

GEI Consultants

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Geotechnical Assessment Report

Delta Small Communities Flood Risk Reduction Program – Community of Courtland

Sacramento County, California

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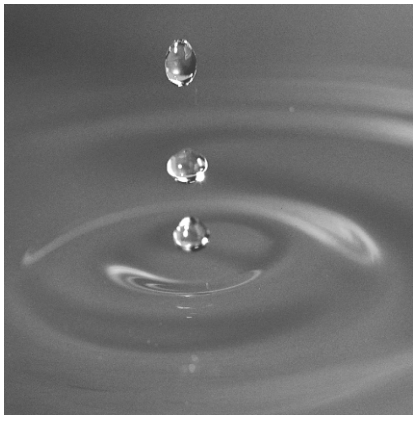


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Abbreviations and Acronyms

AWSE	Assessment Water Surface Elevation
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
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
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 Courtland, 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 Courtland as shown on Figure 1. The geotechnical assessment completed for this Report included additional field exploration and screening level evaluation of existing levee conditions for the levees that surround the community of Courtland. This Report will be used to support the Feasibility Study's evaluation of the structural alternatives for the community of Courtland. 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 levees protecting this community are constructed along the left bank of the Sacramento River (DWR Non-Urban Levee Evaluation [NULE] Segments 126 and 131), and the right banks of The Meadows Slough (NULE Segment 1040) and Snodgrass Slough (NULE Segment 1041), as shown on Figure 1 and discussed in more detailed below. The levee segments surrounding the community of Courtland include State Plan of Flood Control (SPFC) and Non-SPFC levees. SPFC levees are a shared State-federal flood protection system that ensures the maintenance and management obligations are met. Non-SPFC levees are not maintained by State-federal flood protection system. These levees encompass two Reclamation Districts (RDs), RD 755 at the northern, upstream end and RD 551.

Along the Courtland levees there are homes and other structures against the landside levee toe and within 15 feet of the toe, railroad embankments, and highway embankments that are adjacent to and cross over the levee at various locations.

1.2.1 Sacramento River (NULE Segments 126 and 131)

The Sacramento River left bank levees near Courtland (NULE Segments 126 and 131) extend approximately 8.6 miles along Sacramento River near the northerly extension of Snodgrass Slough at the upstream end to the confluence of the Sacramento River and The Meadows Slough at the southern, downstream end. These NULE levee segments are SPFC levees. The northern, upstream 1.8 miles are part of the RD 755 levee system, and the remaining 6.8 miles are part of the RD 551 levee system.

1.2.2 The Meadows Slough (NULE Segment 1040)

The Meadows Slough right bank levee (NULE Segment 1040) is a Non-SPFC levee that is a part of the RD 551 levee system. It is approximately 1.4 miles long, extending from the confluence of Snodgrass Slough and The Meadows Slough westward towards the Sacramento River. The western end of The Meadows Slough does not connect to the Sacramento River and is affected by the backwater conditions of Snodgrass Slough.

1.2.3 Snodgrass Slough (NULE Segments 1041)

The Snodgrass Slough right bank levee (NULE Segment 1041) is a Non-SPFC levee that is a part of the RD 551 levee system. It is about 5.9 miles long and extends from the upstream end near Sacramento River southward to the confluence with The Meadows Slough.

1.3 Background Information and Existing Data

The Courtland levees include approximately 16 miles of levees that are intended to provide flood protection for the community of Courtland and the agricultural lands. The levees were initially constructed by local interests in the early 1900s and generally built using materials dredged from the adjacent rivers and sloughs and placed without compaction.

Based on historic past performance documentation, the Courtland levees have experienced wide-spread seepage as well as waterside erosion. An Existing Geotechnical Data Technical Memorandum (Appendix A) was prepared for Courtland 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 Non-Urban Levee Evaluation (NULE) project. Stationing is shown in Figure 2.

Topographic mapping use 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 United State Army Corps of Engineers (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. Because this project involved exploration activities in a number of parcels owned by private landowners, site access agreements in these areas were

coordinated during the exploration program planning by MBK Engineers (MBK). 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 or track mounted CPT rig (depending on location) 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, 8 out of 10 planned CPTs were completed by GEI between August and November 2019. Two planned CPTs along NULE Segment 1040 were not able to be completed due to project constraints, but are shown on Figure 2. The eight 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 100 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 (included in Appendix C) 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 in 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 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:

- Sieve analysis with hydrometer, ASTM D6913 and D7928
- 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.

The geomorphic analyses performed for the NULE project consisted of Level 2-I analyses and Level 2-II analyses. NULE Level 2-I mapping was based primarily on the compilation and analysis of existing regional geologic and geomorphic information (e.g., soil survey maps, geologic maps). Level 2-I analyses provided geologic and geomorphic maps at a regional scale, preliminary assessments of the hazard of levee underseepage, and information on soft soil areas and subsidence. The North NULE Level 2-I Geomorphic Assessment was completed in April 2010 (DWR, 2011) and included the entire community of Courtland levee system.

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, 2011) and included the Sacramento River and a portion of The Meadows Slough within the community of Courtland.

DWR' report (DWR, 2011) covering the community of Courtland basin, geologic, and underseepage susceptibility maps are included in Appendix C of the Existing Geotechnical Data Technical Memorandum which is Appendix A to this report.

Snodgrass Slough (NULE Segment 1041) is only covered by Level 2-I NULE geomorphic mapping. Based on the Level 2-I mapping, Snodgrass Slough overlies natural levee deposits in the northern half of the segment and flood basin deposits in the southern half. The natural levee deposits (silt, sand, and clay) are interbedded, and may have layers from 2 to 5 feet thick that are probably laterally discontinuous along the levee. The soils in the floodplain deposits are finer, consisting primarily of silt and clay, but mapped peat deposits are also present.

The Meadows Slough (NULE Segment 1040) geomorphic mapping consists of Level 2-I and 2-II NULE mapping. The natural levee deposits that underlie the western end of Meadow Slough are interbedded sand, silt, and clay and may have layers from 2 to 5 feet thick that are probably laterally discontinuous along the levee. The sediments comprising the floodplain deposits underlying the eastern end of the segment consist of clay, silt, and possibly peat. More detailed Level 2-II mapping is generally consistent with Level 2-I mapping along Meadow Slough except that the Level 2-II mapping indicates that the foundation soils are recent overbank deposits (silt, clay, and lesser sand) that may overlie the flood basin deposits. In addition to Recent overbank deposits, recent crevasse splay deposit (fine sand with silt and clay) and Marsh deposits are also mapped within the community of Courtland.

For Sacramento River (NULE Segments 126 and 131), NULE Level 2-II mapping indicates Segments 126 and 131 levees overlay recent overbank deposits consisting of interbedded silt, sand and clay that likely interfingers with adjacent flood plain silt and clay sediments and are likely to vary laterally in extent and character. The Level 2-II mapping also indicates that the levee overlies recent crevasse splays (fine sand, silt, and clay) (DWR, 2011) .

3.3 Sacramento River (NULE Segments 126 and 131)

In addition to geomorphology, historical explorations compiled from available references and CPTs performed for this study area, were used to assess the embankment and subsurface conditions along the Sacramento River levee protecting the community of Courtland (NULE Segments 126 and 131).

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 in Section 2.2 above. As such, embankment composition was assessed based on the conditions identified in the historical explorations. A total of 14 historical explorations were available. The available explorations along NULE Segments 126 and 131 indicate the embankment consists of sand, silt, and clay. The historic exploration logs/sticks are in contained in Appendix A.

3.3.2 Foundation Conditions

Available explorations for the interpretation of foundation conditions were generally limited to explorations through the levee crown and landside toe. Only one exploration was available on the waterside, and it was an overwater boring.

Available explorations along Segment 126 included 11 historical explorations and three CPTs completed for this study area. These explorations indicate a fine-grained blanket ranging in thickness from 9 to 28 feet thick with one exploration showing a shallow unit of coarse/sandy material is present along the segment. The blanket is underlain by a pervious aquifer layer extending to depths up to 100 feet. A fine-grained aquitard layer was encountered in several of the explorations beneath the aquifer, however the exploration with the thickest aquifer did not encounter an aquiclude and was terminated at a depth of approximately 100 feet.

The three available explorations along Segment 131 indicate a shallow unit of coarse/sandy material is present along the reach as shown in two of the explorations, and a third indicates a very thin blanket of approximately 2 feet. A consistent aquitard layer was not encountered.

The historic exploration logs/sticks are in included in Appendix A and the CPT plots for this study area are in Appendix B.

3.4 The Meadows Slough (NULE Segment 1040)

No historical explorations were available for NULE Segment 1040. However, NULE Segment 1040 is the border between the community of Courtland and Locke. Two CPTs were completed along this levee segment for the community of Locke and were used to estimate the levee segment's subsurface conditions along with geomorphology.

3.4.1 Embankment Conditions

The two CPT completed for the community of Locke were performed from the levee crest and used to assess the embankment conditions. These CPTs indicate the embankment consists of sand and silt. The CPT plots are in Appendix B.

3.4.2 Foundation Conditions

The two explorations available for Segment 1040 indicate a fine-grained blanket ranging in thickness from 12 to 35 feet thick. The blanket is underlain by a pervious aquifer layer. One of the explorations indicates the initial aquifer layer is underlain by a 10-foot-thick aquitard beginning approximately 70-feet below the levee crest. The CPT plots are in Appendix B.

3.5 Snodgrass Slough (NULE Segment 1041)

In addition to geomorphology, historical explorations compiled from available references and CPTs performed for this study, were used to assess the embankment and subsurface conditions along the Snodgrass Slough levee protecting the community of Courtland (NULE Segment 1040).

3.5.1 Embankment Conditions

As part of the study, five CPTs were performed from the levee crest and used to assess the embankment conditions along with three historical explorations located on the landside.

These available explorations along NULE segment 1041 indicate the embankment consists predominantly of sand and silt with some clay. The historic exploration logs/sticks are in Appendix A and the CPT plots for this study are in Appendix B.

3.5.2 Foundation Conditions

Explorations along Segment 1041 indicate a fine-grained blanket at the downstream portion of the Segment ranging in thickness from 29 to 32 feet thick. The explorations along the upstream portion of the Segment indicate a much thinner blanket or leaker condition is present. The blanket in the downstream portion of the Segment is underlain by approximately 10 to 17 feet of sand. Explorations along the downstream portion of the reach indicate the presence of a fine-grained aquitard layer approximately 35 feet below the landside toe of the levee.

The historic exploration logs/sticks are in Appendix A and the CPT plots for this study 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 geotechnical assessment presented in this Report was performed to assess existing conditions vulnerability of the levees under 100-year flood conditions. 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. 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 Courtland were subdivided into nine reaches as summarized in Table 2 and shown on Figure 3.

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 Courtland (Appendix A). For the community of Courtland, the FRSP identified one serious seepage site and one critical seepage site.

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.

If no subsurface data is available to characterize the shallow foundation conditions, the nearest explorations in adjacent reaches were reviewed. If considered reasonable based on engineering judgement, these conditions were used to assess the vulnerability of the reach. If the adjacent reach subsurface conditions we not considered reasonable to reflect the conditions of the reach being assessed, then data such as how much head is above the levee toe at the AWSE, and the estimated required blanket thickness were reviewed and the vulnerability was assessed based on engineering judgement applied to those factors.

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 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 4 and Figure 5). 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

Along the Sacramento River, a detailed erosion survey/assessment was performed by MBK and is included in Appendix E. For the purposes of evaluating the vulnerability of the Courtland study area levees along Meadow Slough and Snodgrass Slough to erosion, considerations included a qualitative assessment of the overall levee geometry, oversteepening of the waterside slopes, past erosion performance, documented mitigation, and potential erodibility of the embankment material.

The vulnerability assessment focused on erosion that could threaten the integrity of the levee (referred to as erosion-driven failure) indicated by oversteepened slopes that encroach on the standard levee prism as described above. This is in contrast to minor erosion/sloughing that can be addressed by regular observation and maintenance of the levee slope. If not properly maintained, this type of minor erosion can progress and begin to threaten the levee integrity.

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 crown) to a threshold set three feet above the AWSE.

5 Discussion of Site Specific Assessment

5.1 Sacramento River (NULE Segments 126 and 131)

The Sacramento River levee segments in the Courtland study area was divided into a total of four reaches based on the assessment approach described in Section 4. The reaches and locations of available explorations are shown in Figure 3. The assessment found that none of the Sacramento River reaches have insufficient freeboard for the AWSE. Additionally, none of the Courtland Sacramento River reaches were identified as vulnerable to landside slope instability as the average landside slope is flatter than 2H:1V and there is no documented history of landside slope instability. Segment 126 is located at the downstream portion of the Sacramento River within the Courtland study area. Segment 131 is located at the upstream portion of the Sacramento River within the Courtland study area. The other assessments are described below individually for each reach. Appendix F provides the Courtland Assessment Table that includes the assessment details for cross-sections every 500-feet along the levee.

5.1.1 Reach 131-A

Reach 131-A is 4,700 feet long, located between Station 3012+00 and Station 2965+00. One exploration is located along the levee toe within Reach 131-A and two explorations are located along the levee crest. This reach was identified as vulnerable to underseepage due to a blanket condition shown in the explorations that is thinner at the landside toe than the estimated required blanket thicknesses in the reach, calculated as described in Section 4.1. Additionally, the other two explorations indicate a leaker condition with a creep ratio that does not meet criteria as described in Section 4.1. This is consistent with reports of past performance including seepage and boils documented during past highwater events along the reach. The majority of reach length is identified as a part of FSRP sites. The downstream 3,500 feet of the reach is identified as a serious seepage site and upstream from that there is a 500-foot long critical seepage site (DWR, 2013). The FSRP table and map of these sites are included in the Existing Geotechnical Data Technical Memorandum (Appendix A). This reach was also identified as vulnerable to through seepage because the AWSE is higher than the criteria described in Section 4.2.

Waterside slopes average 2.1H:1V along Reach 131-A. MBK has identified erosion sites within this reach (Appendix E).

5.1.2 Reach 131-B

Reach 131-B is 5,000 feet long, located between Station 2965+00 and Station 2915+00. There are no explorations located within Reach 131-B. This reach was identified as

potentially vulnerable to underseepage due an average head of 9 feet above the landside toe, a low creep ratio, and no blanket thickness data available. This reach was also 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.

Waterside slopes average 2.4H:1V along Reach 131-B. MBK has identified erosion sites within this reach (Appendix E).

5.1.3 Reach 126-A

Reach 126-A is 15,000 feet long, located between Station 2915+00 and Station 2765+00. Four explorations are located along the levee toe within Reach 126-A. This reach was not identified as vulnerable to underseepage due to a blanket condition shown in the explorations that is thicker at the landside toe than the estimated required blanket thicknesses in the reach, calculated as described in Section 4.1. This reach was identified as vulnerable to through seepage because the AWSE is higher than the criteria described in Section 4.3.

Waterside slopes average 2.4H:1V along Reach 126-A. MBK has identified erosion sites within this reach (Appendix E).

5.1.4 Reach 126-B

Reach 126-B is 20,847 feet long, located between Station 2765+00 and Station 2556+53. Eight explorations are located along the levee toe within Reach 126-B and one exploration is located along the levee crest. This reach was identified as vulnerable to underseepage due to a blanket condition shown in the explorations that is thinner at the landside toe than the estimated required blanket thicknesses in the reach, calculated as described in Section 4.1. Additionally, one exploration indicates a leaker condition with a creep ratio that does not meet criteria as described in Section 4.2. This is consistent with reports of past performance including seepage throughout the reach. This reach was also identified as vulnerable to through seepage because the AWSE is higher than the criteria described in Section 4.2.

Waterside slopes average 2.0H:1V along Reach 126-B. MBK has identified erosion sites within this reach (Appendix E).

5.2 Meadow Slough (NULE Segment 1040)

The Meadow Slough levee segment in the Courtland study area was divided into two reaches based on the assessment approach described in Section 4. The reaches and locations of available explorations are shown in Figure 3. The assessment indicates that none of the Meadow Slough reaches have insufficient freeboard. Additionally, none of the

Meadow Slough reaches were identified as vulnerable to landside slope instability as the average landside slope is flatter than 2H:1V and there is no documented history of landside slope instability. The other assessments are described below individually for each reach. Appendix F provides the Courtland Assessment Table that includes the assessment details for cross-sections every 500-feet along the levee.

5.2.1 Reach 1040-A

Reach 1040-A is 5,000 feet long, located at the downstream portion of the Meadow Slough within the Courtland study area from Station 1000+00 to Station 1050+00. There are two explorations located along the crest of the levee within Reach 1040-A. This reach was identified as vulnerable to underseepage due to a blanket condition shown in the explorations that is thinner at the landside toe than the estimated required blanket thicknesses in the reach, calculated as described in Section 4.1. This reach was also identified as vulnerable to through seepage because the AWSE is higher than the criteria described in Section 4.2.

Waterside slopes average 3.1H:1V along Reach 1040-A. There are isolated sections of the reach that were identified as having erosion concerns due to waterside slopes steeper than 3H:1V. These sections account for approximately 30% of the total length of the reach.

5.2.2 Reach 1040-B

Reach 1040-B is 2,300 feet long, located at the upstream portion of the Meadow Slough within the Courtland study area from Station 1050+00 to Station 1073+00. There are no explorations located within Reach 1040-B. This reach was identified as potentially vulnerable to underseepage due a high average head of 14 feet above the landside toe, a low creep ratio, seepage past performance, and no blanket thickness data available. This reach was also 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.

Waterside slopes average 3.9H:1V along Reach 1040-B. The reach was not identified as vulnerable to erosion-driven failure with waterside slopes flatter than 3H:1V.

5.3 Snodgrass Slough (NULE Segment 1041)

The Snodgrass Slough levee segment in the Courtland study area was divided into three reaches based on the assessment approach described in Section 4. The reaches and locations of available explorations are shown in Figure 3. The assessment indicates that none of the Snodgrass Slough reaches have insufficient freeboard. Additionally, none of the Snodgrass Slough reaches were identified as vulnerable to landside slope instability as the average landside slope is flatter than 2H:1V. The other assessments are described below

individually for each reach. Appendix F provides the Courtland Assessment Table that includes the assessment details for cross-sections every 500-feet along the levee.

5.3.1 Reach 1041-A

Reach 1041-A is 14,900 feet long, located at the downstream portion of the Snodgrass Slough within the Courtland study area from Station 1231+00 to Station 1380+00. There are two explorations located along the landside toe and three explorations along the crest of the levee within Reach 1041-A. This reach was identified as not vulnerable to underseepage due to a blanket condition shown in the explorations that is greater at the landside toe than the estimated required blanket thicknesses in the reach, calculated as described in Section 4.1. There are exceptions where ditches are present along the landside toe at isolated locations, but as these are anomalous conditions and this study did not address remediation for anomalous conditions. However, this reach was identified as vulnerable to through seepage because the explorations indicate that embankment material, especially in the downstream portion of the reach, is erodible, and the AWSE is higher than the criteria described in Section 4.2.

Waterside slopes average 3.2H:1V along Reach 1041-A. The reach was not identified as vulnerable to erosion-driven failure. The waterside slopes along the majority of the reach flatter than 3H:1V. In isolated locations where the waterside slopes are steeper than 3H:1V, the levee crest is larger than 20 feet, indicating that the levee is overbuilt at these locations.

5.3.2 Reach 1041-B

Reach 1041-B is 11,000 feet long, located at the middle portion of the Snodgrass Slough within the Courtland study area from Station 1380+00 to Station 1490+00. There is one exploration located along the landside toe and one exploration along the crest of the levee within Reach 1041-B. This reach was identified as vulnerable to underseepage due to a blanket condition shown in the explorations that is thinner at the landside toe than the estimated required blanket thicknesses in the reach, calculated as described in Section 4.1. This reach was identified as vulnerable for through seepage because the explorations indicate that embankment material is erodible and the AWSE is higher than the criteria described in Section 4.2.

Waterside slopes average 3.0H:1V along Reach 1041-B. There are isolated sections of the reach that were identified as having erosion concerns with waterside slopes steeper than 3H:1V. These sections account for approximately 60 percent of the total length of the reach.

5.3.3 Reach 1041-C

Reach 1041-C is 5,300 feet long, located at the upstream portion of the Snodgrass Slough within the Courtland study area from Station 1490+00 to Station 1543+00. There is one exploration along the crest of the levee within Reach 1041-C. This reach was not identified as vulnerable to underseepage due a relatively low head averaging 5.5 feet above the landside toe and a creep ratio that meets the criteria described in Section 4.2. This reach was not identified as vulnerable for through seepage even though the explorations indicate the embankment material is erodible because the AWSE is less than the criteria described in Section 4.3.

Waterside slopes average 2.9H:1V along Reach 1041-C. There are isolated sections of the reach that were identified as having erosion concerns due to waterside slopes steeper than 3H:1V. These sections account for approximately 55 percent of the total length of the reach.

6 Existing Geotechnical Condition Summary

The Courtland levees were assessed using the exiting information as well as the data gathered for this project and assessed based on the approaches described in Section 4. A total of approximately 16 miles were assessed along a total of 4 segments. Each segment was divided into reaches and assessed for underseepage, through seepage, slope stability, erosion, 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 Segments 126 and 131)

The geotechnical evaluation along the Sacramento River indicates that all Sacramento River reaches in the Courtland study area were identified as vulnerable to through seepage and erosion-driven failure. Reaches 126-B, 131-A, and 131-B were identified as vulnerable to underseepage. None of the Sacramento River reaches in the Courtland study area were identified as vulnerable to landside slope instability and all have more than 3 feet of freeboard. See the Evaluation table included in Appendix F for more details.

6.2 Meadow Slough (NULE Segment 1040)

The geotechnical evaluation along the Meadow Slough indicates that all Meadow Slough reaches in the Courtland study area were identified as vulnerable to underseepage and through seepage. Approximately 30 percent of Reach 1040-A was identified as vulnerable to erosion-driven failure. None of the Meadow Slough reaches in the Courtland study area were identified as vulnerable to landside slope instability and all have more than 3 feet of freeboard. See the Evaluation table included in Appendix F for more details.

6.3 Snodgrass Slough (NULE Segment 1041)

The geotechnical evaluation along Snodgrass Slough indicates that Reaches 1041-A and 1041-B were identified as vulnerable to through seepage. Reach 1041-B was identified as vulnerable to underseepage. Approximately 50 percent of Reaches 1041-B and 1041-C were identified as vulnerable to erosion-driven failure. None of the Snodgrass Slough

reaches in the Courtland study area were identified as vulnerable to landside slope instability and all have more than 3 feet of freeboard. See the Evaluation table included in Appendix F for more details.

7 Fix-in-Place Levee Improvement Alternatives

Standardized conceptual remedial alternatives were considered for this screen level assessment. They were identified 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:

	Existing Condition Levee Vulnerabilities Addressed				
Remedial Alternative	**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	
Rock Slope Protection					X

The standardized conceptual remedial alternatives considered in this study, included standardize 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. None of the reaches in the Courtland study area were identified as vulnerable to slope instability.

  - 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.

The summary below provides the identified remedial alternatives and approximate dimensions for each identified reach. 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 the Table 3.

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 Courtland 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 Courtland are located in the Sacramento Delta. Settlement in the Delta is common based on the presence of Marsh deposits (peat and 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 Courtland

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_RD551_001C	Sacramento River	126	Landside Toe	2900+00	38.332934	-121.568177	31.2	11.7	19.5	6.3	77.8
GEI_RD551_002C	Sacramento River	126	Landside Toe	2765+00	38.302015	-121.569677	30.5	12.5	18.0	9.6	75.1
GEI_RD551_003C	Sacramento River	126	Landside Toe	2595+00	38.266500	-121.527400	27.7	10.7	17.0	4.9	101.1
GEI_RD551_006C	Snodgrass Slough	1041	Levee Crown	1285+00	38.28376067	-121.5044545	26.6	2.2	24.4	32.0	101.1
GEI_RD551_007C	Snodgrass Slough	1041	Levee Crown	1347+50	38.299046	-121.512290	24.1	5.0	19.1	28.4	75.6
GEI_RD551_008C	Snodgrass Slough	1041	Levee Crown	1325+00	38.292625	-121.510449	26.5	-0.9	27.4	32.7	101.3
GEI_RD551_009C-B	Snodgrass Slough	1041	Levee Crown	1445+00	38.32345252	-121.5199862	28.7	11.6	17.1	34.5	71.4
GEI_RD551_010C	Snodgrass Slough	1041	Levee Crown	1500+00	38.33736205	-121.5253532	29.4	10.3	19.1	32.1	75.7

[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 Courtland Levee Vulnerability

NULE Alignment ID	NULE Segment	Reach	Start Station	End Station	Vulnerability				Freeboard (% Deficient)	Notes
					Underseepage	Through Seepage	Slope Stability	Erosion		
TMSS-L	1040	1040-A	1000+00	1050+00	X	X	-	X*	0	Reach Characteristics: - Predominantly historical overbank deposits with some crevasse splay deposits on the landside; waterside is underlain by Holocene marsh deposits - Avg 12 feet of head above landside toe - No history of past performance - 2 explorations along reach indicate a blanket ranging from 12 to 35 feet Levee Geometry: - Average Height: 24 feet - Average LS Slope: 5.3H:1V - Average WS Slope: 3.1H:1V - Average Crest Width: 16 feet Conclusions: - Underseepage: Identified as vulnerable due to the high head condition with a blanket that does not meet criteria - Through Seepage: Identified as vulnerable due to an erodible embankment material and head that exceeds criteria - Slope Stability: Not identified as vulnerable due to flat landside slopes - Erosion: Identified as vulnerable due to waterside slopes steeper than 3H:1V at isolated locations throughout the reach and the erodible embankment material - Freeboard: More than 3 feet freeboard present along the reach
TMSS-L	1040	1040-B	1050+00	1073+00	X	X	-	-	0	Reach Characteristics: - Predominantly historical overbank deposits with some crevasse splay deposits on the landside; waterside is underlain by Holocene marsh deposits - History of seepage along the reach - Avg 14 feet of head above landside toe - No explorations performed in this reach Levee Geometry: - Average Height: 26 feet - Average LS Slope: 5.1H:1V - Average WS Slope: 3.9H:1V - Average Crest Width: 16 feet Conclusions: - Underseepage: Identified as potentially vulnerable due to the high head condition, low creep ratio, seepage past performance, and no blanket thickness data available - Through Seepage: Identified as potentially vulnerable due to high head condition that would exceed criteria assuming an erodible embaknment material. - Slope Stability: Not identified as vulnerable due to flat landside slopes - Erosion: Not identified as vulnerable due to waterside slopes flatter than 3H:1V along the reach - Freeboard: More than 3 feet freeboard present along the reach
SDSS-R	1041	1041-A	1231+00	1380+00	-	X	-	-	0	Reach Characteristics: - Predominantly Holocene alluvium of supratidal floodplain on the landside and waterside - History of seepage along the reach - History of LS slough along the Sta. 1305+00 to 1380+00 - Avg 12.5 feet of head above landside toe - Five borings along reach indicate a blanket thickness of greater than 29 feet Levee Geometry: - Average Height: 23 feet - Average LS Slope: 5.0H:1V - Average WS Slope: 3.2H:1V - Average Crest Width: 27.5 feet Conclusions: - Underseepage: Not identified as vulnerable due to the thick blanket condition shown in the explorations, except where ditches are present along the landside toe in isolated locations. - Through Seepage: Identified as vulnerable due to an erodible embankment material (especially in the downstream portion of the reach) and head that exceeds criteria - Slope Stability: Not identified as vulnerable due to flat landside slopes - Erosion: Not identified as vulnerable due to waterside slopes flatter than 3H:1V along a majority of the levee and wide levee sections (>20-foot crest width) at locations that are steeper than 3H:1V.

Table 2. Summary of Courtland Levee Vulnerability

NULE Alignment ID	NULE Segment	Reach	Start Station	End Station	Vulnerability				Freeboard (% Deficient)	Notes
					Underseepage	Through Seepage	Slope Stability	Erosion		
SDSS-R	1041	1041-B	1380+00	1490+00	X	X	-	X*	0	Reach Characteristics: - Predominantly Holocene alluvium basin deposits on the landside and waterside - No history of past performance - Avg 5 feet of head above landside toe - Two explorations along reach indicate the presence of 6.5-foot-thick blanket in one and no blanket in the other Levee Geometry: -Average Height: 17.5 feet -Average LS Slope: 5.7H:1V -Average WS Slope: 3.0H:1V -Average Crest Width: 22.5 feet Conclusions: -Underseepage: Identified as vulnerable due to the presence of a thin blanket at the landside levee toe -Through Seepage: Identified as vulnerable due to erodible embankment material and a head above the landside toe that exceeds criteria -Slope Stability: Not identified as vulnerable due to flat landside slopes -Erosion: Identified as vulnerable due to waterside slopes steeper than 3H:1V at isolated locations throughout the reach
SDSS-R	1041	1041-C	1490+00	1543+00	-	-	-	X*	0	Reach Characteristics: - Predominantly historical crevasse splay deposits on the landside; waterside underlain by Holocene crevasse splay deposits and historical overbank deposits - No history of past performance - Avg 5.5 feet of head above landside toe - One exploration along reach indicates the presence of a leaker condition (no blanket) Levee Geometry: -Average Height: 18 feet -Average LS Slope: 4.5H:1V -Average WS Slope: 2.9H:1V -Average Crest Width: 23 feet Conclusions: -Underseepage: Not identified as vulnerable due to relatively low head and a creep ratio criteria that meets criteria -Through Seepage: Not identified as vulnerable due to head above the landside toe that meets criteria -Slope Stability: Not identified as vulnerable due to flat landside slopes -Erosion: Identified as vulnerable due to waterside slopes steeper than 3H:1V at locations throughout the reach -Freeboard: More than 3 feet freeboard present along the reach
SACR-L	131	131-A	3012+00	2965+00	X	X	-	X	0	Reach Characteristics: - Predominantly historical overbank deposits on the landside; waterside underlain by Holocene overbank deposits. - History of boils, seepage, and WS erosion is typical along segment -Three explorations at approximate Sta. 2985+00, 3005+00, and 3010+00 show a blanket thickness ranging from 0 to 2 ft. - Avg 9 feet of head above landside toe Levee Geometry: -Average Height: 14.5 feet -Average LS Slope: 2.8H:1V -Average WS Slope: 2.1H:1V -Average Crest Width: 32.5 feet Conclusions: -Underseepage: Identified as vulnerable due the presence a thin blanket condition that does not meet criteria in one exploration and leaker conditions shown in two of the explorations with low creep ratios as well as seepage past performance throughout the reach -Through Seepage: Identified as vulnerable due to an erodible embankment material and head above the landside toe that exceeds criteria -Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along a majority of the reach and the one location that is steeper corresponds to an overbuilt section (i.e. wide crest width) -Erosion: Identified as vulnerable due to waterside slopes steeper than 3H:1V at locations throughout the reach and erosion past performance documented at multiple locations with the reach -Freeboard: More than 3 feet freeboard present along the reach

Table 2. Summary of Courtland Levee Vulnerability

NULE Alignment ID	NULE Segment	Reach	Start Station	End Station	Vulnerability				Freeboard (% Deficient)	Notes
					Underseepage	Through Seepage	Slope Stability	Erosion		
SACR-L	131	131-B	2965+00	2915+00	X	X	-	X	0	Reach Characteristics: - Predominantly historical overbank deposits on the landside; waterside underlain by Holocene overbank deposits and historical crevasse splay deposits. - History of WS erosion is typical along segment - LS slough documented at approximately Sta. 2940+00 - Avg 9 feet of head above landside toe Levee Geometry: -Average Height: 16.5 feet -Average LS Slope: 3.1H:1V -Average WS Slope: 2.4H:1V -Average Crest Width: 27 feet Conclusions: -Underseepage: Identified as potentially vulnerable due an average head of 9 feet above the landside toe, a low creep ratio, and no blanket thickness data available. -Through Seepage: Identified as potentially vulnerable due to head above the landside toe that would likely exceed criteria for an erodible embankment -Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along a majority of the reach and the one location that is steeper corresponds to an overbuilt section (i.e. wide crest width) -Erosion: Identified as potentially vulnerable due to waterside slopes steeper than 3H:1V along a majority of the reach and erosion past performance documented throughout the reach -Freeboard: More than 3 feet freeboard present along the reach
SACR-L	126	126-A	2915+00	2765+00	-	X	-	X	0	Reach Characteristics: - Predominantly historical overbank deposits on the landside; waterside underlain by historical overbank deposits and crevasse splay deposits. - History of seepage and WS erosion is typical along segment - 4 explorations ranging from approximate Sta. 2765+00 to 2900+00 show a blanket thickness ranging from 13 to 28 ft - Avg 8 feet of head above landside toe Levee Geometry: -Average Height: 18 feet -Average LS Slope: 2.6H:1V -Average WS Slope: 2.4H:1V -Average Crest Width: 36 feet Conclusions: -Underseepage: Not identified as vulnerable due to the thick blanket condition shown in the explorations. -Through Seepage: Identified as vulnerable due to head above the landside toe that exceeds criteria for an erodible embankment -Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along the reach and no documented landside stability past performance -Erosion: Identified as vulnerable due to waterside slopes steeper than 3H:1V throughout the reach as well as erosion past performance documented throughout the reach -Freeboard: More than 3 feet freeboard present along the reach
SACR-L	126	126-B	2765+00	2556+53	X	X	-	X	0	Reach Characteristics: - Predominantly historical overbank deposits on the landside; waterside underlain by historical overbank deposits and crevasse splay deposits. - History of seepage and WS erosion is typical along segment - 9 explorations ranging from approximate Sta. 2560+00 to 2735+00 show a blanket thickness ranging from 0 to 23 ft - Avg 8 feet of head above landside toe Levee Geometry: -Average Height: 17 feet -Average LS Slope: 2.5H:1V -Average WS Slope: 2.0H:1V -Average Crest Width: 35 feet Conclusions: -Underseepage: Identified as vulnerable due to the presence of a thin blanket condition at multiple locations and a leaker condition shown in the explorations with a low creep ratio as well as seepage past performance throughout the reach -Through Seepage: Identified as vulnerable due to head above the landside toe that exceeds criteria for an erodible embankment -Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along the reach and no documented landside stability past performance -Erosion: Identified as vulnerable due to waterside slopes steeper than 3H:1V throughout the reach as well as erosion past performance documented throughout the reach -Freeboard: More than 3 feet freeboard present along the reach

*Only affects a portion of the reach

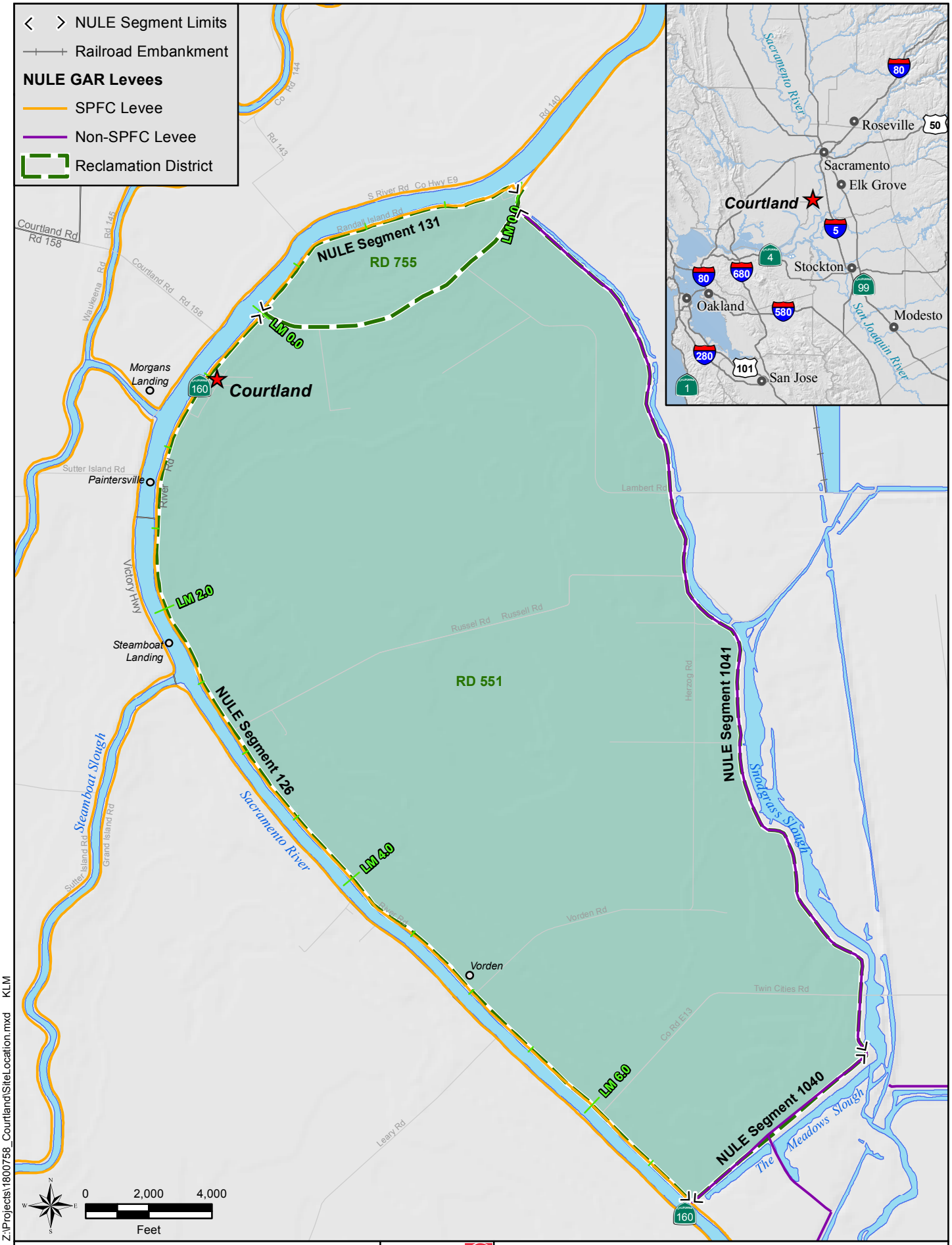
Table 3. Summary of Courtland Remedial Alternatives

NULE Alignment ID	Segment Name	NULE Segment	Reach	Start Station	End Station	Reach Length (feet)	Remediation Alternative 1 Dimensions	Remediation Alternative 2 Dimensions[1]	Vulnerability		
									Underseepage	Through Seepage	Erosion
TMSS-L	The Meadow Slough Left Bank	1040	1040-A	1000+00	1050+00	5,000	65-foot deep cutoff wall 145-foot wide RSP (3,000 feet)	145-foot wide 20-foot tall combo berm 145-foot wide RSP (3,000 feet)	X	X	X*
TMSS-L	The Meadow Slough Left Bank	1040	1040-B	1050+00	1073+00	2,300	95-foot deep cutoff wall	160-foot wide seepage berm	X	X	-
SDSS-R	Snodgrass Slough Right Bank	1041	1041-A	1231+00	1380+00	14,900	20-foot deep cutoff wall	13-foot tall Stability berm	-	X	-
SDSS-R	Snodgrass Slough Right Bank	1041	1041-B	1380+00	1490+00	11,000	55-foot deep cutoff wall 105-foot wide RSP (7,000 feet)	90-foot wide seepage berm 105-foot wide RSP (7,000 feet)	X	X	X*
SDSS-R	Snodgrass Slough Right Bank	1041	1041-C	1490+00	1543+00	5,300	110-foot wide RSP (3,000 feet)	N/A	-	-	X*
SACR-L	Sacramento River Left Bank	131	131-A	3012+00	2965+00	4,700	80-foot deep cutoff wall 90-foot wide RSP	75-foot wide 8-foot tall combo berm 90-foot wide RSP	X	X	X
SACR-L	Sacramento River Left Bank	131	131-B	2965+00	2915+00	5,000	80-foot deep cutoff wall 100-foot wide RSP	85-foot wide 9-foot tall combo berm 100-foot wide RSP	X	X	X
SACR-L	Sacramento River Left Bank	126	126-A	2915+00	2765+00	15,000	20-foot deep cutoff wall 110-foot wide RSP	8-foot tall stability berm 110-foot wide RSP	-	X	X
SACR-L	Sacramento River Left Bank	126	126-B	2765+00	2556+53	20,847	115-foot deep cutoff wall 105-foot wide RSP	85-foot wide 9-foot tall combo berm 105-foot wide RSP	X	X	X

*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.

