Isleton	HILARIDES FAMILY REVOCABLE TRUST
GEI_BALMD_002C	38.1621585	-121.6722959	157-0090-018	River Road, Isleton	HILARIDES FAMILY REVOCABLE TRUST
GEI_BALMD_003C	38.17211244	-121.6517729	157-0090-068	River Road, Isleton	RANCHO VALLE DEL SOL LLC,
GEI_BALMD_004C	38.16293662	-121.6193051	157-0100-006	14583 STATE HIGHWAY 160, Isleton	RIVER VINE RANCH LLC
GEI_BALMD_005C	38.16584248	-121.5982903	157-0040-044	River Road, Isleton	KLD VENTURES LLC
GEI_BALMD_006C	38.18920813	-121.5652334	156-0040-003		RECLAMATION DIST NO 556
GEI_BALMD_007C	38.15201063	-121.5963054	157-0100-080	TERMINOUS RD, Isleton	VOELKER PROPERTIES LLC
GEI_BALMD_008C	38.13469669	-121.5943735	156-0080-048	17151 TERMINOUS RD, Isletong	MADDERN JERRY W & DIXIE LOUISE



14May2019 Z:\Projects\1800488_Isleton\ProposedExplorations_PastPerformance.mxd KLM/RS

Small Communities
Flood Risk Reduction Program

City of Isleton

GEI Consultants

PROPOSED EXPLORATIONS AND PAST PERFORMANCE COMMUNITY OF ISLETON

MAY 2019 **DRAFT** FIGURE

Gilbert Labrie, AIA, Architect

Architecture • Engineering • Consulting
Permitting • Planning

August 21, 2019

Sacramento County Environmental Management Department
10590 Armstrong Avenue, STE A
Mather, Ca 95655

RE: Brannan-Andrus Levee Maintenance District and RD 556

Small Community Flood Risk Reduction Study – Geotechnical Explorations

To Whom It May Concern:

As engineer of record for Brannan-Andrus Levee Maintenance District and Reclamation District No. 556, I authorize GEI and their sub consultant ConTec to perform Cone Penetration Tests within 50 feet of the BALMD landside levee toe and on the RD 556 cross levee..

If you have any questions or concerns, please contact Jeffrey Twitchell at jtwitchell@geiconsultants.com 916-631-4555.

Respectfully,

Gilbert Labrie, AIA, Architect
BALMD and RD 556, District Engineer

Appendix C

Sub-Consultants License

GEI Consultants

STATE OF CALIFORNIA

CONTRACTORS STATE LICENSE BOARD

Pursuant to Chapter 9 of Division 3 of the Business and Professions Code and the Rules and Regulations of the Contractors State License Board, the Registrar of Contractors does hereby issue this license to:

CONETEC INC

License Number 1049248

to engage in the business or act in the capacity of a contractor in the following classifications:

C57 - WELL DRILLING

Witness my hand and seal this day,

January 23, 2019

Issued January 22, 2019

Marlo Richardson, Board Chair

David R. Fogt, Registrar of Contractors

This license is the property of the Registrar of Contractors, is not transferable, and shall be returned to the Registrar upon demand when suspended, revoked, or invalidated for any reason. It becomes void if not renewed.

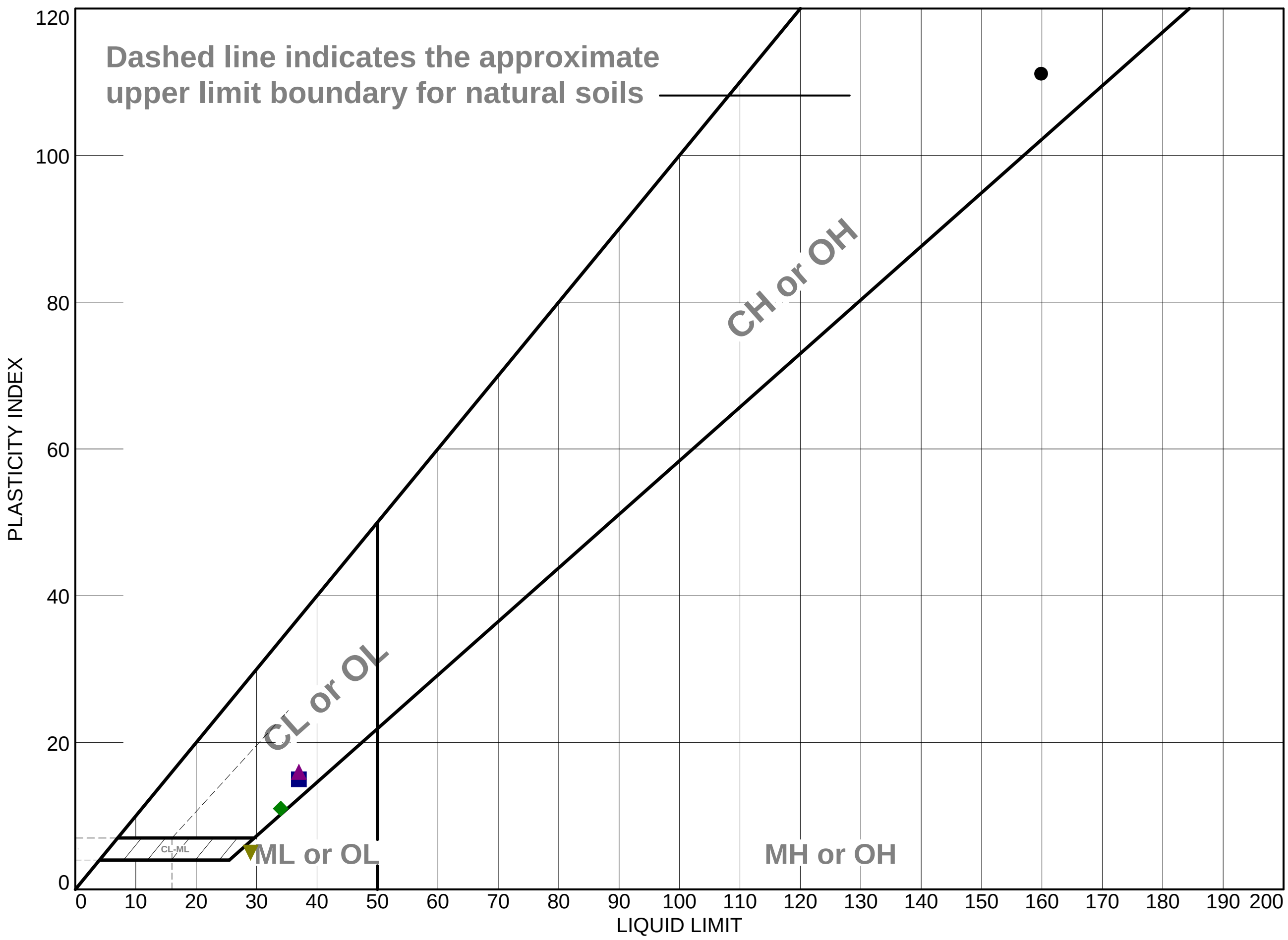
13L-24 (REV. 10/17)

OSP 17 143868

AUDIT NO: 666753

Appendix D Geotechnical Laboratory Data for Testing, October-November 2020

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	ORGANIC fat CLAY, black	160	49	111		59	OH
■	Lean CLAY with SAND, very dark brown	37	22	15		71	CL
▲	Lean CLAY with SAND, dark brown	37	21	16		77	CL
◆	SANDY lean CLAY, greenish gray	34	23	11		58	CL
▼	SILTY SAND, brown	29	24	5		39	SM

Project No. 3755.X 006 **Client:** GEI

Project: Small Communities - Isleton (1800488)

●**Source of Sample:** GEI_BALMD_001C **Depth:** 5-8' **Sample Number:** SO4:AB,SO5:A,SO6:AB

■**Source of Sample:** GEI_BALMD_002C **Depth:** 1-3' **Sample Number:** SO2:AB,SO3:AB

▲**Source of Sample:** GEI_BALMD_003C **Depth:** 1-3' **Sample Number:** SO2:AB,SO3:AB

◆**Source of Sample:** GEI_BALMD_003C **Depth:** 10-12' **Sample Number:** SO6:AB,SO7:AB

▼**Source of Sample:** GEI_BALMD_005C **Depth:** 2-4' **Sample Number:** SO3:AB,SO4:AB

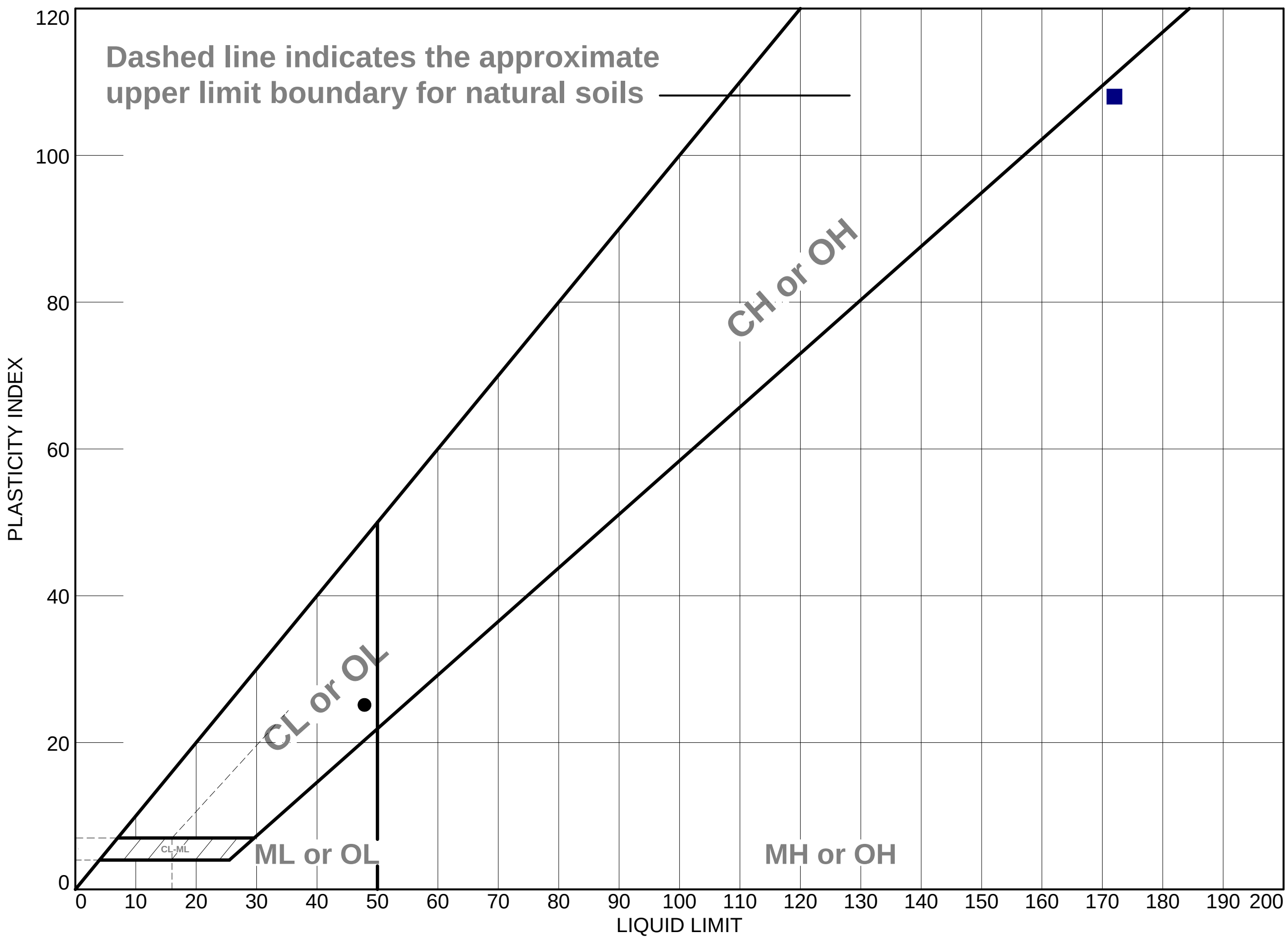
Remarks:

Blackburn Consulting

W. Sacramento, CA

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	CLAYEY SAND, dark brown	48	23	25		42	SC
■	ORGANIC elastic SILT, black	172	64	108		86	OH

Project No. 3755.X 006 **Client:** GEI

Project: Small Communities - Isleton (1800488)

● **Source of Sample:** GEI_BALMD_006C **Depth:** 2.5-6' **Sample Number:** SO3,SO4,SO5,SO6:A

■ **Source of Sample:** GEI_BALMD_007C **Depth:** 10-12' **Sample Number:** SO5:AB,SO6:AB