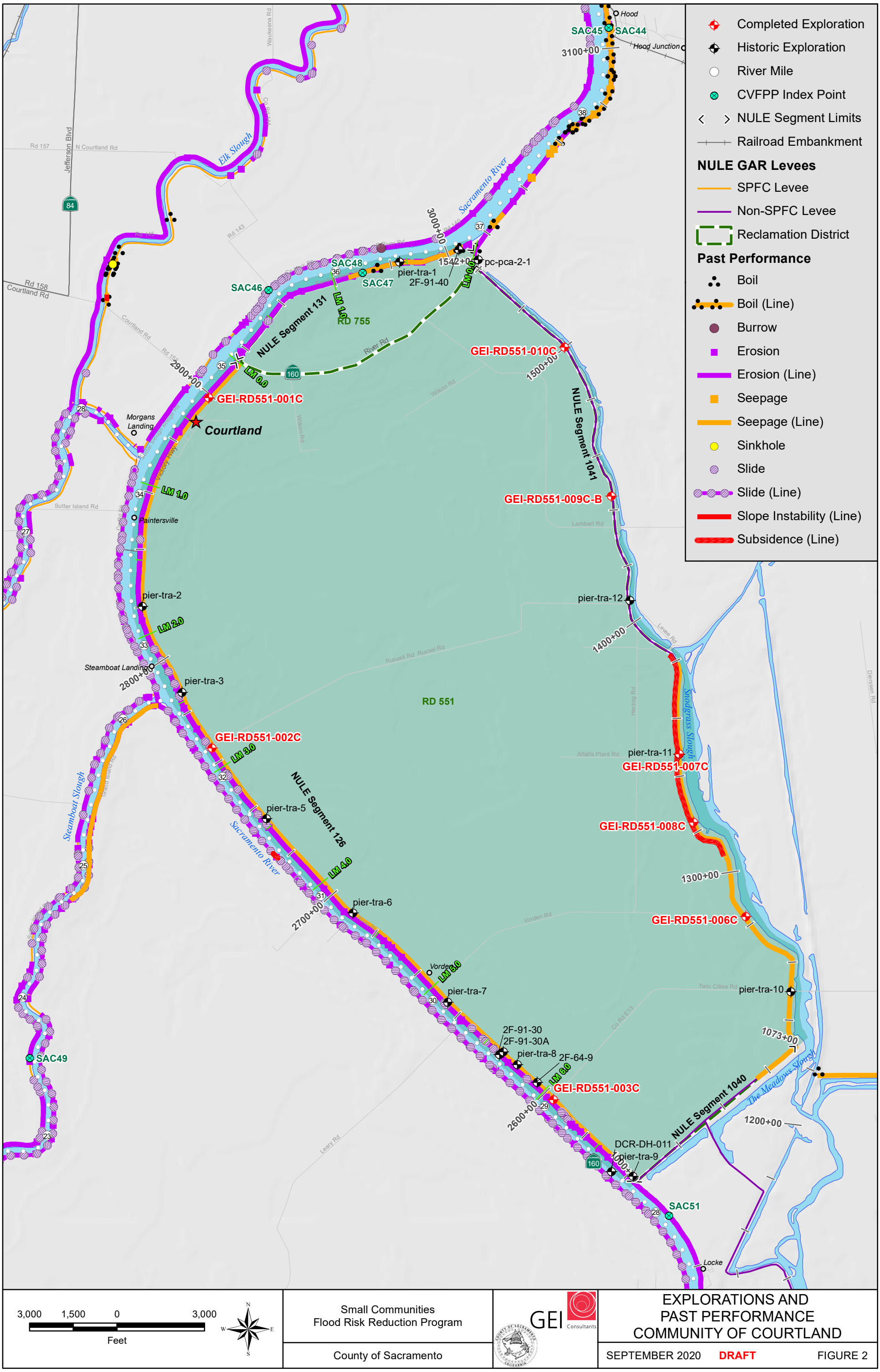
Figures



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10-Apr-2018

Small Communities Flood Risk Reduction Program	GEI Consultants	COMMUNITY OF COURTLAND
County of Sacramento		APRIL 2018 FIGURE 1


Completed Exploration
Historic Exploration
River Mile
CVFPP Index Point
NULE Segment Limits
Railroad Embankment
NULE GAR Levees
SPFC Levee
Non-SPFC Levee
Reclamation District
Past Performance
Boil
Boil (Line)
Burrow
Erosion
Erosion (Line)
Seepage
Seepage (Line)
Sinkhole
Slide
Slide (Line)
Slope Instability (Line)
Subsidence (Line)
SAC45
SAC44
Hood
Hood Junction
3100+00
SAC48
SAC47
SAC46
pier-tra-1
2F-91-40
1542+00
pc-pca-2-1
3000+00
LM 0.0
LM 1.0
RD 755
NULE Segment 131
River Rd
GEI-RD551-010C
1500+00
2900+00
GEI-RD551-001C
Courtland
Morgans Landing
Paintersville
LM 1.0
pier-tra-2
LM 2.0
Steamboat Landing
2800+00
pier-tra-3
GEI-RD551-002C
LM 3.0
NULE Segment 126
pier-tra-5
LM 4.0
2700+00
pier-tra-6
Vorden
LM 5.0
pier-tra-7
2F-91-30
2F-91-30A
pier-tra-8
2F-64-9
LM 6.0
GEI-RD551-003C
2600+00
DCR-DH-011
pier-tra-9
SAC51
Locke
SAC49
RD 551
NULE Segment 1041
GEI-RD551-009C-B
pier-tra-12
1400+00
pier-tra-11
GEI-RD551-007C
GEI-RD551-008C
1300+00
GEI-RD551-006C
pier-tra-10
1073+00
NULE Segment 1040
1200+00
Elk Slough
Sacramento River
Steamboat Slough
Snodgrass Slough
The Meadows Slough
Jefferson Blvd
N Courtland Rd
Rd 157
Rd 158
Courtland Rd
Waukeena Rd
Rd 143
Rd 145
Rd 140
Co Rd W
Victory Hwy
Sutter Island Rd
Grand Island Rd
Russel Rd
Wilson Rd
Vorden Rd
Lambert Rd
Levee Rd
Herzog Rd
Alfalfa Plant Rd
Twin Cities Rd
Co Rd E13
Leary Rd
Dietsen Rd
84
160
Feet
3,000
1,500
0
3,000
N
S
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W
Small Communities
Flood Risk Reduction Program
County of Sacramento
GEI Consultants
EXPLORATIONS AND
PAST PERFORMANCE
COMMUNITY OF COURTLAND
SEPTEMBER 2020
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FIGURE 2
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Completed Exploration
Historic Exploration
River Mile
NULE Segment Limits
NULE Reach Limits
Reclamation District

NULE GAR Levees
SPFC Levee
Non-SPFC Levee

Identified Levee Vulnerability
Erosion
Through Seepage
Underseepage

NOTE: Sacramento River erosion vulnerability was evaluated separately and is not shown here.

Elk Slough
Sacramento River
S River Rd
Courtland Rd
Wilson Rd
Lambert Rd
Levee Rd
Herzog Rd
Russell Rd
Russel Rd
River Rd
Alfalfa Plant Rd
Snodgrass Slough
Steamboat Slough
Grand Island Rd
Sutter Island Rd
Vorden Rd
Twin Cities Rd
Co Rd E13
Leary Rd
Gravel Rd
Dierssen Rd
Sutter Slough
Wauk eena Rd
Morgans Landing
Courtland
Paintersville
Steamboat Landing
Vorden
3000+00
2900+00
2800+00
2700+00
2600+00
1542+00
1500+00
1400+00
1300+00
1200+00
1100+00
1073+00
1000+00
2500+00
LM 1.0
LM 2.0
LM 3.0
LM 4.0
LM 5.0
LM 6.0
LM 0.0
NULE Segment 131
NULE Segment 126
NULE Segment 1041
NULE Segment 1040
RD 755
RD 551
2F-91-40
pier-tra-1
pepca-2-1
pier-tra-2
pier-tra-3
pier-tra-5
pier-tra-6
pier-tra-7
2F-91-30
2F-91-30A
pier-tra-8
2F-64-9
DCR-DH-011
pier-tra-9
pier-tra-10
pier-tra-11
pier-tra-12
GEI-RD551-001C
GEI-RD551-002C
GEI-RD551-003C
GEI-RD551-006C
GEI-RD551-007C
GEI-RD551-008C
GEI-RD551-009C-B
GEI-RD551-010C
36
35
34
33
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25
23
37
38
84
160

0.5 0.25 0 0.5
Miles

Small Communities
Flood Risk Reduction Program

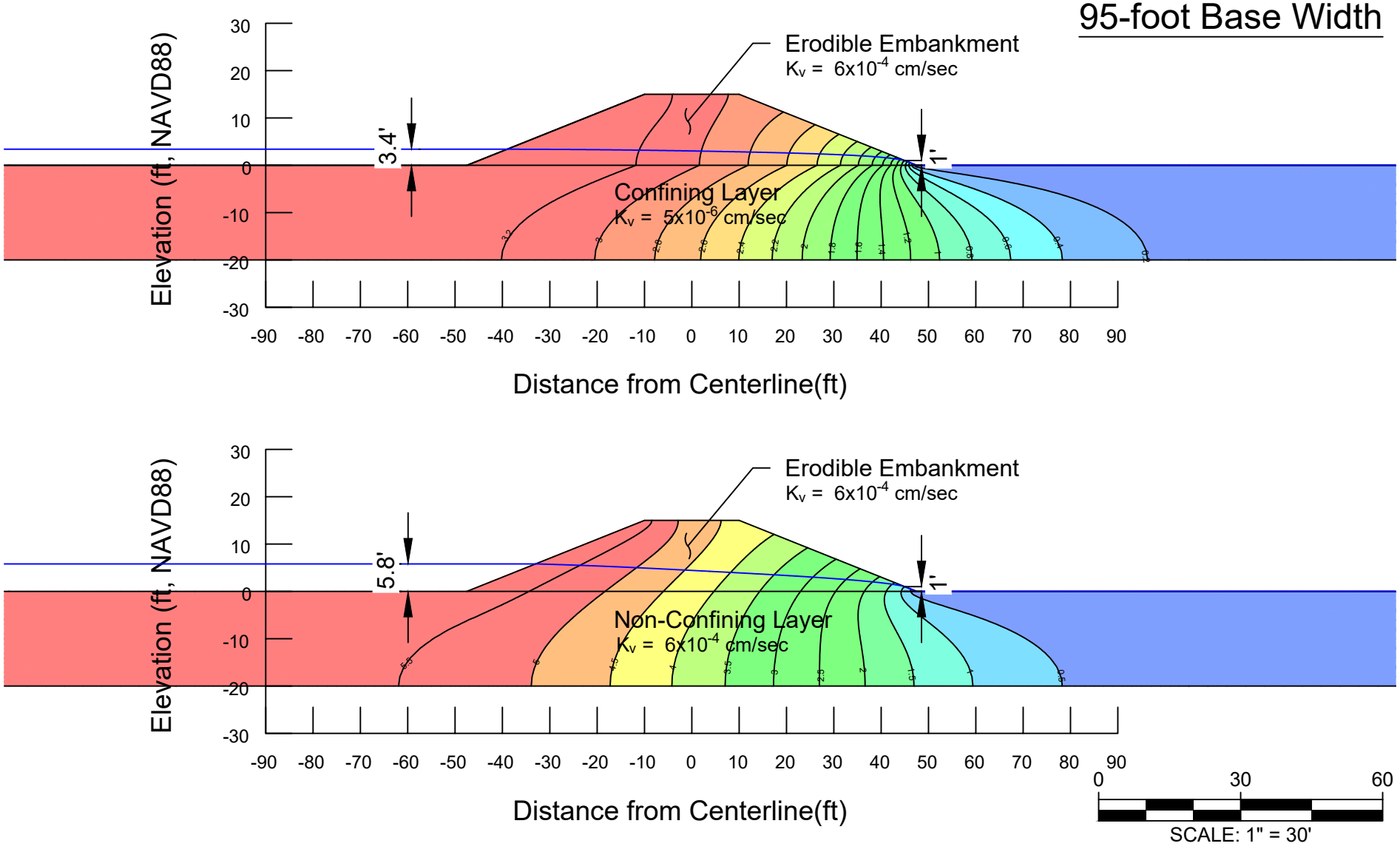
County of Sacramento

GEI Consultants

COURTLAND OVERVIEW OF GEOTECHNICAL VULNERABILITIES

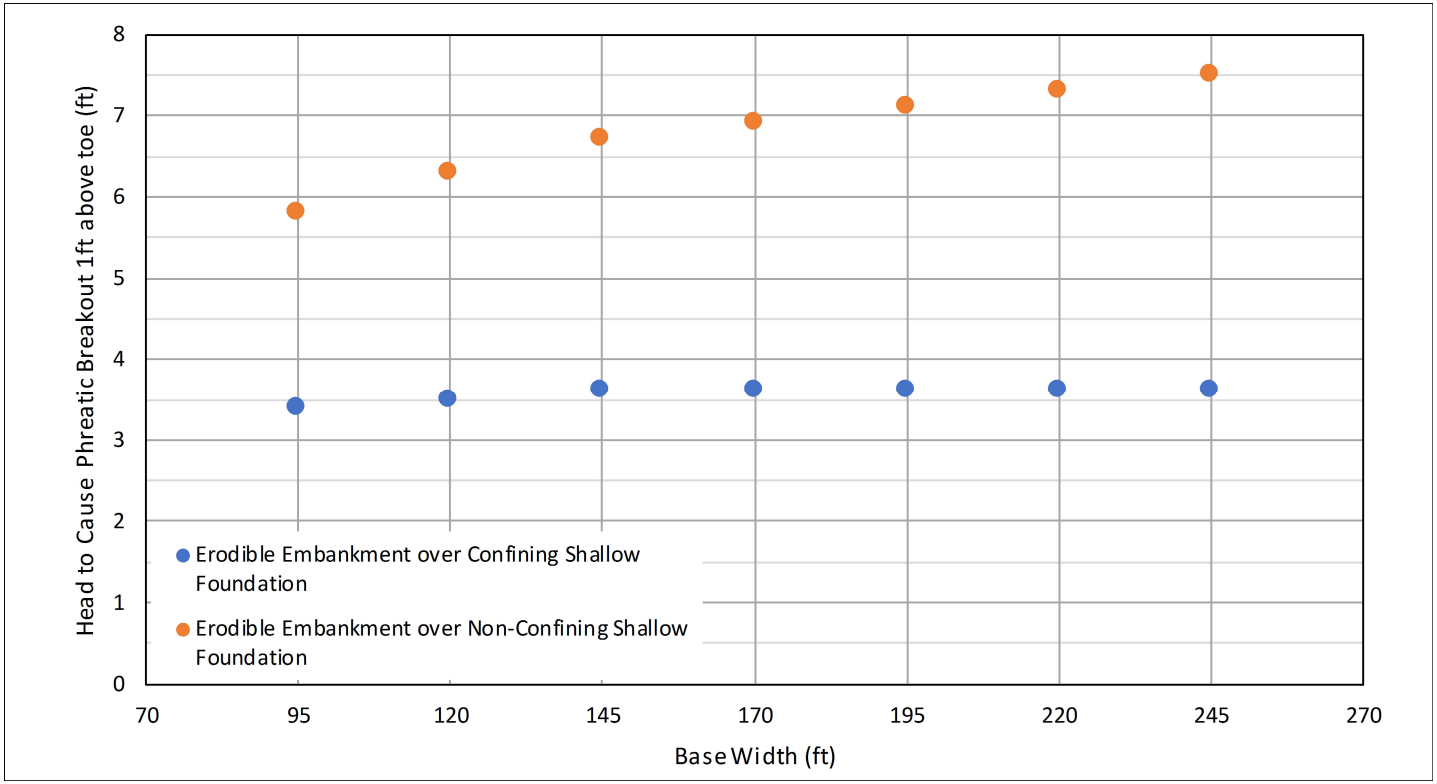
SEPTEMBER 2020 **DRAFT** FIGURE 3

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Delta Small Communities Flood Risk Reduction Program Community of Courtland		GEI Consultants	Through Seepage Criteria Analysis Cases
Sacramento County, CA		Project 1800758	September 2020 Figure 4

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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: $k_v = 6x10^{-4}$ cm/sec
3. Confining Foundation: $k_v = 5x10^{-6}$ cm/sec
4. Non-confining Foundation: $k_v = 6x10^{-4}$ cm/sec

Delta Small Communities Flood Risk Reduction Plan - Community of Courtland

Sacramento County, CA

GEI Consultants

Project 1800758

Head to Cause Phreatic Breakout 1ft above toe

SEPTEMBER 2020 Figure 5

Appendix A

Technical Memorandum

To: George Booth and Shayan Rehman, Sacramento County - Department of Water Resources

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

Date: October 2018

Re: Existing Geotechnical Data Technical Memorandum
SCFRR - Community of Courtland in Sacramento County

Introduction

The purpose of this memorandum is to summarize existing geotechnical information and past performance for the levees protecting the community of Courtland in Sacramento County and identify recommendations for further subsurface investigation. The levees protecting this community are constructed along the left bank of the Sacramento River (California Department of Water Resources [DWR] Non-Urban Levee Evaluation [NULE] Segments 126 and 131), and the right banks of Meadows Slough (NULE Segment 1040) and Snodgrass Slough (NULE Segment 1041), as shown on Figure 1 and discussed in more detailed below. These levees encompass two Reclamation Districts (RDs), RD 755 at the northern, upstream end and RD 551.

Existing levee 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 levees near Courtland (NULE Segments 126 and 131) extends approximately 8.6 miles along Sacramento River near the northerly extension of Snodgrass Slough at the upstream end to the confluence of the Sacramento River and Meadows Slough at the southern, downstream end. These NULE levee segments are SPFC levees. The northern, upstream 1.8 miles are part of the RD 755 levee system, and the remaining 6.8 miles are part of the RD 551 levee system. Along this Sacramento River extent, flow is from north to south. The approximate upstream water surface elevation (WSE) near river mile (RM) 36.7 for the 100-year WSE is 22.8 feet and the downstream 100-year WSE near RM 28.3 is approximately 18.4 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 21.9 feet upstream and 17.6 feet downstream. These WSEs are in reference to the North American Vertical Datum of 1988 (NAVD88).

Meadows Slough Levee

The Meadows Slough right bank levee (NULE Segment 1040) is a Non-SPFC levee that is a part of the RD 551 levee system. It is approximately 1.4 miles long, extending from the confluence of Snodgrass Slough and Meadows Slough westward towards the Sacramento River. The western end of Meadows Slough does not connect to the Sacramento River and is affected by the backwater

conditions. A 100-year and 1955/57 design profile WSEs are not available for the Meadow Slough levee.

Snodgrass Slough Levee

The Snodgrass Slough right bank levee (NULE Segment 1041) is a Non-SPFC levee that is a part of the RD 551 levee system. It is about 5.9 miles long and extends from the upstream end near Sacramento River southward to the confluence with Meadows Slough. A 100-year and 1955/57 design profile WSEs are not available for the Snodgrass Slough levee.

Levee Construction History and Improvements

The levees surrounding the community of Courtland were initially constructed prior to 1906 by local interests and generally built using materials dredged from the adjacent rivers and sloughs and placed without compaction.

Between 1943 and 1955, USACE improved portions of the levees along the Sacramento River (NULE Segments 131 and 126) that did not meet USACE standards. Improvements consisted of levee reconstruction and bank protection work at multiple locations. Additional riverbank protection work was performed from 1963 to 1974 and 1976 to 1985 as part of the Sacramento River Bank Protection Project.

An approximately 1.4-mile section of the non-SPFC Snodgrass Slough levee (NULE Segment 1041), from approximately 1.5 miles upstream of the confluence with Meadows Slough to 2.9 miles upstream of this same confluence, has been referred to as "the Peat Section," as it is likely comprised of dredged peat materials on peat foundation. This area was documented to have settled 2 to 3 feet between 1907 and 1913 and was raised in 1913.

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 personnel. In general, the RD 755 and RD 551 Sacramento River levees have experienced widespread seepage, with boils reported near the northern portion of the basin (within RD 755) during past high-water events. DWR's Flood System Repair Project (FSRP) also identified two critical/serious sites at the upstream limit of RD 755, near the previously reported boils. Occurrences of erosion and rock revetment failure were also noted along the Sacramento River left bank levee. For the rest of the RD 551 basin, the Non-SPFC levees along Snodgrass Slough and Meadows Slough have reports of past seepage and levee subsidence. Past performance is summarized in Table 1 and shown on Figure 2.

In 2012, DWR's Flood System Repair Project (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. The FSRP was designed to be consistent with the state system-wide investment approach of the Central Valley Flood Protection Plan (CVFPP), and the SFPC. The FSRP goal was to help prioritize funded system repair projects to focus on repair of damage or deficiencies that are critical, that have a potential to become critical, or that may impede flood fight capabilities. For the FSRP *critical* and *serious* past performance problems were generally defined as follows:

- *Critical* Past Performance Problem: If not repaired, the site presents a significant risk of failure or would impede flood control function or flood fight activities during the next highwater event.

- *Serious* Past Performance Problem: If not repaired in a timely manner, the site has the potential to become critical during the next high-water event.

DWR's FSRP identified one *critical* site along the levees surrounding the community of Courtland for seepage along NULE Segment 131. One *serious* site was also identified for seepage along NULE Segment 131. A map and table of the *critical* and *serious* sites from the FSRP Levee Performance Problems Evaluation Report (URS, 2013) are included in Appendix A.

Most recently, a July 2018 DWR report titled "2017 Storm Damage – DWR Emergency Rehabilitation" (IFC, 2018) summarized DWR rehabilitation sites and USACE PL 84-99 sites resulting from 2017 storm damage. For DWR's review of the 2017 damage sites, they followed FSRP guidelines to identified sites as *critical* or *serious*. No *critical* 2017 storm damage sites were identified along the levees surrounding the Community of Courtland. Three *serious* 2017 storm damage erosion sites were identified and have been included in Table 1 and shown on Figure 2. The report also notes identification of "area of concern" sites that did not rise to the level of *critical* or *serious*, location information for these sites was not available from DWR review at the time of this Memorandum. No USACE PL 84-99 sites from the 2017 storm damages were identified along the Courtland levees.

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 levees protecting the community of Courtland (NULE Segments 131 and 126) the NULE review found that a minimum of 3 feet of freeboard above the 1955/57 design profile was available throughout both segments. The levees along Meadow Slough and Snodgrass Slough 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 community of Courtland are summarized in Table 2.

Available Geotechnical Information

The DWR NULE project included an assessment (Phase 1 only) of the levees protecting the community of Courtland. The NULE Phase 1 study included all the levees protecting Courtland, 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, existing exploration 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 community of Courtland (NULE Segments 131, 126, 1040, and 1041) are attached in Appendix B.

More recently than the NULE data collection and review, DWR has conducted geotechnical borings in the Delta to obtain information for the proposed alignment of the water conveyance facilities associated with the Bay Delta Conservation Plan (BDCP), also referred to as California WaterFix. Data available for review is limited at this time and subsurface information (log or profile data) from this effort was only found for one boring near the levees surrounding the Community of Courtland. It is an overwater boring at the downstream end of Segment 126 and the approximate location is shown on Figure 2. All available exploration data is described further below.

Geomorphic Setting

Geomorphology mapping developed for the DWR NULE project indicates the levees along the Sacramento River and Meadow Slough primarily overlie historical overbank deposits (Rob) likely consisting of interbedded sand, silt, and clay deposited during high-stage flow, overtopping channel banks. Localized areas of historical crevasse splay deposits (Rcs) 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 available DWR NULE geomorphology mapping for Snodgrass Slough is less detailed but indicates that the northern half of the levee segment overlies natural levee deposits and the southern half overlies flood basin deposits. The natural levee deposits likely consistent of interbedded silt, sand, and clay. The soils in the floodplain deposits are likely finer-grained, consisting primarily of silt and clay. Peat deposits are mapped beneath the levee in the surficial geology mapping over an approximately 0.7-mile extent, starting approximately 1.75 miles upstream from the confluence with Meadows Slough. This mapped peat deposits extent is within the 1.4-mile section of subsidence discussed in the construction history and improvements section. 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 17 known and available explorations along the entire leveed perimeter of RD 551 and RD 755, a distance of approximately 16 miles. The boring locations are shown on Figure 2. The borings are derived mainly from DWR's 1958 Salinity Control Barrier Investigations (12 borings), but also from USACE's Sacramento River Flood Control System Evaluation for the Lower Sacramento Area (4 borings) and the more recent DWR drilling for the BDCP (1 boring record available as discussed above). Available log information for 16 of the 17 explorations is limited to profiles without detailed material descriptions. The Salinity Control Barrier exploration profile for 11 of the borings and the BDCP exploration profile for one of the borings includes some index test laboratory results but detailed results are not available. No laboratory testing was identified for the other 5 explorations. Based on the available information, borings along, or near, the levee show a fine-grained blanket layer that varies in thickness from no blanket to a blanket thickness of 30 feet or thicker below ground surface underlain by a pervious aquifer, but were generally not deep enough to confirm the depth to a deeper aquiclude layer. Only 2 existing borings were found in the area adjacent to Courtland and immediately upstream where past boils have been noted. Available log or profile information for the existing explorations is included in Appendix D.

Caltrans bridge exploration data was also reviewed, and two borings were identified along the Sacramento River near the confluences of Steamboat Slough and Elk Slough. These borings were performed on the opposite bank (right bank) of the Sacramento River, outside the project area and therefore were not included.

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 NULE Segment 126 along Sacramento River, to have a *moderate* likelihood of levee failure at the 1955/57 design WSE based on potential vulnerability to underseepage and erosion. Immediately upstream of Courtland, NULE Segment 131 was assessed to have a *high* likelihood of levee failure at the 1955/57 design WSE based on the potential vulnerability to underseepage. The Non-SPFC levees along Snodgrass Slough (NULE Segment 1041) and Meadows Slough (NULE Segment 1040) 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 and stability. 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 community of Courtland. As discussed above, limited existing geotechnical information is available for the Courtland levee system. Further understanding of the subsurface conditions including the depth of the aquiclude layer will be critical in determining cutoff wall construction depths and requirements during evaluation of potential structural improvements. 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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Table 2 Summary of Levee Geometry

Table 3 Summary of NULE Assessment Results

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Figure 2 Existing Explorations and Past Performance

Appendices

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

Appendix B NULE GAR Segment Write-Ups

Appendix C Geomorphology Technical Memorandum

Appendix D Historic Boring Logs

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Acronyms

BDCP	Bay Delta Conservation Plan
CVFED	Central Valley Floodplain Evaluation and Delineation
CVFPP	Central Valley Flood Protection Plan
DWR	California Department of Water Resources
FSRP	DWR's Flood System Repair Project
GAR	Geotechnical Assessment Report
LiDAR	Light Detection and Ranging
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 Community of Courtland

NULE Segment and Location	Flood Season	Reported Performance Description	Approximate Location (Levee Mile when available)	Mitigation
131 Left Bank Sacramento River RD 755 (SPFC levee)	Recurring	Boil 1,000 feet from landside toe. Boil is not carrying material, but has a high gallons per minute rate.	LM 0.7	None documented
	1986 & 1997	Boil located 30 from levee toe in 1986. Boil 1,000 feet from landside toe in 1997. Seepage observed during highwater at landside toe for about 250 feet.	LM 0.1	Sandbag chimney
	1986	Seepage area	LM 0.1 - 0.9	None documented
	1997	Seepage at landside toe and boil about 1,000 feet from landside toe. Boils have been observed in previous years, but at different locations; not carrying material, but has a high flow rate, Hydrophilic vegetation observed on the landside berm.	LM 0.14 LM 0.2-0.9	None documented
	1997	Sloughing on the waterside slope approximately 110 feet by 4 to 18 feet by 2 to 6 feet. Field visit indicated sloughing still occurring at waterside toe after riprap placed.	LM 0.27	Riprap
	Observed 1997	Scour and sloughing for 150 feet, 15 feet wide and 5 feet deep.	LM 1.5 - 1.53	Riprap
	1997-2008	Multiple erosion sites include one Ayres site. Sites that have been repaired still have erosion present.	Multiple locations	Some sites repaired with riprap
	2017	Erosion - DWR 2017 storm damage "serious" erosion site. Damage sites were identified as serious due to erosion if "a) erosion has encroached into either the waterside levee prism or extended levee prism that may not cause a levee failure in the next high-water event, or b) progressing erosion that is likely to encroach into either the waterside levee prism or extended levee prism"	LM 0.77	Not yet mitigated; on the list of DWR Contingency Planning Sitesbased on July 2018 report

Table 1. Summary of Reported Past Performance - Levees Surrounding the Community of Courtland

NULE Segment and Location	Flood Season	Reported Performance Description	Approximate Location (Levee Mile when available)	Mitigation
126 Left Bank Sacramento River RD 551 (SPFC levee)	during high water	Seepage - when water is high, island (RD 0551, Pierson District) experiences general seepage; no significant boils (reported in 2008)	throughout segment	None documented
	1997	Sloughing/displaced revetment, erosion	LM 1.3 - 1.37 LM 2.1 - 2.46 LM 2.8 - 2.85 LM 3.32 - 3.48 LM 5.13 - 5.15 LM 5.85 - 5.87	None documented
	1997	Erosion - multiple locations, 10 to 14 feet long, 1 to 4 feet deep wavewash/slough on waterside of levee or levee slope	LMs 2.11, 2.4, 3.05, and 5.5	Riprap
	1998	A slips 10 feet up the waterside levee slope; LM 5.32 and 5.38 were previous USACE repair sites for scour and sloughing in 1997.	LMs 5.32 - 5.38, 5.37-5.38, and 5.57	Riprap
	1998	Erosion/Sloughing - multiple locations, sloughing and toe failure of rock revetment	Multiple locations between LM 1.86-6.74	Sites repaired with riprap
	2008	Waterside erosion due to wavewash	throughout segment	None documented
	2012	Erosion - Observed to be about 15 to 20 feet long, 3 to 4 feet wide, and 1 to 2 feet deep on the bank	LM 0.6	Levee slope repaired with fill material
	2017	Erosion - DWR 2017 storm damage "serious" erosion sites. Damage sites were identified as serious due to erosion if "a) erosion has encroached into either the waterside levee prism or extended levee prism that may not cause a levee failure in the next high-water event, or b) progressing erosion that is likely to encroach into either the waterside levee prism or extended levee prism"	LM 5.2 LM 6.22	Not yet mitigated; on the list of DWR Contingency Planning Sitesbased on July 2018 report

Table 1. Summary of Reported Past Performance - Levees Surrounding the Community of Courtland

NULE Segment and Location	Flood Season	Reported Performance Description	Approximate Location (Levee Mile when available)	Mitigation
1040 Right Bank Meadows Slough RD 551 (Non-SPFC levee)	1949-1953	Seepage observed by landowners	Multiple locations within eastern most 0.35 miles of segment	None documented
1041 Right Bank Snodgrass Slough RD 551 (Non-SPFC levee)	1907-1913	Subsidence of 2 to 3 feet (over approxmately 1.4 miles)	Beginning 1.5 miles upstream of the confluence with Meadow Slough	Levee raised in 1913
	1949-1953	Seepage observed by landowners (over approximately 2.8 miles)	From confluence with Meadow Slough upstream 2.8 miles	None documented

Table 2. Summary of Levee Geometry[1] - Levees Surrounding the Community of Courtland

NULE Segment	Segment Location	Approximate Levee Height	Approximate Crest Width	Approximate Landside Slopes	Approximate Waterside Slopes
131	Left Bank Sacramento River - RD 755 (SPFC levee)	14 to 20 feet above the landside toe	20 to 30 feet	1.7H:1V to 3H:1V	1.7H:1V to 3H:1V
126	Left Bank Sacramento River - RD 551 (SPFC levee)	15 to 22 feet above the landside toe	20 to 40 feet	1.5H:1V to 3H:1V	1.8H:1V to 3.3H:1V
1040	Right Bank Meadows Slough RD 551 (Non-SPFC levee)	16 to 27 feet above the landside toe	10 to 15 feet	4.5H:1V to 6H:1V	3H:1V to 4H:1V
1041	Right Bank Snodgrass Slough RD 551 (Non-SPFC levee)	22 to 30 feet above the landside toe	10 to 25 feet	4H:1V to 6H:1V	3H:1V to 4H:1V

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

Table 3. Summary of NULE GAR Asessement Results - Levees Surrounding the Community of Courtland

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]
131	Left Bank Sacramento River - RD 755 (SPFC levee)	1957 Design WSE	High	High	Low	Lacking Sufficient Data[2]	Moderate
126	Left Bank Sacramento River - RD 551 (SPFC levee)	1957 Design WSE	Moderate	Moderate	Low	Low	Moderate
1040	Right Bank Meadows Slough RD 551 (Non-SPFC levee)	1.5 feet below levee crest	Moderate	Moderate	Lacking Sufficient Data (Low to Moderate)[3]	Low	Low
1041	Right Bank Snodgrass Slough RD 551 (Non-SPFC levee)	1.5 feet below levee crest	Moderate to High	Moderate	Lacking Sufficient Data (Moderate to High)[3]	Low	Low

[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.

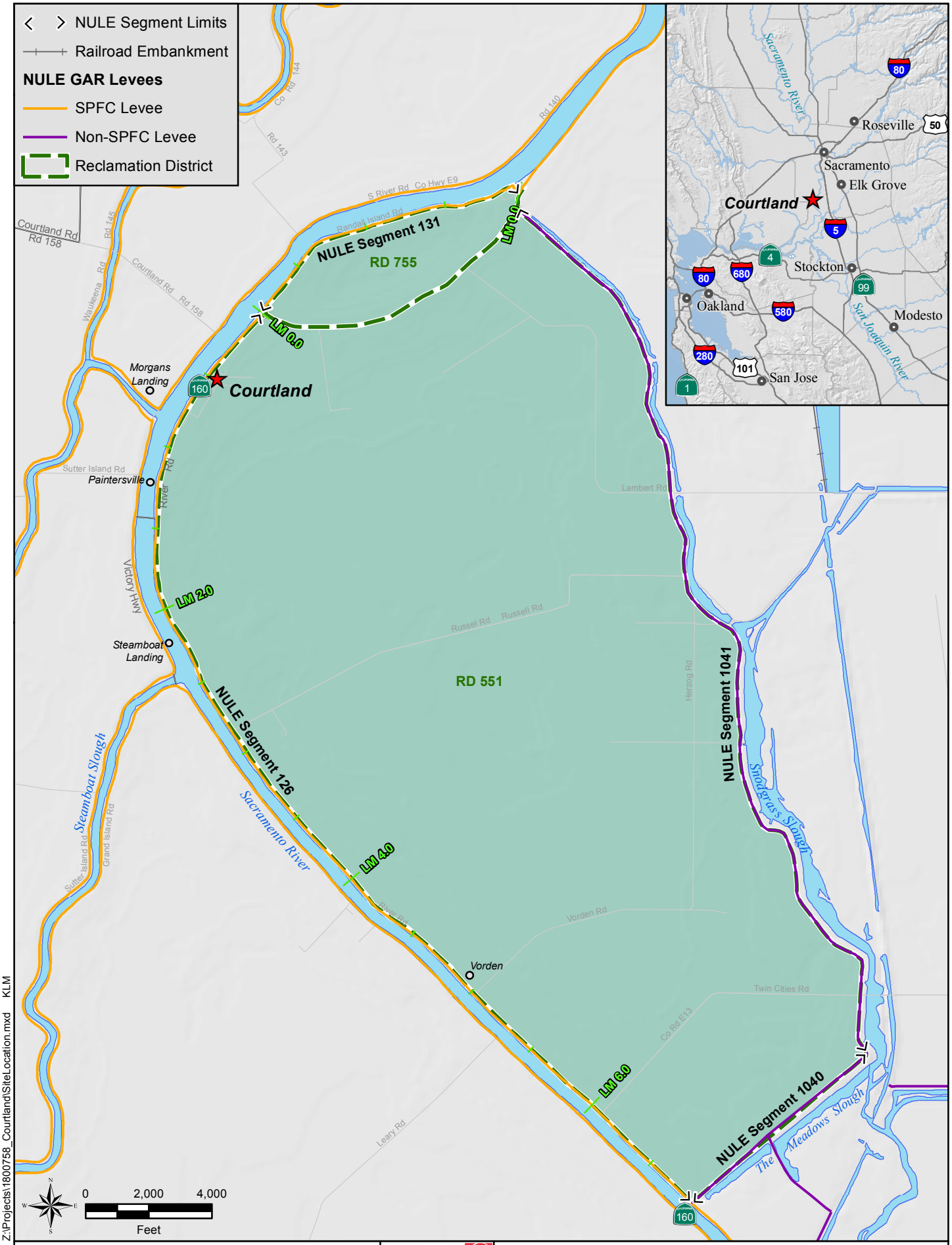
[3]The segment was lacking sufficient data about past performance or hazard indicators to assign a hazard level, or there was poor correlation between past performance and hazard indicator scores.