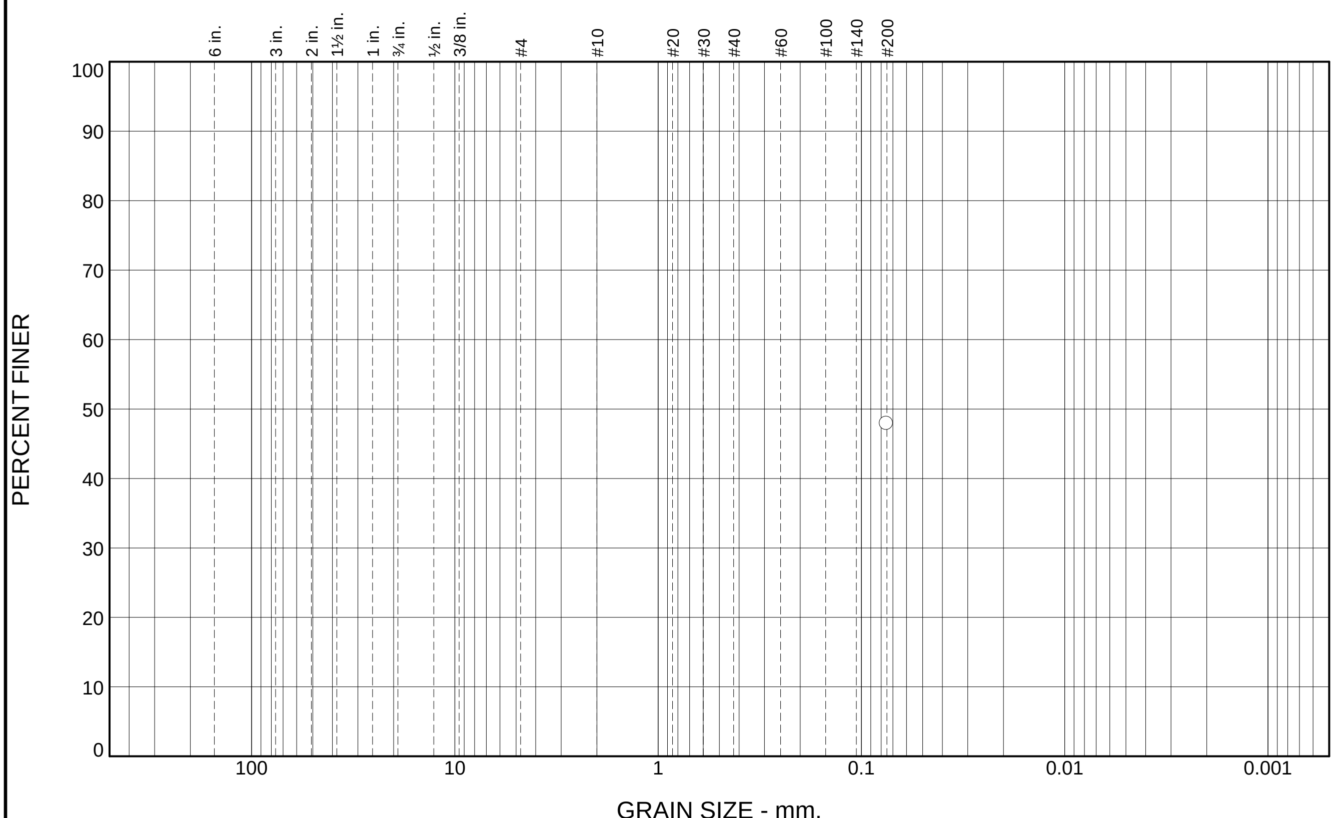
Remarks:

Blackburn Consulting

W. Sacramento, CA

Figure

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						48	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	48		

* (no specification provided)

Soil Description

brown

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

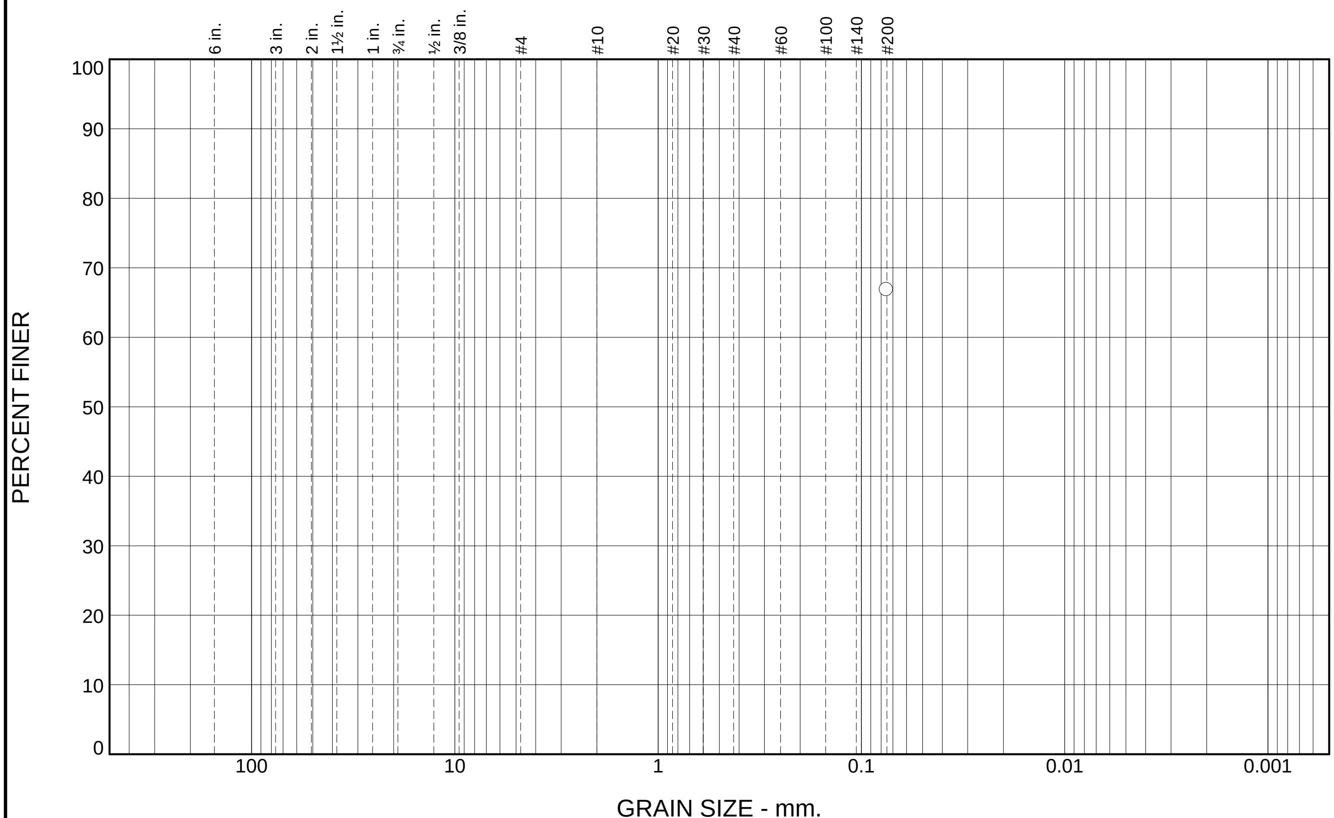
Source of Sample: GEI_BALMD_001C **Depth:** 1-3'
Sample Number: SO1:AB,SO2:A **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						67	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	67		

* (no specification provided)

Soil Description

very dark brown

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

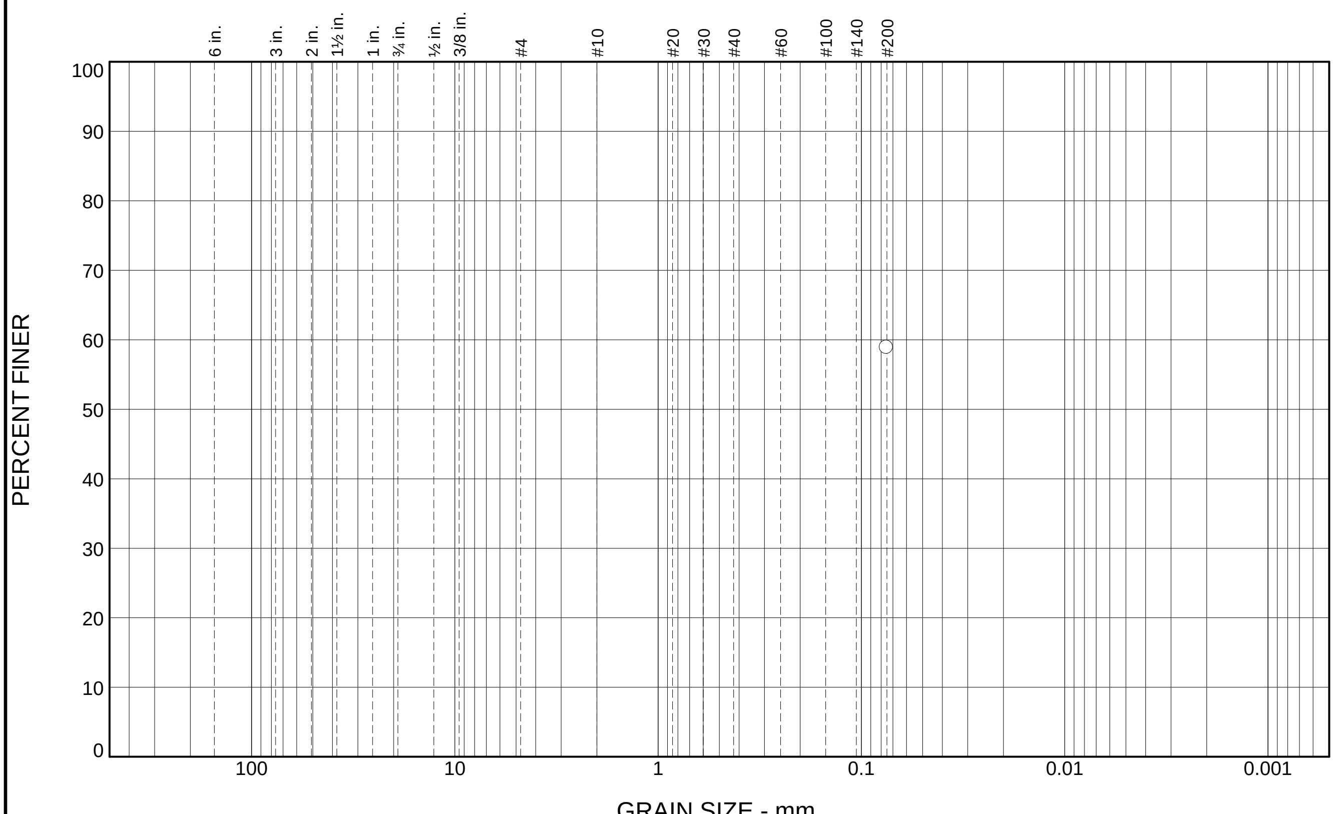
Source of Sample: GEI_BALMD_001C **Depth:** 3-4'
Sample Number: SO3:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						59	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	59		

* (no specification provided)

Soil Description

ORGANIC fat CLAY, black

Atterberg Limits

PL= 49 LL= 160 PI= 111

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= OH AASHTO=

Remarks

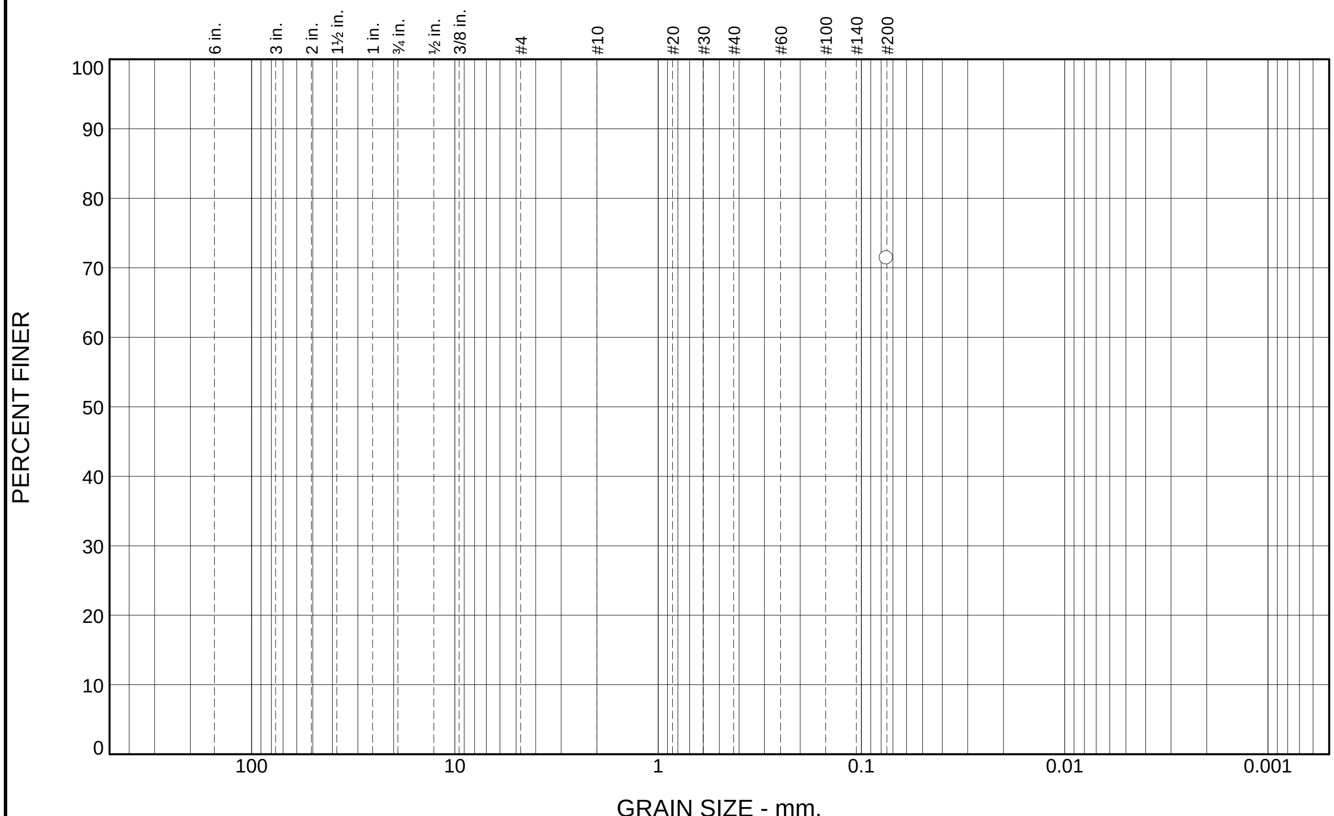
Source of Sample: GEI_BALMD_001C **Depth:** 5-8'
Sample Number: SO4:AB,SO5:A,SO6:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						71	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	71		

* (no specification provided)

Soil Description

Lean CLAY with SAND, very dark brown

Atterberg Limits

PL= 22 LL= 37 PI= 15

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO=

Remarks

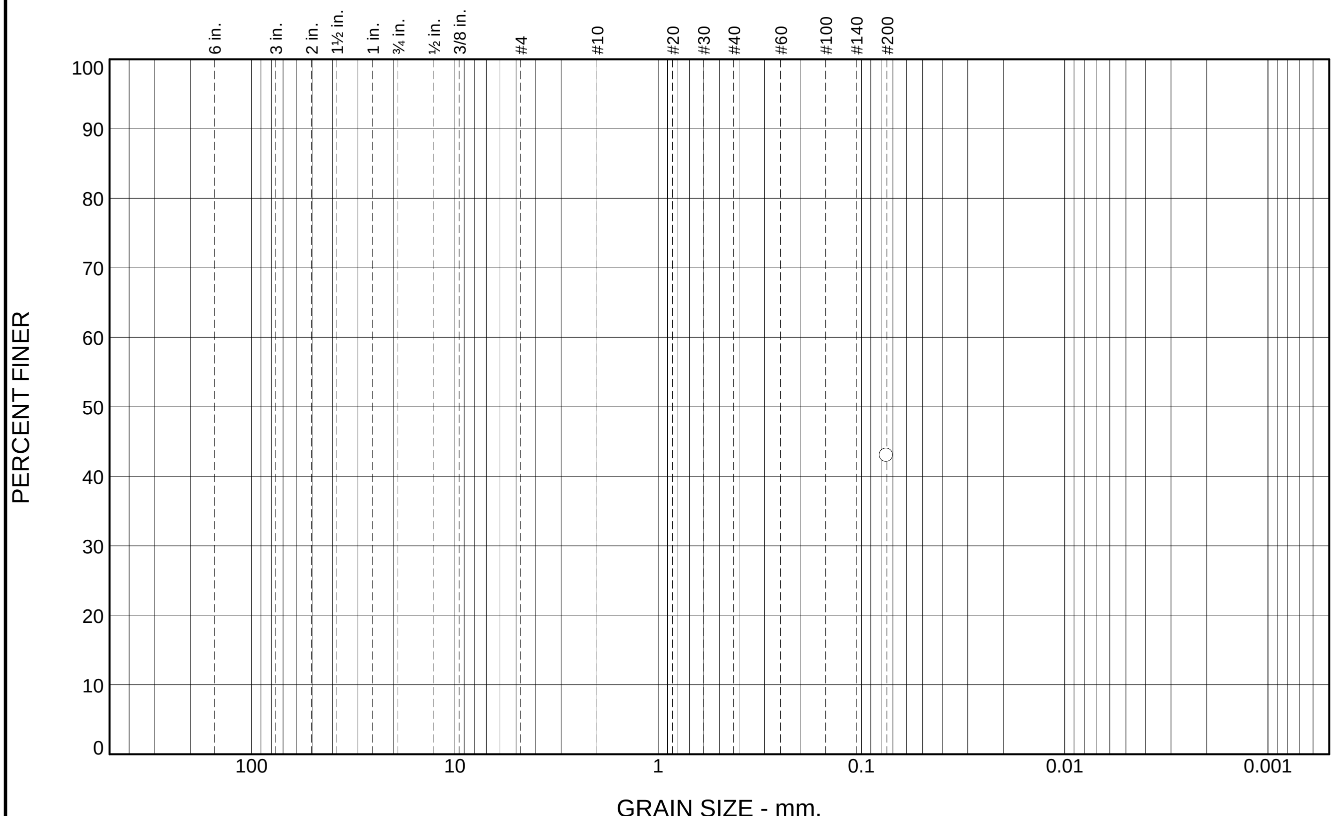
Source of Sample: GEI_BALMD_002C **Depth:** 1-3'
Sample Number: SO2:AB,SO3:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						43	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	43		

* (no specification provided)

Soil Description

black

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

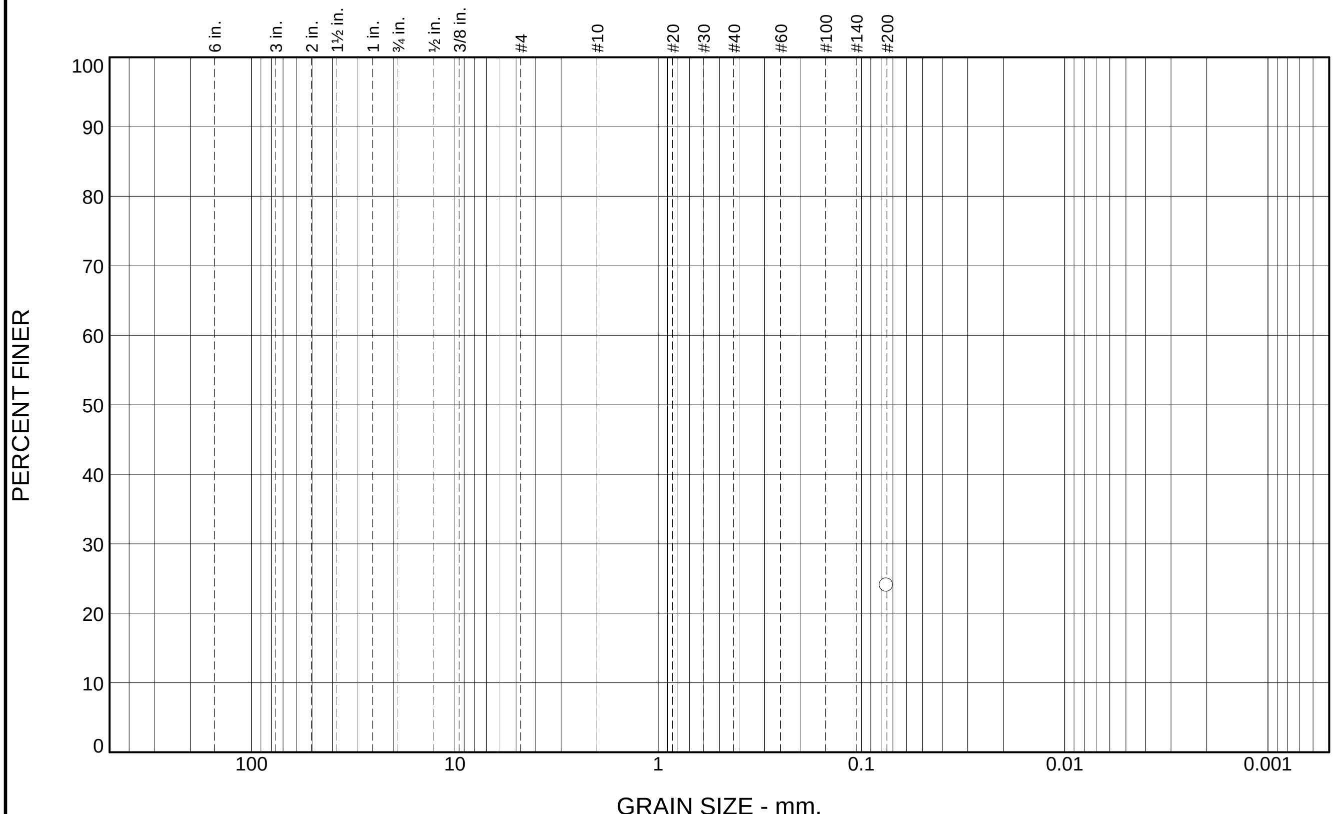
Source of Sample: GEI_BALMD_002C **Depth:** 7-9'
Sample Number: SO4:AB,SO5:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						24	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	24		

* (no specification provided)

Soil Description

black

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

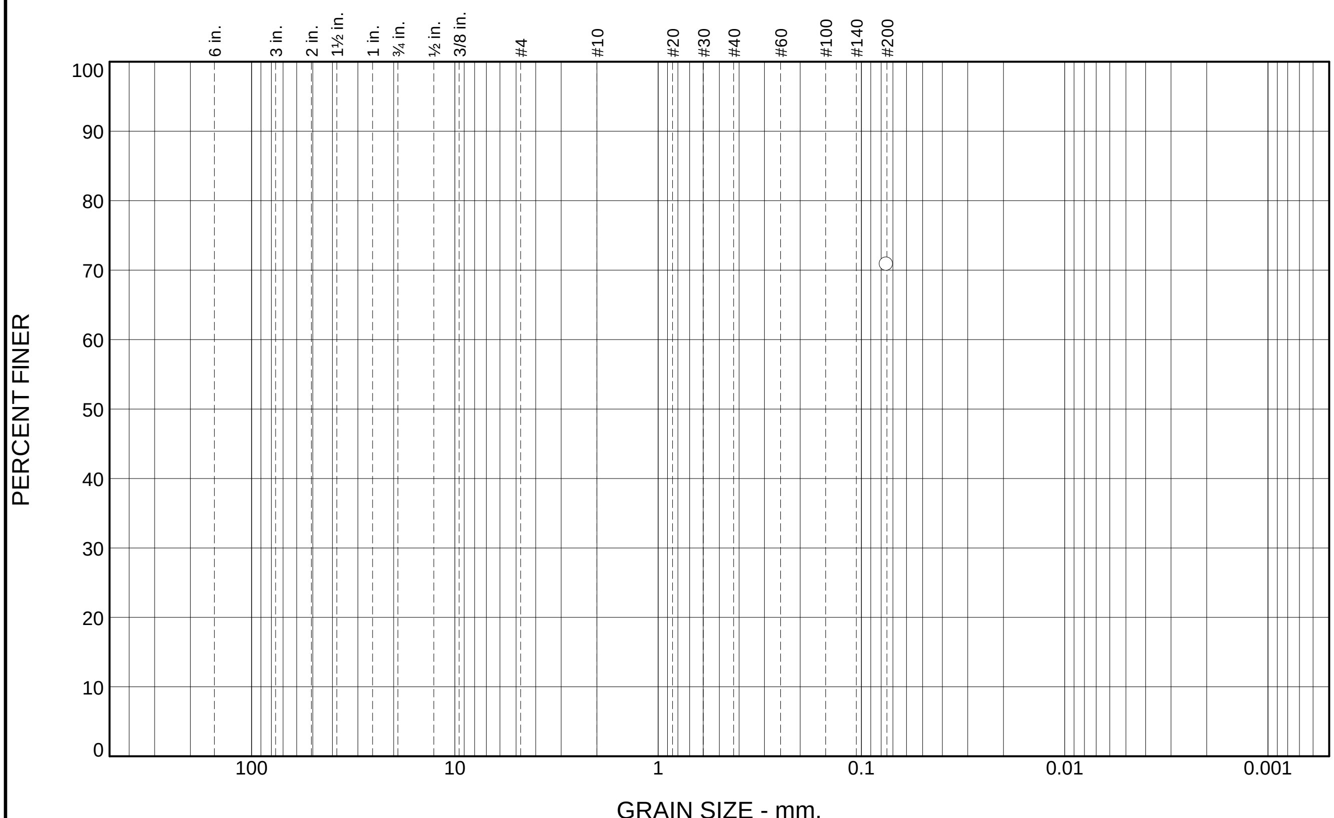
Source of Sample: GEI_BALMD_002C **Depth:** 40-44'
Sample Number: SO7:AB,SO8:AB,SO9:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						71	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	71		

* (no specification provided)