Figures

Figure 1 Site Location
Figure 2 Existing Explorations and Past Performance

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10-Apr-2018

Small Communities Flood Risk Reduction Program	GEI Consultants	COMMUNITY OF COURTLAND
County of Sacramento		SEPTEMBER 2018 FIGURE 1

River Mile
Existing Exploration
NULE Segment Limits
Railroad Embankment

NULE GAR Levees

SPFC Levee
Non-SPFC Levee
Reclamation District

Past Performance

Boil
Boil (Line)
Burrow
Erosion
Erosion (Line)
Seepage
Seepage (Line)
Sinkhole
Slide
Slide (Line)
Slope Instability (Line)
Subsidence (Line)

Hood
Hood Junction
Courtland
Morgans Landing
Paintersville
Steamboat Landing
Locke
Elk Slough
Sacramento River
Steamboat Slough
The Meadows Slough
Snodgrass Slough
Jefferson Blvd
N Courtland Rd
Courtland Rd
Rd 157
Rd 158
Rd 145
Rd 143
Waukeena Rd
Co Rd 144
River Rd
Victory Hwy
Sutter Island Rd
Grand Island Rd
Wilson Rd
Lambert Rd
Levee Rd
Russel Rd
Herzog Rd
Alfalfa Plant Rd
Vorden Rd
Twin Cities Rd
Co Rd E13
Leary Rd
Dierssen Rd
RD 755
RD 551
NULE Segment 131
NULE Segment 126
NULE Segment 1041
NULE Segment 1040
LM 0.0
LM 1.0
LM 2.0
LM 3.0
LM 4.0
LM 5.0
LM 6.0
pier-tra-1
2F-91-40
pc-pca-2-1
pier-tra-2
pier-tra-3
pier-tra-5
pier-tra-6
pier-tra-7
pier-tra-8
2F-64-9
2F-91-30
2F-91-30A
pier-tra-9
DCR-DH-011
pier-tra-10
pier-tra-11
pier-tra-12
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3,000 1,500 0 3,000
Feet

Small Communities
Flood Risk Reduction Program

County of Sacramento

GEI Consultants

EXISTING EXPLORATIONS AND PAST PERFORMANCE COMMUNITY OF COURTLAND

SEPTEMBER 2018 FIGURE 2

08-Oct-2018 Z:\Projects\1800758_Courtland\ExistingExplorations_PastPerformance_20200927.mxd KLM

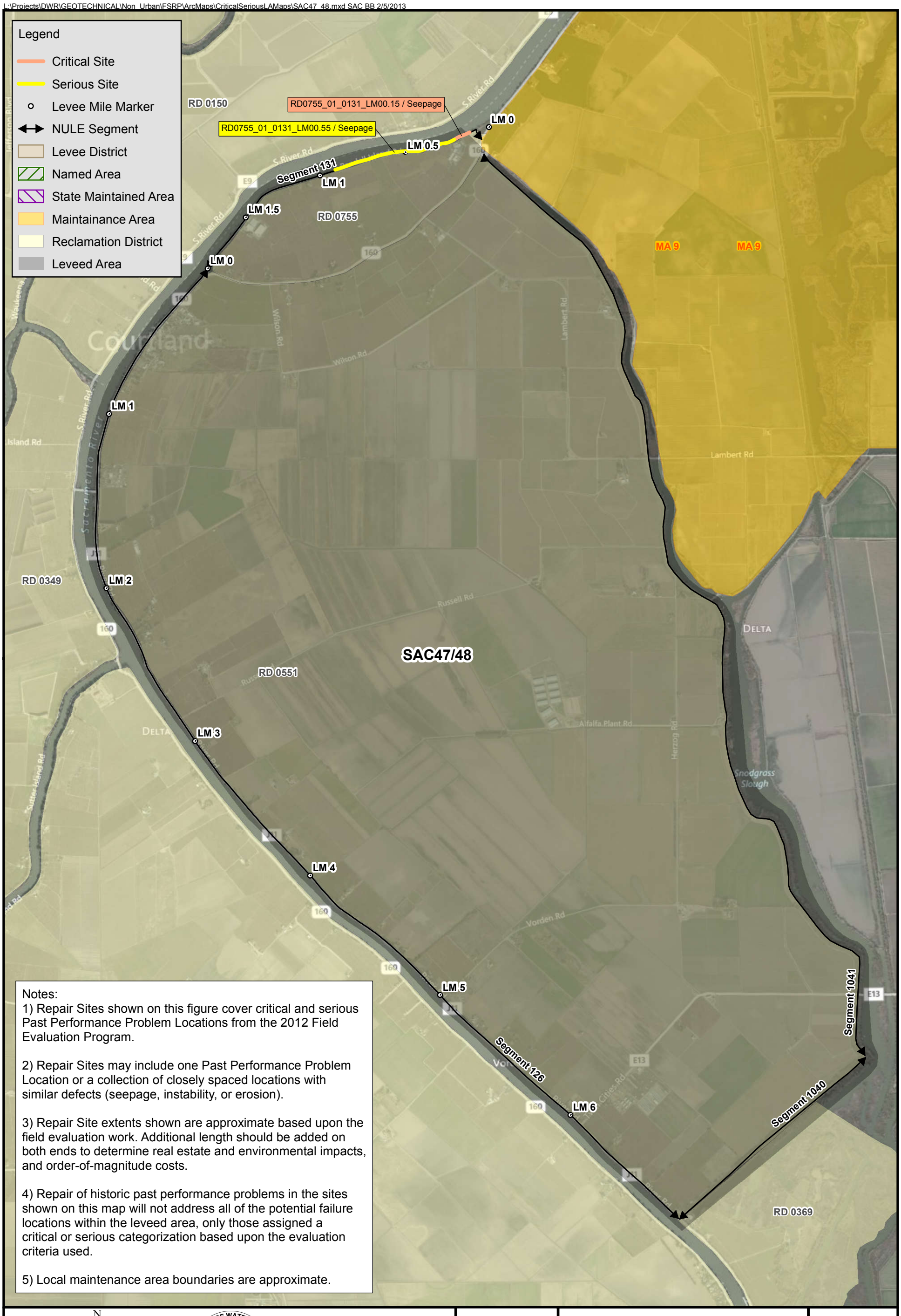
Appendix A

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

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L:\Projects\DWR\GEOTECHNICAL\Non_Urban\FSRP\ArcMaps\CriticalSeriousLAMaps\SAC47_48.mxd SAC BB 2/5/2013



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.

N

0 0.25 0.5

Miles

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

Critical and Serious Sites SAC47/48

Flood System Repair Project

Figure SAC47/48-1

TABLE SAC47/48-2
CRITICAL AND SERIOUS SITES

SAC47/48

Area Name: RD 551 & Courtland

Includes Segments: 126, 131, 1040, 1041

Reconnaissance Team No. 5

Reconnaissance Dates: July 31 to August 2, 2012

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
RD0755_01_0131_LM00.15	131-2001 131-2014	131	Unit No. 1	Sacramento River	RD 0755	Seepage	Critical	0.1 to 0.2	500 ft	Boil on LS was documented in 1986; boil was sandbagged (131-2013 and 131-2014). Boil 1,000 ft from LS toe documented in 1997 (131-2001). Seepage observed during high water at LS toe for 250 ft stretch according to MBK engineer (LMA engineer).	September 28, 2012
RD0755_01_0131_LM00.55	131-2000 131-2013, 131-2008	131	Unit No. 1	Sacramento River	RD 0755	Seepage	Serious	0.2 to 0.9	3,500 ft	Boil 1,000 ft from LS levee toe was documented in 1997 (131-2000). Boils in existence from previous years, but changed locations; not carrying material, but has a high gpm rate (131-2008). Hydrophytic vegetation was observed on the LS berm.	September 28, 2012

Note: POI same as Past Performance Problem

Appendix B

NULE GAR Segment Write-Ups

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RD 0755, UNIT 1, SEGMENT 131 SUMMARY

This segment summary presents collected information and the assessment results for Segment 131. 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 131: Segment Description and Assessment Summary

Segment 131 is a non-urban Project levee located on the left (southeast) bank of the Sacramento River in Sacramento County, California (see attached map). The segment extends along the west side of Randall Island from the confluence of the Sacramento River and Snodgrass Slough southward to just north of Courtland. The following table summarizes segment information.

Segment 131 Information

Maintenance Authority	Unit	Levee Miles*	NULE Stationing*
RD 0755	1	0 to 1.8	Sacramento River Left Bank 2915+00 to 3012+00

* 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 131 categorizations for each potential failure mode.

Segment 131 Potential Failure Mode Assessment Summary

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

Based on these NULE Phase 1 levee assessments, the overall categorization for Segment 131 is Hazard Level C.

Segment 131: 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 RD 0755 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

Based on historic topographic maps (Courtland 1:62,500) (Doc-8590), the Segment 131 levee was initially constructed prior to 1906 by local interests. Information about the methods used for initial construction of the levee was not available. Levees along the Sacramento River were generally built using materials dredged from the river channel and placed without compaction (Doc-5249). Portions of the levee that did not meet Project standards were improved by the USACE to Project standards between 1943 and 1955 (Doc-2116). The improvements included bank protection work at LM 0.5 in 1943, at LM 0.3 in 1945, at LM 1.0 in 1947 and 1948, and at unlisted locations from 1954 to 1955. The following table presents the 1953 MOU geometric criteria for Segment 131.

Segment 131 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 maintenance personnel. Based on the available information, performance events in Segment 131 include multiple erosion events reported in 1997, 1998, 2006, 2007, and 2008, and underseepage and through seepage. There are no documented reports of slope instability. The following table summarizes reported performance events.

Segment 131 Reported Levee Performance Events

Flood Season	Reported Performance Event	Approximate Location (Levee Mile)	Mitigation
Recurring	Boil 1,000 feet from landside toe.	0.70	None documented.
1986	Boil located 30 feet from levee toe (Doc-1044).	0.1	Mitigated with sandbag chimney.
1986	Seepage area (Doc-1044).	0.1 – 0.9	Mitigation not reported.
1997	Seepage at landside toe without details (Doc-5520).	0.14	Mitigation not reported.
1997 1998 2006 2007 2008	Multiple erosion sites including one Ayres site (Doc-1540, Doc-633, Doc-2364, Doc-1694, Doc-3822, and CLD)	Multiple locations	Some locations mitigated using rip-rap revetment; mitigation not documented at other locations.
Unknown	Boil listed in CLD without details.	0.1	Mitigation not listed.

Underseepage

The seepage area between LM 0.1 and LM 0.9 was described in 1993 as seepage and boils that are “generally confined to a drainage ditch.” (Doc-1044) The boils were reportedly “controlled by seepage water filling the ditch.” The recurring boil at LM 0.70 deposited approximately 10 cubic yards of sand near the boil starting in late December 1996, but was flowing as much as 100 gallons of clear water per minute in March 1997 (Doc-5520). RD 0755 personnel noted that the boil had changed locations over the years, and that it flows for longer periods of time during low water than in the previous years (Doc-5477).

In addition to the underseepage documented in the Table of Segment 131 Reported Levee Performance Events, the CLD lists a relief well at LM 1.60 about 1,800 feet from the levee toe. Relief wells are typically installed in areas of underseepage. Details on the relief well were not found.

Through Seepage

Seepage is documented to occur at the levee toe at LM 0.14 and between LM 0.1 and LM 0.9 (Doc-5520 and Doc-1044). Seepage at the levee toe may result from through seepage rather than underseepage.

Erosion

The segment has had ongoing erosion problems since 1956. Multiple erosion sites along the segment were identified during inspections following the 1997, 1998, 2006, and 2007 flood seasons (Doc-256, Doc-1540, and Doc-1694, and as listed in the CLD). The 1997 and 1998 erosion sites were not documented as impacting the levee crown. One 2008 Ayres site (non-ranked 2009-2010 DWR repair site) is located along the segment. The site (RM 35.4L), at about LM 1.3, is described as a 300-foot-long area where the levee toe and lower levee slope have eroded.

Improvements

Improvements include riverbank protection work performed under the Sacramento River Bank Protection Project (SRBPP) during Phase 1, from 1966 to 1968 and from 1970 to 1971, and during Phase 2 in 1981 and 1985 (Doc-8587). The completed riverbank protection work included the placement of revetment at multiple locations along the segment.

Planned Improvements

The Ayres site at RM 35.4L is a 2009-2010 DWR repair site. Based on the document review, no other improvements to Segment 131 are currently planned.

Segment 131: 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 131 levee heights range from approximately 14 to 20 feet above the landside toe. Including the rounded shoulders, crest width ranges from approximately 20 to 30 feet. LiDAR survey data indicate the landside slopes are approximately 1.7H:1V to 3.0H:1V. The waterside slopes are approximately 1.7H:1V to 3.0H:1V.

Penetrations

According to the DWR Pipe Inventory, 19 pipes penetrate the levee segment. Pipe diameters range from 6 to 24 inches. The pipes are approximately 4 to 8.5 feet below the levee crown.

Animal Activity

The presence of beavers was reported by RD 0755 in a 2008 interview, and animal burrows were documented during the site reconnaissance. Animal persistence based on data from DWR is “Medium” from LM 0.49 to LM 1.23 and “None Documented” elsewhere in the segment.

Maintenance

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

Other Features

A concrete retaining wall is present on the waterside slope at LM 0.63, and a second retaining wall is present on the landside of the levee crown at approximate LM 0.72 (Doc-8179). No information on the walls’ construction dates, construction details, or purpose was found in the available documents.

Segment 131: 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 131.

In Segment 131, the levee foundation consists of silty sand, sand and silt. The levee consists primarily of sand.

Geomorphic Setting

According to the Level 2-II mapping, Segment 306 is in the Sacramento Valley flood basin. Based on the geomorphology Level 2-II mapping, the Segment 306 levee overlies recent overbank deposits consisting of interbedded silt, sand, and clay that likely interfinger with adjacent flood plain silt and clay sediments. The deposits are also likely to vary laterally in extent and character. The Level 2-II mapping includes a Holocene channel deposit consisting of well-sorted sand at LM 0.25.

Geotechnical Investigations

Geotechnical investigations for Segment 131 performed by others include one boring in the DWR Salinity Control Barrier Study (Doc-8306) and one boring for the Sacramento River Flood Control System Evaluation (Doc-1044). One of these borings was drilled through the crest of the levee, and the other one was drilled near the landside levee toe. The stick logs of these borings, which range in depth from 40 to 63 feet, indicate that the soil in the levee prism consists of sand, and the soil in the foundation consists of silty sand, sand, and silt.

Other Subsurface Information

The NRCS USCS soil map indicates the existing levee overlies coarse-grained surface soils (SC-SM) between LM 0.0 to LM 0.8, and fine-grained surface soils (CL/ML) between LM 0.8 and LM 1.8. The NRCS USCS map is generally consistent with the Level 2-II mapping and borings.

Levee Composition

The available boring data indicate that the levee consists of loose sand.

Segment 131: Geotechnical Assessment Results

The overall Segment 131 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 131 Underseepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	**Minimum Credible**	**Maximum Credible**	**Best Estimate**	**Minimum Credible**	**Maximum Credible**	
68	56	68	Multiple, recurring boils	Multiple, recurring boils	Multiple, recurring boils	Hazard Level C

Hazard indicators suggesting that underseepage could occur include levee foundation materials (overbank deposits of silty sand, sand and silt) that have high to very high underseepage susceptibility, and a levee section that is relatively narrow for the differential head between the assessment water surface elevation and the levee toe. The WHIS is consistent with the past performance history of multiple, recurring boils in the segment. Based on the WHIS and the past performance history of multiple, recurring boils, Segment 131 is categorized as Hazard Level C for the underseepage potential failure mode.

Stability

Segment 131 Stability Assessment Results*

WHIS			Performance Summary			Categorization
Best Estimate	**Minimum Credible**	**Maximum Credible**	**Best Estimate**	**Minimum Credible**	**Maximum Credible**	
53	43	53	None documented	None documented	None documented	Hazard Level A*

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

Hazard indicators that suggest that levee instability is less likely to occur include the levee crest width, the moderate differential head between the assessment water surface elevation and the levee toe levee and the absence of soft soil in the foundation. Segment 131 is categorized as Hazard Level A for the stability potential failure mode based on the WHIS and the past performance history showing an absence of documented levee instability in the segment.

Through Seepage

Segment 131 Through Seepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	**Minimum Credible**	**Maximum Credible**	**Best Estimate**	**Minimum Credible**	**Maximum Credible**	
65	50	70	None documented	None documented	Wet area	Lacking Sufficient Data

Hazard indicators suggesting that through-seepage could occur include the levee composition of loose sand, medium animal activity, a moderate number of levee penetrations, and a levee section that is relatively narrow for the differential head between the assessment water surface elevation and the levee toe. Segment 131 is categorized as Lacking Sufficient Data due to the inconsistency between the WHIS, which suggests that through seepage may be likely, and the Best Estimate past performance history of no documented through seepage in the segment.

Erosion

Segment 131 is categorized as Hazard Level B for erosion. The segment has a history of erosion events. The most recent were reported in 1997, 1998, 2006, 2007, and 2008. One 2008 Ayers site (2009/2010 DWR repair site, non-ranked) is located along the segment. The reported erosion sites did not impact the levee crown. Based on the LiDAR data, erosion of the waterside slope may be occurring along about 30 percent of the segment.

Segment 131: Other Levee Assessments

Freeboard

Data from the LiDAR survey indicate that the levee crest for this segment is above the 1955/1957 WSE. A minimum freeboard of 3 feet is present throughout the 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 the overtopping risk to the NULE levees. Documents indicate this levee segment has not been overtopped.

Geometry

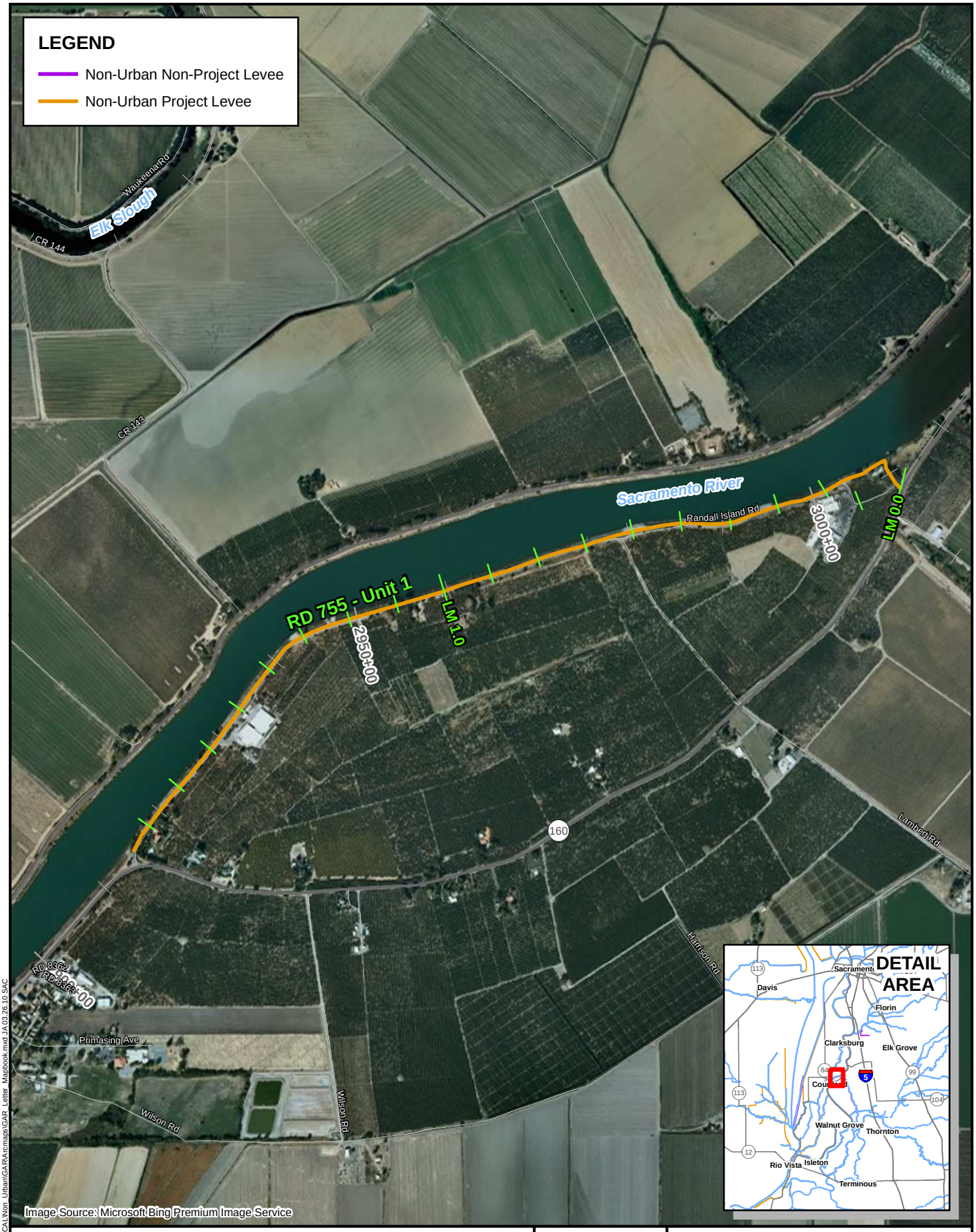
Using the LiDAR data, the levee geometry was compared with a standard levee prism defined by the Segment 131 1953 MOU geometric criteria. This check was performed by assessing whether the levee indicated by topography developed from the LiDAR data was larger than or equal to the standard levee prism 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 131, approximately 10 percent of the levee is smaller than the standard levee prism.

Segment 131: Hazard Mitigation

The following table presents identified hazards for Segment 131, and the estimated extent of the hazard. Comments are provided to assist with identifying potential remedial requirements.

Segment 131 Hazards

Hazard	Extent (percent)	Comments
Underseepage	80	Sand layer to at least 55 feet below the levee toe elevation (boring ends in the sand layer). Extent is based on the portion of the segment that has a relatively narrow base width, as indicated by LiDAR data.
Through Seepage	90	Clean sand levee. Extent is based on portions of that segment that have a relatively narrow levee section, as indicated by LiDAR data.
Erosion	30	Estimated based on areas of oversteepened slopes, as interpreted from LiDAR data.



L:\Projects\DWR\GEOTECHNICAL\Non_Urban\GARA\mxds\GAR_Letter_Mapbook.mxd JA 03.26.10 SAC

0 700 1,400
Feet

N

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

Segment 131

RD 0755

Geotechnical Assessment Report

NORTH NON-URBAN LEVEE EVALUATIONS

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

				Begin	End
Levee Segment Name:	Sacramento River, Left Bank, Randall		NULE Station (ft):	2915+00	3012+00
Levee Segment Number:	131		Levee Mile:	0	1.8
			Segment/Reach Length:	1.8 (miles)	9700 (feet)
Brief Description of Segment/Reach:	Randall - RD 0755		Crest Width Design Criterion (ft):	20	
Local Maintenance Authority:	RD 0755		Design Guidance Document:	1953 MOU	
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:

The Segment 131 levee was initially constructed by local interests. Based on an early topographic map (Courtland, 1:62,500), initial construction occurred prior to 1906. Specific documentation of the construction methods for the levee were not found. Levees along the Sacramento River were generally built using materials dredged from the river channel placed without compaction (Doc-5249). Portions of the levee were improved by USACE to project standards between 1943 and 1955 (Doc-2116). The improvements included bank protection work at RM 36.2 in 1943, RM 36.4 in 1945, RM 35.7 in 1947 and 1948 and at unlisted locations in 1954 to 1955.

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*	Documents reviewed indicate boils in 1986, 1997 and a recurring boil at LM 0.70 located approximately 1000 ft from toe.
Landside slope stability		*None documented*	*None documented*	*None documented*	N/A
Through seepage		*None documented*	*None documented*	*Wet area*	Documents reviewed indicate seepage at landside toe at LM 0.14 and between LM 0.1 to LM 0.9, but the severity of the seepage is not described

In addition to Ayres 2008/DWR 2009 studies, are there erosion occurrences identified in this study?	Yes	**If yes, please describe:**	The CLD includes multiple occurrences of erosion, and the documents reviewed indicate 11 occurrences of erosion

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	N/A	N/A	N/A	N/A
	Comments:	The Ayres report identified a new erosion site within Segment 131. The site is not rated or ranked.		**Comments:**	The Ayres report identified a new erosion site within Segment 131. The site is not rated or ranked.
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:**	N/A
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*	The documents reviewed included one boring log that indicates sand in the northern portion of the segment. The NRCS USC map indicates that the surficial soil is predominantly sand. The likely method of construction was by dredging of sand from the river.
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*	The documents reviewed included one boring log that indicates sand in the northern portion of the segment. The NRSC USC map indicates that the surficial soil is predominantly sand. The likely method of construction was by dredging of sand from the river.
II- GEOLOGY - ***at selected cross section***	**(Scale of mapping)**				
Underseepage susceptibility *for underseepage assessment*	1:62,500	*5 - Very high*	*4 - High*	*5 - Very high*	Mapped as very high in Underseepage Susceptibility Map (NULE Level 2-II). A range of high to very high susceptibility was selected based the map and boring data.
Dispersive soils *for stability assessment*	1:24,000	*1 - Not dispersive*	*1 - Not dispersive*	*1 - Not dispersive*	SAR map shows soils are not like dispersive
Piping potential *for underseepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Piping potential map shows very high piping potential.
Piping potential *for through seepage assessment*	1:24,000	*2 - Low*	*2 - Low*	*4 - High*	Based on available boring data, levee mainly consists of sand.
Soft soils *for stability assessment*	1:62,500	*1 - Not present*	*1 - Not present*	*1 - Not present*	Soft soils are not mapped within this levee segment.
III- OTHER INDICATORS - ***at selected cross section***					
Animal persistence/burrows? *for through seepage assessment*		*3 - Medium*	*3 - Medium*	*3 - Medium*	DWR rating; medium LM 0.49 - LM 1.23, not documented elsewhere
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?	Yes	**If yes, please describe:**	LM~ 0.7: 16-inch pipe through the levee, 5.0 feet below the crown. Pump on pile structure in the stream. Walkway to the pump. (App. No. 7357 - Green McKeown, Inc.) - LM ~0.7: 18-inch drainpipe through the levee, 4.5 feet below the crown. 4-inch pipe 15 feet high on the waterward shoulder. (App. No. 1716 - Green McKeown, Inc.) - LM ~0.7: 12-inch abandoned drainpipe through a 24-inch pipe through the levee, 8.0 feet below the crown. (App. No. 11222 - Green McKeown, Inc.)
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:	4 - >10 to 20	**Notes:**	19 pipes ranging in size from 6 to 30 inches in diameter and between 4 and 10.5 feet below the levee crest. 11 of the pipes are below the evaluation water surface elevation (about 5 feet below the levee crown). One cluster of 3 pipes at LM ~0.7 (~Station 2975+00)
DWR's LMA maintenance rating from Maintenance Deficiency Summary Report:	Unacceptable	**Notes:**	Fall 2008; rating is unacceptable for 0.1 mile of unspecified debris between LM 0.65 and 0.66.

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	2970+00	**Cross-section Station**	2990+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)	28		29			
Levee toe elevation (landside) (ft)	8		14			
Levee crest width (ft)	20	1	20	1		
Evaluation water elevation (ft)	24		24			
Levee slope - landside (xH : 1V); **Enter x**	2.9	2	1.5	5		
Levee slope - waterside (xH : 1V); **Enter x**	2.3					
Freeboard above evaluation flood elevation (ft) (= levee crest elevation - evaluation water elevation)	4.0					
Levee height (ft) (= levee crest elevation - landside toe elevation)	20.0	5	15.0	4		
Levee prism base width (ft)	124.0					
Head (ft) (= evaluation water level - landside toe elevation)	16.0	4	10.0	3		
Head-to-base-width ratio (= head / base width)	0.129	3				
Base-width to head ratio (= base width / head)	8					

V- ANOMALIES

	Anomalies?	**Description**	**Effect on Performance**
Underseepage	No	N/A	N/A
Stability	No	N/A	N/A
Through Seepage	No	N/A	N/A
Erosion	No	N/A	N/A

MITIGATION AND PAST BREACHES

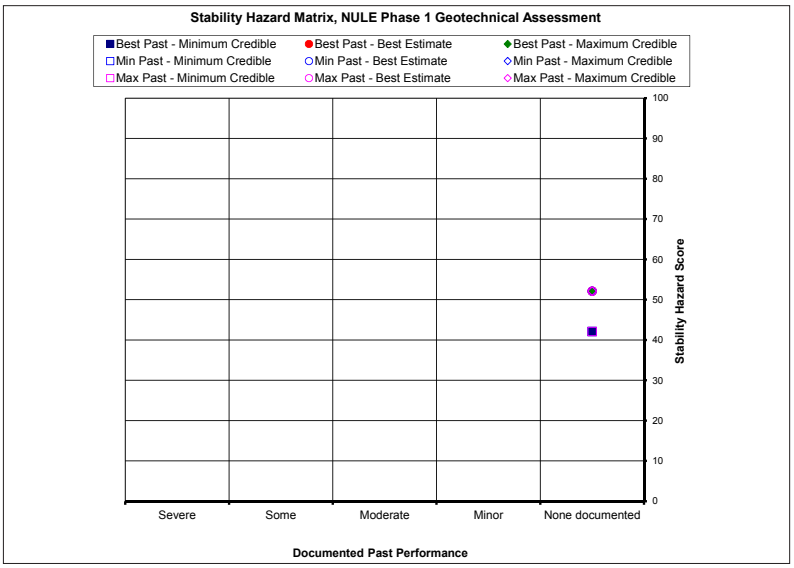
Existing constructed mitigation (List all)	Improvements include riverbank protection work performed under the Sacramento River Bank Protection Project (SRBPP) during Phase 1 in 1966 to 1968 and 1970 to 171 and during Phase 2 in 1981 and 1985. The completed riverbank protection work included placement of revetment at multiple locations along the segment.
Has there been a past breach?	None Identified
If yes, describe nature of the breach and how it has been mitigated?	

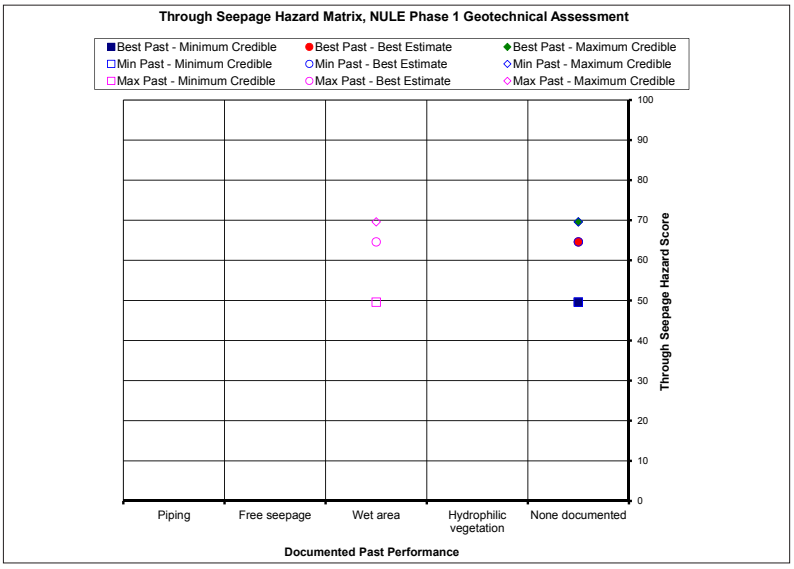
SUMMARY

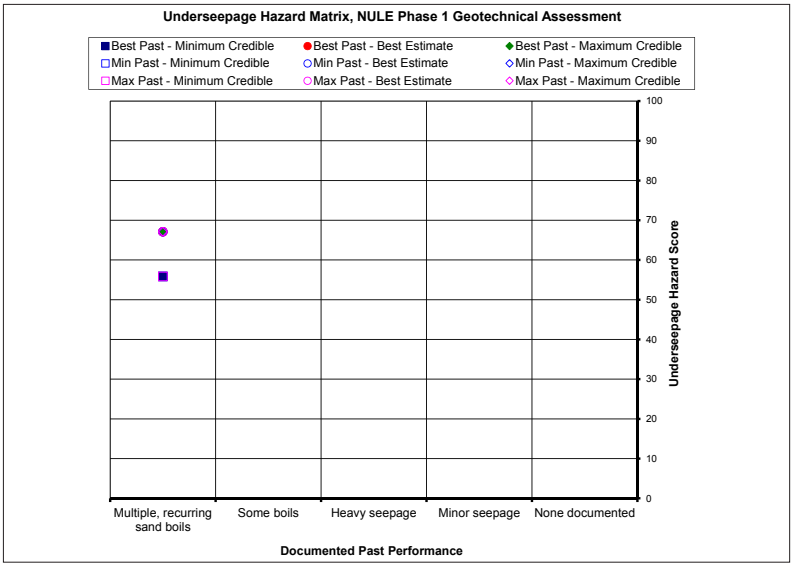
Failure Mode	**Weighted Hazard Indicator Score (Best)**	**Weighted Hazard Indicator Score (Minimum Credible)**	**Weighted Hazard Indicator Score (Maximum Credible)**	**Past performance issues?**	**Are past performance and Weighted Hazard Indicator Score consistent?**	**Levee categorization**
Underseepage	**68**	56	68	Multiple, recurring sand boils	Yes	***Hazard Level C***
Justification:	The relatively high WHIS is consistent with past performance data of documented multiple, recurring boils within the segment.					
Suggested additional data:	Confirm the presence, purpose and condition of a relief well at LM 1.6 with RD.					
Stability	**53**	43	53	None documented	Yes	***Hazard Level A***
Justification:	The relatively low WHIS is consistent with the past performance data of no documented levee instability within the segment.					
Suggested additional data:	N/A					
Through Seepage	**65**	50	70	None documented	No	***Hazard Level LD***
Justification:	The segment is categorized as lacking sufficient data due to the inconsistency between the relatively high WHIS and the Best Estimate past performance data of no documented through-seepage within the segment.					
Suggested additional data:	Subsurface data to evaluate the seepage properties of the levee, confirmation of location of seepage with respect to the levee slope.					
Erosion				Yes		***Hazard Level B***
Justification:	The segment has a history of erosion events with the most recent reported in 1997, 1998, 2006, 2007 and 2008. One 2008 Ayers site (2009/2010 DWR repair site, non-ranked) is located along the segment. The reported erosion sites were not documented as impacting the levee crown. Based on the LiDAR data, erosion of the waterside slope may be occurring along about 30 percent of the segment.					
Suggested additional data:	N/A					

Freeboard Check	Does levee pass freeboard check?	**Yes**	
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:	Failed on about 10% of waterside (Stations 2957+50 to 2962+50, 3002+50 to 3007+50).		
Are there anomalies along the segment with respect to geometry?	No	Describe anomalies:	0
Summary Characterization of Levee Segment	Hazard Level C	**Comment / Justification:**	the potential failure mode categorizations for underseepage is Hazard Level C resulting in an overall categorization of Hazard Level C.

Evaluator:	JWR	Evaluation Date:	3/9/2010
Checked By:	TK	Check Date:	3/9/2010
Senior Reviewer:	KLK, SP, RSA	Review Date:	3/10/2010


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

RD 0551, UNIT 1, SEGMENT 126 SUMMARY

This segment summary presents collected information and the assessment results for Segment 126. 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 126: Segment Description and Assessment Summary

Segment 126 is a non-urban Project levee on the left (east) bank of the Sacramento River in Sacramento County, California (see attached map). The segment extends along the west side of Pierson Tract from just north of Courtland southward to the confluence of Meadows Slough and the Sacramento River. The following table summarizes information for Segment 126.

Segment 126 Information

Maintenance Authority	Unit	Levee Miles*	NULE Stationing*
RD 0551	1	0 to 6.8	Sacramento River Left Bank 2556+53 to 2914+86

* 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 126 categorizations for each potential failure mode.

Segment 126 Potential Failure Mode Assessment Summary

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

Based on these NULE Phase 1 levee assessments, the overall categorization for Segment 126 is Hazard Level B.

Segment 126: 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

Based on an early topographic map (Courtland, 1:62,500), the Segment 126 levee was initially constructed prior to 1906 by local interests. Specific documentation of the construction methods for the levee were not available. Portions of the levee that did not meet Project standards were improved by the USACE to Project standards in 1954 and 1955 (Doc-2116). The improvements included levee reconstruction and bank protection at several locations along the segment. The locations of the improvements were not available. The following table presents the 1953 MOU geometric criteria for Segment 126.

Segment 126 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 maintenance personnel. Based on the available information, performance events in Segment 126 include multiple erosion events, reported in 1997, 1998, and 2008, and underseepage. There are no documented reports of slope instability or through seepage. The following table summarizes reported performance events.

Segment 126 Reported Levee Performance Events

Flood Season	Reported Performance Event	Approximate Location (Levee Mile)	Mitigation
1998	Erosion, toe failure of rock revetment or slip: total of 31 sites along the segment (Doc – 1540, CLD)	Multiple locations between 1.86 – 6.74	Not documented.
Reported in 2008	Seepage: when water is high, island (RD 0551, Pierson District) experiences general seepage but no significant boils (Doc-8314).	–	Repair not made.
Reported in 2008	The low spot in the middle of the island (Pierson) fills up during high water and then drains; water drains faster than it comes in (Doc-8314).	–	Repair not made.
2008	Waterside erosion due to wave wash; base of the erosion is visible (Doc-8314)	–	Repair not made.

Underseepage

In addition to the underseepage documented in the table of Segment 126 Reported Levee Performance Events, the CLD lists relief wells at LM 1.38, LM 2.7, LM 5.04, LM 5.69, LM 5.80, LM 6.12, and LM 6.29. Relief wells are typically installed in areas of underseepage. Details of the relief wells were not found.

Erosion

The segment has experienced ongoing erosion problems since 1956. Multiple erosion sites along the segment were identified during inspections following the 1997 and 1998 flood seasons (Doc-256, Doc-1540, and Doc-1694, and as listed in the CLD). The erosion events reoccurred at sites mitigated under the Sacramento River Bank Protection Project (SRBPP) between 1963 and 1981. The 1997 and 1998 erosion sites were not documented as impacting the levee crown.

Improvements

Improvements include riverbank protection work performed under the Sacramento River Bank Protection Project (SRBPP) during Phase 1 in 1963 to 1974 and during Phase 2 in 1976 and 1981 (Doc-8587). The completed riverbank protection work included placement of revetment at multiple locations along the segment.

Planned Improvements

Based on the documents reviewed, no improvements to Segment 126 are currently planned.

Segment 126: 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 126 levee heights range from approximately 15 to 22 feet above the landside toe. Including the rounded shoulders, crest widths range from approximately 20 to 40 feet. LiDAR survey data indicate the landside slopes are approximately 1.5H:1V to 3.0H:1V. The waterside slopes are approximately 1.8H:1V to 3.3H:1V. A ditch is along the landside toe of Segment 126, from approximately Station 2597+00 to Station 2610+00 and from Station 2830+00 to Station 2841+00.

Penetrations

According to the DWR Pipe Inventory, 52 pipes penetrate the levee segment. Pipe diameters range from 1 to 16 inches. The pipes are approximately 2 to 10.4 feet below the levee crown.

Animal Activity

Squirrel activity on the portion of the levee north of Courtland (LM 0.0 to LM 0.25) was reported by RD 0551 in a 2008 interview. Animal persistence based on data from DWR is "Low" from LM 0.0 to LM 1.4 and "None Documented" from LM 1.4 to LM 6.8.

Maintenance

The DWR assessments performed in the fall of 2008 indicate that DWR rates the levee maintenance as "Unacceptable (U)" for this segment.

Other Features

Based on the LiDAR data and the DWR assessment in the fall of 2008, the landside slope of the levee has been oversteepened to about 1H:1V between LM 2.27 to LM 2.32 by landscaping.

Segment 126: 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 126.

In Segment 126, the levee foundations consist of silt and clay overlying sand, and the levees consist of sand and some silt.

Geomorphic Setting

Segment 126 is in the Sacramento Valley flood basin. Geomorphology Level 2-II mapping indicates the Segment 126 levee overlies recent overbank deposits consisting of interbedded silt, sand and clay that likely interfingers with adjacent flood plain silt and clay sediments and are likely to vary laterally in extent and character. The Level 2-II mapping also indicates that the levee overlies recent crevasse splays (fine sand, silt, and clay) at about LM 0.9 to LM 1.0, LM 2.37, and LM 4.78.

Geotechnical Investigations

Geotechnical investigations for Segment 126 performed by others include seven borings in the DWR Salinity Control Barrier Study (1958) and three borings for the Sacramento River Flood Control System Evaluation (USACE, 1993) (Doc-1044). One of these borings was drilled through the crest of the levee, and the other nine were drilled near the landside levee toe. These borings range in depth from 15 to 80 feet. The stick logs of these borings indicate that the soil in the levee prism consists mostly of sand and some silt, while the soil in the foundation consists of silt and clay overlying a thick sand layer.

Other Subsurface Information

According to the USCS soil map, the levee overlies fine-grained surface soils (CL/ML). The USCS map does not indicate the variation of soil types shown in the Level 2-II mapping or that was found in the borings.

Levee Composition

The available boring data indicate that the levee consists of loose sand and some silt.