Soil Description

dark yellowish brown

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

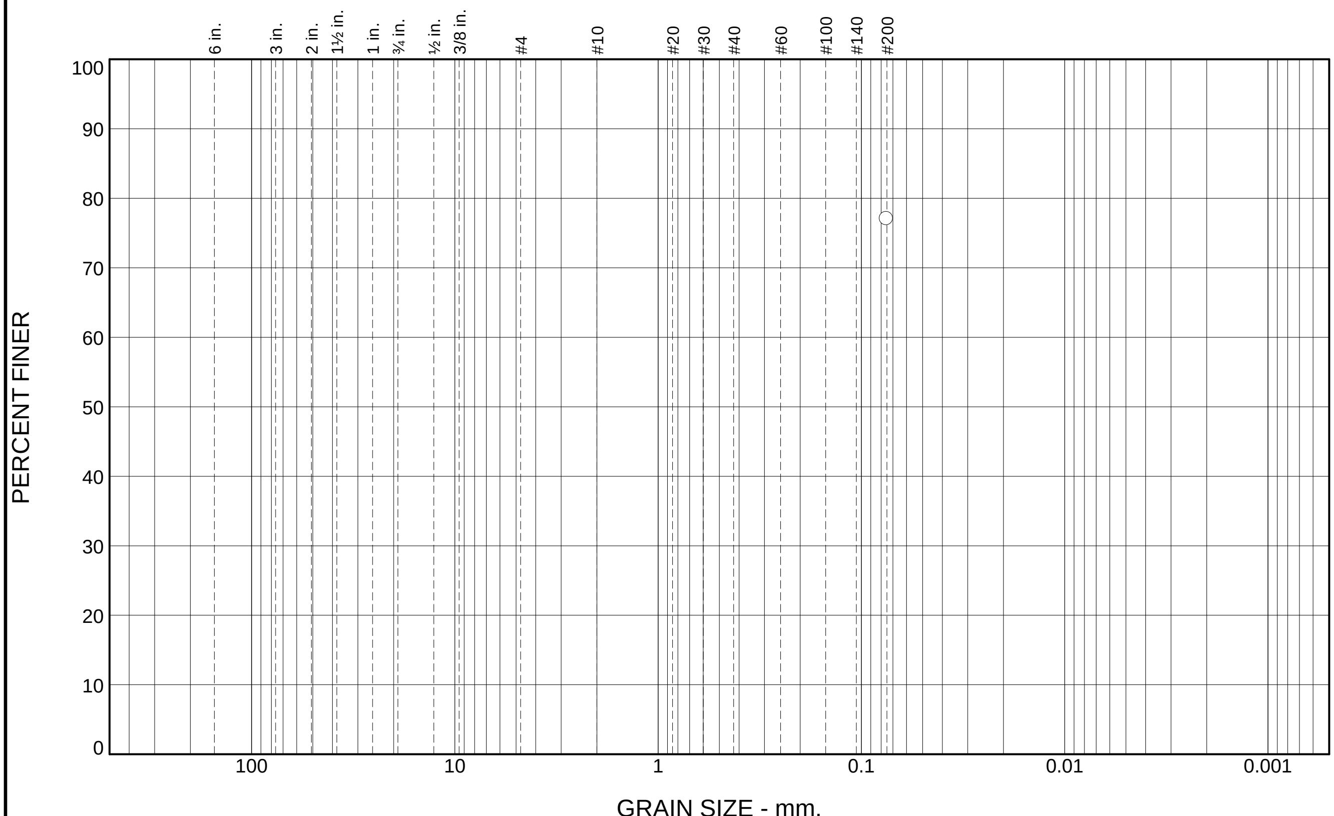
Source of Sample: GEI_BALMD_003C **Depth:** 0-1'
Sample Number: SO1:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						77	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	77		

* (no specification provided)

Soil Description

Lean CLAY with SAND, dark brown

Atterberg Limits

PL= 21 LL= 37 PI= 16

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO=

Remarks

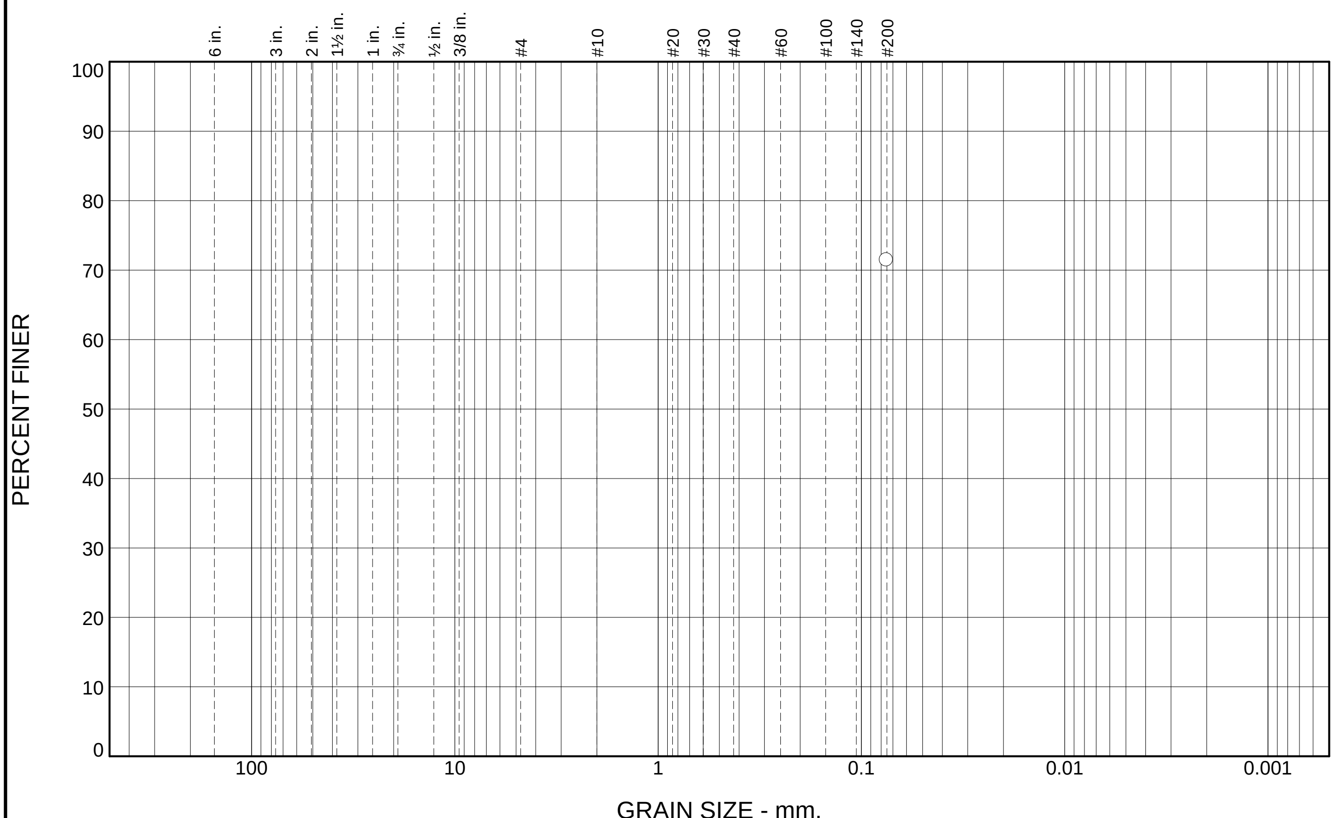
Source of Sample: GEI_BALMD_003C **Depth:** 1-3'
Sample Number: SO2:AB,SO3:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						71	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	71		

* (no specification provided)

Soil Description

very dark grayish brown

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

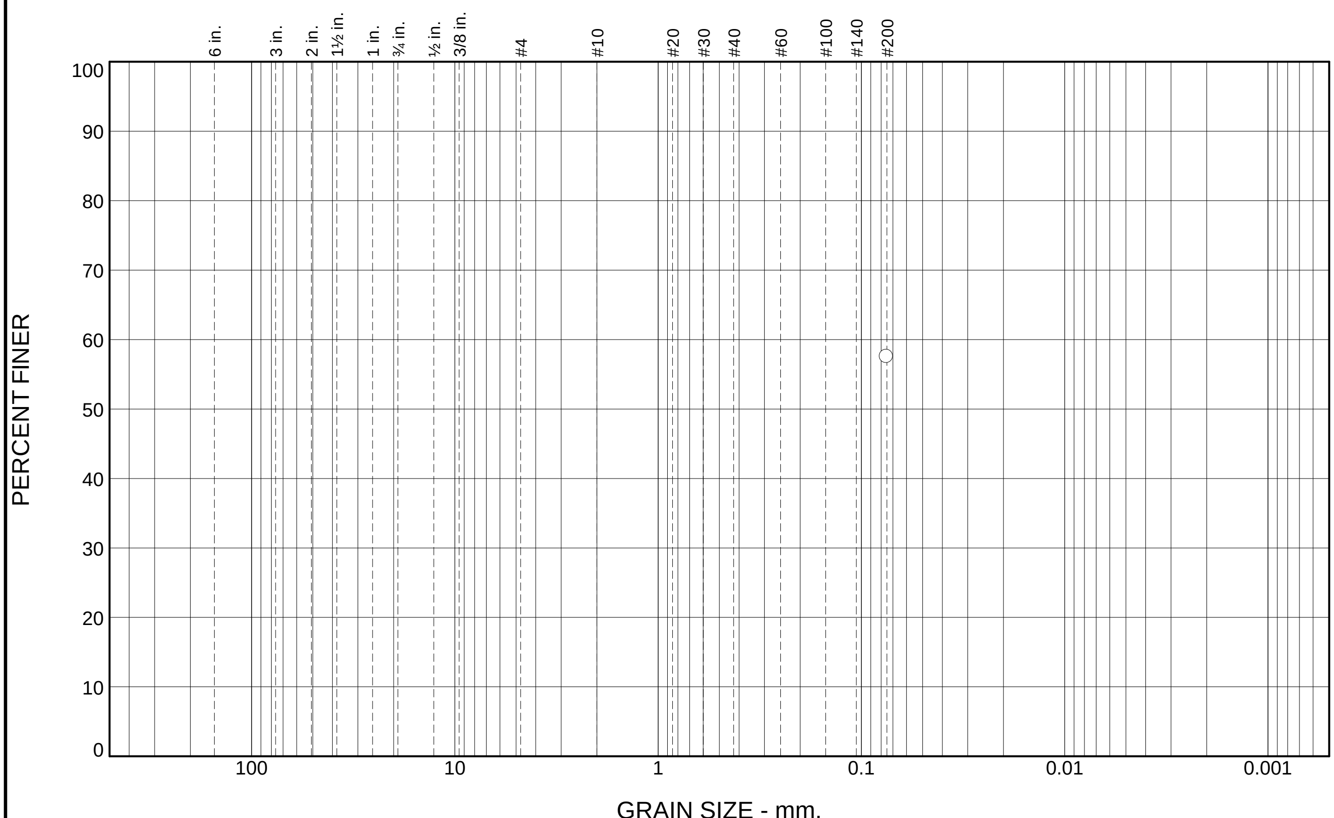
Source of Sample: GEI_BALMD_003C **Depth:** 3-4'
Sample Number: SO4:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						58	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	58		

* (no specification provided)

Soil Description

SANDY lean CLAY, greenish gray

Atterberg Limits

PL= 23 LL= 34 PI= 11

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO=

Remarks

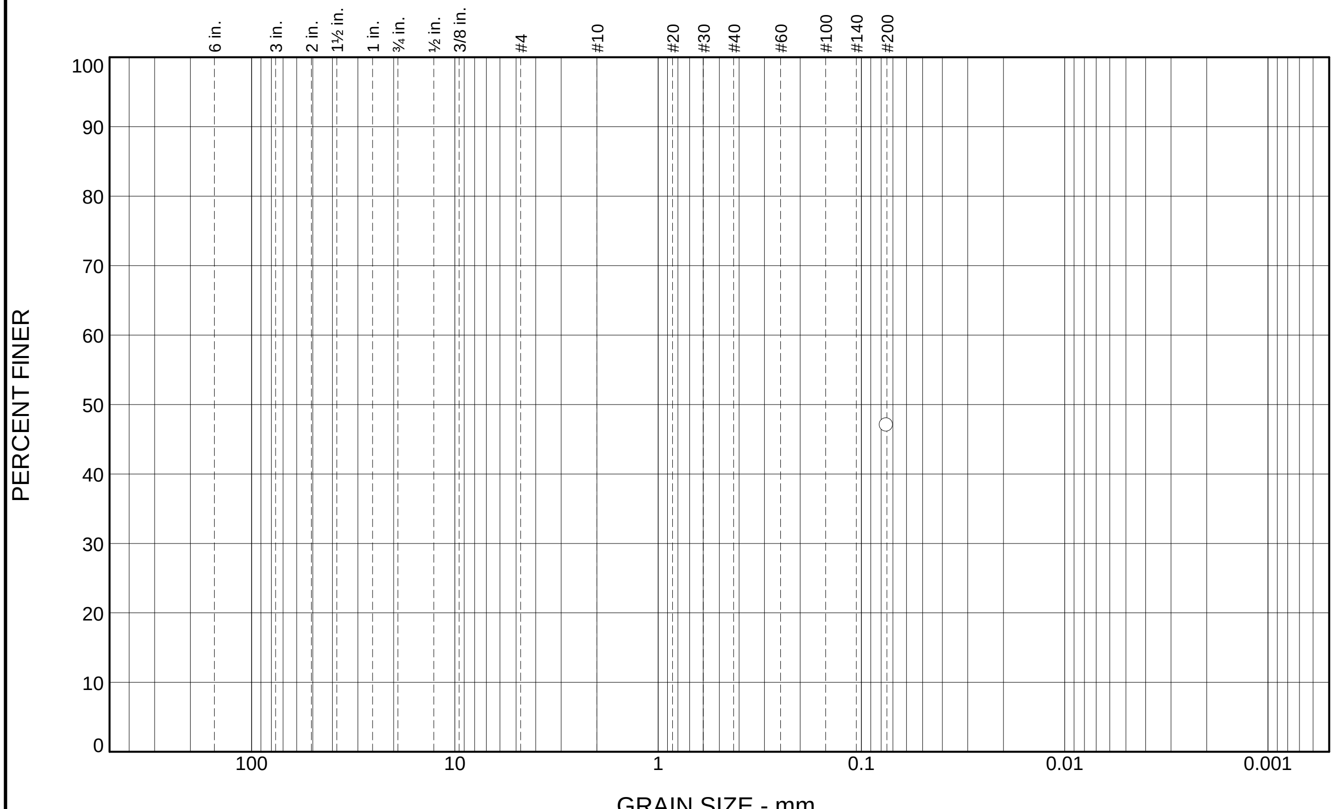
Source of Sample: GEI_BALMD_003C **Depth:** 10-12'
Sample Number: SO6:AB,SO7:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						47	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	47		

* (no specification provided)

Soil Description

dark yellowish brown

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

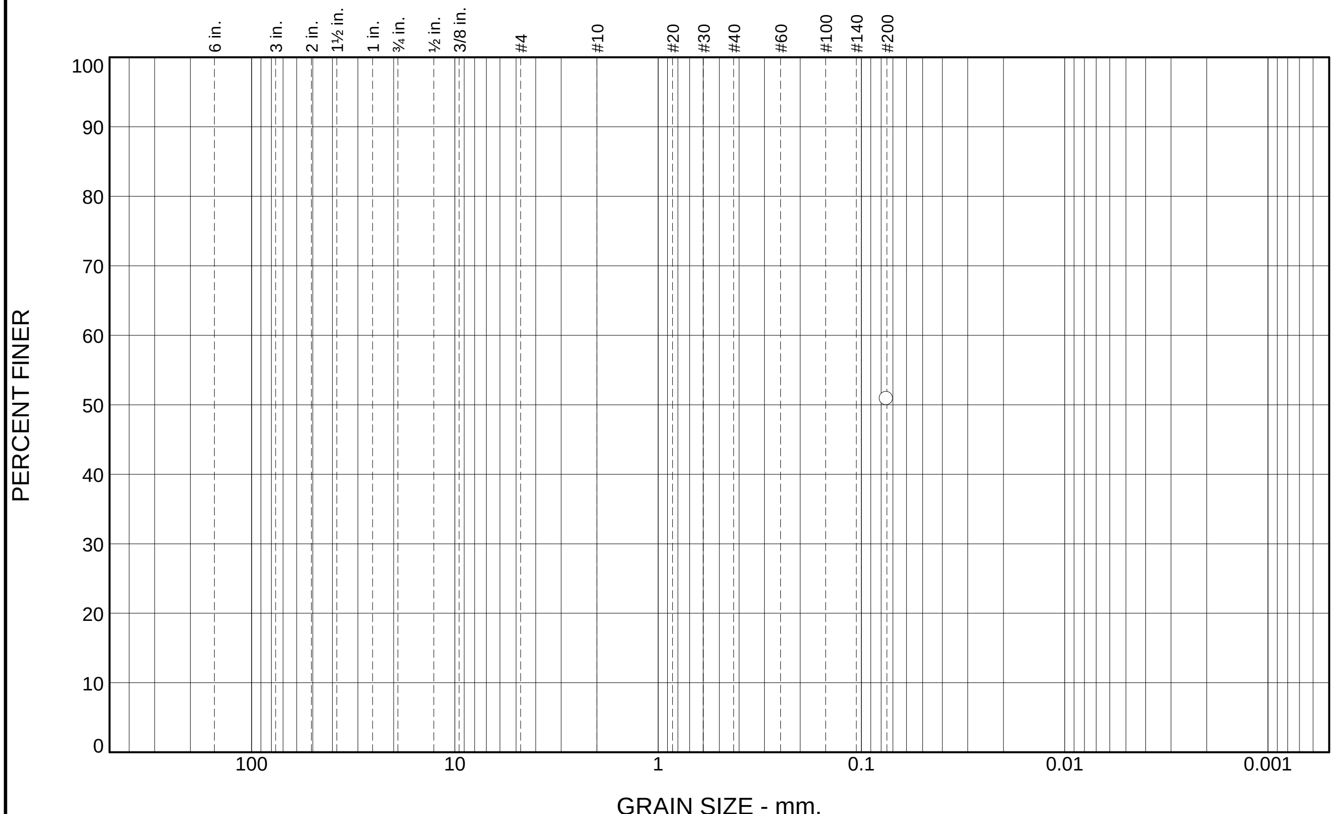
Source of Sample: GEI_BALMD_004C **Depth:** 0-2'
Sample Number: SO1:AB,SO2:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						51	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	51		

* (no specification provided)

Soil Description

dark yellowish brown

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

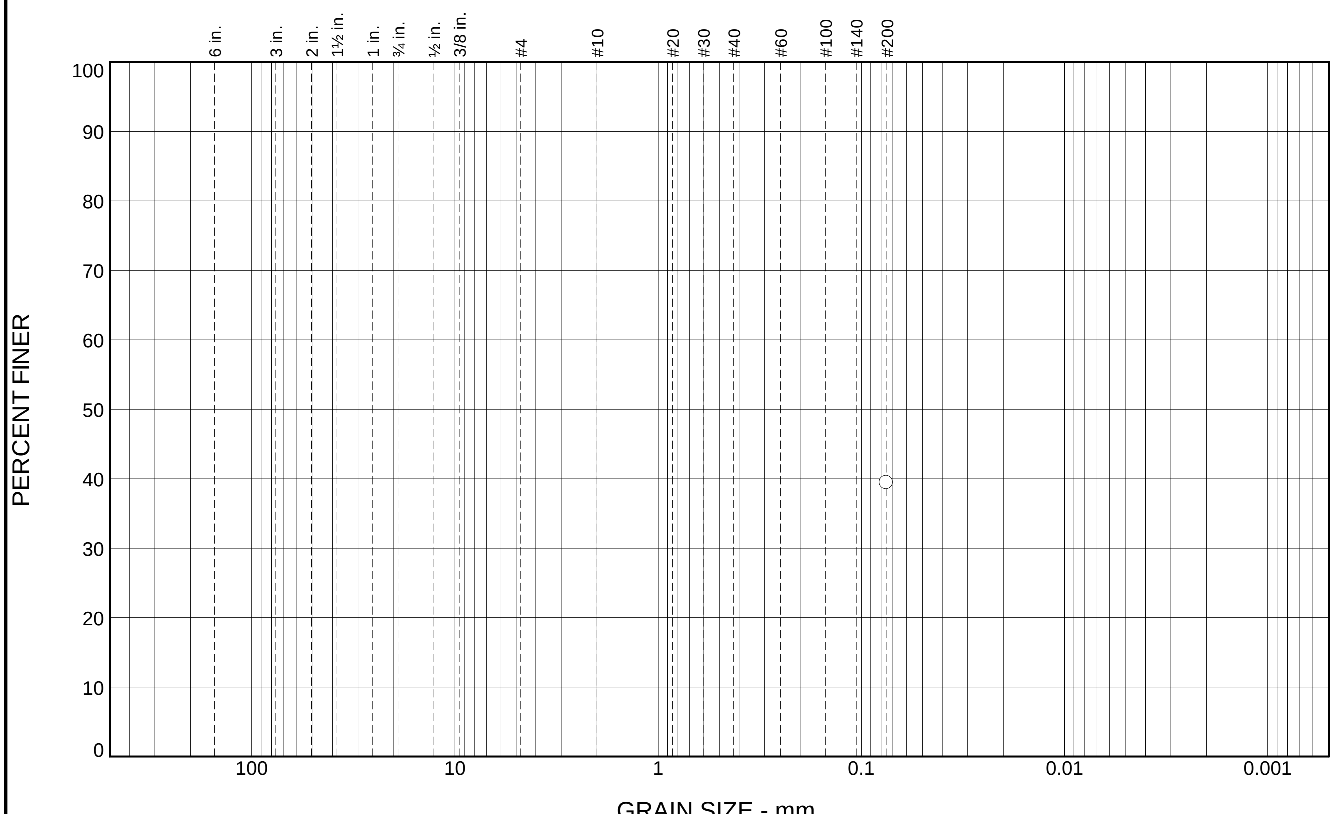
Source of Sample: GEI_BALMD_005C **Depth:** 0-2'
Sample Number: SO1:AB,SO2:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						39	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	39		

* (no specification provided)

Soil Description

SILTY SAND, brown

Atterberg Limits

PL= 24 LL= 29 PI= 5

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

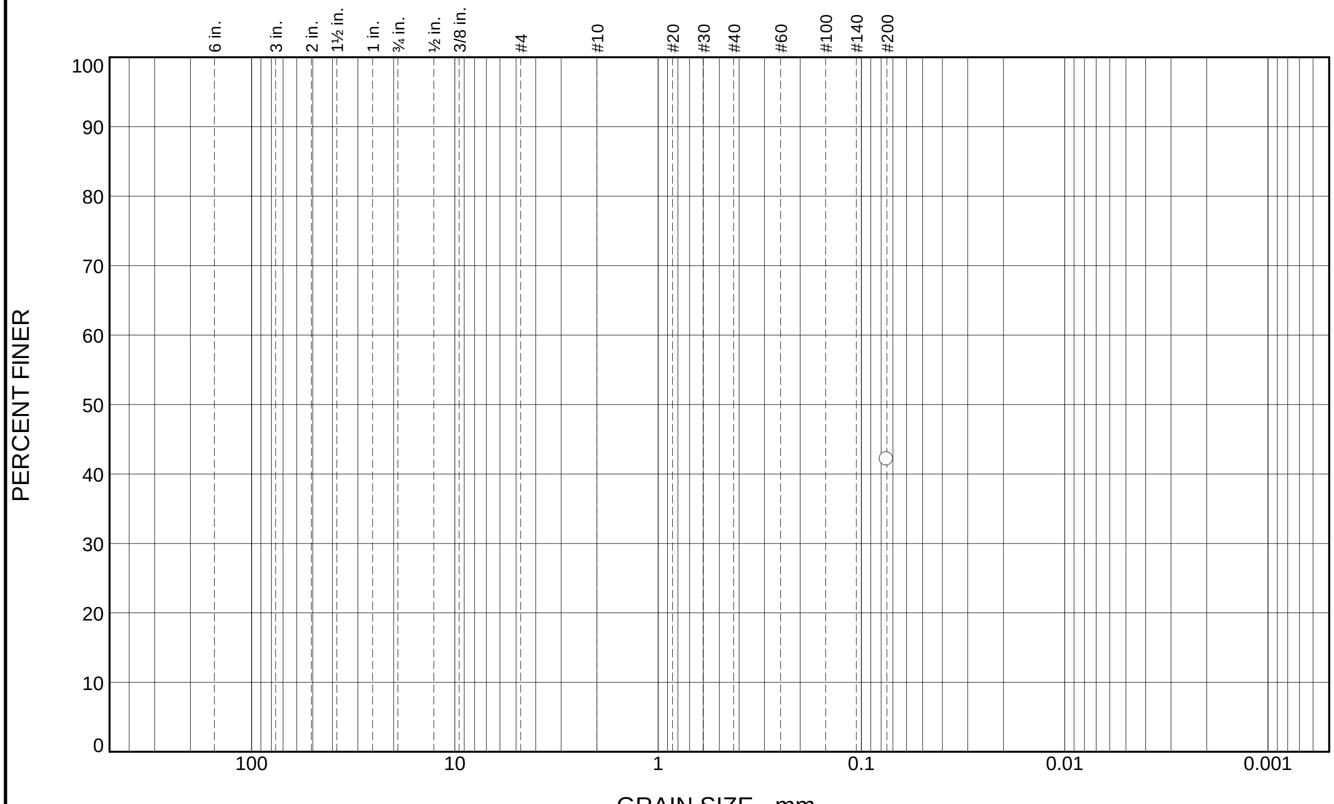
Source of Sample: GEI_BALMD_005C **Depth:** 2-4'
Sample Number: SO3:AB,SO4:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						42	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	42		

* (no specification provided)