Segment 126: Geotechnical Assessment Results

As discussed in Volume 1, Section 2 of this report, the overall assessment is based on the individual potential failure mode categorizations. Because the potential failure mode categorizations for underseepage and erosion were Hazard Level B, the overall categorization for Segment 126 is Hazard Level B. 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 was 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 126 Underseepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	**Minimum Credible**	**Maximum Credible**	**Best Estimate**	**Minimum Credible**	**Maximum Credible**	
55	54	55	Heavy seepage	Minor seepage	Heavy seepage	Hazard Level B

Hazard indicators that suggest that underseepage could occur include levee foundation materials (overbank deposits of silt, sand and clay) that have high to very high underseepage susceptibility and a levee section that is moderate to wide for the differential head between the assessment water surface elevation and the levee toe. Segment 126 is categorized as Hazard Level B due to the consistency between the hazard indicators that suggest that underseepage may occur and the past performance history of documented heavy seepage in the segment.

Stability

Segment 126 Stability Assessment Results*

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
46	36	46	None documented	None documented	None documented	Hazard Level A*

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

Hazard indicators that suggest that levee instability is less likely to occur include the wide levee crest, low differential head between the assessment water surface elevation and the levee toe and the absence of soft soil in the foundation. Segment 126 is categorized as Hazard Level A due to the consistency between the hazard indicators that suggest that levee instability is less likely to occur, and the absence of instability past performance data in the segment.

Through Seepage

Segment 126 Through Seepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
55	35	55	None documented	None documented	None documented	Hazard Level A

Although the levee composition of loose sand would suggest that through seepage could occur, other hazard indicators that suggest that through-seepage is less likely to occur include a levee section that is wide for the differential head between the assessment water surface elevation and the levee toe and the absence of animal activity. Segment 126 is categorized as Hazard Level A due to the consistency between the hazard indicators that suggest that through seepage is less likely to occur, and the absence of through seepage past performance data in the segment.

Erosion

Segment 126 is categorized as Hazard Level B for erosion. The segment has a history of erosion events. The most recent were reported in 1997 and 1998, and during the 2008 interview with RD 0551 personnel (Doc-8314). Documented mitigation of several of the erosion sites reported during the 1997 and 1998 flood season was not found. The 1997 and 1998 erosion sites were not documented as impacting the levee crown.

Segment 126: Other Levee Assessments

Freeboard

Data from the LiDAR survey indicate that the levee crest for Segment 126 is above the 1955/57 WSE. A minimum freeboard of 3 feet is present throughout the segment.

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 the overtopping risk to the NULE levees. Documents do not indicate this levee segment has been overtopped.

Geometry

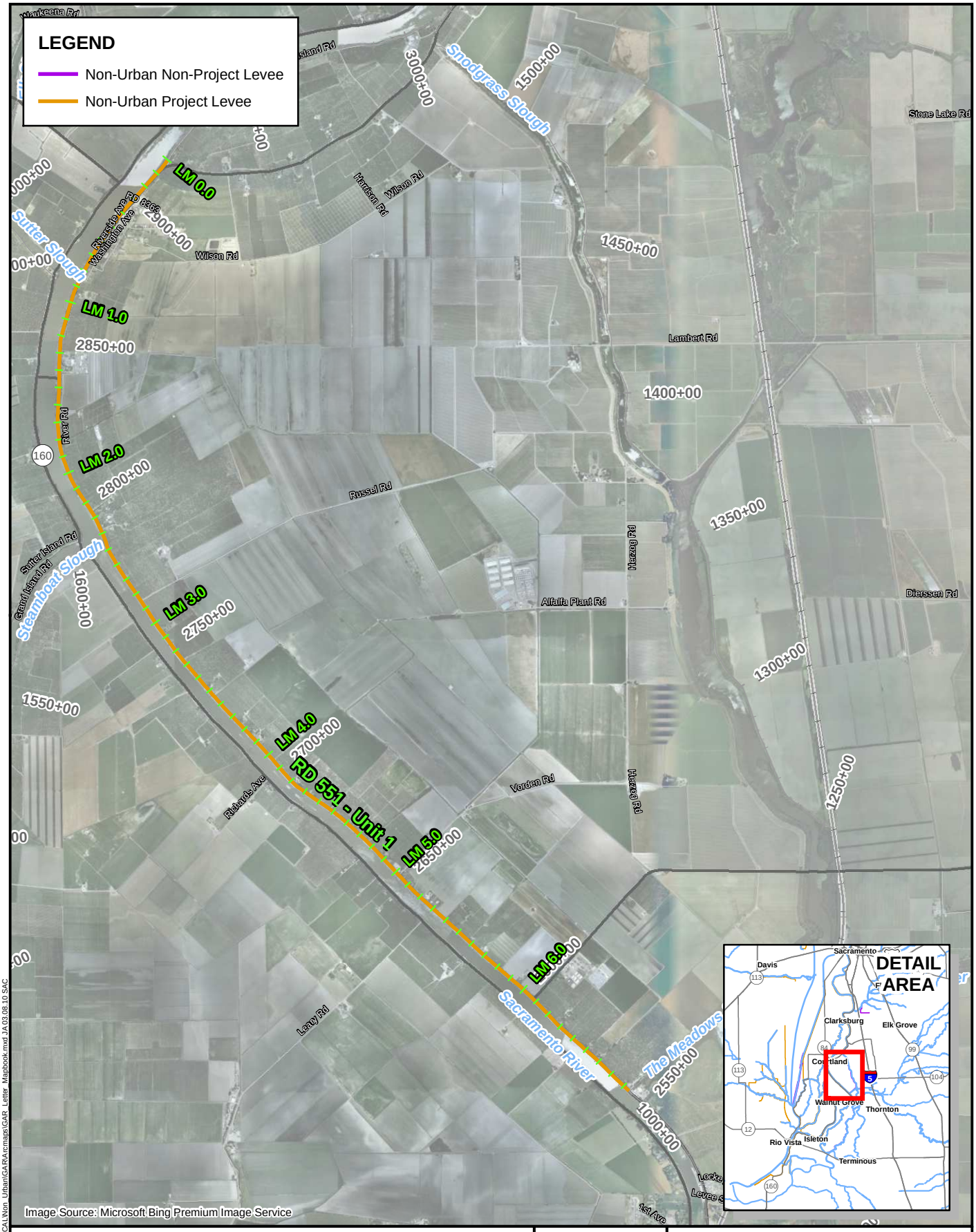
Using the LiDAR data, the levee geometry was compared with a standard levee prism defined by the Segment 126 1953 MOU geometric criteria. This check was performed by assessing whether the levee indicated by topography developed from the LiDAR data was larger than or equal to the standard levee prism 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 126, 100 percent of the levee meets the standard levee prism.

Segment 126: Hazard Mitigation

The following table presents identified hazards for Segment 126 and the estimated extent of the hazard. Comments are provided to assist with identifying potential remedial requirements.

Segment 126 Hazards

Hazard	Extent (percent)	Comments
Underseepage	40	Sand layer up to 75 feet below the levee toe elevation. Extent is based on portion of the segment that has a relatively thin (< 10 foot) landside blanket
Erosion	10	Estimated based on areas of oversteepened slopes, as interpreted from LIDAR data.



0 2,000 4,000
Feet

N

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

Segment 126

RD 0551

Geotechnical Assessment Report

NORTH NON-URBAN LEVEE EVALUATIONS

L:\Projects\DWR\GEOTECHNICAL\Non_Urban\GARA\mxds\GAR_Letter_Mapbook.mxd JA 03.08.10 SAC

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

				Begin	End
Levee Segment Name:	RD 0551		NULE Station (ft):	2556+53	2914+86
Levee Segment Number:	126		Levee Mile:	0	6.8
Brief Description of Segment/Reach:	RD 0551 - Pierson		Segment/Reach Length:	6.8 (miles)	35833 (feet)
			Crest Width Design Criterion (ft):	20	
Local Maintenance Authority:	RD 0551		Design Guidance Document:	1953 MOU	
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:

Based on an early topographic map (Courtland, 1:62,500), the Segment 126 levee was initially constructed prior to 1906 by local interests. Specific documentation of the construction methods for the levee were not available. Portions of the levee that did not meet Project standards were improved by the USACE to Project standards in 1954 and 1955 (Doc-2116). The improvements included levee reconstruction and bank protection at several locations along the segment. The locations of the improvements were not available.

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*	2008 interview with RD 0551 reports general seepage, but no significant boils; One low spot in the middle of the island fills up during high water and then drains.
Landside slope stability		*None documented*	*None documented*	*None documented*	N/A
Through seepage		*None documented*	*None documented*	*None documented*	N/A

In addition to Ayres 2008/DWR 2009 studies, are there erosion occurrences identified in this study?	Yes	**If yes, please describe:**	The segment has had erosion occurrences reported in 1997, 1998 and 2008.

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:**	N/A
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 data from borings and NULE Level 2-II mapping.
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 data from borings and NULE Level 2-II mapping.
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*	Mapped as very high in Underseepage Susceptibility Map (NULE Level 2-II).
Dispersive soils *for stability assessment*	1:24,000	*1 - Not dispersive*	*1 - Not dispersive*	*1 - Not dispersive*	SAR map shows soils are likely not dispersive
Piping potential *for underseepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Piping potential map shows high piping potential, borings through levee segment indicate silt is present in foundation.
Piping potential *for through seepage assessment*	1:24,000	*4 - High*	*2 - Low*	*4 - High*	Borings through levee show sand and silt.
Soft soils *for stability assessment*	1:24,000	*1 - Not present*	*1 - Not present*	*1 - Not present*	Based on boring information.
III- OTHER INDICATORS - ***at selected cross section***					
Animal persistence/burrows? *for through seepage assessment*		*1 - None documented*	*1 - None documented*	*1 - None documented*	Based on DWR data - Low LM 0 to 1.4 and none documented LM 1.4 to 6.8.
Is a landside ditch or borrow pit present within 200 ft of toe? *for underseepage assessment*	Ditch at toe of levee (w/in one levee height of toe)	5			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:	5 - More than 20	**Notes:**	58 pipes ranging in size from 1 to 16 inches in diameter and between 2 and 10.4 feet below the levee crest. 42 of the pipes are below the evaluation water surface elevation (about 5 feet below the levee crown).		
DWR's LMA maintenance rating from Maintenance Deficiency Summary Report:	Unacceptable	**Notes:**	Fall 2008; Unacceptable rating for vegetation and trees and vehicles that have been abandoned on the levee shoulder.		

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	2835+00	**Cross-section Station**	2725+00	**Cross-section Station**	2725+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)	31		29		29	
Levee toe elevation (landside) (ft)	13.5		10		10	
Levee crest width (ft)	23	1	32	1	32	1
Evaluation water elevation (ft)	20.7		19.8		19.8	
Levee slope - landside (xH : 1V); **Enter x**	2.57	3	1.84	4	1.84	4
Levee slope - waterside (xH : 1V); **Enter x**	3.15				2.08	
Freeboard above evaluation flood elevation (ft) (= levee crest elevation - evaluation water elevation)	10.3					
Levee height (ft) (= levee crest elevation - landside toe elevation)	17.5	4	19.0	4	19.0	4
Levee prism base width (ft)	123.1				106.5	
Head (ft) (= evaluation water level - landside toe elevation)	7.2	2	9.8	2	9.8	2
Head-to-base-width ratio (= head / base width)	0.058	1			0.1	2
Base-width to head ratio (= base width / head)	17				11	

V- ANOMALIES

	Anomalies?	**Description**	**Effect on Performance**
Underseepage	No	N/A	N/A
Stability	No	N/A	N/A
Through Seepage	No	N/A	N/A
Erosion	No	N/A	N/A

MITIGATION AND PAST BREACHES

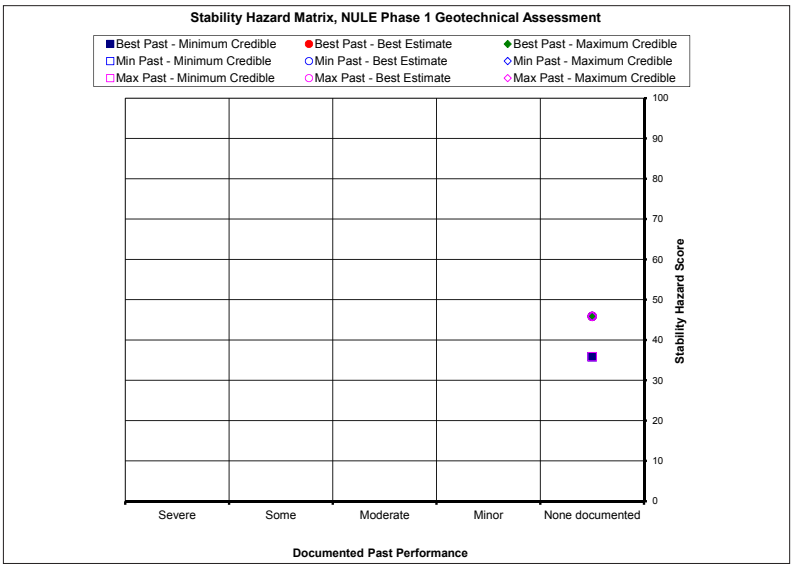
Existing constructed mitigation (List all)	Multiple erosion sites repaired in 1997 (Doc-2393 and Doc-1540); Waterside slope reconstruction and riverbank protection were performed at multiple locations (Doc-3399).
Has there been a past breach?	None Identified
If yes, describe nature of the breach and how it has been mitigated?	

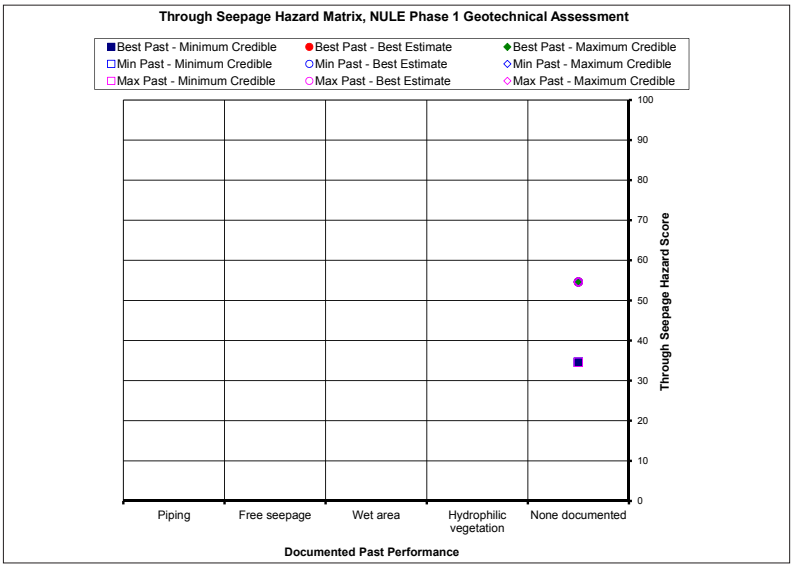
SUMMARY

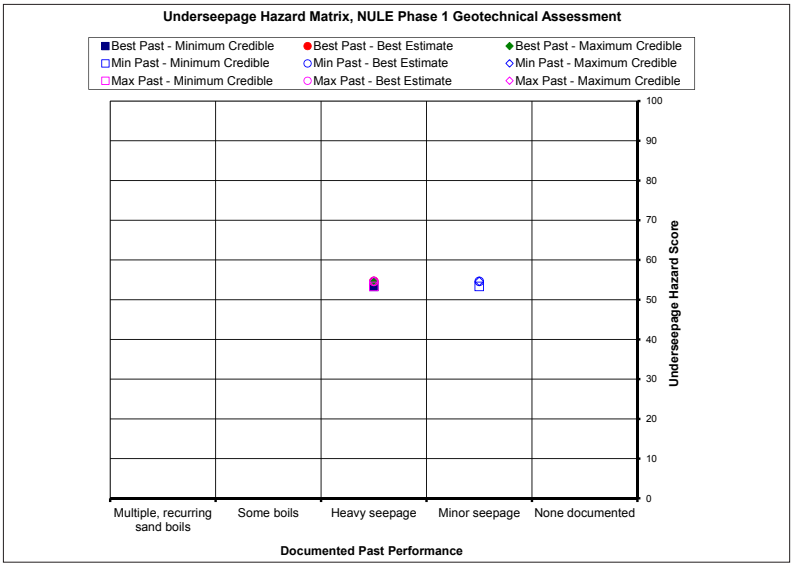
Failure Mode	**Weighted Hazard Indicator Score (Best)**	**Weighted Hazard Indicator Score (Minimum Credible)**	**Weighted Hazard Indicator Score (Maximum Credible)**	**Past performance issues?**	**Are past performance and Weighted Hazard Indicator Score consistent?**	**Levee categorization**
Underseepage	**55**	54	55	Heavy seepage	Yes	***Hazard Level B***
Justification:	Segment 126 is categorized as Hazard Level B due to the consistency between the hazard indicators that suggest that underseepage may occur and the past performance history of documented heavy seepage in the segment.					
Suggested additional data:	Confirm the presence, purpose and condition of relief wells at LM 1.38, LM 2.7, LM 5.04, LM 5.69, LM 5.80, LM 6.12 and LM 6.29 with RD.					
Stability	**46**	36	46	None documented	Yes	***Hazard Level A***
Justification:	Segment 126 is categorized as Hazard Level A due to the consistency between the hazard indicators that suggest that levee stability is less likely to occur, and the absence of instability past performance data in the segment.					
Suggested additional data:	N/A					
Through Seepage	**55**	35	55	None documented	Yes	***Hazard Level A***
Justification:	Segment 126 is categorized as Hazard Level A due to the consistency between the hazard indicators that suggest that through seepage is less likely to occur, and the absence of through seepage past performance data in the segment.					
Suggested additional data:	N/A					
Erosion				Yes		***Hazard Level B***
Justification:	The segment has a history of erosion events with the most recent reported in 1997, 1998 and during the 2008 interview with RD 0551 personnel. Documented mitigation of several of the erosion sites reported during the 1997 and 1998 flood season was not found. The 1997 and 1998 erosion sites were not documented as impacting the levee crown.					
Suggested additional data:	N/A					

Freeboard Check	Does levee pass freeboard check?	**Yes**	
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?	**Yes**	
Provide details about where along segment (and by how much) levee does not pass geometry check:	N/A		
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 and erosion were Hazard Level B resulting in an overall categorization of Hazard Level B.

Evaluator:	JWR	Evaluation Date:	2/9/2010
Checked By:	TK	Check Date:	2/9/2010
Senior Reviewer:	Review Team	Review Date:	2/10/2010







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RD 0551, SEGMENT 1040 SUMMARY

This segment summary presents collected information and the assessment results for Segment 1040. The summary is based on data that were readily available 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 1040: Segment Description and Assessment Summary

Segment 1040 is a non-urban, non-Project levee located on the right (north) bank of the Meadows Slough in Sacramento County, California (see attached map). The segment extends from the intersection of the Snodgrass Slough and the Meadows Slough westward to the intersection of the Meadows Slough and the Sacramento River. The following table summarizes segment information.

Segment 1040 Information

Maintenance Authority	Unit	Levee Miles*	NULE Stationing*
RD 0551	—	0 to 1.4	The Meadows Slough Right Bank 1000+00 to 1073+00

* The levee mile and stationing alignments differ.

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. It is our understanding from interviews with the RD (Doc-8314 and locals meeting held on April 14, 2010) that the levee is significantly higher than flood levels and as such the water surface elevation used in the assessment may be overstated. The following table presents the Segment 1040 categorizations for each potential failure mode.

Segment 1040 Potential Failure Mode Assessment Summary

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

Based on these NULE Phase 1 levee assessments for Segment 309, through seepage and erosion are categorized as Hazard Level A, underseepage is categorized as Hazard Level B, and stability is categorized as Hazard Level LD. If additional data were obtained, it is very unlikely that the LD for stability 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 1040: 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

Based on historic topographic maps (Courtland, 1:62,500) (Doc-8590), the Segment 1040 levee was initially constructed prior to 1906 by local interests. The RD 0551 1919 Plan of Reclamation indicates that Segment 1040 was likely constructed using materials dredged from the adjacent Meadows Slough, and presents the plan for raising and enlarging the levee using similar methods (Doc-5232). The plan indicated the levee was to be constructed with a crest width of 9 feet, a waterside slope of 3H:1V and a landside slope of 5H:1V. The following table presents the 1953 MOU geometric criteria for Segment 1040.

Segment 1040 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 RD 0551 maintenance personnel (Doc-8314). Based on the available information, performance events in Segment 1040 include underseepage. The following table summarizes reported performance events.

Segment 1040 Reported Levee Performance Events

Flood Season	Reported Performance Event	Approximate Location (Station)	Mitigation
1949–1953	Seepage observed by landowners (Doc-914).	1055+00 to 1073+00	Mitigation not indicated.

Improvements

Documentation of improvements to the levee since initial construction were not available.

Planned Improvements

Based on the URS review, no improvements to Segment 1040 are currently planned.

Segment 1040: 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 1040 levee heights range from approximately 16 to 27 feet above the landside toe. The height gradually increases from about 16 feet near Station 1000+00 to about 27 feet near Station 1055+00 and then decreases to 24 feet near the end at Snodgrass Slough. Including the rounded shoulders, crest width ranges from approximately 10 to 15 feet. LiDAR survey data indicate the landside slopes are approximately 4.5H:1V to 6H:1V. The waterside slopes are approximately 3H:1V to 4H:1V.

Penetrations

Information regarding penetrations through the levee segment was not available.

Animal Activity

Animal activity was not reported in the reviewed documents. Animal persistence based on data from DWR is not available for Segment 1040.

Maintenance

DWR assessments were not available for Segment 1040.

Other Features

Segment 1040 has four ditches that do not run parallel to the levee. The ditches are located near NULE Stations 1025+50, 1032+50, 1038+50 and 1058+00.

Segment 1040: 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 1040.

In Segment 1040, the levee foundation consists of silt underlain by sand in the western half and is underlain by clay and possibly peat in the eastern half. The levee may be primarily silt with some sand at the west end, becoming more clayey to possibly peaty towards the east.

Geomorphic Setting

According to the Level 2-I mapping, Segment 1040 is in the Sacramento River floodplain and natural levees domain (SR). The natural levee deposits that underlie the western end of the segment are interbedded sand, silt, and clay and may have layers from 2 to 5 feet thick that are probably laterally discontinuous along the levee. The sediments comprising the floodplain deposits underlying the eastern end of the segment consist of clay, silt, and possibly peat. Recent, more detailed Level 2-II mapping is generally consistent with Level 2-I mapping along Segment 1040 except that the Level 2-II mapping indicates that Segment 1040 foundation soils are recent overbank deposits (silt, clay, and lesser sand) that may overlie the flood basin deposits. A recent crevasse splay deposit (fine sand with silt and clay) is mapped from Station 1014+00 to 1030+00. Marsh deposits are mapped on the waterside of the segment from Station 1032+00 to the end of the Level 2-II mapping area near Station 1058+00.

Geotechnical Investigations

Geotechnical investigations for Segment 1040 performed by others include one boring in the DWR Salinity Control Barrier Study (1958) (Doc-8306). This boring was drilled near the landside levee toe to a depth of about 40 feet at the western end of the segment. The boring's stick log indicates that the soil encountered in the foundation consists of silt underlain by sand.

Other Subsurface Information

The NRCS USCS soil map indicates the existing levee overlies fine-grained (CH) surface soils. The NRCS USCS map does not indicate the variation of soil types that is indicated in the Level 2-II mapping or that was found in the borings.

Levee Composition

The available data indicate that the Segment 1040 levee may be primarily silt with some sand at the west end, becoming more clayey to possibly peaty towards the east.

Segment 1040: Geotechnical Assessment Results

The overall Segment 1040 categorization is Hazard Level B. As discussed in Volume 1, Section 2 of this report, the overall assessment is based on the individual potential failure mode categorizations. For this segment, through seepage and erosion are categorized as Hazard Level A, underseepage is categorized as Hazard Level B, and stability is categorized as Hazard Level LD. If additional data were obtained, it is very unlikely that the LD for stability 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 Weighted Hazard Indicator Score was calculated for each potential failure mode at the assessment water surface elevation, the top of levee less 1.5 feet. It is our understanding from interviews with the RD (Doc-8314 and locals meeting held on April 14, 2010) that the levee is significantly higher than flood levels and as such the water surface elevation used in the assessment may be overstated. 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 1040 Underseepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	**Minimum Credible**	**Maximum Credible**	**Best Estimate**	**Minimum Credible**	**Maximum Credible**	
66	53	68	Minor seepage	Minor seepage	Heavy seepage	Hazard Level B

Hazard indicators suggesting that underseepage could occur include levee foundation materials (silt and sand in the west and possibly peat in the east) that have high to very high underseepage susceptibility and a levee section that is moderate for the differential head between the assessment water surface elevation and the levee toe. Segment 1040 is categorized as Hazard Level B based on the consistency between the hazard indicators that suggest that underseepage may occur and the past performance data of minor seepage in the segment.

Stability

Segment 1040 Stability Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
61	36	66	None documented	None documented	None documented	LD (A and B)

Hazard indicators suggesting that levee instability could occur include the levee composition of weak, clayey soil in the eastern portion of the segment, a levee height of up to 27 feet above the levee toe, the high differential head between the assessment water surface elevation and the levee toe, and soft soils in the foundation. Given the inconsistency between the hazard indicators, which suggest that levee instability may occur, and the lack of a past performance history of levee instability in the segment, Segment 1040 is categorized as Lacking Sufficient Data for the stability potential 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.Through Seepage

Segment 1040 Through Seepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	Minimum Credible	Maximum Credible	Best Estimate	Minimum Credible	Maximum Credible	
38	30	55	None documented	None documented	None documented	Hazard Level A

Hazard indicators suggesting that through seepage is less likely to occur include the levee composition of silt and sand in the west and clayey soil in the east, no documented penetrations, no documented animal persistence and a levee section that is moderate for the differential head between the assessment water surface elevation and the levee toe. Given the consistency between the best estimate hazard indicators, which suggests a low likelihood of through seepage, and the lack of a past performance history of through seepage in the segment, Segment 1040 is categorized as Hazard Level A for the through seepage potential failure mode.

Erosion

Segment 1040 is categorized as Hazard Level A for erosion. Erosion features were not identified in the available documents. Based on the LiDAR data, minor erosion of the waterside levee toe may be occurring along about 30 percent of the segment.

Segment 1040: 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 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. The documents reviewed do not indicate this levee segment has been overtopped.

Geometry

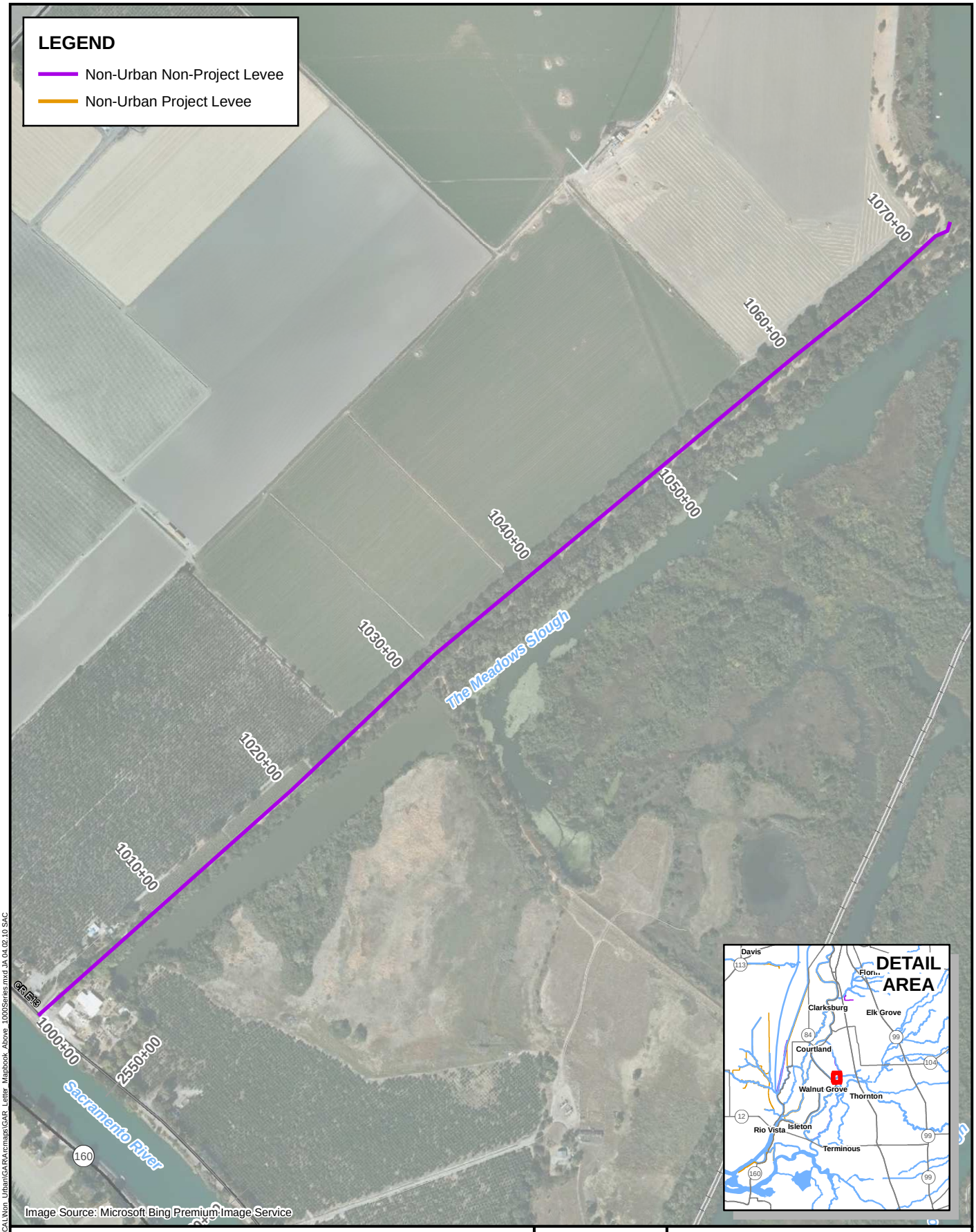
Using the LiDAR data, the levee geometry was compared with a standard levee prism defined by the Segment 1040 1953 MOU geometric criteria. This check was performed by assessing whether the levee indicated by topography developed from the LiDAR data was larger than or equal to the standard levee prism 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 1040, approximately 65 percent of the levee is smaller than the standard levee prism due to a narrow crest width.

Segment 1040: Hazard Mitigation

The following table presents identified hazards for Segment 1040 and the estimated extent of the hazard. Comments are provided to assist with identifying potential remedial requirements.

Segment 1040 Hazards

Hazard	Extent (percent)	Comments
Underseepage	70	Extent is the western end of the segment where the segment ties into the levees along the Sacramento River; a portion of the segment overlies a recent crevasse splay, as shown on Level 2-II mapping (sand layers underlying the levee may extend to 40 feet below the levee toe); at the eastern end of segment, soft soils (possibly peat) are the likely source of underseepage past performance.
Stability	30	Extent is the eastern end of segment where soft soils are likely.



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Feet

N

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

Segment 1040
Geotechnical Assessment Report

NORTH NON-URBAN LEVEE EVALUATIONS

L:\Projects\DWR\GEOTECHNICAL\Non Urban\GARA\mxds\GAR Letter Mapbook Above 1000Series.mxd JA 04.02.10 SAC

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

				Begin	End
Levee Segment Name:	TMSS-L 1000+00-1073+00		NULE Station (ft):	1000+00	1073+00
Levee Segment Number:	1040		Levee Mile:	0	1.4
			Segment/Reach Length:	1.4 (miles)	7300 (feet)
Brief Description of Segment/Reach:	Right bank of The Meadows Slough		Crest Width Design Criterion (ft):	20	
Local Maintenance Authority:	RD 0551		Design Guidance Document:	Plan of Reclamation - RD 0551 (Doc-5232)	
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: The Segment 1040 levee was initially constructed by local interests. Based on an early topographic map (Courtland, 1:62,500), initial construction occurred prior to 1906. The RD 0551 1919 Plan of Reclamation indicates that Segment 1040 was likely initially constructed using materials dredged from the adjacent Meadows Slough and presented the plan for raising and enlarging the levee using similar methods (Doc-5232).

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		*Minor seepage*	*Minor seepage*	*Heavy seepage*	Seepage in the eastern end (1055+00 to 1073+00) of the segment as reported by landowners between 1949 to 1954 (Doc-914).
Landside slope stability		*None documented*	*None documented*	*None documented*	None indicated in interview with RD.
Through seepage		*None documented*	*None documented*	*None documented*	None indicated in interview with RD.

In addition to Ayres 2008/DWR 2009 studies, are there erosion occurrences identified in this study?	No	**If yes, please describe:**	

		Ayres Methodology 2			Ayres Methodology 4		
North NULE	**Erosion sites from the Ayres 2008 study**						
		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:**	N/A
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*		*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*	*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 NULE Level 2-II mapping
Composition of levee material *for stability assessment*		*4 - CH, MH; moderately dispersive soils; loose sand, sand with silt, or non-plastic silt*	*3- soils are more clayey than category 1 soils, with liquid limits greater than 35 and less than 50*	*5 - OL, OH, Peat, dispersive soil*	Based on NULE Level 2-II mapping
II- GEOLOGY - ***at selected cross section*** **(Scale of mapping)**					
Underseepage susceptibility *for underseepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Recent overbank and crevasse splay deposits were mapped in NULE Level 2-II
Dispersive soils *for stability assessment*	1:24,000	*1 - Not dispersive*	*1 - Not dispersive*	*1 - Not dispersive*	SAR map shows soils are likely not dispersive
Piping potential *for underseepage assessment*	1:24,000	*4 - High*	*1 - None or no data*	*5 - Very high*	Mapped as none in piping potential map; Available boring information shows possible presence of silt in foundation.
Piping potential *for through seepage assessment*	1:24,000	*4 - High*	*1 - None or no data*	*5 - Very high*	Based on NULE Level 2-II mapping.
Soft soils *for stability assessment*	1:24,000	*5 - Present*	*1 - Not present*	*5 - Present*	Based on NULE Level 2-II mapping
III- OTHER INDICATORS - ***at selected cross section***					
Animal persistence/burrows? *for through seepage assessment*		*1 - None documented*	*1 - None documented*	*1 - None documented*	Animal activity was not indicated in the reviewed documents or RD 0551 interview. DWR data is not available for this 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:	1 - None documented	**Notes:**	No penetrations were documented during the site reconnaissance; The DWR penetration inventory does not cover Segment 1040.		
DWR's LMA maintenance rating from Maintenance Deficiency Summary Report:	LMA Not rated by DWR	**Notes:**	N/A		

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	1010+00	**Cross-section Station**	1050+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)	27.5		29			
Levee toe elevation (landside) (ft)	6.5		3			
Levee crest width (ft)	12	4	18	2		
Evaluation water elevation (ft)	26		27.5			
Levee slope - landside (xH : 1V); **Enter x**	5	1	4.5	1		
Levee slope - waterside (xH : 1V); **Enter x**	3.1		3.5			
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	26.0	5		
Levee prism base width (ft)	182.1					
Head (ft) (= evaluation water level - landside toe elevation)	19.5	4	24.5	5		
Head-to-base-width ratio (= head / base width)	0.107	3				
Base-width to head ratio (= base width / head)	9					

V- ANOMALIES

	Anomalies?	**Description**	**Effect on Performance**
Underseepage	Yes	Segment 1040 has four ditches that do not run parallel to the levee. The ditches are located near NULE Station 1025+50, 1032+50, 1038+50 and 1058+00.	Potential location for seepage and boils.
Stability	Yes	Encroachment of agricultural fields into levee prism.	Potential levee instability.
Through Seepage	No	N/A	N/A
Erosion	No	N/A	N/A

MITIGATION AND PAST BREACHES

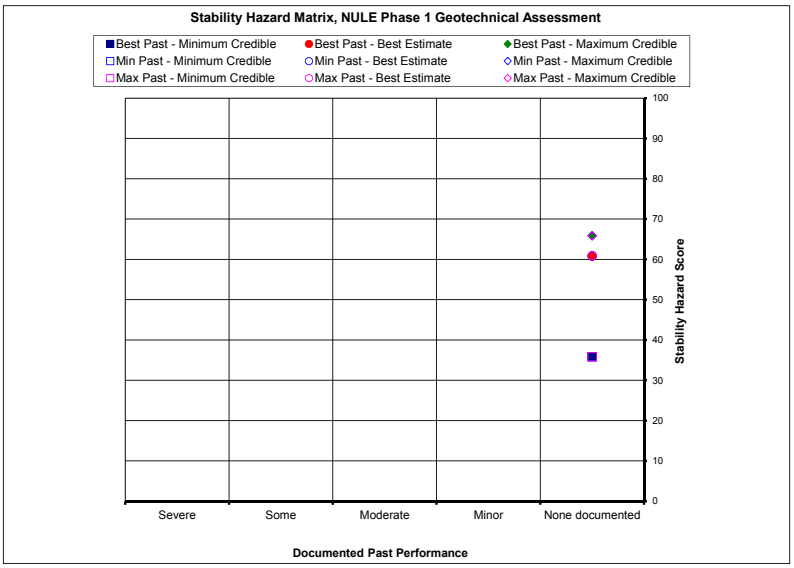
Existing constructed mitigation (List all)	Existing constructed mitigation was not found in the available documents.	
Has there been a past breach?	None Identified	
If yes, describe nature of the breach and how it has been mitigated?		

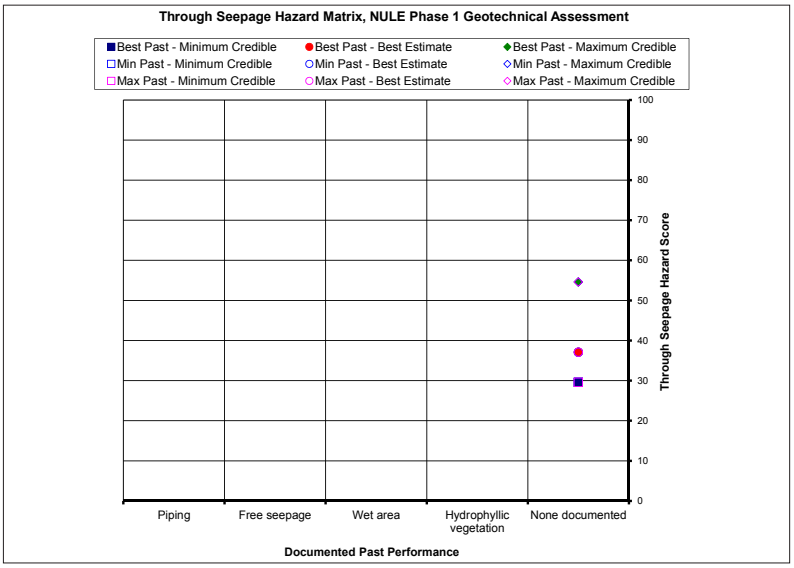
SUMMARY

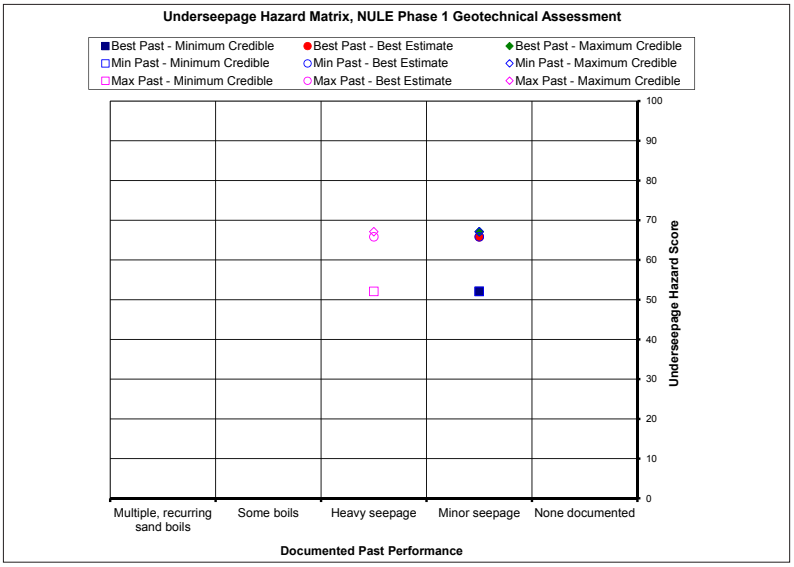
Failure Mode	**Weighted Hazard Indicator Score (Best)**	**Weighted Hazard Indicator Score (Minimum Credible)**	**Weighted Hazard Indicator Score (Maximum Credible)**	**Past performance issues?**	**Are past performance and Weighted Hazard Indicator Score consistent?**	**Levee categorization**
Underseepage	**66**	53	68	Minor seepage	Yes	***Hazard Level B***
Justification:	Segment 1040 is categorized as Hazard Level B due to the consistency between the hazard indicators that suggests that underseepage may occur and the past performance data of minor seepage within the segment.					
Suggested additional data:	Confirm underseepage past performance with RD; field investigations to confirm foundation material type.					
Stability	**61**	36	66	None documented	No	***Hazard Level LD***
Justification:	Segment 1040 is categorized as Lacking Sufficient Data due to the inconsistency between the hazard indicators that suggests that levee instability may occur and the past performance data of no documented levee instability within the segment. 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:	Confirm past performance data with RD. Borings to characterize foundation and levee.					
Through Seepage	**38**	30	55	None documented	Yes	***Hazard Level A***
Justification:	Segment 1040 is categorized as Hazard Level A due to the consistency between the Best Estimate WHIS that suggests a low likelihood of through-seepage and the past performance data of no documented through-seepage within the segment.					
Suggested additional data:	Borings to confirm levee materials.					
Erosion				No		***Hazard Level A***
Justification:	Erosion features were not identified in the available documents. Based on the LIDAR data, minor erosion of the waterside levee toe may be occurring along about 30 percent of the segment.					
Suggested additional data:	Confirm with RD that past performance erosion events have not occurred.					