Soil Description

CLAYEY SAND, dark brown

Atterberg Limits

PL= 23 LL= 48 PI= 25

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SC AASHTO=

Remarks

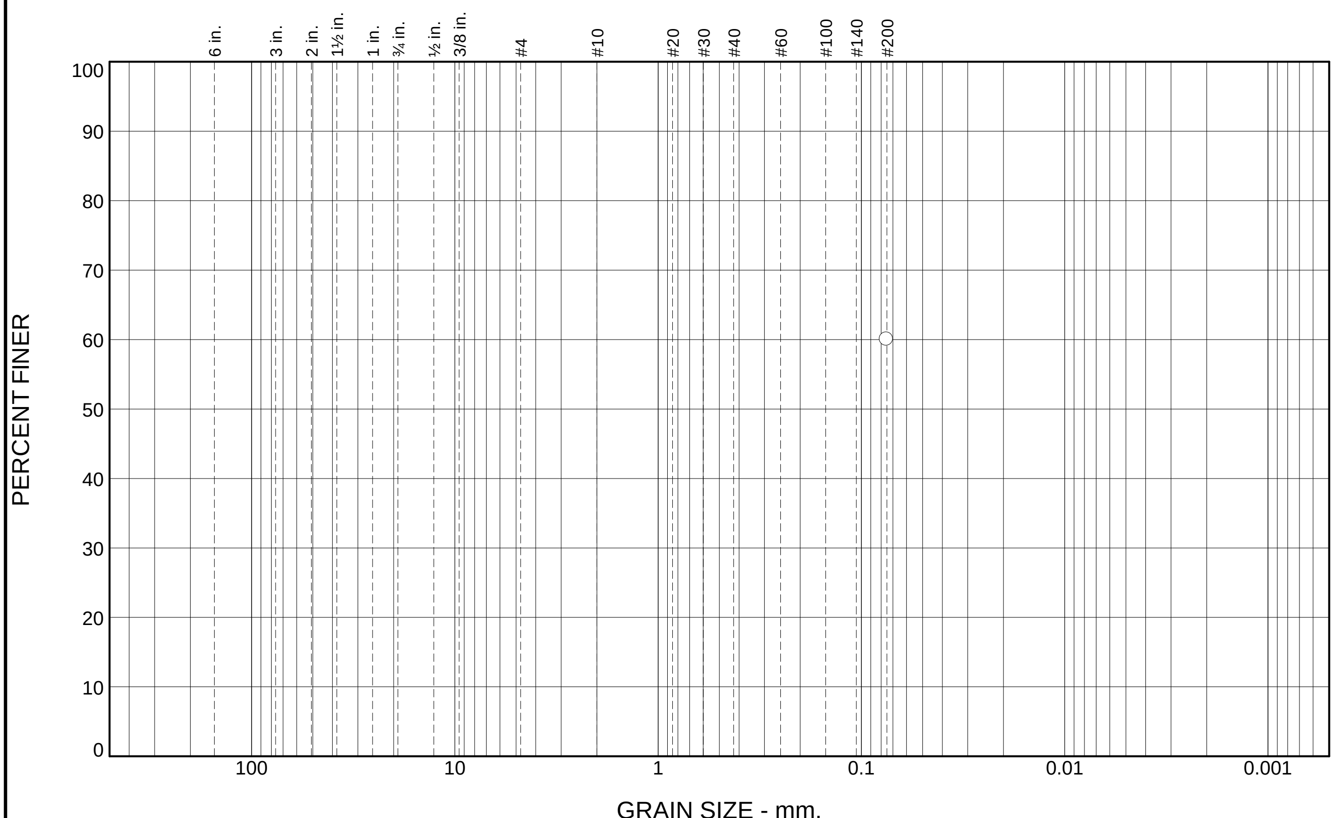
Source of Sample: GEI_BALMD_006C **Depth:** 2.5-6'
Sample Number: SO3,SO4,SO5,SO6:A **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						60	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	60		

* (no specification provided)

Soil Description

dark yellowish brown

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

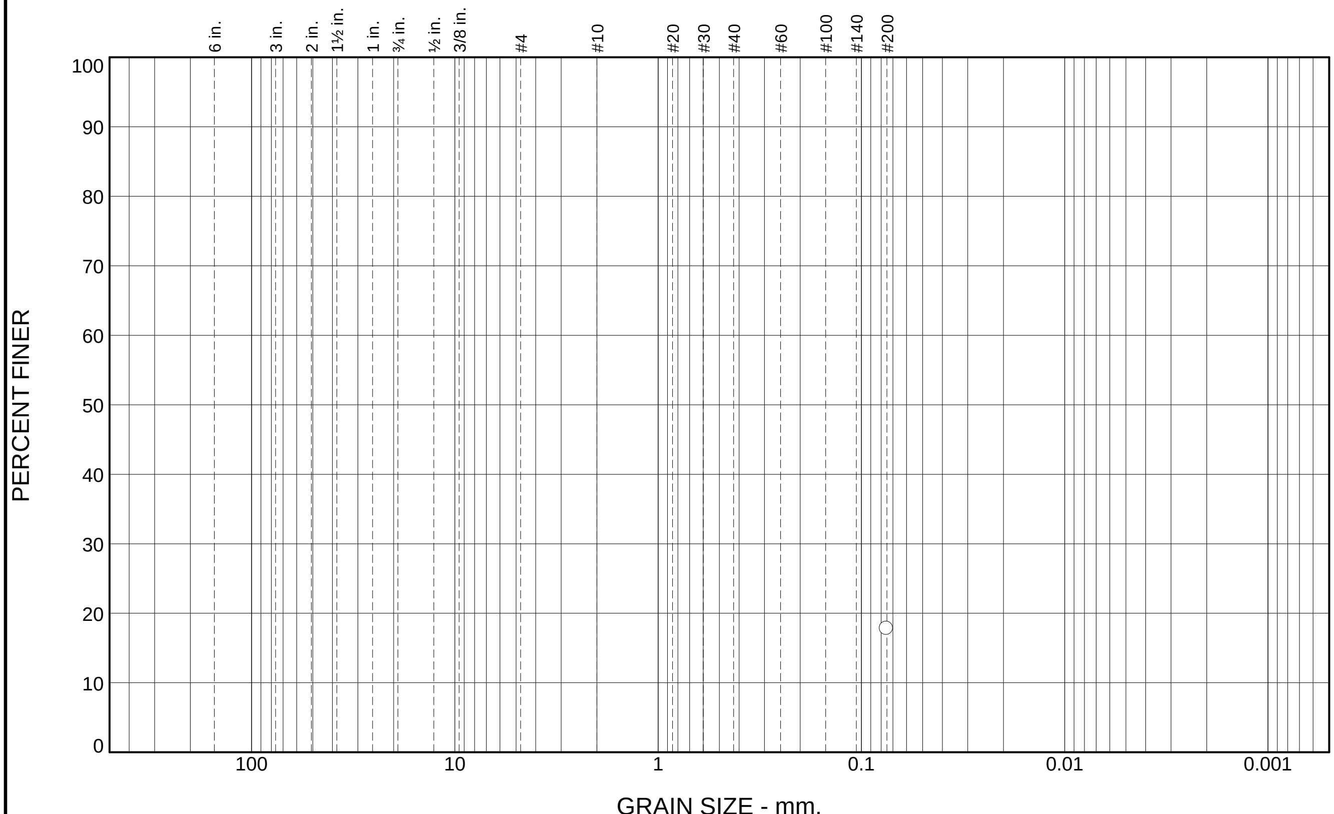
Source of Sample: GEI_BALMD_006C **Depth:** 7-9'
Sample Number: SO7:AB,SO8:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						18	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	18		

* (no specification provided)

Soil Description

dark brown

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

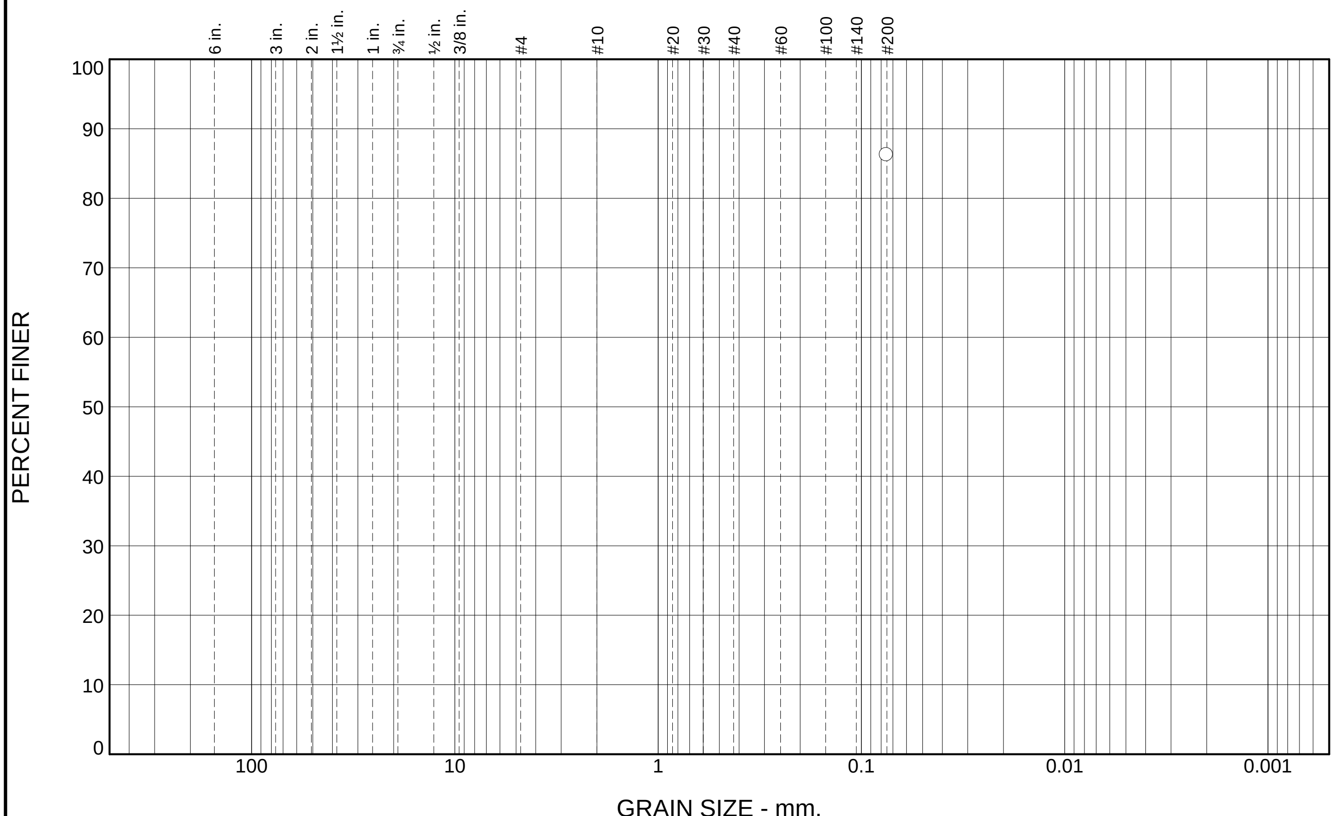
Source of Sample: GEI_BALMD_007C **Depth:** 4-6'
Sample Number: SO2:AB,SO3:A **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						86	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	86		

* (no specification provided)

Soil Description

ORGANIC elastic SILT, black

Atterberg Limits

PL= 64 LL= 172 PI= 108

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= OH AASHTO=

Remarks

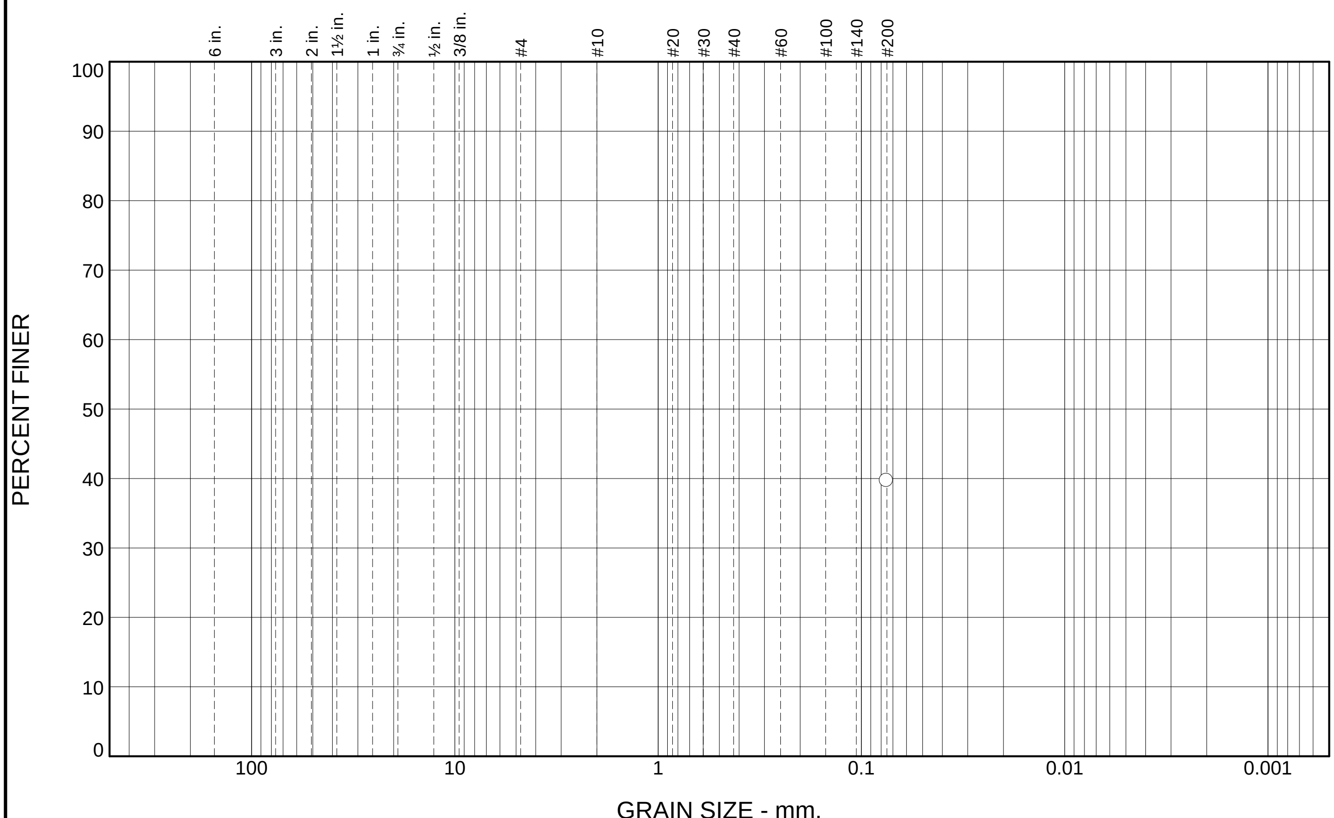
Source of Sample: GEI_BALMD_007C **Depth:** 10-12'
Sample Number: SO5:AB,SO6:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						40	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	40		

* (no specification provided)

Soil Description

dark yellowish brown

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

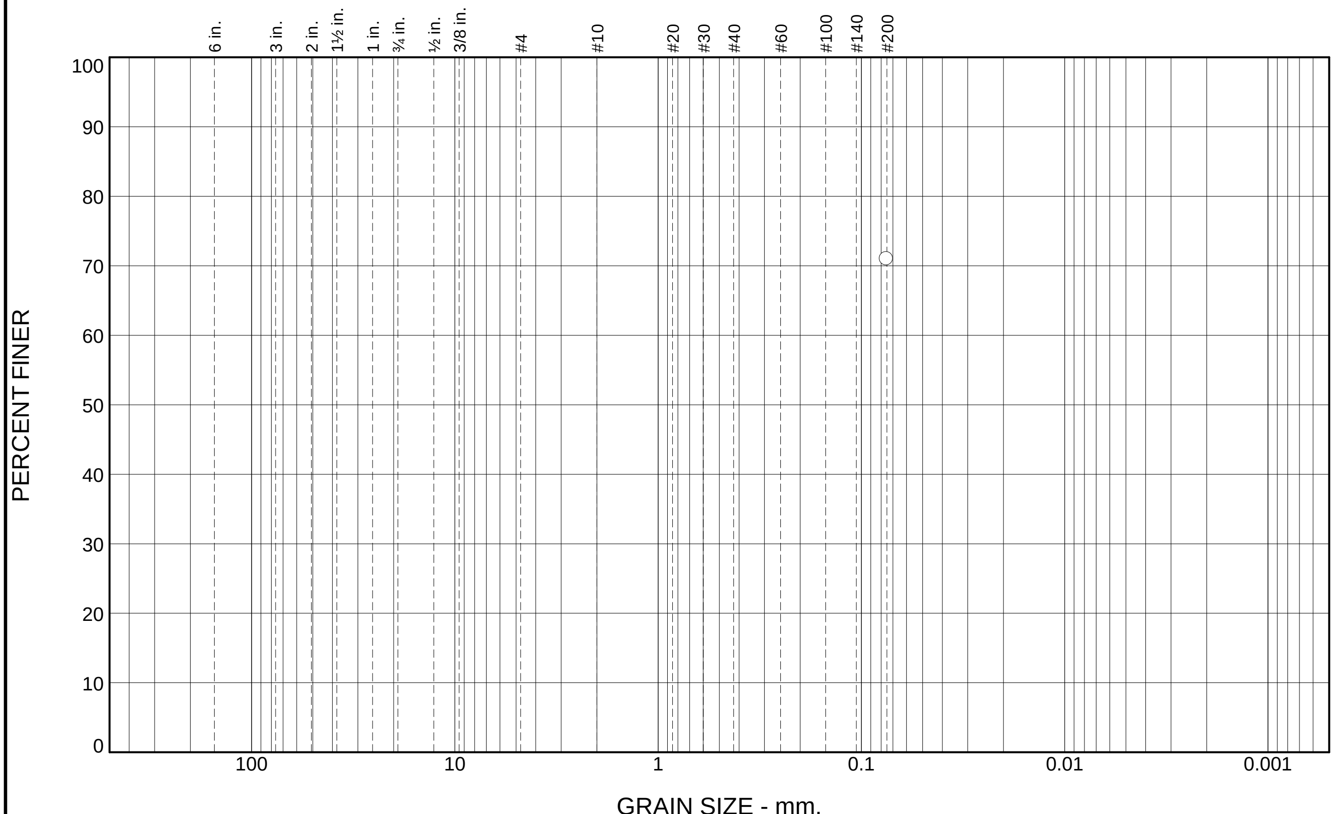
Source of Sample: GEI_BALMD_008C **Depth:** 0-2'
Sample Number: SO1:AB,SO2:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)
Project No: 3755.X 006 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						71	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	71		

* (no specification provided)

Soil Description

dark yellowish brown

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Source of Sample: GEI_BALMD_008C **Depth:** 2-4'
Sample Number: SO3:AB,SO4:AB **Date:**

Blackburn Consulting

W. Sacramento, CA

Client: GEI
Project: Small Communities - Isleton (1800488)

Project No: 3755.X 006 **Figure**

Appendix E Detailed Reach Evaluation Summary Table, May 2021

Appendix E - Preliminary Evaluation of Levees Protecting the Community of Isleton with Exploration Recommendations

Segment	NULE Alignment ID	Reach	NULE Station	Levee Geometry: Crest Elev (ft)	LS Toe Elev (ft)	LS Levee Height (ft)	WS Base Width (ft)	LS Base Width (ft)	Crest Width (ft)	Base Width (ft)	Ditch Location	Bottom of Ditch Elev.	Berm Width (ft) (if present)	Average LS Slope (xH:1V)	Average WS Slope (xH:1V)	AWSE (ft)	Available Freeboard (ft)	Index Indicators: Net Head above toe (ft)	Net Head above ditch (ft)	Creep Ratio $C_r = W/h_o$	Critical Blanket at Toe (ft)	Critical Blanket at Ditch (ft)	Exploration	Exploration Stationing	Blanket Thickness-Each Expl (ft)	Selected Blanket Thickness at Toe (ft)	Selected Blanket Thickness at Ditch (ft)	Underseepage at Toe	Underseepage at Ditch	Shallow Foundation Material	Levee Material (CL, ML, SM)	Erodibility	Base Width Bin	Confining/ Draining Shallow Foundation	T/S Max Net Head Criteria	Through Seepage	Stream ID	NULE Station	Geomorphology	Geomorph Source (Level 2-I or 2-II)	Geomorphology Notes	Past Performance (Green "X" = FSRP Site): Boils	Seepage	LS Slip/ Slough/ Subsidence	WS Erosion/ Slip/Slough	Past Performance Notes	Evaluation Notes
378	SACR-L	378-A	1975+00	22.8	7.1	15.7	21.48	30.47	34.38	86	--	--		2.1	1.8	15.60	7.2	8.5	--	10.1	10.4	NA	GEI_BALMD_004C	1967+50	0.0	0.0		DNM-Leaker		SM		Erodible	95.0	draining	5.8	DNM	SACR-L	1975+00	Rob, Rdc	II	Rdc on south side, Rob on north side and south side		X		X		Reach Characteristics: - Predominantly underlain by Historical overbank deposits and Historical crevasse splay deposits. - Average 8 feet of head above landside toe. - History of waterside erosion and seepage all throughout reach. Additionally, history of landside slope stability issues at north end of reach. - Two explorations along the reach - both indicated a leaker condition with creep ratios of approximately 10.1 and 13.8. Levee Geometry: - Average Height: 13 feet - Average LS Slope: 2.8H:1V - Average WS Slope: 2.7H:1V - Average Crest Width: 66 feet Conclusions: - Underseepage: Identified as vulnerable due to a leaker condition that does not meets creep ratio criteria. - Through Seepage: Identified as potentially vulnerable due to an assumed erodible embankment material and head that does not meet criteria. - Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along the reach and a crest width that generally indicates the levee is overbuilt at the locations were slopes are steeper than 2H:1V. - Freeboard: More than 3 feet of freeboard present along 95% of the reach.
378	SACR-L	378-A	1980+00	23.1	8.7	14.4	13.67	33.20	28.91	76	--	--		2.4	1.1	15.61	7.5	6.9	--	10.9	7.9	NA											95.0				SACR-L	1980+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	1985+00	22.9	7.2	15.7	9.77	45.70	30.08	86	--	--		3.0	2.1	15.63	7.3	8.4	--	10.2	10.3	NA											95.0				SACR-L	1985+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	1990+00	18.5	12.0	6.5	67.58	37.50	55.86	161	--	--	10	3.9	9.4	15.64	2.9	3.6	--	47.0	2.6	NA											145.0				SACR-L	1990+00	Rob, Rcs	II	Rdc on south side, Rob on north side and south side		X		X		
378	SACR-L	378-A	1995+00	18.8	10.4	8.4	17.58	22.27	23.44	63	--	--		3.0	2.3	15.66	3.1	5.3	--	12.0	5.2	NA											95.0				SACR-L	1995+00	Rob, Rcs	II	Rdc on south side, Rob on north side and south side		X		X		
378	SACR-L	378-A	2000+00	21.2	7.9	13.3	24.61	28.91	41.80	95	--	--		2.5	1.9	15.68	5.5	7.8	--	12.2	9.3	NA											95.0				SACR-L	2000+00	Rcs, Rob	II	Rdc on south side, Rob on north side and south side		X		X		
378	SACR-L	378-A	2005+00	21.3	7.9	13.5	16.80	33.59	36.72	87	--	--		2.7	1.4	15.69	5.6	7.8	--	11.1	9.3	NA											95.0				SACR-L	2005+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2010+00	20.4	7.5	12.9	25.78	42.97	37.11	106	--	--		2.2	2.0	15.71	4.7	8.2	--	12.8	10.0	NA											95.0				SACR-L	2010+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2015+00	20.3	8.1	12.1	23.83	81.25	33.20	138	--	--		7.0	1.9	15.73	4.5	7.6	--	18.2	8.9	NA											120.0				SACR-L	2015+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2020+00	22.4	9.1	13.3	21.48	29.30	32.03	83	--	--		2.3	1.7	15.74	6.7	6.7	--	12.4	7.5	NA											95.0				SACR-L	2020+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2025+00	22.4	6.0	16.4	35.55	42.97	38.28	117	--	--		2.0	2.5	15.77	6.6	9.8	--	12.0	12.4	NA											95.0				SACR-L	2025+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2030+00	22.0	6.7	15.3	39.45	40.63	45.70	126	--	--		1.8	2.8	15.79	6.2	9.1	--	13.8	11.4	NA	GEI_BALMD_005C	2030+47	0.0	0.0		DNM-Leaker		SP, CL/ML		Erodible	120.0	draining	6.3	DNM	SACR-L	2030+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2035+00	20.5			36.7		201.7	238	--	--			2.8	15.81	4.7	15.8	--	--	22.1	NA											220.0				SACR-L	2035+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2040+00	20.8	7.9	12.9		33.59	167.21	201	--	--		2.6		15.83	5.0	8.0	--	--	9.5	NA											195.0				SACR-L	2040+00	Rob, single thread channel	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2045+00	21.3	7.9	13.5		45.31	164.57	210	--	--		3.3		15.85	5.5	8.0	--	--	9.6	NA											195.0				SACR-L	2045+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2050+00	22.1	8.4	13.7	24.22	77.73	135.55	238	--	--		3.0	2.3	15.87	6.3	7.5	--	31.8	8.8	NA											220.0				SACR-L	2050+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2055+00	22.3	7.5	14.8	33.20	39.84	58.98	132	--	--		2.1	2.4	15.91	6.4	8.4	--	15.6	10.3	NA											120.0				SACR-L	2055+00	Rob	II	Rob on north and south sides		X		X		
378	SACR-L	378-A	2060+00	22.1	8.3	13.9	58.20	31.25	26.17	116	--	--		1.8	4.4	15.92	6.2	7.6	--	15.1	9.0	NA											95.0				SACR-L	2060+00	Rob	II	Rob on north and south sides		X	X	X		
RD556 SCL	ILNCL	RD556-A	0+00	22.2	20.0	2.2	22.33	42.21	119.65	184	--	--		21.5	9.8	16.40	5.8	-3.6	--	-51.2	-9.0	NA											170.0				ILNCL	0+00	Rob	II	Rob on west side						Reach Characteristics: - Predominantly underlain by Historical overbank deposits and Holocene peat and muck. - Average 6.5 feet of head above landside toe. - No documented past performance. -One exploration along the reach - indicated a blanket condition approximately 56 feet thick. Levee Geometry: - Average Height: 18 feet - Average LS Slope: 2.7H:1V - Average WS Slope: 2.8H:1V - Average Crest Width: 21 feet Conclusions: - Underseepage: Not identified as vulnerable due to a blanket condition that meets criteria. - Through Seepage: Identified as vulnerable due to an erodible embankment material and head that does not meet criteria. - Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along the reach. - Freeboard: Less than 3 feet of freeboard present along 90% of the reach.
RD556 SCL	ILNCL	RD556-A	5+00	11.9	-4.9	16.8	42.21	52.33	21.98	117	0	-5		2.7	2.9	16.40	-4.5	21.3	21.3	5.5	30.8	38.5											95.0				ILNCL	5+00	Rob, Hpm	II	Rob on West side, Hpm on east side						
RD556 SCL	ILNCL	RD556-A	10+00	11.2	-5.8	17.0	47.09	51.63	15.70	114	--	--		3.1	2.7	16.40	-5.2	22.2	--	5.2	32.3	NA	GEI_BALMD_006C	11+91	56.0	56.0		Meets		CL	ML, SM	Erodible	95.0	confining	3.4	DNM	ILNCL	10+00	Rob, Hpm	II	Rob on West side, Hpm on east side						
RD556 SCL	ILNCL	RD556-A	15+00	11.4	-7.9	19.3	62.79	76.40	11.86	151	--	--		2.6	2.8	16.40	-5.0	24.3	--	6.2	35.7	NA											145.0				ILNCL	15+00	Rob, Hpm	II	Rob on West side, Hpm on east side						
RD556 SCL	ILNCL	RD556-A	20+00	11.3	-6.5	17.8	43.26	75.70	34.19	153	--	--		2.3	2.7	16.40	-5.1	22.9	--	6.7	33.4	NA											145.0				ILNCL	20+00	Rob, Hpm	II	Rob on West side, Hpm on east side						