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:	The freeboard check was not performed as a water surface elevation was not available for the check.		
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:	65% of segment does not meet geometry criteria due to narrow crest width.		
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 categorization for stability is Lacking Sufficient Data. Underseepage is categorized as Hazard Level B. If additional data were obtained, it is very unlikely that the LD for stability 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.

Evaluator:	TK	Evaluation Date:	3/16/2010
Checked By:	JWR	Check Date:	3/16/2010
Senior Reviewer:	Review Team	Review Date:	3/17/2010







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RD 0551, SEGMENT 1041 SUMMARY

This segment summary presents collected information and the assessment results for Segment 1041. The summary is based on data that were readily available 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 1041: Segment Description and Assessment Summary

Segment 1041 is a non-urban, Non-Project levee located on the right (west) bank of the Snodgrass Slough in Sacramento County, California (see attached map). The segment extends from the intersection of the Sacramento River and the Snodgrass Slough southward to the intersection of the Meadows Slough and the Snodgrass Slough. The following table summarizes segment information.

Segment 1041 Information

Maintenance Authority	Unit	Levee Miles*	NULE Stationing*
RD 0551	—	0 to 5.9	Snodgrass Slough Right Bank 1231+00 to 1543+00

* The levee mile and stationing alignments differ.

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. It is our understanding from interviews with the RD (Doc-8314 and locals meeting held on April 14, 2010) that the levee is significantly higher than design flood levels and as such the water surface elevation used in the assessment may be overstated. The following table presents the Segment 1041 categorizations for each potential failure mode.

Segment 1041 Potential Failure Mode Assessment Summary

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

Based on these NULE Phase 1 levee assessments for Segment 1041, through seepage and erosion are categorized as Hazard Level A, underseepage is categorized as Hazard Level B, and stability is categorized as Lacking Sufficient Data. If additional data were obtained, it is very unlikely that the LD for stability failure mode would be categorized as Hazard Level A. Therefore, the overall categorization for the segment is LD (B or C). The overall categorization of LD (B or C) means that, if additional data were obtained to resolve the LD, the overall categorization for this segment would be either Hazard Level B or Hazard Level C.

Segment 1041: 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

Based on historic topographic maps (Courtland, 1:62,500) (Doc-8590), the Segment 1041 levee was initially constructed prior to 1906 by local interests. The 1919 RD 0551 Plan of Reclamation not only indicated that Segment 1041 was likely initially constructed using materials dredged from the adjacent Snodgrass Slough but also presented the plan for raising and enlarging the levee using similar methods (Doc-5232). The plan indicated that the levee was to be constructed with crest widths that ranged from 9 to 25 feet, waterside slopes of 3H:1V and landside slopes of 4H:1V to 5H:1V. The central 7,350 feet of the segment (about Station 1306+00 to Station 1383+50) is known as the Peat Section, as it is comprised of dredged peat material on peat foundation. The Peat Section was documented as having settled 2 to 3 feet between about 1907 and 1913, and was raised in 1913 to an elevation of 28 feet. The following table presents the 1953 MOU geometric criteria for Segment 1041.

Segment 1041 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 RD 0551 maintenance personnel. Based on the available information, performance events in Segment 1041 include underseepage and instability. There are no documented reports of erosion or through seepage. The following table summarizes reported performance events.

Segment 1041 Reported Levee Performance Events

Flood Season	Reported Performance Event	Approximate Location (Station)	Mitigation
1913	Subsidence of 2 to 3 feet between 1907 and 1913 (Doc-5232).	1306+00 to 1383+50	Levee raised in 1913 (Doc-5232).
1949–1953	Seepage observed by landowners (Doc-914).	1231+00 to 1380+00	Mitigation not indicated.

Underseepage

In addition to the seepage event shown in the table of Segment 1041 Reported Levee Performance Events above, the CLD lists a piezometer point at Station 1538+50. Piezometer points may be installed in areas of underseepage. Details of the piezometer point were not listed.

Stability

The magnitude of subsidence documented in 1913 could indicate levee instability in the Peat Section. In addition, cracking of the levee was reported during excavations for “deadmen” in the outer slope of the Peat Section of the levee sometime prior to 1919 (Doc-5232). At the time of the excavation, a dredge cut was located at the toe of the levee. The improvements outlined in 1919 included filling the dredge cut and constructing a 100-foot-wide berm on the waterside of the levee.

Improvements

Documentation of improvements to the levee since its initial construction, were not available.

Planned Improvements

Based on the URS review, no improvements to Segment 1041 are currently planned.

Segment 1041: 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 1041 levee heights range from approximately 22 to 30 feet above the landside toe. Including the rounded shoulders, crest width ranges from approximately 10 to 25 feet. LiDAR survey data indicate the landside slopes are approximately 4H:1V to 6H:1V. The waterside slopes are approximately 3H:1V to 4H:1V. A ditch is present along the landside toe of Segment 1041 from approximately NULE Station 1285+00 to Station 1349+00. The levee crest is paved between NULE Station 1434+00 to Station 1397+00.

Penetrations

Information regarding penetrations through the levee segment was not available. During the site reconnaissance, five pipes were observed to penetrate the levee segment. The pipe diameters and distance below the levee crown were not available. Four of the pipes are clustered at Station 1345+50.

Animal Activity

Animal activity was not reported in the reviewed documents. Animal persistence based on data from DWR is not available for Segment 1041.

Maintenance

DWR assessments were not available for Segment 1041.

Other Features

Segment 1041 has four ditches that do not run parallel to the levee. The ditches are located near Stations 1285+00, 1317+50, 1323+00 and 1345+50. A pump station is also located at Station 1345+50. The west abutment of the Twin Cities Road bridge is located at Station 1250+00.

Segment 1041: 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 1041.

In Segment 1041, the levee foundation consists of interbedded layers of silt, clay, organic soils, and sandy soils. The levee materials are likely to be a mixture of silt, clay, and sand in the north, and silt, clay, and peat in the south.

Geomorphic Setting

Based on Level 2-I mapping, Segment 1041 is in the Sacramento Valley flood basin. The Level 2-I mapping indicates that the segment overlies flood basin deposits of the Sacramento River Floodplain and Natural Levees (SR) domain. The Level 2-I mapping indicates that the northern half of the segment overlies natural levee deposits and the southern half overlies flood basin deposits. The natural levee deposits (silt, sand, and clay) are interbedded, and may have layers from 2 to 5 feet thick that are probably laterally discontinuous along the levee. The soils in the floodplain deposits are finer, consisting primarily of silt and clay. Peat deposits are mapped between Station 1328+00 to Station 1362+00.

Geotechnical Investigations

Geotechnical investigations for Segment 1041 performed by others include three borings in the DWR Salinity Control Barrier Study (Doc-8306). These borings, located on the southern half of the segment, were drilled near the landside levee toe to depths ranging from 30 to 40 feet. The stick logs of these borings indicate that the soil encountered in the foundation consists of interbedded layers of silt, clay, organic soils, and sandy soils. All of these borings encountered organic soils that varied in thickness from 5 to 20 feet.

Three borings drilled for the Peripheral Canal Study (Doc-8306) were located near the landside toe of the levees on the opposite bank. These borings were used to characterize the foundation materials on the northern half of Segment 1041. They encountered predominantly silt and clay materials, with thin layers of sandy soils. None of these borings encountered organic soils.

Other Subsurface Information

The NRCS USCS soil map indicates the northern half of the existing levee overlies primarily fine-grained (CL/ML and CL) soils with a mapped occurrence of coarse-grained (SM and SC) soils between Station 1430+00 to Station 1442+00. The southern half of the segment is predominantly mapped as overlying weak, fine-grained soils (CH and OH). The NRCS USCS mapping is consistent with the variation of soil types that is indicated in the Level 2-I mapping and that was found in the borings.

Levee Composition

Based on the available data and levee construction history, the levee materials are likely to be a mixture of silt, clay, and sand in the north, and silt, clay and peat in the south.

Segment 1041: Geotechnical Assessment Results

The overall Segment 1041 categorization is LD (B or C). As discussed in Volume 1, Section 2 of this report, the overall assessment is based on the individual potential failure mode categorizations. For this segment, through seepage and erosion are categorized as Hazard Level A, underseepage is categorized as Hazard Level B, and stability is categorized as Lacking Sufficient Data. If additional data were obtained, it is very unlikely that the LD for stability failure mode would be categorized as Hazard Level A. Therefore, the overall categorization for the segment is LD (B or C). 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 top of levee less 1.5 feet. It is our understanding from interviews with the RD (Doc-8314 and locals meeting held on April 14, 2010) that the levee is significantly higher than design flood levels and as such the water surface elevation used in the assessment may be overstated. 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 1041 Underseepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	**Minimum Credible**	**Maximum Credible**	**Best Estimate**	**Minimum Credible**	**Maximum Credible**	
68	56	78	Minor seepage	Minor seepage	Heavy seepage	Hazard Level B

Hazard indicators suggesting that underseepage could occur include levee foundation materials (sand and silt in the north and peat in the south) that have moderate to high underseepage susceptibility and a levee section that is moderate for the differential head between the assessment water surface elevation and the levee toe. Given the consistency between the hazard level indicators that suggests that underseepage may occur and the past performance data of minor seepage, Segment 1041 is categorized as Hazard Level B for the underseepage potential failure mode.

Stability

Segment 1041 Stability Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	**Minimum Credible**	**Maximum Credible**	**Best Estimate**	**Minimum Credible**	**Maximum Credible**	
76	66	81	None documented	None documented	Severe	LD (B or C)

Hazard indicators suggesting that levee instability could occur include a levee composition of weak, clayey soil and peat, a levee height of up to 25 feet above the levee toe, a high differential head between the assessment water surface elevation and the levee toe, and soft soils in the foundation. Segment 1041 is categorized as Lacking Sufficient Data based on the inconsistency between the hazard indicators, which suggest that levee instability may occur, and the Best Estimate past performance history of no documented levee instability in the segment. Given the hazard indicators, and if additional data were obtained to resolve the LD, it is very unlikely that the additional data would re-categorize the segment to Hazard Level A.

Through Seepage

Segment 1041 Through Seepage Assessment Results

WHIS			Performance Summary			Categorization
Best Estimate	**Minimum Credible**	**Maximum Credible**	**Best Estimate**	**Minimum Credible**	**Maximum Credible**	
45	30	60	None documented	None documented	None documented	Hazard Level A

Hazard indicators suggesting that through seepage is less likely include a levee composition of clayey soil and peat, a moderate number of documented penetrations, and a levee section that is moderate for the differential head between the assessment water surface elevation and the levee toe. Given the consistency between the hazard indicators, which suggest that through seepage is less likely to occur, and the lack of past performance history for through seepage, Segment 1041 is categorized as Hazard Level A for the through seepage potential failure mode.

Erosion

Segment 1041 is categorized as Hazard Level A for erosion. Erosion features were not identified in the available documents. Based on the LIDAR data, erosion of the waterside slope and waterside levee toe may be occurring along about 20 percent of the segment.

Segment 1041: Other Levee Assessments

Freeboard

Freeboard was not assessed because a 1955/1957 water surface elevation was not available for the assessment. An anomalous feature for freeboard along the segment is Lambert Road, which is constructed through the levee at NULE Station 1434+00, thus reducing the crest elevation from about 28 feet to 21 feet.

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. The reviewed documents do not indicate this levee segment has been overtopped.

Geometry

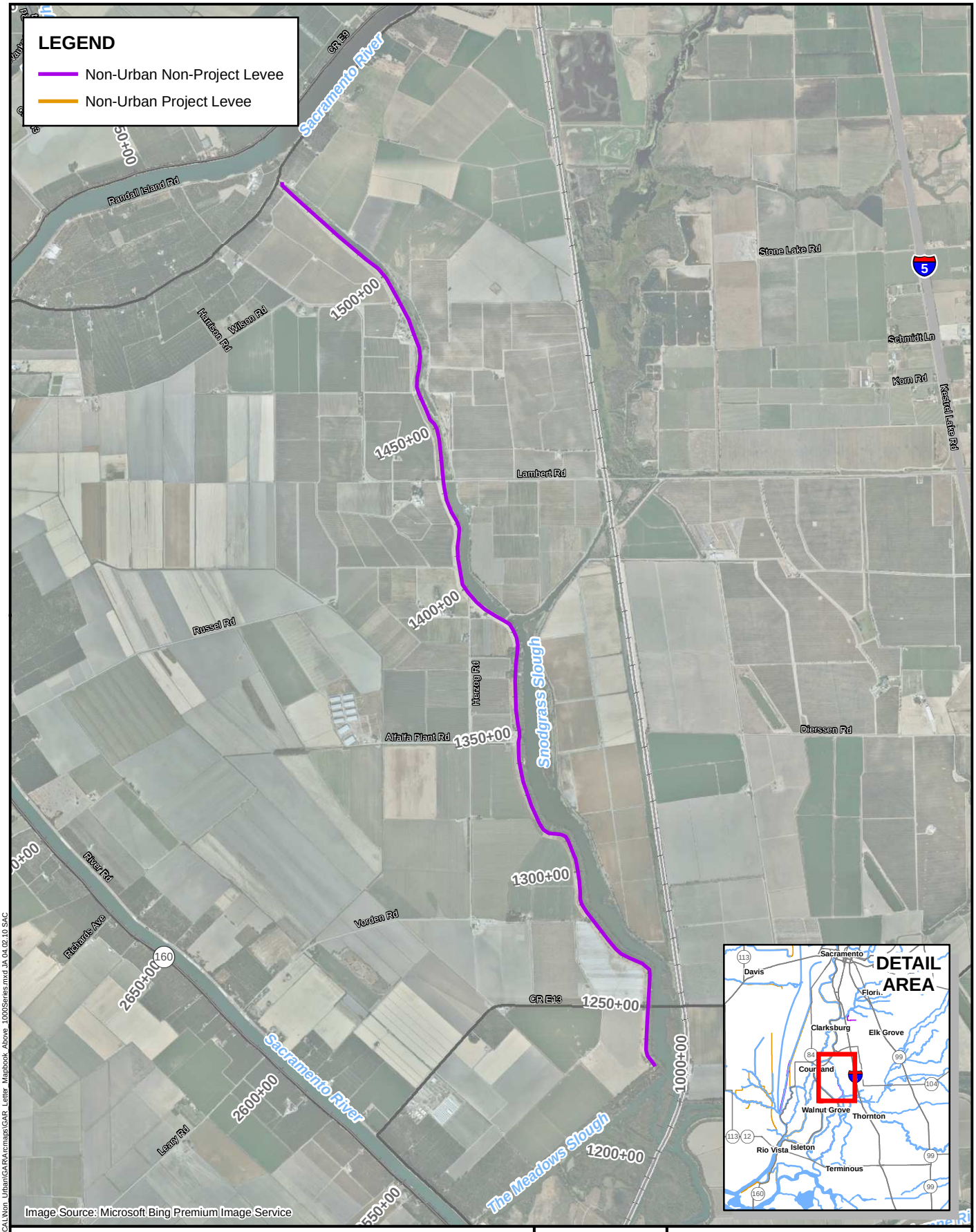
Using the LiDAR data, the levee geometry was compared with a standard levee prism defined by the Segment 1041 1953 MOU geometric criteria. This check was performed by assessing whether the levee indicated by topography developed from the LiDAR data was larger than or equal to the standard levee prism 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 1041, approximately 50 percent of the levee is smaller than the standard levee prism due to a narrow crest width.

Segment 1041: Hazard Mitigation

The following table presents identified hazards for Segment 1041 and the estimated extent of the hazard. Comments are provided to assist with identifying potential remedial requirements.

Segment 1041 Hazards

Hazard	Extent (percent)	Comments
Underseepage	80	Extent is the northern portion of the northern half of the segment (based on borings and Level 2-I mapping) and the southern half of the segment (based on the presence of peat and past performance of underseepage).
Stability	30	Extent is what has been described in the past as the Peat Section.



0 2,000 4,000
Feet

N

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Segment 1041
Geotechnical Assessment Report

NORTH NON-URBAN LEVEE EVALUATIONS

L:\Projects\DWR\GEOTECHNICAL\Non Urban\GARA\mxds\GAR Letter Mapbook Above 1000Series.mxd JA 04.02.10 SAC

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

			Begin	End
Levee Segment Name:	SDSS-R 1231+00-1542+50	NULE Station (ft):	1231+00	1543+00
Levee Segment Number:	1041	Levee Mile:	4.4	10.3
Brief Description of Segment/Reach:	Right bank of Snodgrass Slough from Randall Island south to the intersection with Meadows Slough.	Segment/Reach Length:	5.9 (miles)	31200 (feet)
		Crest Width Design Criterion (ft):	20	
Local Maintenance Authority:	RD 0551	Design Guidance Document:	Plan of Reclamation - RD 0551 (Doc-5232)	
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:	The Segment 1041 levee was initially constructed by local interests. Based on an early topographic map (Courtland, 1:62,500), initial construction occurred prior to 1906. The RD 0551 1919 Plan of Reclamation indicates that Segment 1041 was likely initially constructed using materials dredged from the adjacent Snodgrass Slough and presented the plan for raising and enlarging the levee using similar methods (Doc-5232). The central 7,350 feet of the segment (about NULE Station 1306+00 to Station 1383+50) is known as the Peat Section being comprised of dredged peat material on peat foundation. The Peat Section was documented as having settled two to three feet between about 1907 and 1913 and was raised in 1913 to elevation 28 feet.

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		*Minor seepage*	*Minor seepage*	*Heavy seepage*	Seepage in the southern half (1231+00 to 1380+00) of the segment from Snodgrass Slough was reported by landowners between 1949 to 1954 (Doc-914).
Landside slope stability		*None documented*	*None documented*	*Severe*	Past performance is based on settlement of 2 to 3 feet between 1907 and 1913 and cracking of levee during excavation of "deadman" prior to 1919 (Doc-5232)
Through seepage		*None documented*	*None documented*	*None documented*	N/A

In addition to Ayres 2008/DWR 2009 studies, are there erosion occurrences identified in this study?	No	**If yes, please describe:**	

		Ayres Methodology 2			Ayres Methodology 4		
North NULE	**Erosion sites from the Ayres 2008 study**	**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:**	N/A
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*		*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*	*2 - SC, CL-ML, CL (LL<35); (non dispersive);soils are generally somewhat clayey with relatively low permeability such as clayey sand or clayey silt, lean sandy clay or lean clay with liquid limits less than 35.*	*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 NULE Level 2-I mapping
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 NULE Level 2-I mapping

II- GEOLOGY - ***at selected cross section***	**(Scale of mapping)**				
Underseepage susceptibility *for underseepage assessment*	1:24,000	*4 - High*	*3 - Moderate*	*5 - Very high*	Based on boring data and NULE Level 2-I mapping
Dispersive soils *for stability assessment*	1:24,000	*1 - Not dispersive*	*1 - Not dispersive*	*1 - Not dispersive*	SAR map shows soils are likely not dispersive.
Piping potential *for underseepage assessment*	1:24,000	*5 - Very high*	*4 - High*	*5 - Very high*	Piping potential map shows very high potential.
Piping potential *for through seepage assessment*	1:24,000	*5 - Very high*	*2 - Low*	*5 - Very high*	Based on boring data and NULE Level 2-I mapping
Soft soils *for stability assessment*	1:24,000	*5 - Present*	*5 - Present*	*5 - Present*	Based on boring data and NULE Level 2-I mapping

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

Animal persistence/burrows? *for through seepage assessment*		*1 - None documented*	*1 - None documented*	*1 - None documented*	Animal activity was not indicated in the reviewed documents or RD 0551 interview. DWR data is not available for this segment.
Is a landside ditch or borrow pit present within 200 ft of toe? *for underseepage assessment*	Ditch at toe of levee (w/in one levee height of toe)	5			2 to 3 foot deep ditch located at levee toe
Is a landside ditch or borrow pit present within 200 ft of toe? *for stability assessment*	Ditch at toe of levee (w/in one levee height of toe)	5			4 to 5 foot deep ditch located at levee toe
Is waterside blanket present? *for underseepage assessment*	No				0
Are there locations where penetrations and historical underseepage are coincident?	Yes	**If yes, please describe:**	The 4 clustered pipes at NULE Station 1345+50 are within the seepage area reported in 1949 to 1954.		
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:**	According to the site reconnaissance, 5 pipes were observed to penetrate the levee segment. The pipe diameters and distance below the levee crown were not available. Four of the pipes are clustered at NULE Station 1345+50.		
DWR's LMA maintenance rating from Maintenance Deficiency Summary Report:	LMA Not rated by DWR	**Notes:**	N/A		

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	1530+00	**Cross-section Station**	1305+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)	28		26			
Levee toe elevation (landside) (ft)	9.5		2.5			
Levee crest width (ft)	20	1	18	2		
Evaluation water elevation (ft)	26.5		24.5			
Levee slope - landside (xH : 1V); **Enter x**	4	2	4	2		
Levee slope - waterside (xH : 1V); **Enter x**	3.1					
Freeboard above evaluation flood elevation (ft) (= levee crest elevation - evaluation water elevation)	1.5					
Levee height (ft) (= levee crest elevation - landside toe elevation)	18.5	4	23.5	5		
Levee prism base width (ft)	151.4					
Head (ft) (= evaluation water level - landside toe elevation)	17.0	4	22.0	5		
Head-to-base-width ratio (= head / base width)	0.112	3				
Base-width to head ratio (= base width / head)	9					

V- ANOMALIES

	Anomalies?	**Description**	**Effect on Performance**
Underseepage	Yes	Segment 1041 has four ditches that do not run parallel to the levee. The ditches are located near NULE Stations 1285+00, 1317+50, 1323+00 and 1345+50.	Potential location for seepage and boils.
Stability	No	N/A	N/A
Through Seepage	No	N/A	N/A
Erosion	No	N/A	N/A

MITIGATION AND PAST BREACHES

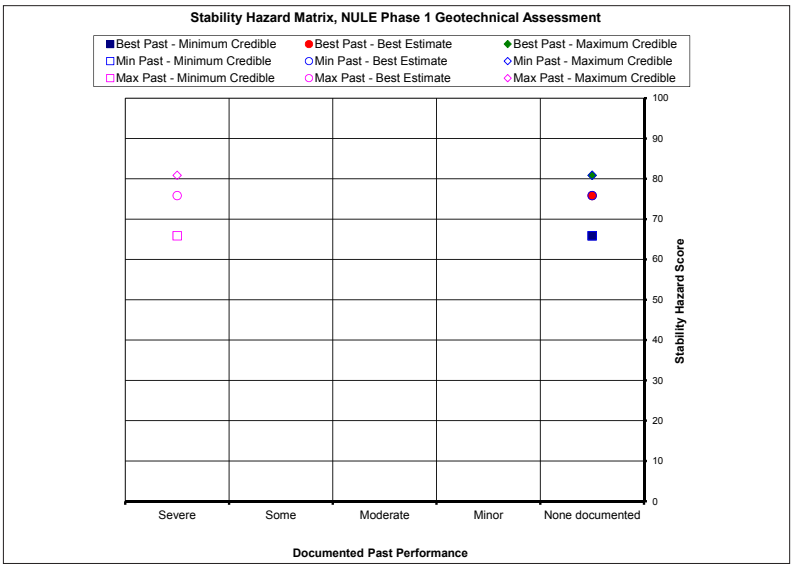
Existing constructed mitigation (List all)	Existing constructed mitigation was not found in the available documents.	
Has there been a past breach?	None Identified	
If yes, describe nature of the breach and how it has been mitigated?		

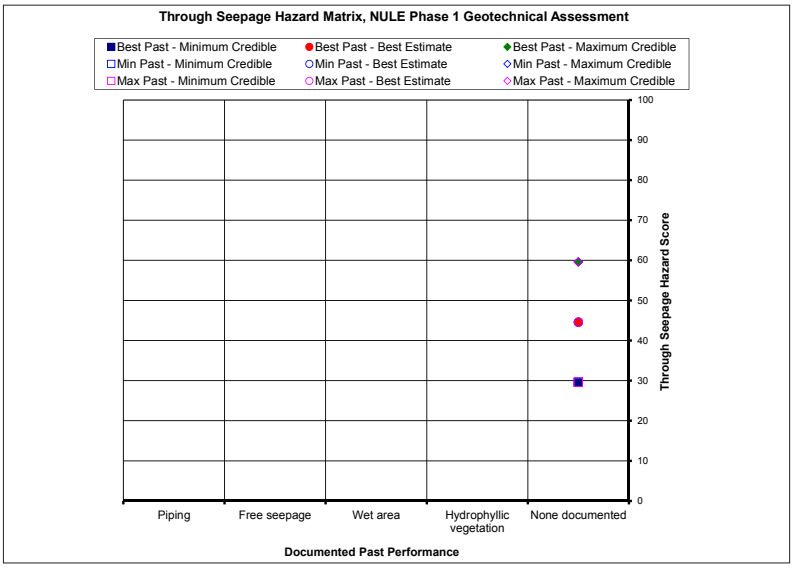
SUMMARY

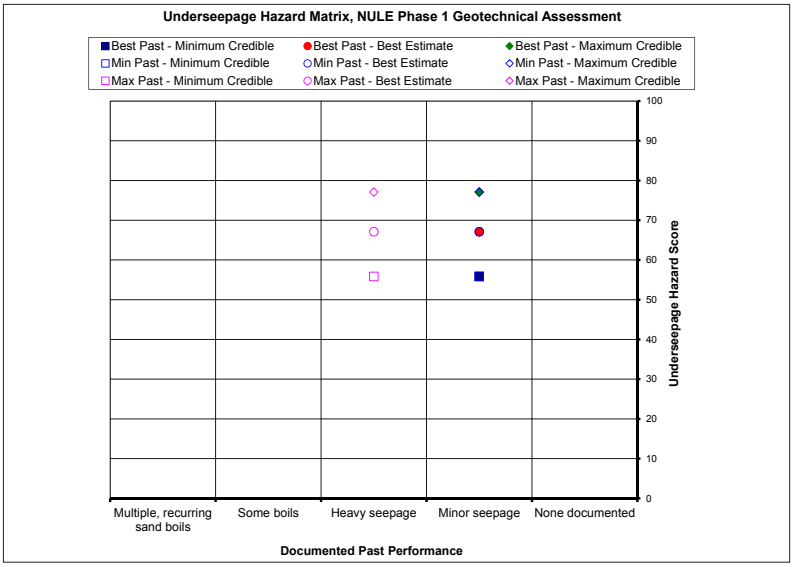
Failure Mode	**Weighted Hazard Indicator Score (Best)**	**Weighted Hazard Indicator Score (Minimum Credible)**	**Weighted Hazard Indicator Score (Maximum Credible)**	**Past performance issues?**	**Are past performance and Weighted Hazard Indicator Score consistent?**	**Levee categorization**
Underseepage	**68**	56	78	Minor seepage	Yes	***Hazard Level B***
Justification:	Segment 1041 is categorized as Hazard Level B due to the consistency between the hazard level indicators that suggests that underseepage may occur and the past performance data of minor seepage within the segment.					
Suggested additional data:	Confirm past performance data with RD.					
Stability	**76**	66	81	None documented	No	***Hazard Level LD***
Justification:	Segment 1041 is categorized as Lacking Sufficient Data due to the inconsistency between the hazard indicators that suggests that levee instability may occur and the Best Estimate past performance data of no documented levee instability within the segment. Given the hazard indicators, and if additional data were obtained to resolve the LD, it is very unlikely that the additional data would re-categorize the segment to Hazard Level A.					
Suggested additional data:	Confirm past performance data with RD.					
Through Seepage	**45**	30	60	None documented	Yes	***Hazard Level A***
Justification:	Segment 1041 is categorized as Hazard Level A due to the consistency between the hazard indicators that suggests a low likelihood of through-seepage and the past performance data of no documented through-seepage within the segment.					
Suggested additional data:	Borings to confirm levee composition.					
Erosion				No		***Hazard Level A***
Justification:	Erosion features were not identified in the available documents. Based on the LIDAR data, erosion of the waterside slope and waterside levee toe may be occurring along about 20 percent of the segment.					
Suggested additional data:	Confirm with RD that past performance erosion events have not occurred.					

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:	The freeboard check was not performed as a water surface elevation was not available for the check.		
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:	About 50% of the segment does not meet geometry criteria due to narrow crest width.		
Are there anomalies along the segment with respect to geometry?	No	Describe anomalies:	0
Summary Characterization of Levee Segment	Hazard Level LD	**Comment / Justification:**	For this segment, the categorization for Stability is Lacking Sufficient Data. This results in an overall categorization of Lacking Sufficient Data. However, the categorization for underseepage is Hazard Level B. Because at least one of the failure modes is categorized as LD, and at least one of the failure modes is categorized as Hazard Level B, the overall categorization for the segment is LD (B or C). The overall categorization of LD (B or C) means that, if additional data were obtained to resolve the LD, the overall categorization for this segment would be either Hazard Level B or Hazard Level C.

Evaluator:	TK	Evaluation Date:	3/16/2010
Checked By:	JWR	Check Date:	3/16/2010
Senior Reviewer:	Review Team	Review Date:	3/17/2010







1041-charts.indd RKC SAC 2011-03-25, 8:20 AM

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Segment 1041 LAT Results
Geotechnical Assessment Report

NORTH NON-URBAN LEVEE EVALUATIONS

Appendix C

Geomorphology Technical Memorandums

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WILLIAM LETTIS & ASSOCIATES, INC.

Prepared For	Department of Water Resources Division of Flood Management
Project	Non-Urban Levee Evaluations Project Task Order UT05-03
Date	December 20, 2010
Subject	Level 2-II Geomorphic Assessment and Surficial Mapping of South of Sacramento Study Area
Prepared By	Cooper Brossy, Fugro William Lettis & Associates (FWLA), October 2009
Reviewed By	Justin Pearce, FWLA, October 2009; Keith Knudsen, Jackie Bott, Lisa Dougherty, URS; Lewis Hunter, U.S. Army Corps of Engineers

INTRODUCTION

This technical memorandum presents the results of surficial geologic mapping and geomorphic assessment in the South of Sacramento Study Area. The Study Area includes approximately 53 miles of non-urban Project levees along the Sacramento River, Elk Slough, and appurtenant structures directly south of Sacramento and West Sacramento, California (Figure 1).

The primary goal of thisl assessment is to develop and analyze map data about the type and distribution of surface and shallow subsurface deposits underlying NULE Project levees to develop an assessment of levee underseepage susceptibility hazard, and secondarily, to develop an initial conceptual model allowing reasonable stratigraphic interpretations between widely-spaced subsurface explorations. Plate 1 presents the surficial geologic map of the South of Sacramento Study Area.

TECHNICAL APPROACH

This assessment 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 surficial deposits in the Study Area, and develop levee underseepage susceptibility hazard maps.

The project team analyzed the following data:

- Vintage 1937 aerial photography[1] (Table 1a)

[1] All photographs are black and white, stereo-pairs, ~1:20,000 scale, flown August, 18, 1937.

Table 1a. Aerial Photography.

County Code	Roll Number	Frame Numbers
ABC	49	48 and 49
ABB	49	50 through 59
ABC	49	60 and 61
ABB	50	26 through 29
ABC	50	15
ABB	50	16 and 17
ABC	49	8 through 16
ABB	49	17 through 19
ABC	49	20 and 21

- Early and modern USGS topographic maps (Table 1b)
- Published surficial geologic maps (Helley and Harwood, 1985; Atwater, 1982)
- Early and modern soil survey maps (Cole et al., 1954; Tugel, et al., 1992)
- Other maps and documents (e.g., California Debris Commission, 1908)

Knowledge of fluvial processes and the ability to recognize depositional environments in the geologic record are key to identifying locations along levees where underseepage is most likely to occur (Llopis et al., 2007). Through surficial geologic mapping, primary geomorphic features and associated surficial geologic deposits like crevasse splay and overbank deposits, meander scroll deposits and other features commonly associated with large active river systems and distributary channels are identified (e.g., Saucier, 1994).

The South of Sacramento Study Area's surficial geologic map (Plate 1) 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 should be considered accurate to within about 200 feet on either side of the line.

Map units shown on Plate 1 primarily are based on analysis of 1937 aerial photography and soil surveys in conjunction with early topographic maps. The map is a compilation of the latest Holocene and historical geologic conditions up until 1937. These 1937 aerial photographs are the primary data set for interpreting surficial geologic deposits because they are the oldest high-quality images pre-dating much of the urbanization and landscape alteration in present-day Sacramento and Solano Counties. These data also represent a close approximation to surficial deposits that were likely present at ground surface prior to levee construction. The 1937 photographs in this Study Area were taken in the month of August. Integration of data from the 1937 photography, older and more recent topographic maps, geologic maps, soil surveys and historical documents provide sufficient information to delineate many of the pre-historical and historical surficial deposits in detail. Taken together, these data provide key insights to the characteristics of deposits beneath the levees, and

serves as a technical framework for assessing underseepage susceptibility in the South of Sacramento Study Area. **Error! Reference source not found.** Table 1b lists the topographic maps used during map development for this project.

Table 1b. USGS Topographic Maps.

Quadrangle Name	Publication Date	Photo Revision Date	Series	Scale	Survey Date
Clarksburg (formerly Babel Slough)	1916	N/A	7.5-Minute	1:31,680	1906
Clarksburg	1967	1980	7.5-Minute	1:24,000	N/A
Courtland	1908	N/A	15-Minute	1:62,500	1906
Courtland	1978	1983	7.5-Minute	1:24,000	N/A
Davisville	1907	N/A	15-Minute	1:62,500	1905
Florin	1909	N/A	7.5-Minute	1:31,680	1907
Florin	1968	1980	7.5-Minute	1:24,000	N/A
Sacramento West	1948	1992	7.5-Minute	1:24,000	N/A

For underseepage hazard assessment, levee foundations were assigned a susceptibility class based on their underlying surficial geologic deposits. Map data were imported into a geographic information system (GIS) and spatially intersected with NULE Project levee lines; susceptibility categories were then assigned to levee segments as shown in **Error! Reference source not found.**. Underseepage susceptibility category assignments were made based on geologic age and depositional environment, as well as relative hydraulic conductivity. The validity of these hazard assignments were tested during the Level 2-I work phase by analyzing levee past performance data as an indicator for underseepage susceptibility.

GEOLOGIC SETTING

The South of Sacramento Study Area lies in the south-central Sacramento Valley (Figure 1), and occupies a topographically low position at about 0 to 10 feet elevation above mean sea level. The Study Area is directly south of the confluence of the Sacramento and American Rivers, two large waterways that drain a substantial portion of northern California. Farther south is the Sacramento-San Joaquin Delta (Delta), a formerly extensive area of tule marshes whose sediments are characterized by organic-rich peat and peaty mud deposits (Atwater, 1982). Downstream of its confluence with the American River, the Sacramento River has irregular sinuosity with both large and small radius-of-curvature meander bends. It also has both narrow and wide distributary channels, including Elk Slough, Sutter Slough, and Snodgrass Slough. The river has, in places, laterally migrated over the past hundreds of thousands of years and deposited a sediment load rich in sand and gravel (Shlemon, 1967). As a result, geologically older and erosion-resistant Pleistocene Riverbank Formation is present at the ground surface south and east of the City of Sacramento, and younger alluvium is inset into this formation. Over the past several hundreds of years, erosion along the Sacramento River occurred on the outsides of bends, depositing younger sand-rich sediment

(e.g., point bar) that occurs on the insides of the river bends. Because of the low topographic position and its location between the confluence of these two large rivers and the Delta, the South of Sacramento Study Area has been subjected to repeated inundation by floodwaters over the past several thousand years via distributary channels and floodplain overflow. Floodwaters deposit fine sand and silt-rich alluvium along the flanks of the river bank and finer-grained clay and silt are carried in suspension onto the distal floodplain and low lying flood basins. This hydraulic sorting process created a natural levee (or channel ridge) landform with a topographic gradient that slopes away from the river (Atwater, 1982).

Historical accounts document two large flood events along the Sacramento and American Rivers known to have been destructive to early settlers. One occurred in water-year 1850, and another larger flood occurred in January 1862, inundating and substantially damaging the recently founded City of Sacramento. These flood events quickly spurred construction of flood protection levees along many of the banks of the Sacramento River, as well as a cultural re-alignment of the American River in 1868. Furthermore, hydraulic mining activity in the Sierra Nevada Range began in 1850 and supplied a substantial amount of sediment to many creeks and rivers draining those watersheds (James, 1999). Primary geomorphic responses to this activity were aggradation (i.e., backfilling) of channels, exacerbated flooding related to decreases in channel cross section area, and deposition of mining-related sediment on the adjacent floodplain. Additional large historical flood events occurred subsequently in the area, such as 1904, 1907, and 1955, among others (Ellis, 1939).

SURFICIAL GEOLOGIC MAPPING

Previous geologic mapping in the South of Sacramento Study Area was performed by Atwater (1982) and Helley and Harwood (1985). Both maps recognize two primary depositional environments: one proximal to the modern river channel (floodplain) and the other in low lying areas distal to the modern river channel (flood basin). Surficial deposits in these two environments are generally latest Holocene to historical in age, receiving sedimentation prior to construction of the flood protection levees. The alluvial deposits consist chiefly of silt, clay, and fine sand flanking the modern river channels. Floodbasin deposits principally consist of silt and clay, commonly elastic, representing deposition in low-energy environments (e.g., slack water). This analysis uses this previously developed geologic framework as a basis for more detailed mapping of late Quaternary deposits and geomorphic features (Plate 1).