Appendix E - Preliminary Evaluation of Levees Protecting the Community of Isleton with Exploration Recommendations

Segment	NULE Alignment ID	Reach	NULE Station	Levee Geometry: Crest Elev (ft)	LS Toe Elev (ft)	LS Levee Height (ft)	WS Base Width (ft)	LS Base Width (ft)	Crest Width (ft)	Base Width (ft)	Ditch Location	Bottom of Ditch Elev.	Berm Width (ft) (if present)	Average LS Slope (xH:1V)	Average WS Slope (xH:1V)	AWSE (ft)	Available Freeboard (ft)	Index Indicators: Net Head above toe (ft)	Net Head above ditch (ft)	Creep Ratio $C_c=W/h_{cr}$	Critical Blanket at Toe (ft)	Critical Blanket at Ditch (ft)
40	GGAS-R	40-A	1220+00	15.6	0.0	15.6	32.42	31.64	18.75	83	0	0		2.3	4.0	14.09	1.5	14.1	14.1	5.9	19.3	24.2
40	GGAS-R	40-A	1215+00	15.2	-0.4	15.6	22.66	49.61	21.48	94	0	0		2.2	2.9	14.02	1.2	14.4	14.4	6.5	19.9	24.8
40	GGAS-R	40-A	1210+00	15.3	-0.4	15.7	27.34	52.34	12.50	92	0	0		2.8	4.3	13.97	1.4	14.4	14.4	6.4	19.8	24.7
40	GGAS-R	40-A	1205+00	15.5	-0.7	16.1	35.55	44.14	21.48	101	0	-1		2.0	4.0	13.91	1.6	14.6	14.6	6.9	20.1	25.2
40	GGAS-R	40-A	1200+00	16.0	4.5	11.5	36.33	69.53	17.58	123	--	--	13	2.2	3.1	13.87	2.1	9.3	--	14.6	11.7	NA
40	GGAS-R	40-A	1195+00	15.7	6.5	9.2	40.23	25.00	20.70	86	--	--		3.0	4.1	13.81	1.9	7.3	--	11.8	8.4	NA
40	GGAS-R	40-A	1190+00	15.6	4.3	11.3	26.56	69.92	21.88	118	--	--	19	2.8	3.3	13.74	1.9	9.5	--	14.5	12.0	NA
40	GGAS-R	40-A	1185+00	15.2	-0.8	16.0	53.13	39.06	19.14	111	0	-1		2.5	3.8	13.67	1.5	14.5	14.6	7.7	19.9	25.2
40	GGAS-R	40-A	1180+00	15.9	5.1	10.8	14.06	33.98	28.13	76	--	--		2.5	2.3	13.61	2.3	8.5	--	8.9	10.5	NA
40	GGAS-R	40-A	1175+00	16.0	5.6	10.4	41.41	30.86	18.75	91	36	1		3.2	3.2	13.58	2.4	8.0	12.4	11.4	9.6	20.8
40	GGAS-R	40-A	1170+00	16.0	4.3	11.7	36.33	57.42	25.39	119	--	--	18	2.2	3.0	13.56	2.4	9.3	--	14.8	11.7	NA
40	GGAS-R	40-A	1165+00	14.5	1.2	13.3	36.33	58.98	16.02	111	--	--	12	2.9	3.8	13.54	1.0	12.3	--	10.0	16.5	NA
40	GGAS-R	40-A	1160+00	14.5	-0.8	15.3	28.13	72.27	21.48	122	--	--	16	2.7	4.1	13.51	1.0	14.3	--	--	19.7	NA
40	GGAS-R	40-A	1155+00	14.5	0.5	14.0	31.25	78.91	16.80	127	51	-9	17	3.6	4.0	13.45	1.1	12.9	22.4	11.1	17.5	34.0
40	GGAS-R	40-A	1150+00	14.4	0.3	14.1	25.39	72.27	19.53	117	50	-7	15	3.2	4.3	13.40	1.0	13.1	20.3	10.1	17.8	30.6
40	GGAS-R	40-A	1145+00	14.4	-0.5	14.9	29.30	71.09	21.48	122	50	-7	14	2.7	3.8	12.92	1.5	13.5	20.1	10.1	18.3	36.2
40	GGAS-R	40-A	1140+00	14.0	-2.4	16.4	25.39	75.00	23.83	124	32	-8	12	2.2	2.6	12.93	1.1	15.3	20.5	8.9	21.3	37.1
40	GGAS-R	40-A	1135+00	13.7	-5.2	18.9	13.28	66.41	26.56	106	35	-8		3.1	2.2	12.71	1.0	17.9	20.4	5.9	25.5	36.9
40	GGAS-R	40-A	1130+00	13.7	-5.3	19.1	16.02	65.63	26.56	108	31	-7		2.4	2.6	12.68	1.1	18.0	19.9	6.0	25.6	35.8
40	GGAS-R	40-A	1125+00	13.9	0.4	13.5	16.02	67.58	41.80	125	33	-10	14	2.6	2.9	12.61	1.3	12.2	22.3	11.4	16.3	40.7
40	GGAS-R	40-A	1120+00	13.9	-1.3	15.2	19.14	84.77	24.61	129	45	-10	18	3.0	2.8	12.57	1.3	13.9	22.2	10.5	19.1	40.3
40	GGAS-R	40-A	1115+00	13.9	-0.9	14.8	21.48	82.03	26.17	130	40	-9	19	2.8	2.5	12.54	1.3	13.5	22.0	11.0	18.4	40.0
40	GGAS-R	40-A	1110+00	14.5	3.2	11.3	22.66	25.78	19.92	68	--	--		2.3	5.0	12.45	2.1	9.2	--	7.4	11.6	NA
40	GGAS-R	40-A	1105+00	13.5	-1.9	15.3	25.78	60.55	41.41	128	--	--	17	2.1	3.1	12.39	1.1	14.3	--	10.1	19.6	NA
40	GGAS-R	40-A	1100+00	13.5	-4.8	18.3	18.36	110.55	14.45	143	--	--	22	5.0	2.7	12.34	1.1	17.1	--	9.6	24.2	NA

NULE Station	Exploration	Exploration Stationing	Blanket Thickness-Each Expl (ft)	Selected Blanket Thickness at Toe (ft)	Selected Blanket Thickness at Ditch (ft)	Underseepage at Toe	Underseepage at Ditch	Shallow Foundation Material	Levee Material (CL, ML, SM)	Erodibility	Base Width Bin	Confining/ Draining Shallow Foundation	T/S Max Net Head Criteria	Through Seepage	Stream ID	NULE Station	Geomorphology	Geomorph Source (Level 2-I or 2-II)	Geomorphology Notes
1220+00	2F-66-2	1217+63							ML	Erodible	95.0		5.8	DNM	GGAS-R	1220+00	Rcs, Rob	II	Rcs on west side, Rob on east side
1215+00											95.0				GGAS-R	1215+00	Rcs, single thread channel	II	Channel on west side
1210+00											95.0				GGAS-R	1210+00	Rob, Rcs	II	Rcs on west side, Rob on east side
1205+00											95.0				GGAS-R	1205+00	Rob	II	Rob on east and west sides
1200+00											120.0				GGAS-R	1200+00	Rob	II	Rob on east and west sides
1195+00											95.0				GGAS-R	1195+00	Rob	II	Rob on east and west sides
1190+00											95.0				GGAS-R	1190+00	Rob	II	Rob on east and west sides
1185+00											95.0				GGAS-R	1185+00	Rob	II	Rob on east and west sides
1180+00											95.0				GGAS-R	1180+00	Rob	II	Rob on east and west sides
1175+00	2F-91-43	1175+00	0.0	0.0	0.0	DNM-Leaker	DNM-Leaker	SP	SP	Erodible	95.0	draining	5.8	DNM	GGAS-R	1175+00	Rob	II	Rob on east and west sides
1170+00											95.0				GGAS-R	1170+00	Rob	II	Rob on east and west sides
1165+00											95.0				GGAS-R	1165+00	Rcs, single thread channel	II	Rob on east and west sides, channel in west side
1160+00											120.0				GGAS-R	1160+00	Rob, single thread channel	II	Rob on east and west sides, channel in west side
1155+00											120.0				GGAS-R	1155+00	Rob, single thread channel	II	Rob on east and west sides, channel in west side
1150+00	2F-91-43A	1148+93	3.0	3.0	0.0	DNM-Grad	DNM-Leaker	CL, SP		Erodible	95.0	confining	3.4	DNM	GGAS-R	1150+00	Rob	II	Rob on east and west sides
1145+00											120.0				GGAS-R	1145+00	Rob	II	Rob on east and west sides
1140+00											120.0				GGAS-R	1140+00	Hpm, Rob	II	Hpm on north side, Rob on south side
1135+00											95.0				GGAS-R	1135+00	Hpm, Rob	II	Hpm on north side, Rob on south side
1130+00											95.0				GGAS-R	1130+00	Rdc, Rob, single thread channel	II	Rdc on north side, Rob on south side
1125+00	GEI_BALMD_007C	1127+31	3.5	3.5	0.0	DNM-Grad	DNM-Leaker	CL, SP		Erodible	120.0	confining	3.4	DNM	GGAS-R	1125+00	Rdc, Rob	II	Rdc on north side, Rob on south side
1120+00											120.0				GGAS-R	1120+00	Rob	II	Rob on west and east sides
1115+00											120.0				GGAS-R	1115+00	Rob	II	Rob on west and east sides
1110+00	2F-91-44 2F-91-44A	1112+03	0 4	0.0		DNM-Leaker		SC	SP	Erodible	95.0	draining	5.8	DNM	GGAS-R	1110+00	Rdc, Rob	II	Rdc on west side, Rob on east side
1105+00											120.0				GGAS-R	1105+00	Rdc, Rob	II	Rdc on west side, Rob on east side
1100+00											120.0				GGAS-R	1100+00	Rob	II	

NULE Station	Past Performance (Green "X" = FSRP Site): Boils	Seepage	LS Slip/ Slough/ Subsidence	WS Erosion/ Slip/Slough	Past Performance Notes
1220+00			X	X	
1215+00				X	
1210+00			X	X	
1205+00			X	X	Slides identified as Past Performance.
1200+00				X	
1195+00				X	
1190+00				X	
1185+00				X	
1180+00	X		X	X	Cracking identified as Past Performance.
1175+00	X	X	X	X	
1170+00		X		X	Slides identified as Past Performance.
1165+00		X	X	X	
1160+00		X	X	X	
1155+00		X	X		Slides identified as Past Performance. Cracking identified as Past Performance.
1150+00	X	X	X		Slides identified as Past Performance. Cracking identified as Past Performance.
1145+00		X	X		Slides identified as Past Performance. Cracking identified as Past Performance.
1140+00		X	X		Slides identified as Past Performance.
1135+00		X	X		Slides identified as Past Performance.
1130+00		X	X		Slides identified as Past Performance.
1125+00		X	X		Slides identified as Past Performance.
1120+00		X	X		Slides identified as Past Performance.
1115+00		X	X		Slides identified as Past Performance.
1110+00	X		X		Slides identified as Past Performance.
1105+00	X				
1100+00	X				

Evaluation Notes

Reach Characteristics:
- Predominantly underlain by Historical overbank deposits, Historical crevasse splay deposits, Historical distributary channel deposits, and Holocene peat and muck.
- Average 13 feet of head above landside toe.
- History of waterside erosion along northern half of reach, landside slope stability issues (including slides and cracking) throughout majority of reach, seepage along approximate Sta. 1115+00 to 1175+00, and boils along approximate Sta. 1100+00 to 1110+00, Sta. 1150+00, and Sta. 1175+00 to 1180+00.
- Six explorations along the reach - three indicated a blanket condition approximately 3-4 feet thick, two indicated a leaker condition with creep ratio of approximately 7.4 and 11.4, and the last exploration only drilled through levee material.

Levee Geometry:
- Average Height: 14 feet
- Average LS Slope: 2.7H:1V
- Average WS Slope: 3.4H:1V
- Average Crest Width: 23 feet

Conclusions:
- Underseepage: Identified as vulnerable due to the high head condition with a landside blanket that does not meet criteria and a leaker condition that does not meets creep ratio criteria.
- Through Seepage: Identified as vulnerable due to an erodible embankment material and head that does not meet criteria.
- Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along the reach.
- Freeboard: Less than 3 feet of freeboard present along the reach.