Surficial geologic mapping in the South of Sacramento Study Area delineates individual alluvial deposits based on relative age and depositional process or environment, using the regional mapping as an initial framework (Plate 1). Three ages of deposits are recognized at the ground surface within the map area: mid-to-late Pleistocene (about 450,000 to 11,000 years), Holocene (less than 11,000 years), and historical (post-1849). The section below briefly describes the primary geologic deposits within the map area from oldest to youngest, giving a framework for understanding the Study Area's geomorphology and related surficial and shallow surficial deposits.

The oldest unit exposed in the South of Sacramento Study Area (Figure 1, Plate 1) is the lower member of the Riverbank Formation (map unit Qrl). The lower Riverbank Formation is mid- to late-Pleistocene age (no older than 450,000 years old; Helley and Harwood, 1985). This unit is

composed of weathered reddish gravel, sand, and silt, and underlies old river terraces and alluvial fans. It is exposed in the southeastern part of the map area as a preserved alluvial fan surface topographically higher than the modern floodplain (Plate 1).

Late Holocene deposits underlying the modern floodplain along the Sacramento River are categorized as channel, floodplain, and flood basin deposits (Plate 1). Channel deposits (map unit Hch), and meander scrolls (map unit Hms) consist of fine- to coarse-grained sand, silty sand, and clayey sand. Holocene overflow channels (Hofc) are present adjacent to the main channel, usually on the inside of a bend, and are active during high-stage flow events when they collect water overtopping channel banks. These overflow channels then direct water downstream where it re-enters the main channel. Abandoned channels may contain fine-grained material in the upper several feet of the deposit, from post-abandonment infilling (Saucier, 1994; Tugel et al. 1992). Holocene floodplain deposits include crevasse splays (map unit Hcs) and overbank deposits (map unit Hob). Crevasse splay deposits are formed from the breaching of river banks or natural levees during high flood stages and deposition on the floodplain via small distributary channels. Overbank deposits are formed from the localized overtopping of river banks or natural levees, and deposition from shallow sheet flow. Holocene flood basin deposits (map unit Hn) consist of soft silt and clay laid down by slow-moving floodwater in a relatively low-energy depositional environment. Marsh deposits (map unit Hs) are identified on early topographic maps depicting the extent of fresh water marshes and tule fields with a bush-like symbol. Peat and mud deposits (map unit Qpm) are locally present in the Study Area, and consist of fine-grained sediments with various amounts of organic matter (Atwater, 1982).

Historical deposits mapped in the South of Sacramento Study Area include stream channel and floodplain deposits, as well as cultural artificial fill deposits (Plate 1). The term “historical” denotes deposits laid down since 1849, and indicate these with an “R” as a map unit symbol. Historical channel deposits (map unit Rch), bars (map unit Rb), or meander scrolls (map unit Rms) are adjacent to the present-day Sacramento River and are generally, but not exclusively, present on the waterside of the modern-day levees. These deposits likely consist of stratified, intermixed and interbedded silt, sand and trace gravel. They were probably derived from re-working, transport, and deposition of hydraulic mining detritus (James, 1999). Historical crevasse splay and overbank deposits are differentiated based on cross-cutting and their superposition relationships with existing cultural deposits present on the 1937 aerial photographs. In general, younger deposits overlie or onlap older deposits. Historical deposits typically have stronger topographic expression than older deposits, as well as brighter tonal contrasts in the 1937 aerial photos, indicating younger or sandier deposits. Artificial fills (map units AF, L, RR) are culturally-emplaced levee, canal berm, or railroad embankment deposits. These deposits include undivided fill, levee structures, road, and railroad fills; they are included on the surficial geologic map where prominent in the 1937 aerial photographs.

Soils developed on Holocene and historical natural levee features (overbank and crevasse splay deposits) adjacent to the river include the Columbia silty loam of Cole et al (1954) and the Valpac loam of Tugel et al. (1992). Cole et al. (1954) indicate that debris from hydraulic mining probably contributed material to these deposits. In Solano County (west of the river), the soils associated with floodplain deposits include Tyndall very fine sandy loam, Sycamore silt loam, and distally the Merritt silty clay loam (Andrews, 1972). Farther from the Sacramento River, the flood basin environment

hosts the Scribner clay loam (Tugel et al., 1992), Omni silty clay, and Sacramento clay (Andrews, 1972). Presence of the Gazwell mucky clay indicates that mucky clay and mucky peat from fresh water marshes exists in the near-surface (Tugel et al., 1992); this soil is associated with map unit Hpm. The Dierssen sandy clay loam is associated with the Riverbank Formation based on Tugel et al.'s (1992) description of the Dierssen being developed in dominantly granitic material and also exhibiting a silica-cemented hardpan. Limited areas of sandier deposits indicated by the presence of the Tinnin soil series are also found along the eastern margin of the Study Area, and are associated with Eolian (wind blown) sands from old dune fields along the distal margins of the Pleistocene alluvial fans (Atwater, 1982).

Other soils that are very young (Andrews et al., 1972) include areas of Tyndall very fine sandy loam and Maria silt loam that make up much of the material forming natural levees along the Babel Slough distributary channel and the large splay deposits that emanate from the Babel Slough channel. Along Elk Slough, extensive areas of Lang silt loam, Tyndall very fine silt loam, and Valdez silt loam soil are present proximal to the channel and are associated with historical crevasse splay and overbank deposits. The Tyndall very fine sandy loam and the Lang silt loam also occur locally along the Sacramento River and sometimes have distinct tongue-like or meandering shapes that suggest they formed on deposits that prograded out over the pre-existing natural levee hosting the Sycamore series soils.

CONCEPTUAL GEOMORPHIC MODEL

Based on synthesis of surficial geologic mapping, early topographic maps, soil surveys, geologic maps, and review of readily available subsurface borehole information, a preliminary conceptual model was developed to describe general relationships among surface and subsurface geologic deposits in the South of Sacramento Study Area (Figure 1). This conceptual model provides a consistent basis for understanding both the types and distribution of surficial geologic deposits, primary geomorphic processes, and the shallow subsurface stratigraphy in the Study Area.

Subsurface Stratigraphy

In general, the deposits beneath the floodplain of the Sacramento River and distributary channels consist of fluvial and alluvial fan stratigraphic layers. Available subsurface data suggest lateral variability in the extent and character of the deposits below the present-day floodplain, as well as upward-fining of sediment textures (Figure 2).

Sediments directly beneath the Elk Slough and Sacramento River NULE Project levees are Holocene overbank and crevasse splay deposits consisting of sandy silt and silty beds 16 to 20 feet thick (Figure 2). This layer is relatively thicker beneath the Sacramento River than Elk Slough; however, both layers likely laterally interfinger with adjacent sediments because of the dynamic depositional processes. Between these two channels is a flood basin environment consisting of laterally extensive silt and clay up to 25 feet thick.

Underlying the Holocene sediments of the Sacramento River natural levee are relatively clean sands (Figure 2) that were probably deposited by a Pleistocene course of the river that carried a coarser-

grained sediment load as compared to present (Shlemon, 1967). Based on available data, the thick package of sand does not appear to be present beneath the Elk Slough distributary channel, suggesting that the sandy stratigraphic layer is not laterally continuous in the westerly direction. Instead, available subsurface data at Elk Slough show a hard (N-value of 70) clay layer present near Elevation −18 feet. The hard clay layer is interpreted as buried Pleistocene fan surface that dips easterly (Figure 2). Subsurface data east of the Sacramento River is not available, and interpretations of stratigraphy are speculative in this area.

Randall Island

Randall Island is somewhat different from other islands in the Delta region. Chiefly, other islands (e.g., Merritt Island) are laterally bound by large sloughs or rivers, whereas Randall Island is only bound on one side by the river, the island being nearly attached to the eastern alluvial landmass (Plate 1, Figure 3). Moreover, inspection of topographic contours indicates a natural levee landform flanking the eastern margin of Randall Island along a narrow channel, as well as a natural levee landform along the Sacramento River, each separated by a small flood basin (Plate 1). As of 1937, Randall Island was bound on the eastern side by a narrow channel; the channel was flanked on its eastern side by a short artificial levee (Figure 3). The presence of developed natural levee landforms along the narrow channel raises the question of the natural levee's origin along the narrow channel, as well as the geomorphic origin of the narrow channel itself. The topographic gradients of the natural levee landforms along the Sacramento River are slightly, but not wholly, different from those along the narrow channel (Figure 3). For example, the basin-ward gradient of the Randall Island natural levees is slightly steeper than those along the Sacramento River (Figure 3). Landform differences suggest that depositional history influenced natural levee development.

Speculatively, the process responsible for the development of Randall island and its natural levee morphology include:

- A paleo-Sacramento River along the course of the narrow eastern channel.
- Avulsion of the Sacramento River toward the west but incomplete abandonment of the original course.
- Sedimentation and partial infilling of the former river course to form the narrow channel.
- Activation of the narrow channel and consequent overbank sedimentation during pre-artificial levee flood discharge events.

Whatever the genesis of Randall Island, geomorphic observations suggest that coarse-grained deposits of a former Sacramento River channel may be in the subsurface of the present–day NULE Project levee at the head and mouth of the narrow channel. Observations also suggest that, if present, these deposits may form a conduit underlying the levee at an oblique angle near the head of the narrow channel, and a sub-orthogonal angle at the confluence (Plate 1; Figure 3).

Secondly, map data indicate that the narrow channel along eastern margin of Randall Island historically contributed sediment to the natural levee and adjacent floodplain based on the following observations:

- The large levee fill prism at the head of the Snodgrass Slough and Randall Island channels visible in the 1937 aerial photographs (Figure 3) suggest these channels historically contributed extensive overbank deposition downstream.
- These aerial photographs show a very short artificial levee continuing downstream along the southeast bank of the Randall Island channel. A road runs along the crest of the levee (Figure 3).
- The presence of this artificial levee further suggests this channel was active historically, delivering and depositing sediment to the floodplain to the southeast (Plate 1).

In general, the conceptual model illustrates that natural levee landforms are expressed adjacent to the river and slough as relatively fine-grained with a silty top stratum, and locally overlie coarser-grained strata of the former Sacramento River. This stratigraphic arrangement likely represents a geotechnical blanket layer along the Sacramento River, but not necessarily Elk Slough (Figure 2). A thick layer of fine-grained sediment is present in between the Sacramento River and Elk Slough channel because of Holocene floodwater deposition. Buried Sacramento River channel deposits may underlie the present-day levee where the narrow channel joins the river. Additional subsurface data are needed to clarify the lateral relationships of the deposits away from the present-day levees.

APPLICATION TO STUDY AREA LEVEES

The preceding sections briefly summarize the major map units comprising levee foundations and shallow stratigraphic relationships in the South of Sacramento Study Area. These factors (sediment type, permeability and shallow stratigraphic relationships) exert controls on underseepage processes when incorporated into 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 in Table 2 were assigned based on geologic age, depositional environment, stratigraphic relationships and inferred relative soil permeability. Table 2 lists the units present beneath Study Area levees; underseepage assignments are not shown for deposits present elsewhere in the NULE Project area. Analysis results are described below.

Underseepage Susceptibility of Mapped Geologic Units

Based on the susceptibility assignments shown in Table 2 and surficial geologic deposits (Plate 1), the underseepage susceptibility of much of the levee foundation in the South of Sacramento Study Area is high to very high (Table 2).

Table 2. Underseepage Susceptibility Summary.

Unit Symbol	Unit Name	Susceptibility Rating	Mileage	Percent
Rob	Historical overbank deposits	Very High	24.7	46.0
Rcs	Historical crevasse splay deposits	Very High	4.8	8.9
Rch	Historical channel deposits	Very High	0.1	0.2
Rdf	Historical distributary fan deposits	Very High	0.1	0.2
Rdc	Historical distributary channel deposits	Very High	0.1	0.1
Hob	Holocene overbank deposit	High	19.4	36.1
Hms	Holocene meander scroll deposits	High	1.2	2.1
Hcs	Holocene crevasse splay deposits	High	1.1	2.1
Hs 1906	Holocene marsh deposits	High	1.6	3.0
Hofc	Holocene overflow channel deposits	Moderate	0.2	0.4
Hdc	Holocene distributary channel deposits	Moderate	<0.1	<0.1
Pf	Pleistocene alluvial fan deposits	Low	0.4	0.8
Rb	Holocence channel bar deposits	Very High	0.0	0.0
Rsl	Holocence slough channel deposits	Very High	0.0	0.0
Hpm	Holocene peat and mud	Very High	0.0	0.0
Hch	Holocence channel deposits	High	0.0	0.0
Hsl	Holocene slough channel deposits	High	0.0	0.0
Ha	Holocene alluvium undifferentiated	High	0.0	0.0
Qe	Quaternary eolian deposits	Moderate	0.0	0.0
Hn	Holocene basin deposits	Low	0.0	0.0
Qru	Pleistocene Riverbank Formation (upper member)	Low	0.0	0.0
Qrl	Pleistocene Riverbank Formation (lower member)	Low	0.0	0.0

Of the 53.7 total non-urban levee miles in the Study Area, about 30 miles of levee (55 percent of total) overlie very high susceptibility foundations. The primary very high susceptibility geologic unit is historical overbank deposits (map unit Rob; about 25 miles). Secondarily, historical crevasse splay deposits (map unit Rcs) contribute just less than 5 miles of levee to the very high susceptibility category (Table 2). The historical deposits likely consist of sediment derived from upstream hydraulic mining debris. In the Study Area, the very high susceptibility class is associated with adverse past levee underseepage performance including seepage and sand boils.

About 23 miles of non-urban levees in the South of Sacramento Study Area (43 percent of total) overlie high susceptibility foundations; they are composed primarily of map unit Hob (about 19 miles; Table 2). Other high susceptibility units include Holocene crevasse splays, meander scroll deposits, and marsh deposits.

Analysis results show 0.24 miles of moderate susceptibility foundations (Table3), and 0.44 miles of low susceptibility foundations (map unit Pf). In sum, moderate and low susceptibilities total no more than 2 percent of the levee miles in the South of Sacramento Study Area.

SUMMARY

Initial surficial geologic mapping and geomorphic analysis demonstrates a complex relationship of fluvial deposits at the surface and beneath the floodplain of the Sacramento River and Elk Slough. The surface and subsurface distributions of sandy and clayey deposits are a function of former river positions on the landscape, characteristics of former fluvial systems, and historical geomorphic processes adjacent to the river channel (i.e., flooding and deposition). Overall, the non-urban levee in the South of Sacramento Study Area is chiefly underlain by geologically young, unconsolidated, silty and sandy-silty fluvial deposits. Thick clean sands underlie this top stratum along the Sacramento River levees; less so along Elk Slough. As such, surficial geology along the length of the alignment indicates a relatively high potential for shallow subsurface seepage given certain hydraulic conditions, and suggests geotechnical blanket layer conditions along the Sacramento River.

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. The project team 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.

The project team 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. The project team has not performed independent validation or verification of data reported by others.

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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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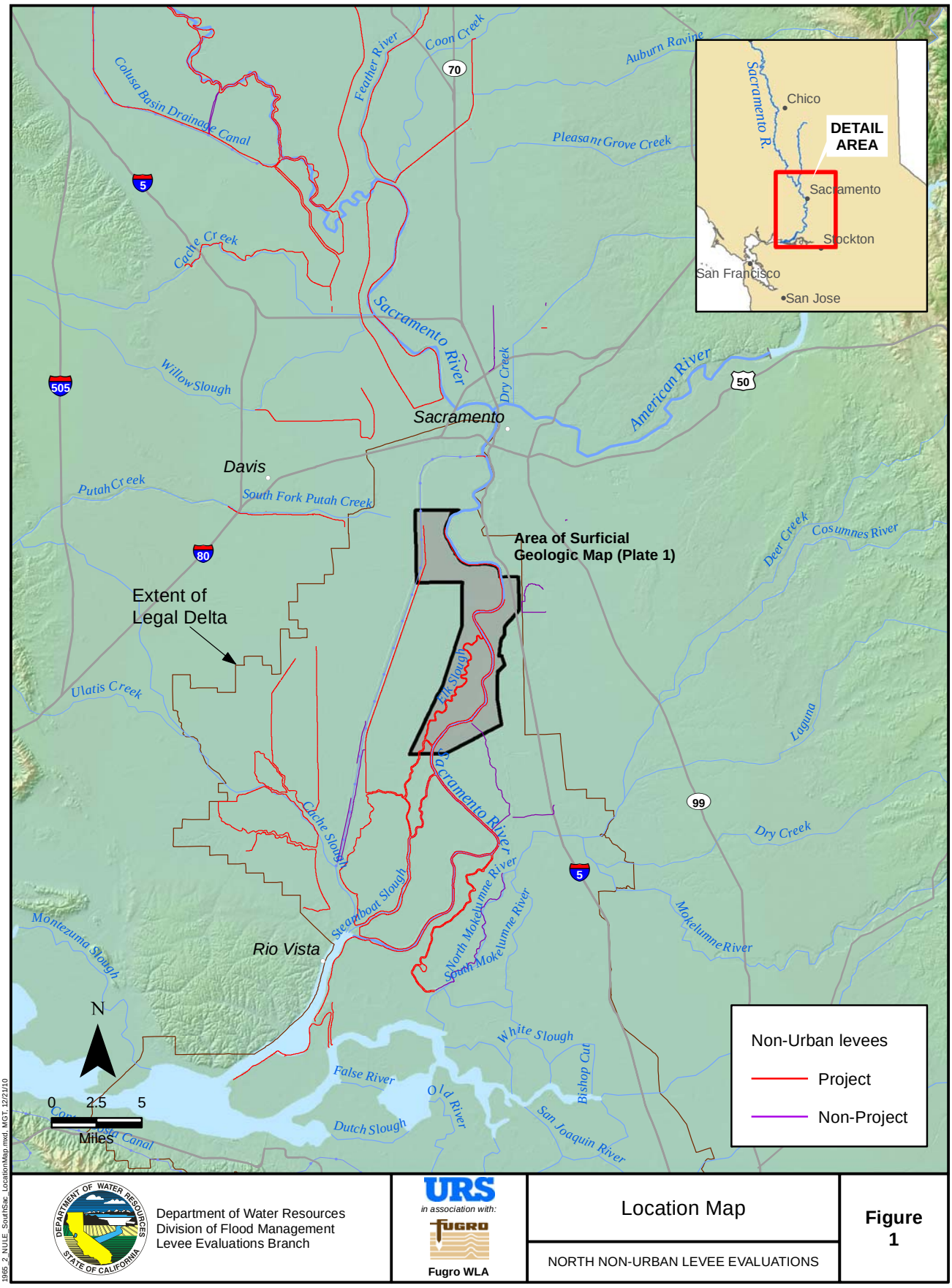
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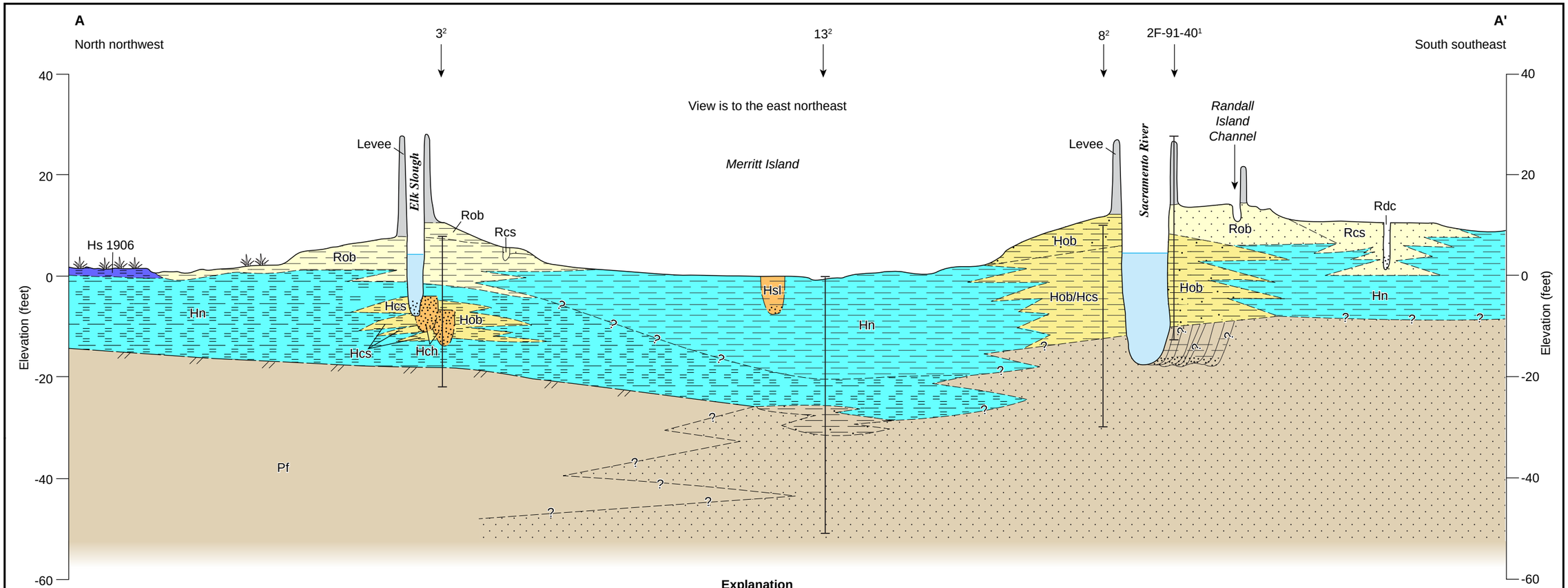
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Location Map

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 1

1965_2_NULE_SouthSac_LocationMap.mxd, MGT, 12/21/10



Explanation

Symbols

- Borehole
- Probable calcareous clay hardpan
- Contact, approximately located
- Contact, location uncertain

General Textures

- Clay
- Silt
- Sand

Geologic Units

Af	Artificial fill	Hcs	Holocene crevasse splay
Rdc	Recent distributary channel	Hsl	Holocene slough
Rob	Historical overbank	Hn	Flood basin
Rcs	Historical crevasse splay	Hs	Marsh deposits
Hob	Holocene overbank	Pf	Pleistocene alluvial fan
Hch	Holocene channel (buried)		

20 feet
0
0 1200 feet
Vertical exaggeration = 60x

Notes:
1. Borehole from 1993 ACOE Sacramento River flood control system evaluation, lower Sacramento River area, Phase IV.
2. Borehole from DWR salinity control barrier investigation, Merritt Island explorations.
3. Topographic data from ftp://gforge.casil.ucdavis.edu/pub/delta-vision/LiDAR/
4. See Plate 1 for cross section location.

Graphics, Projects, 1965 North Urban Levees, 2_ South Sacramento, modified 10.20.10

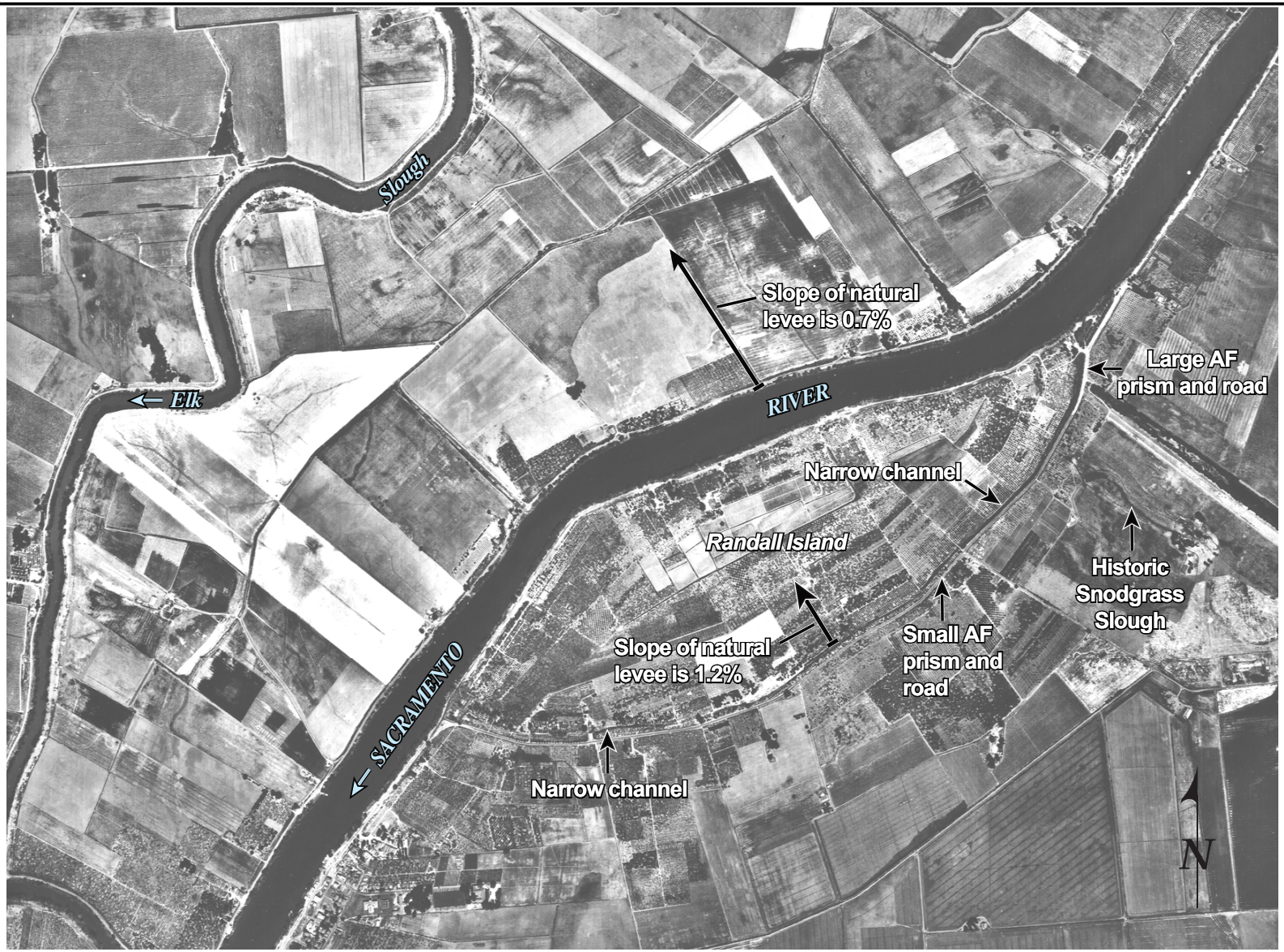
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Conceptual Cross Section across Elk Slough, Merritt Island, and Lower Sacramento River, South Sacramento Study Area

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 2



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1937 aerial photograph ABC-49-49. Based on 10 measurements, the slope of the natural levees confining the Randall Island channel is generally 0.5–1.5%, whereas the slope of the Sacramento River natural levees is generally 0.3–1%.

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 3

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

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 are accurate to within about 250', and are generally gradational.

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

Canal

Levee; artificial fill prism, generally <60 ft in width.

Cross Section (A – A')

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

C — Canal, circa 1937.

BP/Hs — Borrow pit present in 1937; unit after slash indicates the deposit in which the borrow pit is located.

Geologic Units

HISTORICAL

- AF — Artificial fill, circa 1937.
- L — Levee (made of artificial fill), circa 1937.
- RR — Railroad embankment (made of artificial fill), circa 1937.
- Rla — Lacustrine deposits; fine sand, silt and clay. Date indicates year of historical dataset.
- 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.
- Rch — Channel deposits; well sorted sand and trace 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.
- Rsl — Slough deposits; silt, clay, and sand, fining upward facies, low-energy channel deposits.

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.
- Hofc — Overflow channel deposits; vertically stratified sand, silt and clay in channels occupied when high-stage water overtops channel banks.
- Hpm — Peat and mud; peat and organic-rich silt and clay.
- Hch — Channel deposits; well sorted sand and trace fine gravel.
  - Hms — Channel meander scroll deposits; interbedded sand, silt and clay from lateral channel migration.
- Hdc — Distributary channel deposits, sand, silt, and clay; channelized flow conducting sediment to floodplain.
- Hsl — Slough deposits; silt, clay, and sand, fining upward facies, low-energy channel deposits.
- Ha — Alluvial deposits, undifferentiated; sand, silt, and minor lenses of gravel.
- Hl 1906 — Lacustrine deposits; silt and clay. Date indicates year of historical dataset.
- Hn — Basin deposits; fine sand, silt and clay.
- Hs 1937 — Marsh deposits; silt and clay, possibly with organic-rich beds; perennially or seasonally submerged. Date indicates year of historical dataset used to map the marsh.

PLEISTOCENE

- Qe — Eolian deposits; poorly consolidated sandy windblown material.
- Pf — Alluvial fan deposits; semi-consolidated silt, sand, sandy clay and fine to coarse subrounded gravel.
- Qru — Riverbank Formation; upper member, semi-consolidated to consolidated gravel, sand, silt and minor clay.
- Qrl — Riverbank Formation; lower member; consolidated gravel, sand, silt, and clay, generally capped by a paleo-soil with strong duripan horizon.

Stratigraphic Correlation Chart

Time: Epoch	Depositional Environment: Channel deposits	Floodplain and alluvial-fan deposits	Flood basin deposits	Cultural deposits
Historical	Rch; Rb; Rdc; Rsl	Ra; Rob; Rcs; Rdf	Hn; Hs; Rla; Hpm; Hl 1906	L; AF; RR
Holocene	Hch; Hms; Hdc; Hsl	Ha; Hob; Hcs; Hofc		
Pleistocene		Pf; Qe; Qru; Qrl		

Map projection: UTM NAD83 Zone 10N

Topographic base USGS 7.5' quadrangles:
Clarksburg, published 1967, revised 1980; map scale 1:24,000, five foot contour interval.
Courtland, published 1978, revised 1993; map scale 1:24,000, five foot contour interval.
Florin, published 1968, revised 1980; map scale 1:24,000, five foot contour interval.
Sacramento West, published 1948, revised 1992; map scale 1:24,000, five foot contour interval.

Geologic Mapping by C. Brossy, J. Pearce, A. Streig
Digital Cartography by M. Ticci

N

0 2,000 ft

0 1 km

1:24,000

Scale is 1 in = 2,000 ft when printed at 28 inch by 38 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 the South Sacramento Study Area

NORTH NON-URBAN LEVEE EVALUATIONS

Plate 1

NULE Level 2-II: South of Sacramento Geomorphic Assessment

1965_2_NULE_SouthSac_Plate.mxd MGT 12/21/2010

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Project	Non-Urban Levee Evaluations Project Task Order U-103
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Prepared By	Justin Pearce, Fugro William Lettis & Associates (FWLA), April 2010
Reviewed By	Janet Sowers, FWLA, March 2010; Keith Knudsen, Jennifer Mendonca, URS, April, 2010; Steve Belluomini, Keith Millard, DWR, 2010

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

[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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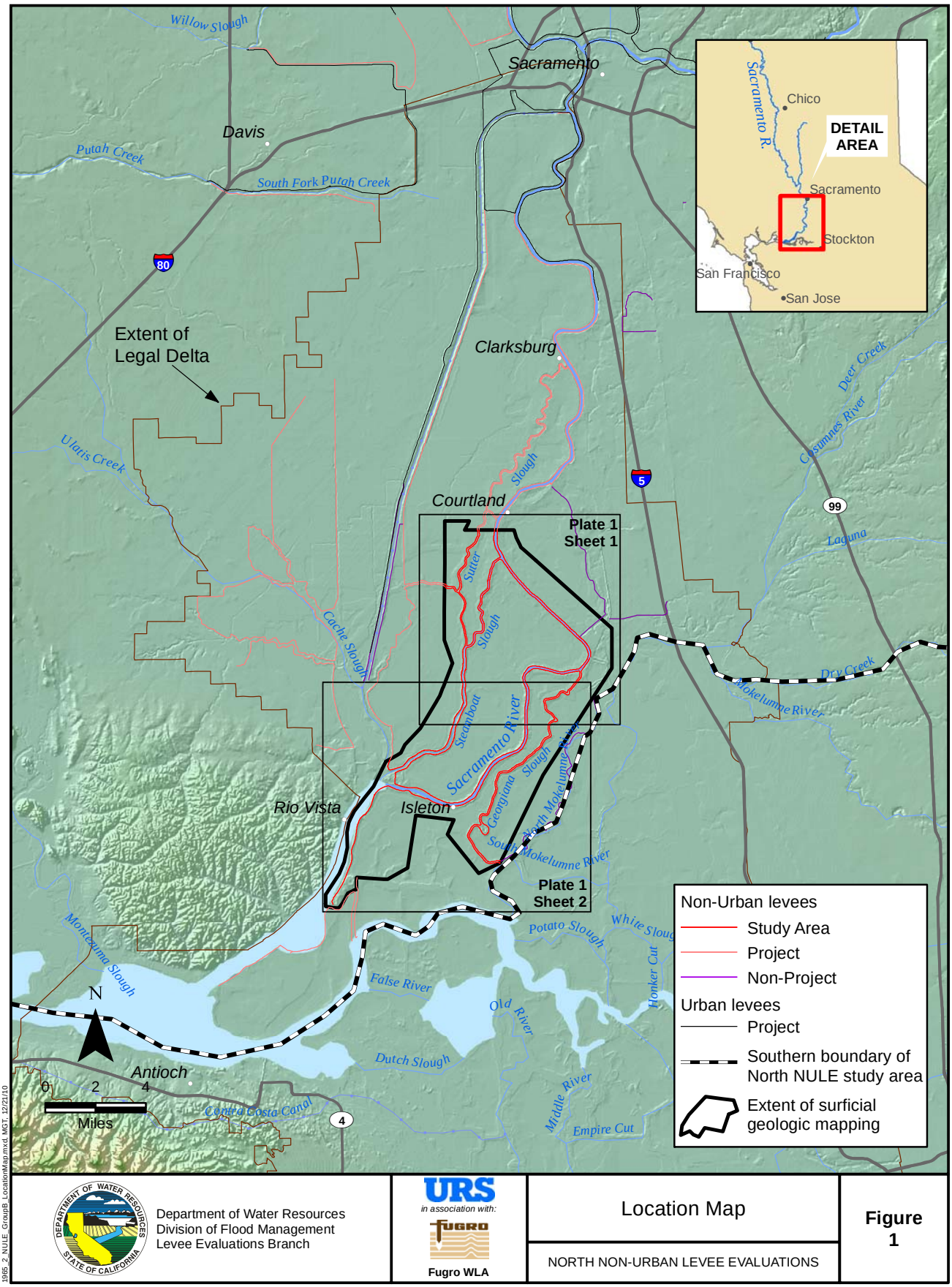
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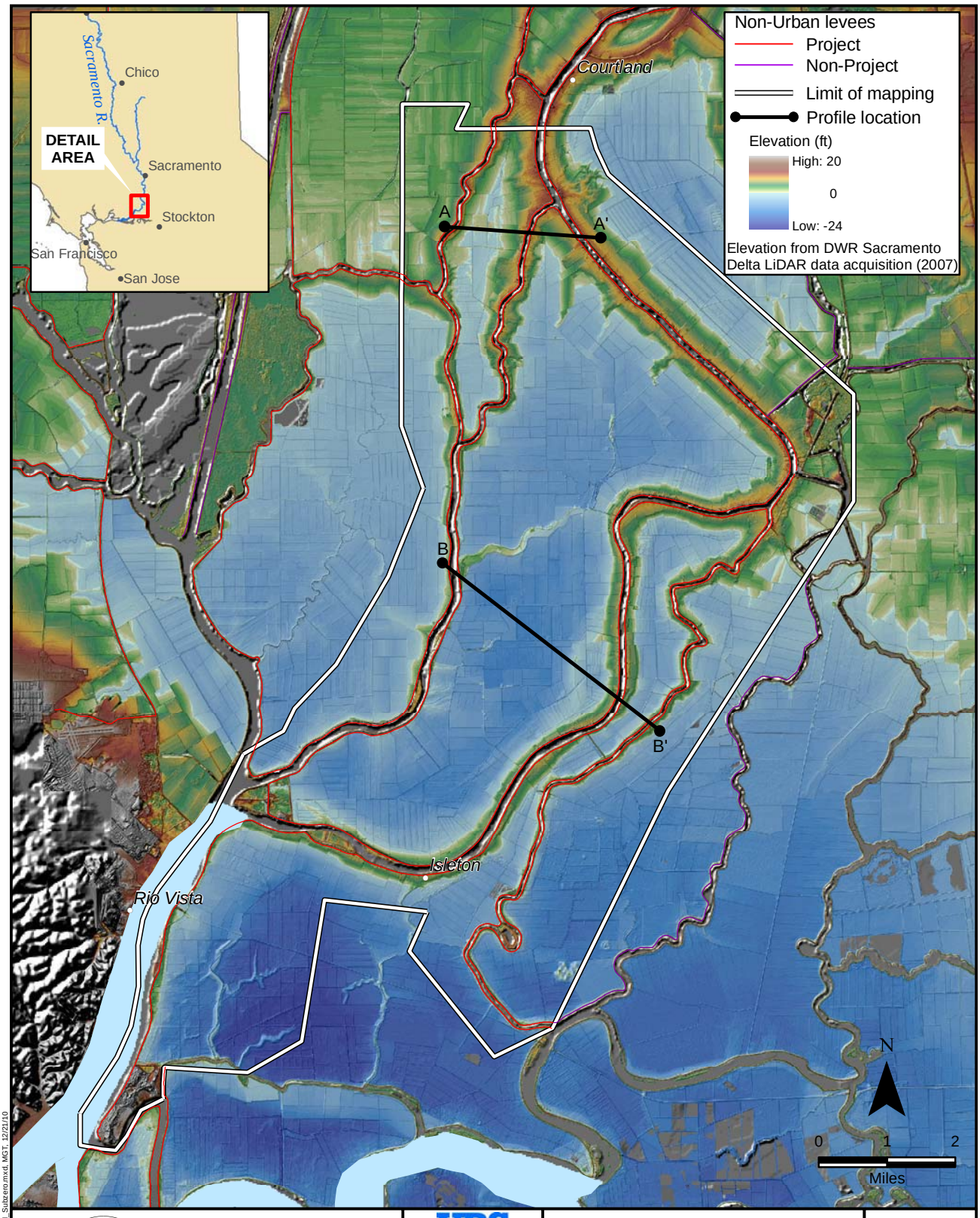
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Location Map

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 1



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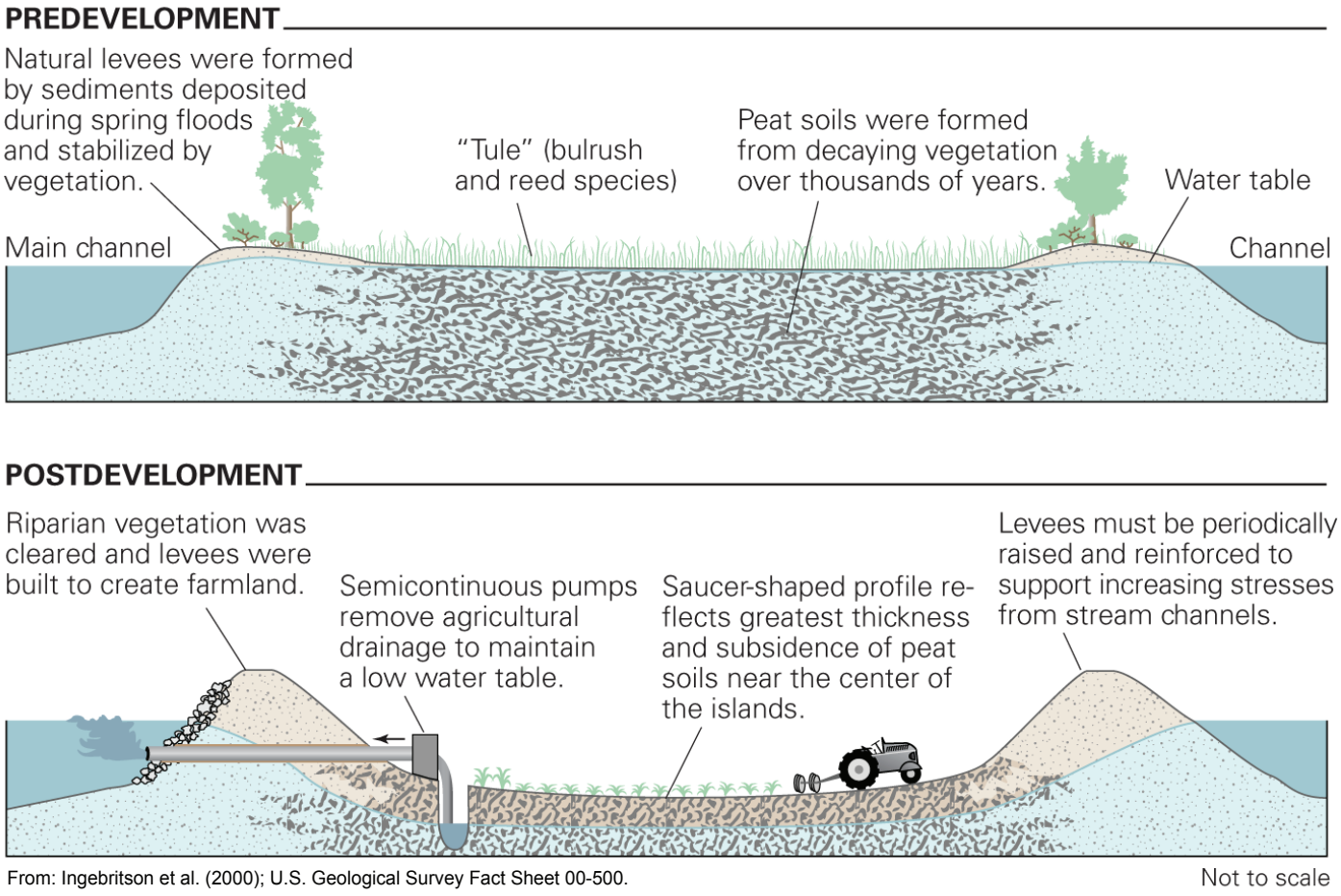
URS in association with: Fugro WLA

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

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 2

1965_2_NULE_GroupB_DEM_Subzero.mxd, MGT, 12/21/10



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

Not to scale

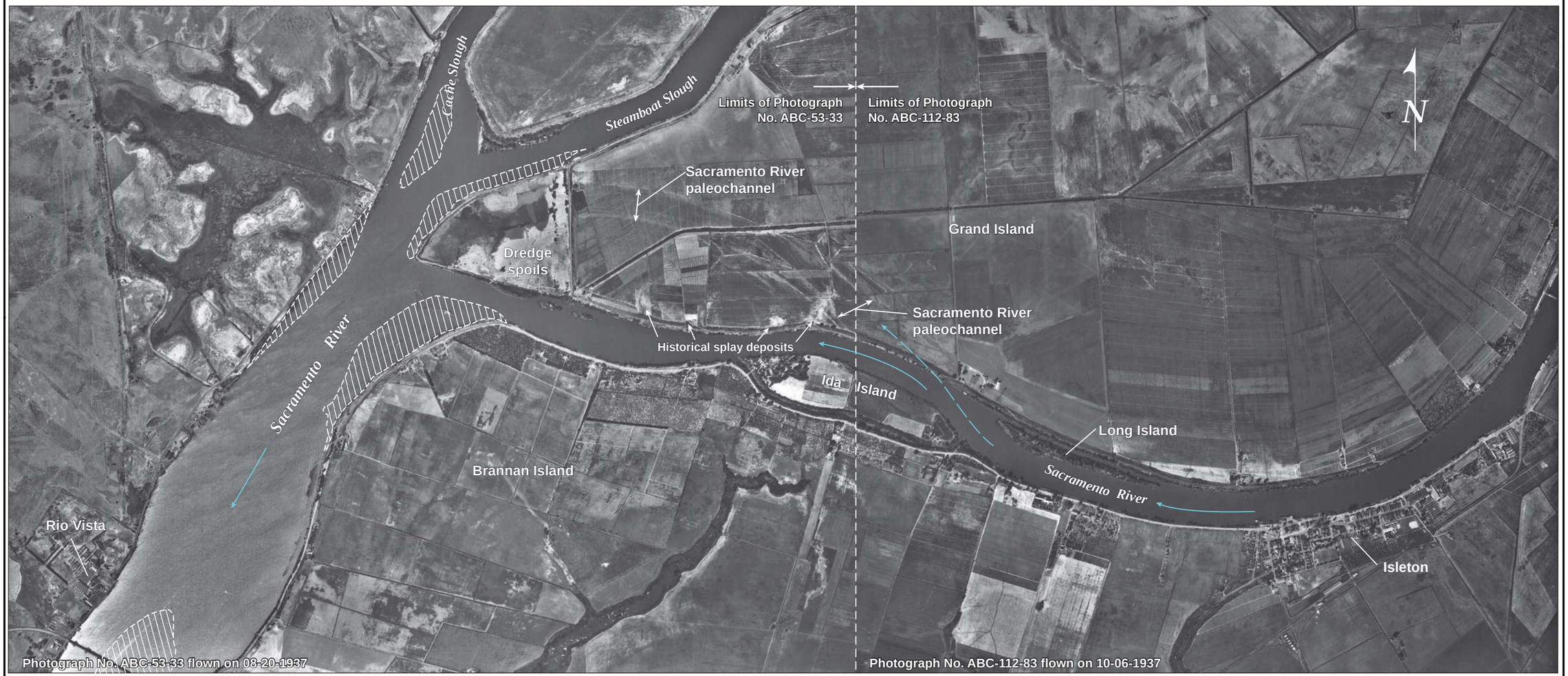
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Division of Flood Management
Levee Evaluations Branch

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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

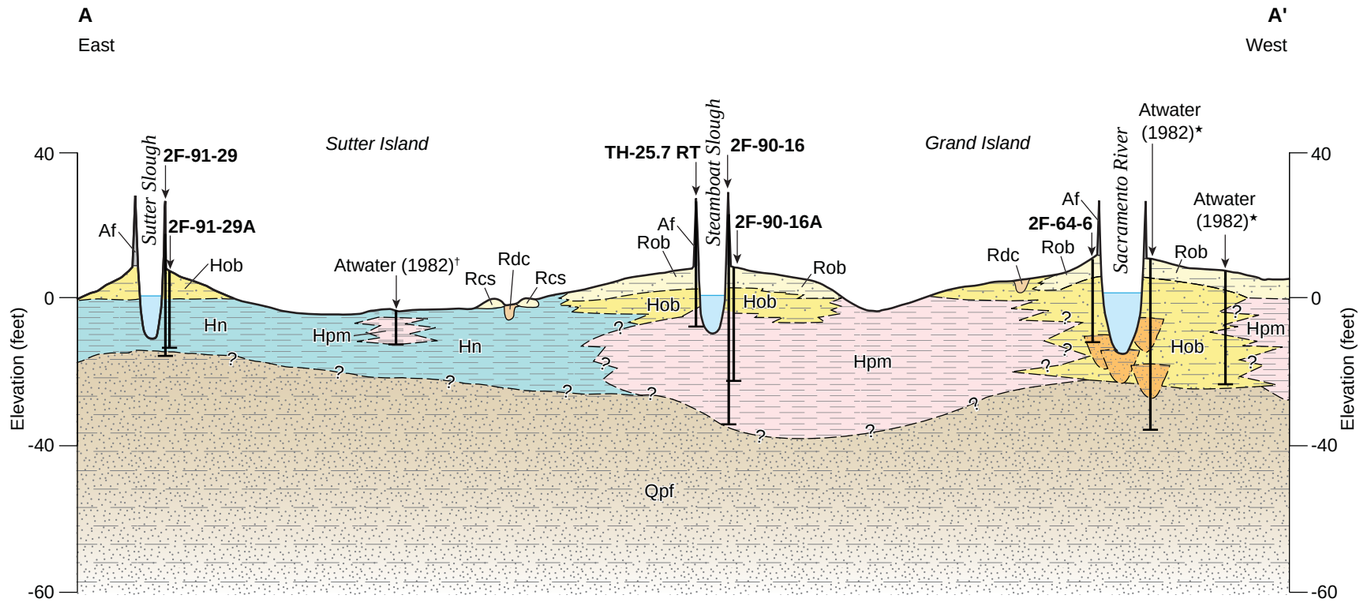
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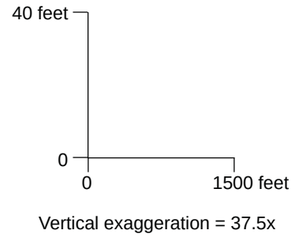
1937 Aerial Photograph of the Sacramento River near Isleton

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 4



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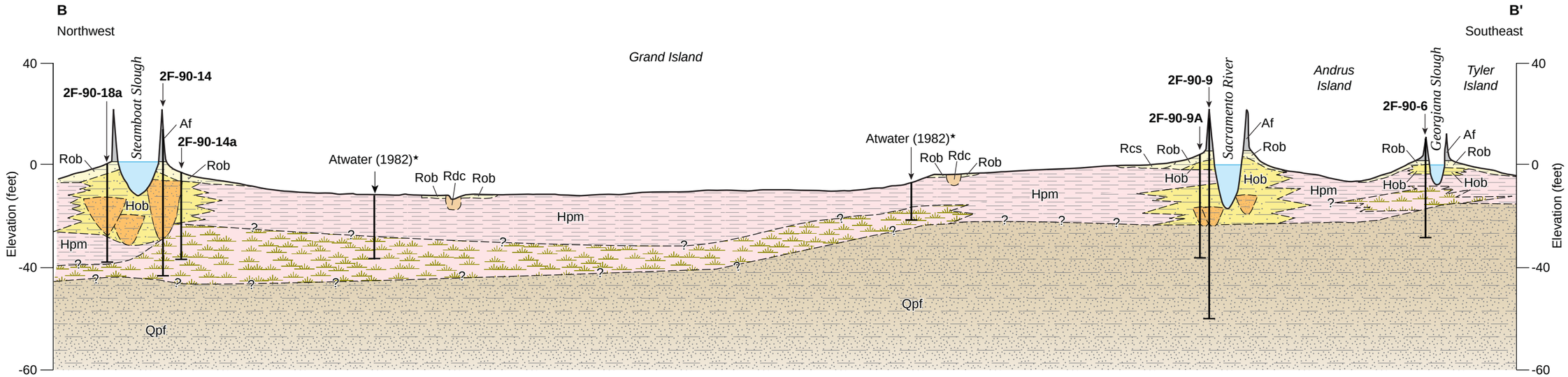
URS in association with: WLA William Lettis & Associates, Inc

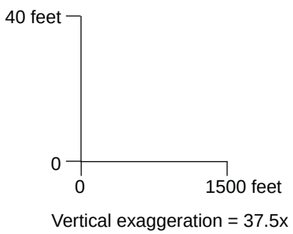
Conceptual Geologic Cross Section A - A'

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 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

HISTORICAL

- L — Levee (made of artificial fill), circa 1937.
- 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	Depositional Environment									
Epoch	Channel deposits			Floodplain and alluvial-fan deposits			Flood basin deposits			Cultural deposits
Historical	Rch	Rb	Rdc	Ra	Rob		Hn	Hs	Rpm	L
		Rofc	Rsl		Rcs	Rdf			Hpm	
Holocene	Hch	Hsl		Ha	Hob					
		Hdc			Hcs					
Pleistocene				Qe						

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.

Cross section location (B — B')

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

C — Canal, circa 1937.

Geologic Units

HISTORICAL

- AF — Artificial fill, circa 1937.
- L — Levee (made of artificial fill), circa 1937.
- DS — Dredge spoils; material from channel dredging and typically hydraulically emplaced.
- 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	Depositional Environment				
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 IE 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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Appendices

Appendix A	Hydrologic Soil Groups

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

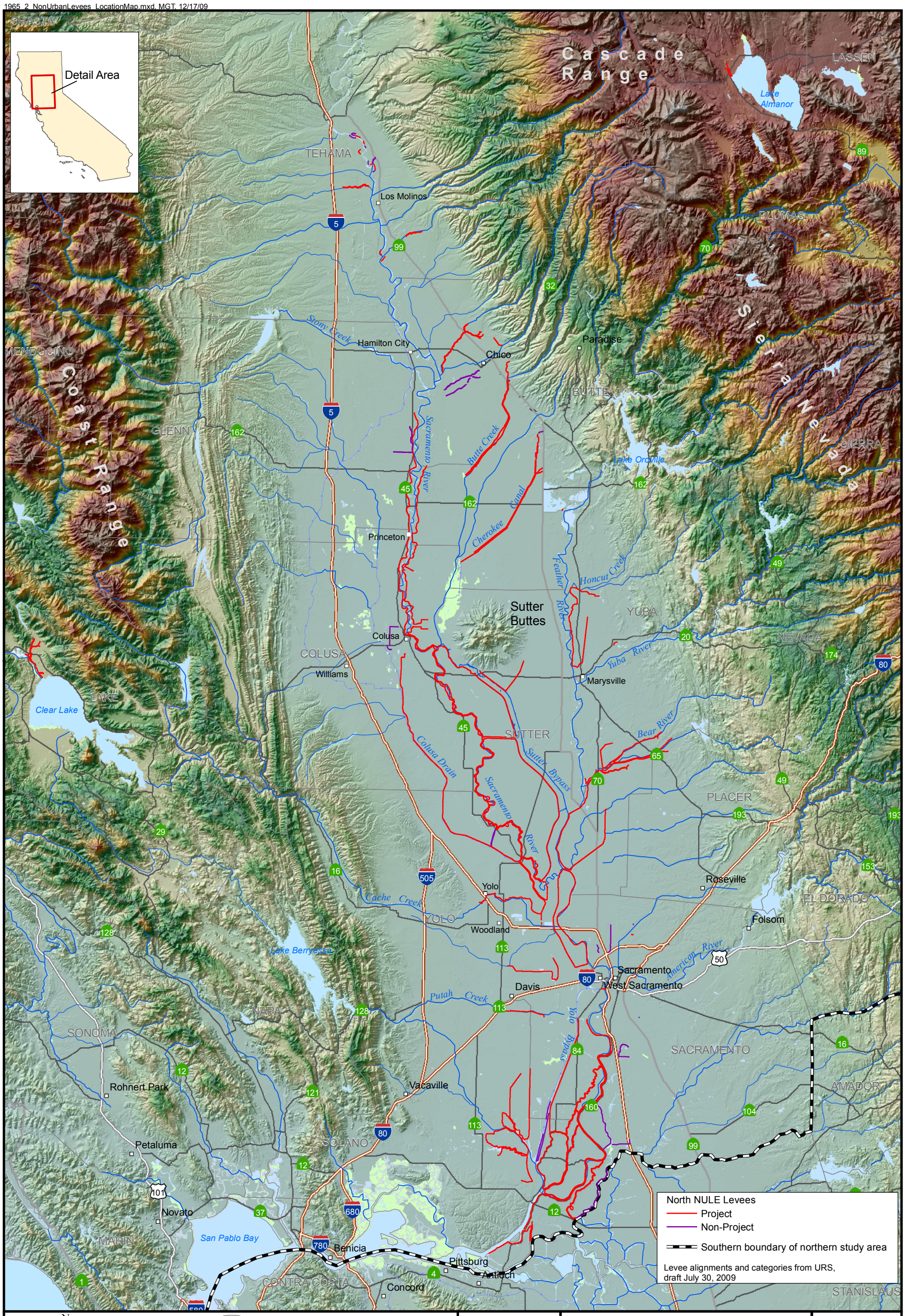
Performance Problem	Susceptibility Class	Miles Affected Levee	Percent Total Miles Affected	Affected Miles per Levee Mile (%)
Failure	VH	0.67	36	0.61
	H	0.64	35	0.15
	M	0.14	8	0.19
	L	0.39	21	0.20
	All classes	1.85	100	0.22
Seepage/Boils	VH	6.82	13	6.20
	H	40.84	76	9.27
	M	3.70	7	4.95
	L	2.20	4	1.11
	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



1965_2_NonUrbanLevees_DomainsMap.mxd, MGT, 12/17/09

Limit of Sacramento Valley.
Domains continue beyond map extent.

Geomorphic Domains

- CFo — Cascade Range fans - older
- CFy — Cascade Range fans - younger
- CRF — Coast Range fans
- CRH — Coast Range hills
- D — Delta
- FB — Flood Basin
- FR — Feather River
- SB — Sutter Buttes volcanics
- SBF — Sutter Buttes alluvial fans
- SNFo — Sierra Nevada fans - older
- SNFy — Sierra Nevada fans - younger
- SNFy-FB — Sierra Nevada fan - flood basin
- SR — Sacramento River floodplain
- SRm — Sacramento River meander belt
- ST — Sierran tributary
- STs — Sierran tributary - small

Cascade Range
Coast Ranges
Sierra Nevada
Lake Almanor
Lake Oroville
Clear Lake
Lake Berryessa
Los Molinos
Hamilton City
Chico
Paradise
Princeton
Colusa
Williams
Marysville
Yolo
Woodland
West Sacramento
Sacramento
Davis
Vacaville
Rohnert Park
Petaluma
Novato
Benicia
Pittsburg
Antioch
Concord
Roseville
Folsom
Sycamore Slough
Stony Creek
Butte Creek
Cherokee Canal
Honcut Creek
Feather River
Yuba River
Bear River
Colusa Drain
Sutter Bypass
Sacramento River
Cache Creek
Putah Creek
Yolo Bypass
American River
LASSEN
PLUMAS
SIERRA
NEVADA
YUBA
BUTTE
SUTTER
PLACER
EL DORADO
AMADOR
STANISLAUS
COLUSA
GLENN
LAKE
NAPA
SONOMA
SOLANO
YOLO
MARIN
CONTRA COSTA
SACRAMENTO

North NULE Levees
- Project
- Non-Project
- Southern boundary of northern study area

Levee alignments and categories from URS, draft July 30, 2009

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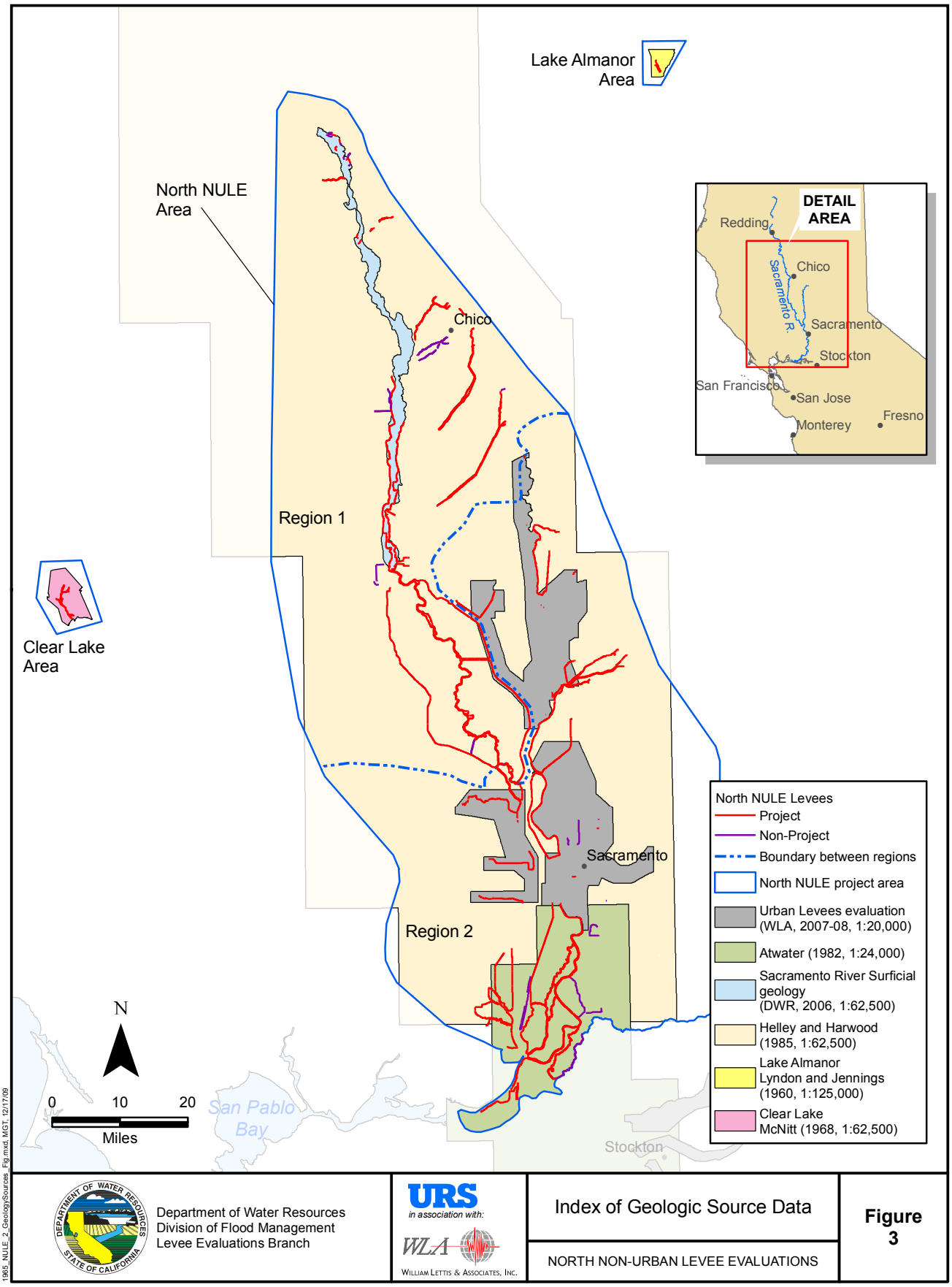
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Division of Flood Management
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North NULE Geomorphic Domains

North Non-Urban Levee Evaluations

Figure 2



1965_NULE_2_GeologySources_Fig.mxd, MGT, 12/17/09

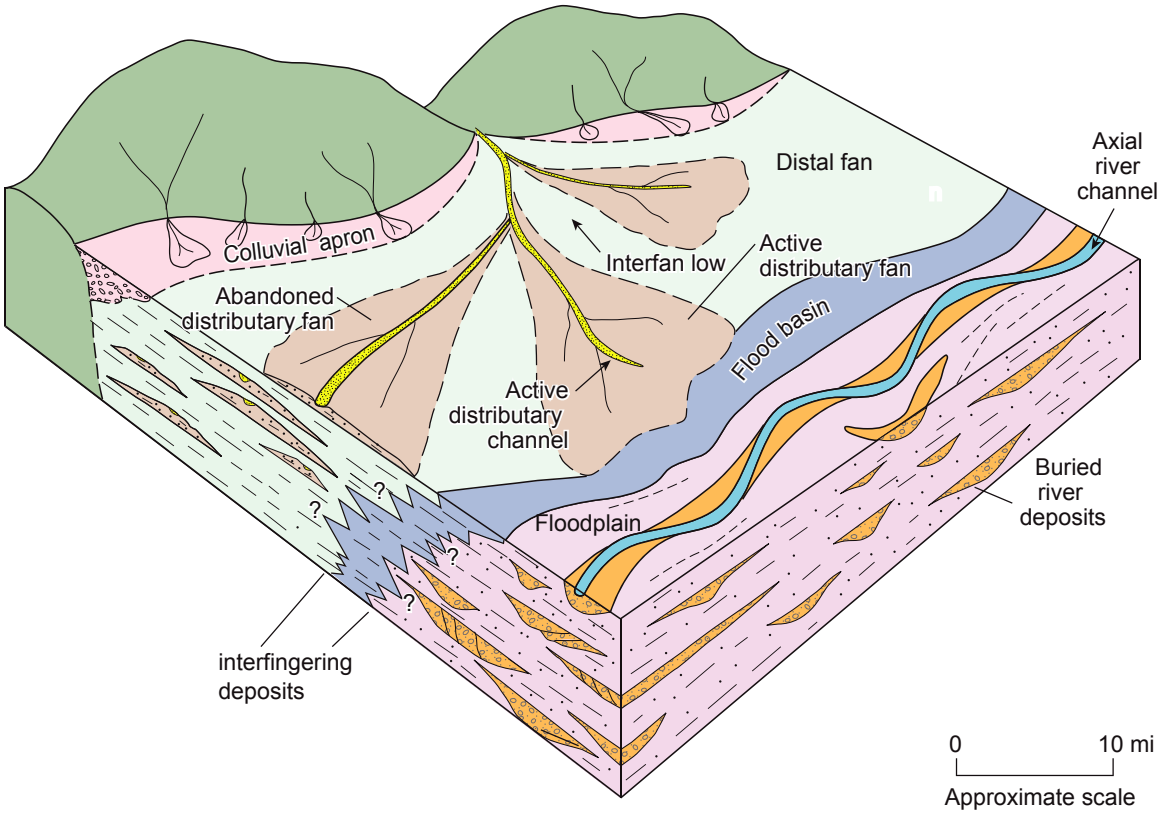
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Index of Geologic Source Data

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

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Levee Evaluations Branch

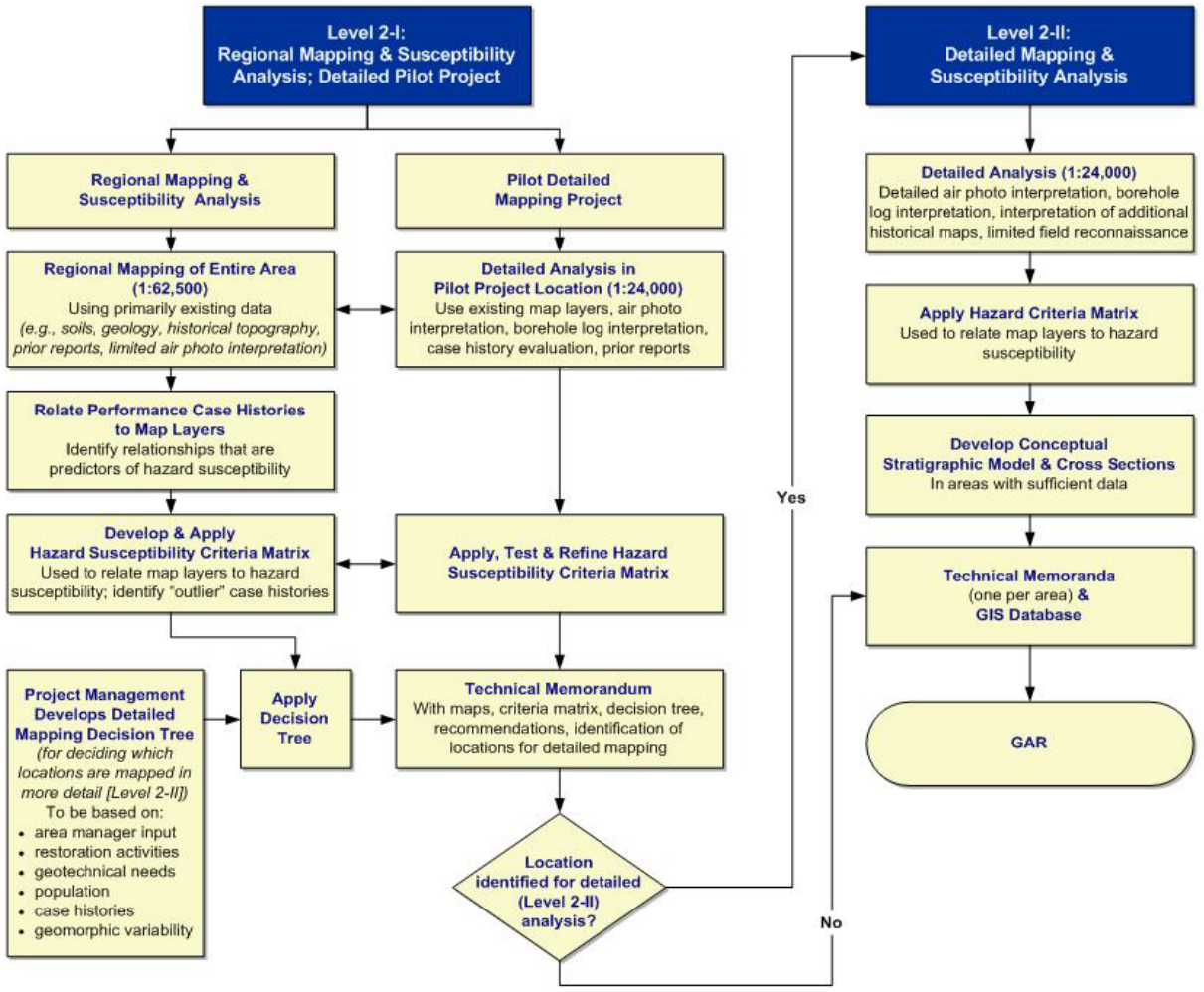
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Conceptual Block Diagram

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 4

1965_NULE5_block al jtp Modified 07.08.09



1965_NUE-workflow_Fig.5.Modified 07.08.09

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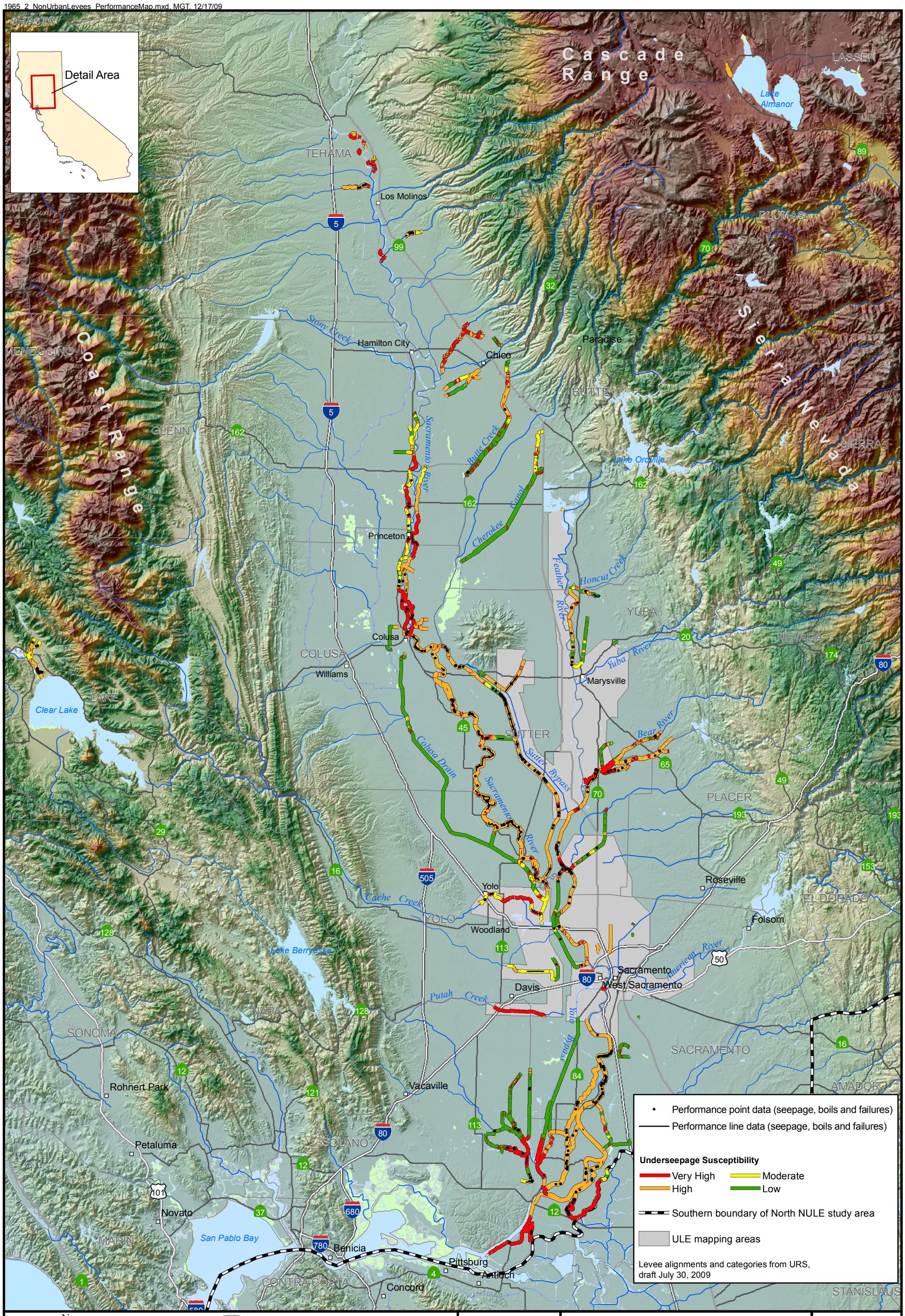
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Workflow Diagram

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 5

1965_2_NonUrbanLevees_PerformanceMap.mxd, MGT, 12/17/09



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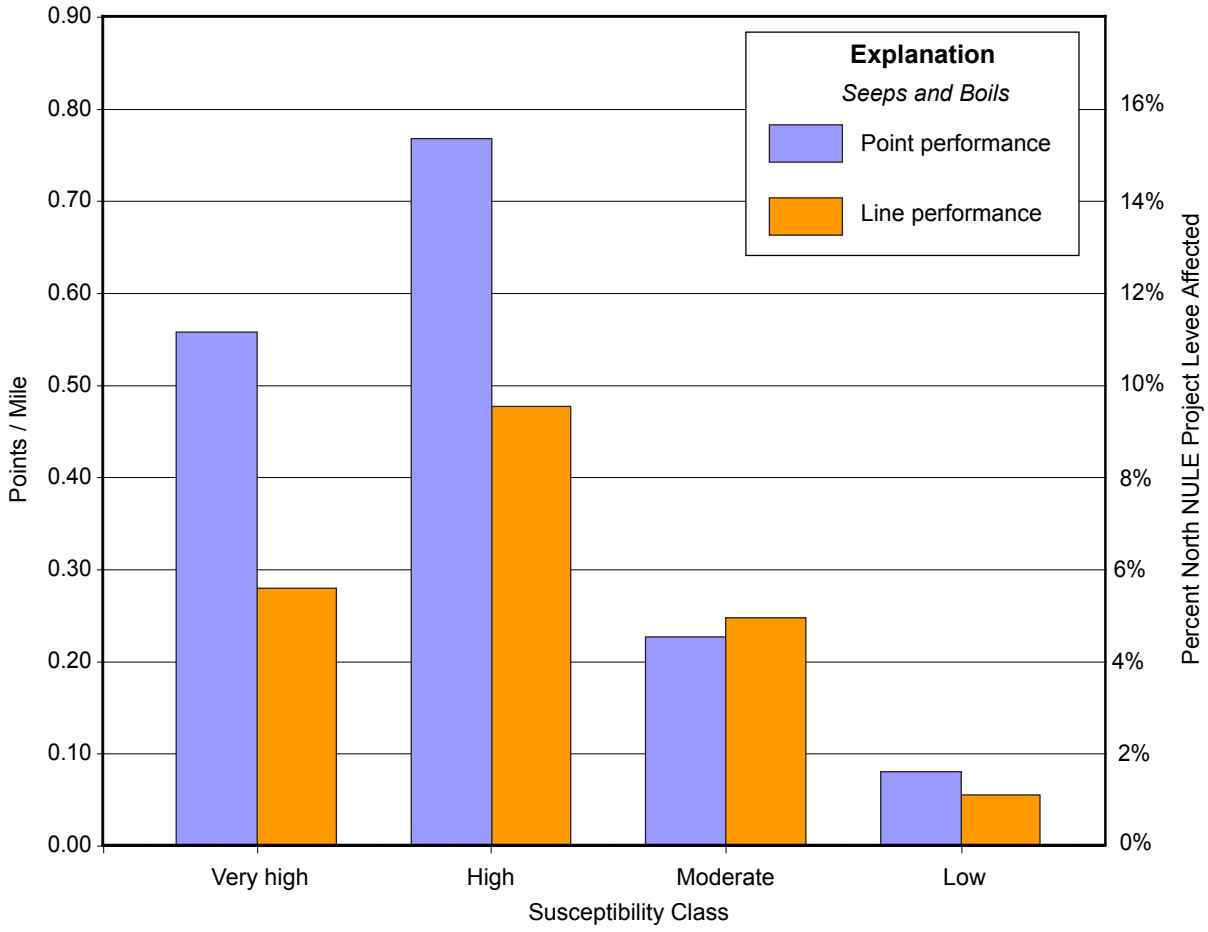
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North NULE Performance Map

North Non-Urban Levee Evaluations

Figure 6



1965_NULE_7_Plot Seepage and Boil Frequency_Fig.7,Modified 121709

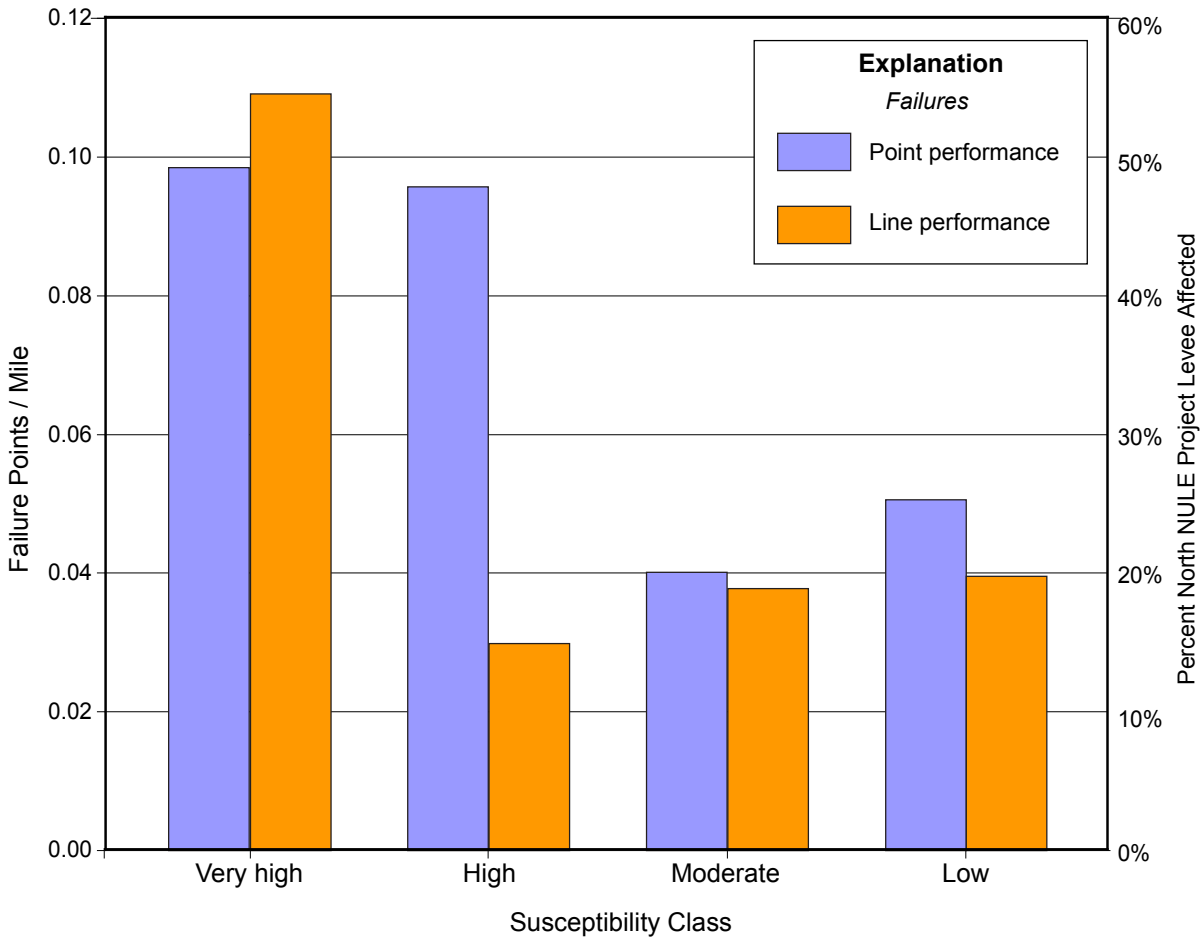
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Plot of Seepage and Boil Frequency by Susceptibility Class

NORTH NON-URBAN LEVEE EVALUATIONS

Figure 7



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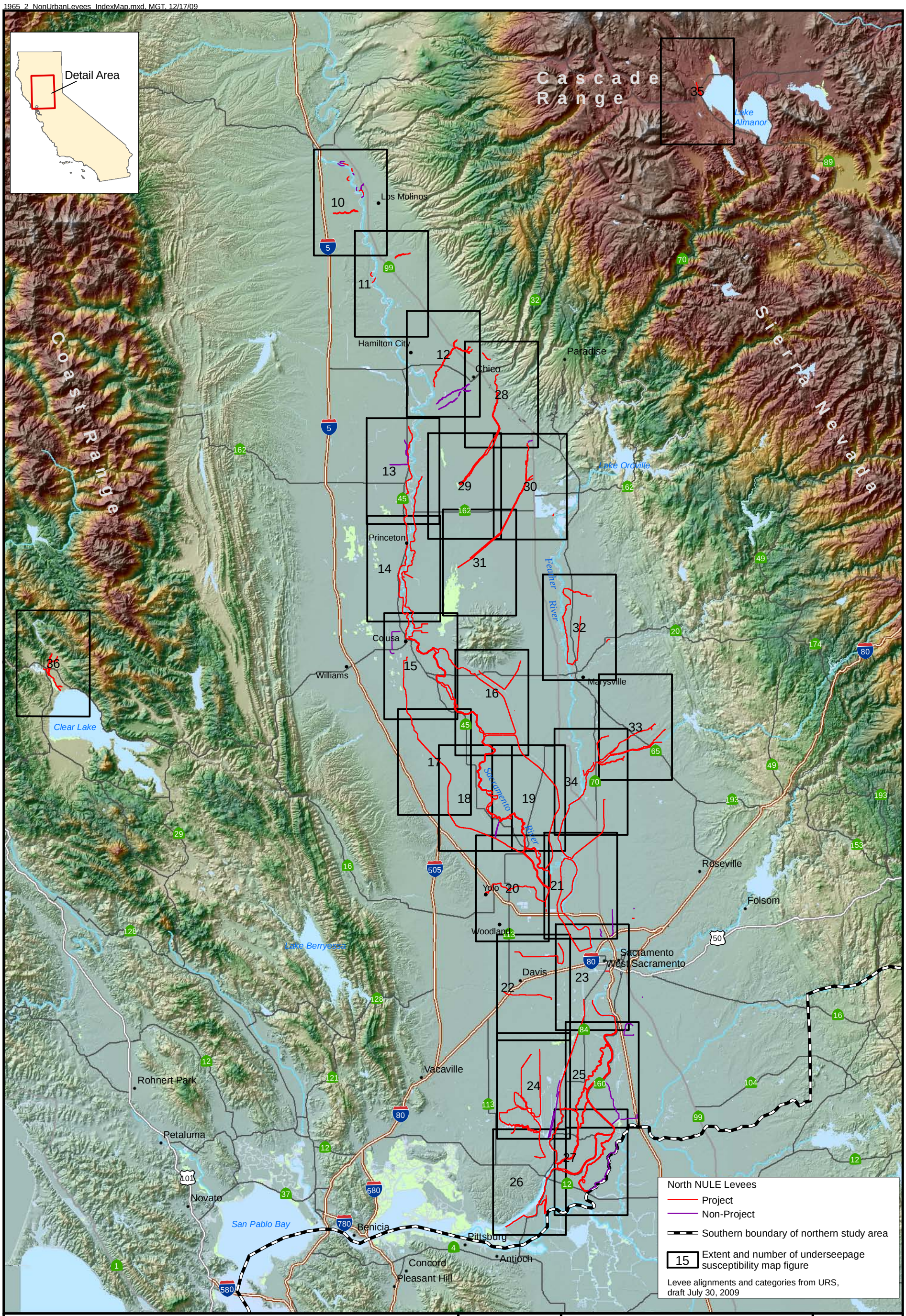
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Plot of Failures
by Susceptibility Class

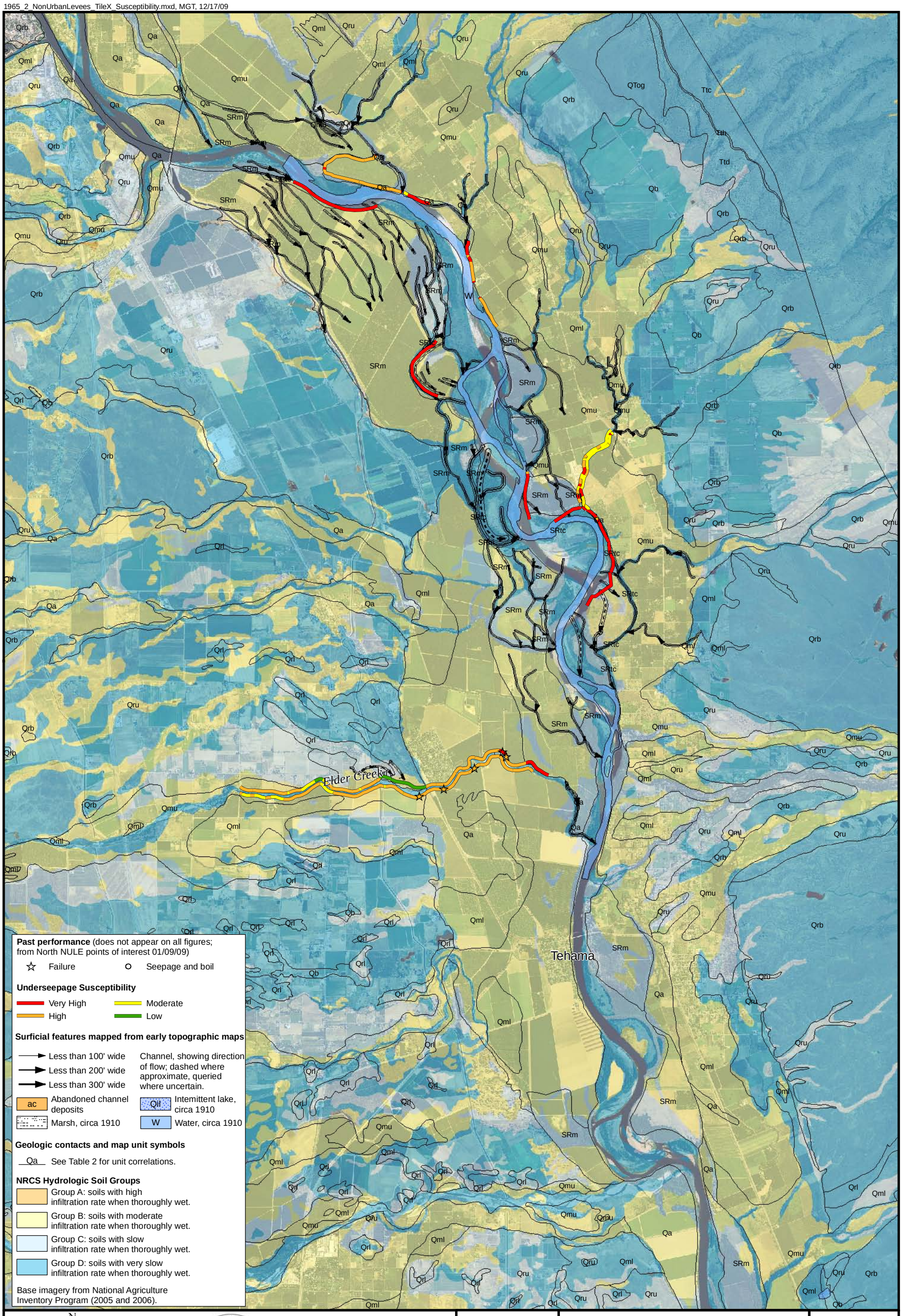
NORTH NON-URBAN LEVEE EVALUATIONS

Figure 8

1965_NULE_7_Plot Seepage and Boil Frequency_Fig.8.Modified 121709


Detail Area
Cascade Range
Coast Range
Sierra Nevada
Lake Almanor
Los Molinos
Hamilton City
Chico
Paradise
Princeton
Colusa
Williams
Marysville
Clear Lake
Lake Berryessa
Lake Oroville
Yolo
Woodland
Davis
Sacramento
West Sacramento
Roseville
Folsom
Vacaville
Rohnert Park
Petaluma
Novato
San Pablo Bay
Benicia
Pittsburg
Antioch
Concord
Pleasant Hill
Feather River
Sacramento River
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North NULE Levees
Project
Non-Project
Southern boundary of northern study area
15 Extent and number of underseepage susceptibility map figure
Levee alignments and categories from URS, draft July 30, 2009
N
0 5 10
Miles
Department of Water Resources
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Levee Evaluations Branch
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North NULE Index Map
North Non-Urban Levee Evaluations
Figure 9

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 10

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Vina

HWY 99

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

Very High Moderate
High Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide
Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac Abandoned channel deposits
Qil Intemittent lake, circa 1910
Marsh, circa 1910
W Water, circa 1910

Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.
Group B: soils with moderate infiltration rate when thoroughly wet.
Group C: soils with slow infiltration rate when thoroughly wet.
Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

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Levee Evaluations Branch

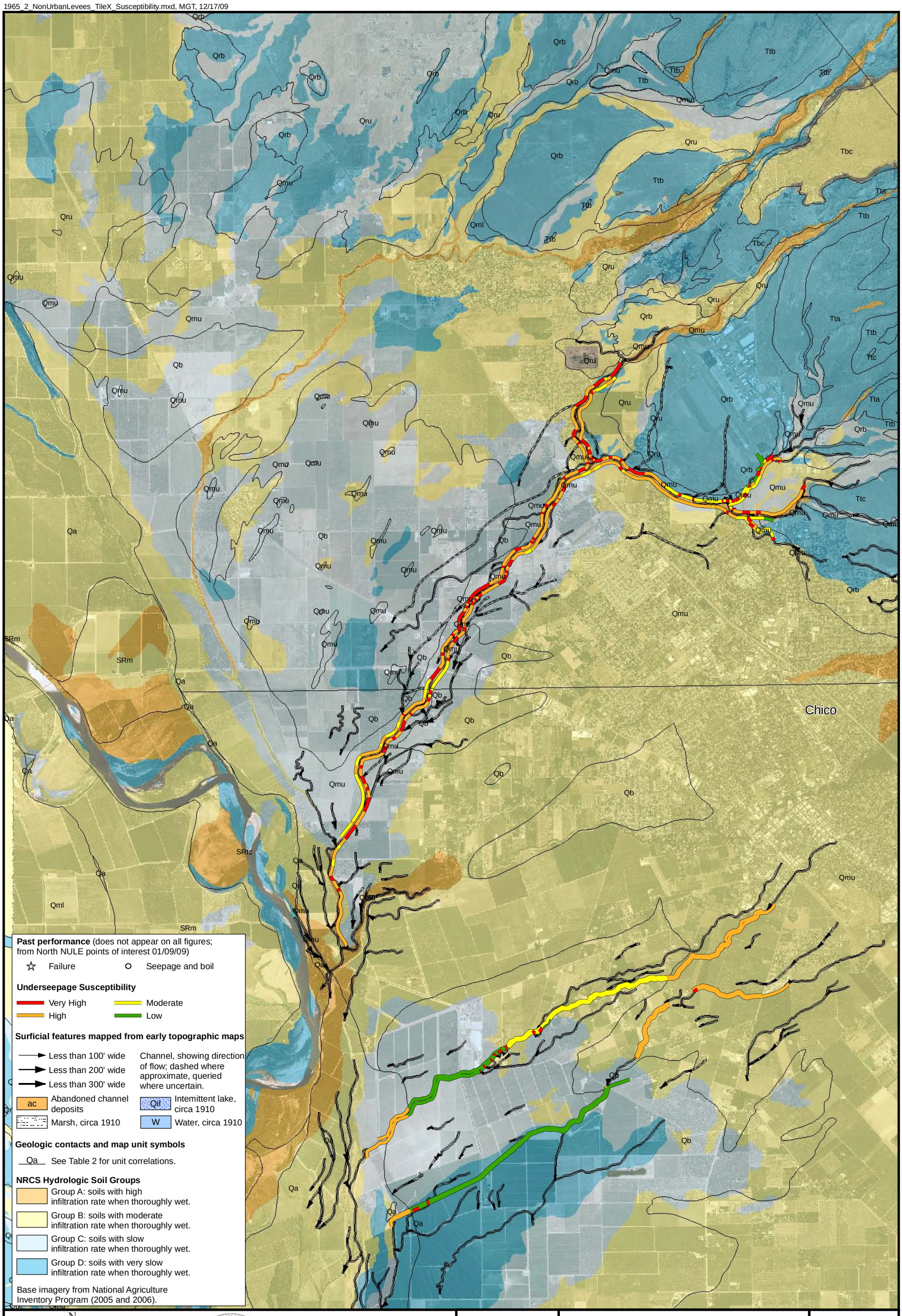
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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 11

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



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mi

1:62,500

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Levee Evaluations Branch

URS

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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 12

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

- Very High
- High
- Moderate
- Low

Surficial features mapped from early topographic maps

- Less than 100' wide
- Less than 200' wide
- Less than 300' wide

Channel, showing direction of flow; dashed where approximate, queried where uncertain.

- ac — Abandoned channel deposits
- Qil — Intermittent lake, circa 1910
- Marsh, circa 1910
- W — Water, circa 1910

Geologic contacts and map unit symbols

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- Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

N

0 0.5 1 mi

1:62,500

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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 13

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

Very High Moderate
High Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide
Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac Abandoned channel deposits
Qil Intemittent lake, circa 1910
Marsh, circa 1910
W Water, circa 1910

Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.
Group B: soils with moderate infiltration rate when thoroughly wet.
Group C: soils with slow infiltration rate when thoroughly wet.
Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

Princeton
Moulton Weir

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Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

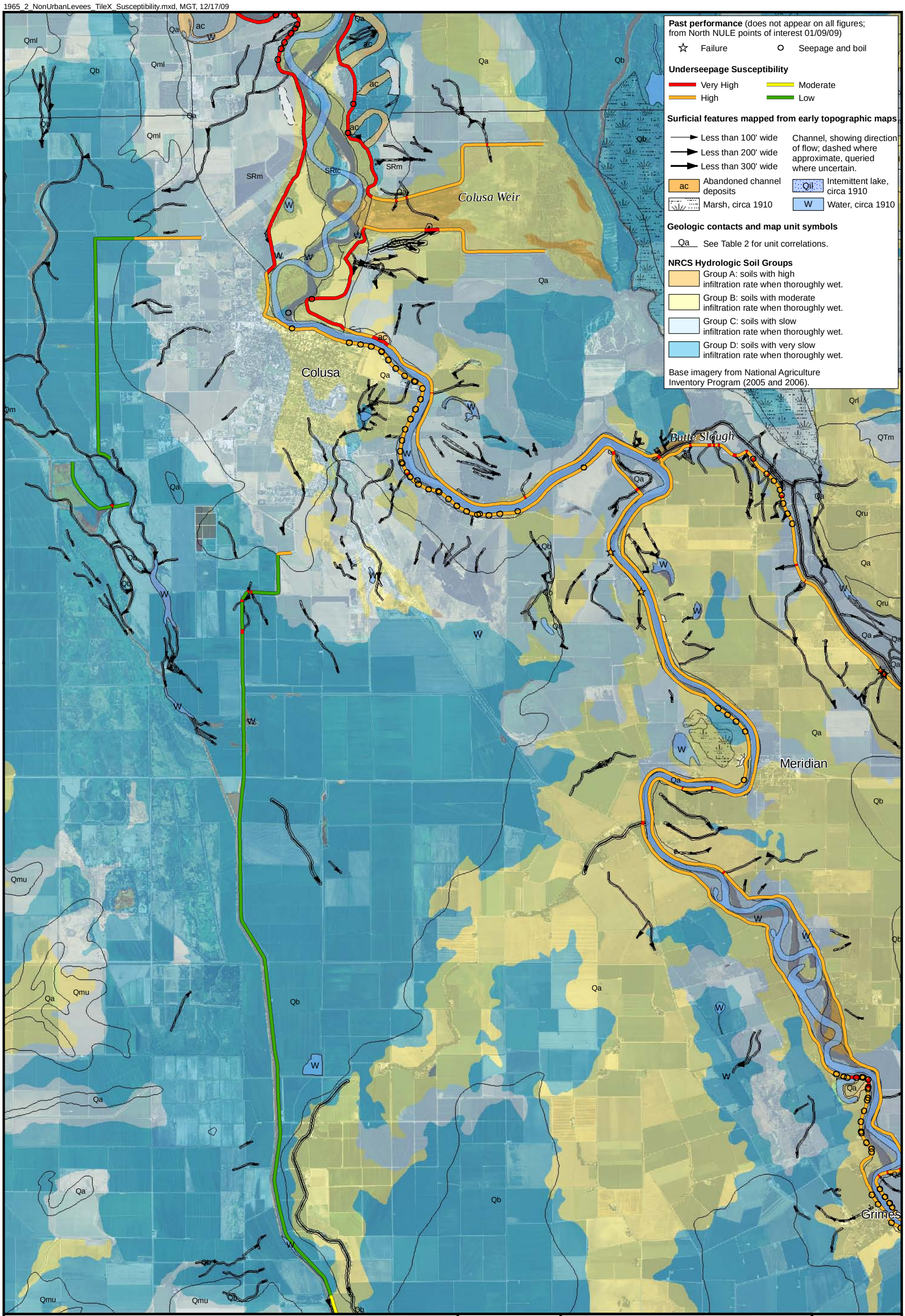
URS
in association with:
WLA
William Lettis & Associates, Inc.

Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 14

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure O Seepage and boil

Underseepage Susceptibility

Very High
High
Moderate
Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide

Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac Abandoned channel deposits

Qil Intermittent lake, circa 1910

Marsh, circa 1910

W Water, circa 1910

Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.

Group B: soils with moderate infiltration rate when thoroughly wet.

Group C: soils with slow infiltration rate when thoroughly wet.

Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

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Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

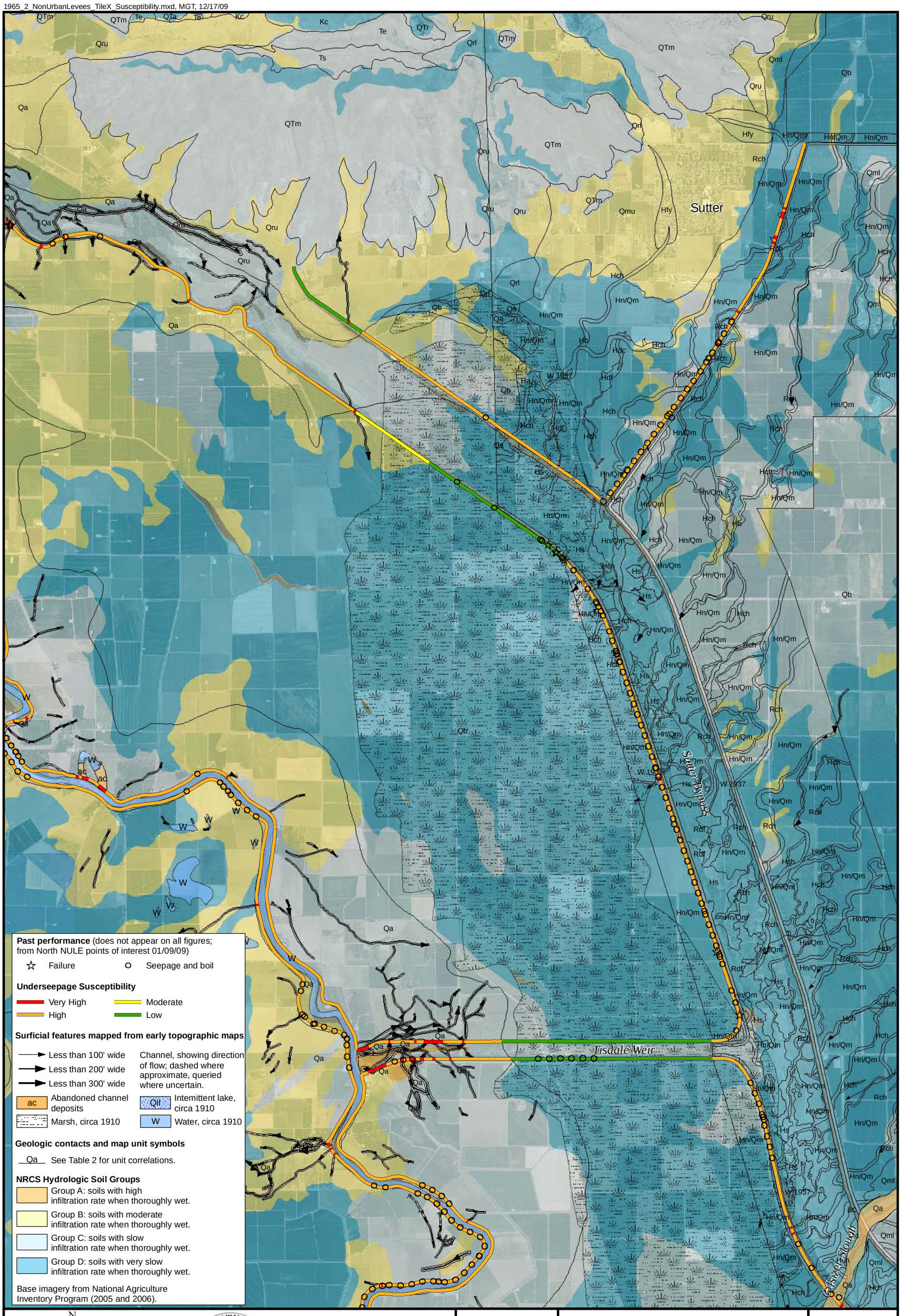
URS
in association with:
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William Lettis & Associates, Inc.

Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 15

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



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Levee Evaluations Branch

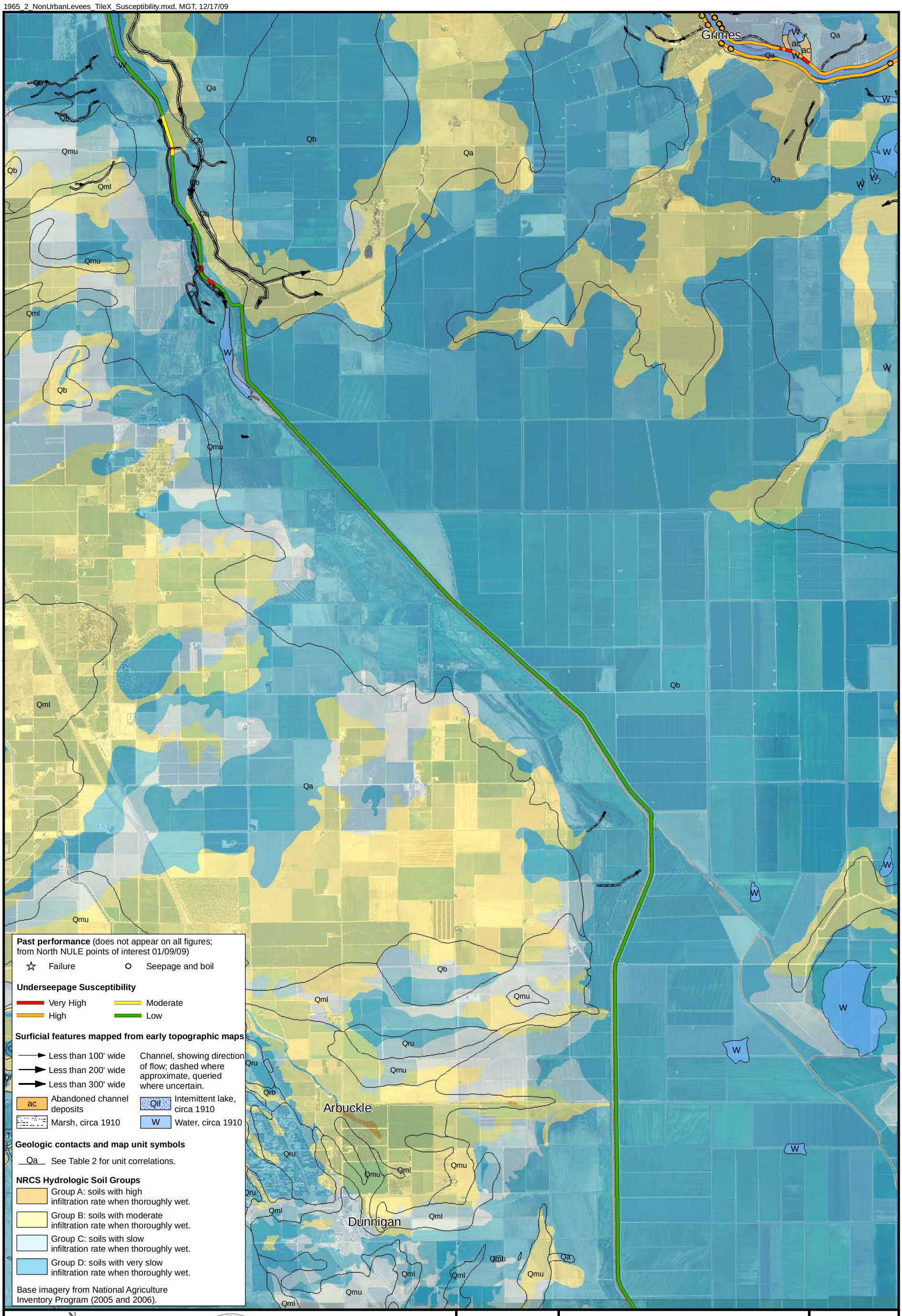
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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 16

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

Very High Moderate
High Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide
Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac Abandoned channel deposits
Oil Intemittent lake, circa 1910
Marsh, circa 1910
W Water, circa 1910

Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.
Group B: soils with moderate infiltration rate when thoroughly wet.
Group C: soils with slow infiltration rate when thoroughly wet.
Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

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Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

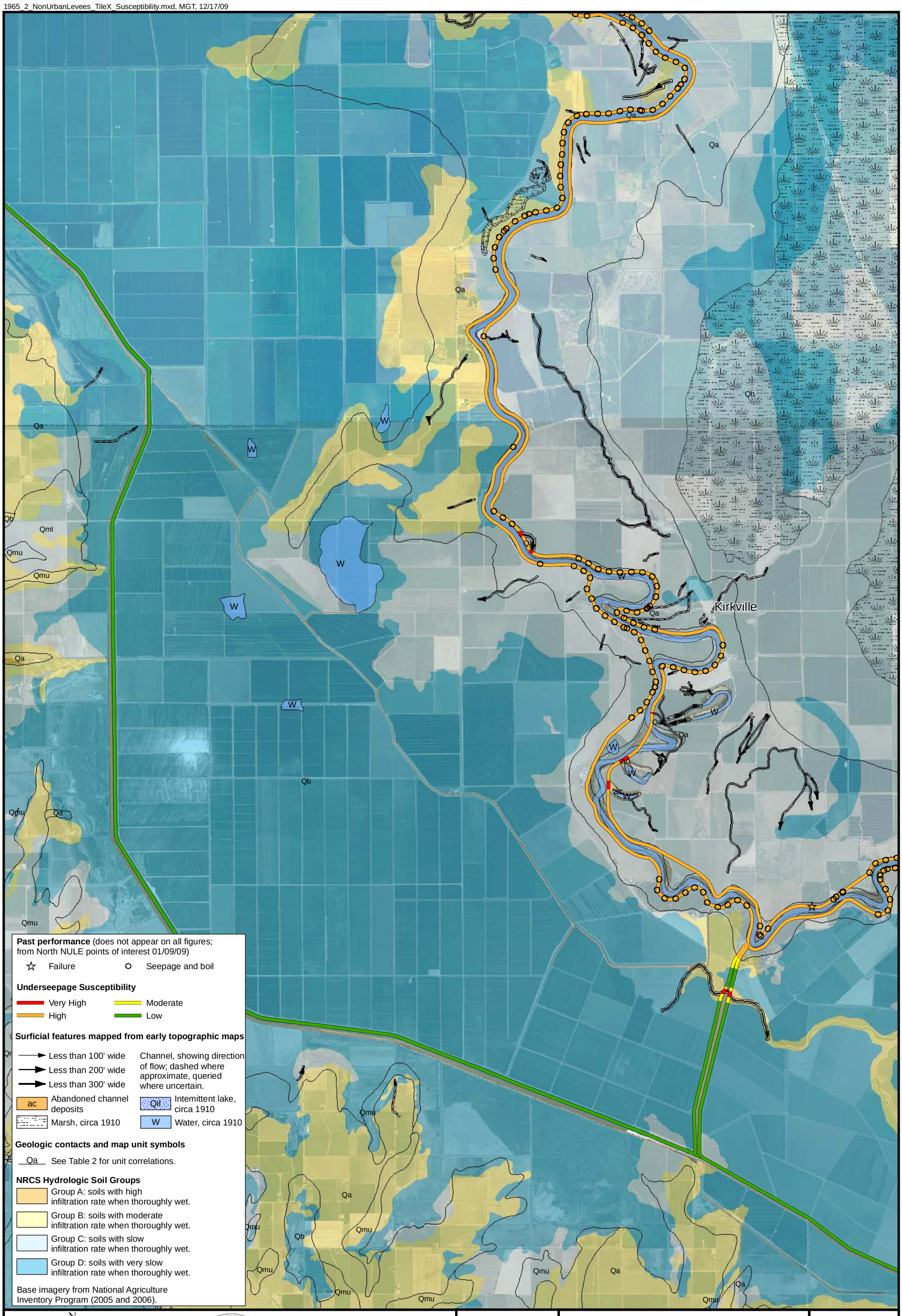
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in association with:
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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 17

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 18

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

Very High
High
Moderate
Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide
Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac Abandoned channel deposits

Qil Intemittent lake, circa 1910

Marsh, circa 1910

W Water, circa 1910

Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.

Group B: soils with moderate infiltration rate when thoroughly wet.

Group C: soils with slow infiltration rate when thoroughly wet.

Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

Gilsizer Slough

Sutter Bypass

Nelson Slough

Kirkville

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Levee Evaluations Branch

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in association with:

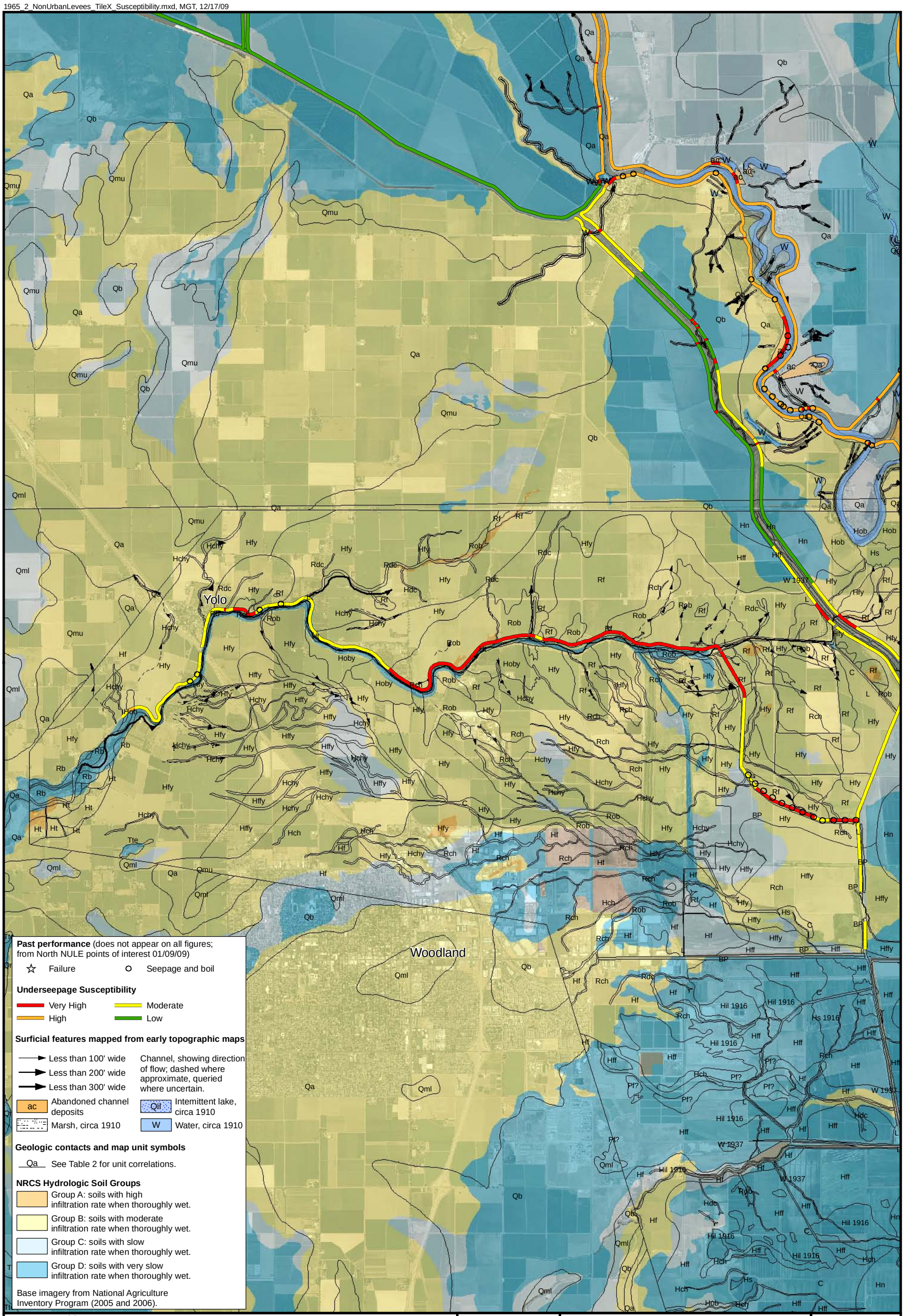
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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 19

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

- Very High
- High
- Moderate
- Low

Surficial features mapped from early topographic maps

- Less than 100' wide
- Less than 200' wide
- Less than 300' wide

Channel, showing direction of flow; dashed where approximate, queried where uncertain.

- ac — Abandoned channel deposits
- Qlf — Intemittent lake, circa 1910
- Marsh, circa 1910
- W — Water, circa 1910

Geologic contacts and map unit symbols

Qa — See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

- Group A: soils with high infiltration rate when thoroughly wet.
- Group B: soils with moderate infiltration rate when thoroughly wet.
- Group C: soils with slow infiltration rate when thoroughly wet.
- Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

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Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

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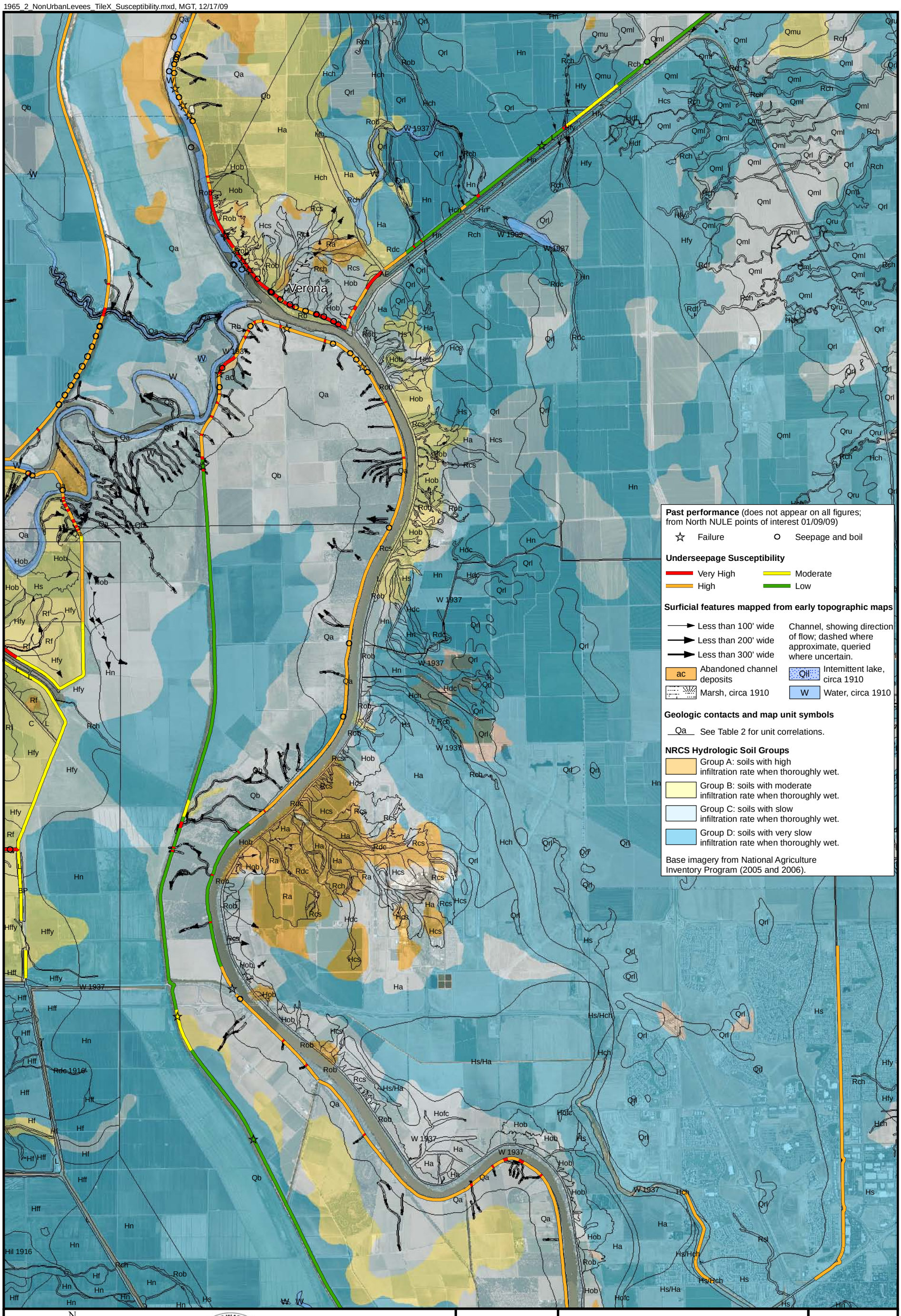
WLA — William Lettis & Associates, Inc.

Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 20

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Davis

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure

o Seepage and boil

Underseepage Susceptibility

- Very High
- High
- Moderate
- Low

Surficial features mapped from early topographic maps

- Less than 100' wide
- Less than 200' wide
- Less than 300' wide

Channel, showing direction of flow; dashed where approximate, queried where uncertain.

- ac — Abandoned channel deposits
- Qil — Intemittent lake, circa 1910
- Marsh, circa 1910
- W — Water, circa 1910

Geologic contacts and map unit symbols

Qa — See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

- Group A: soils with high infiltration rate when thoroughly wet.
- Group B: soils with moderate infiltration rate when thoroughly wet.
- Group C: soils with slow infiltration rate when thoroughly wet.
- Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

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Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

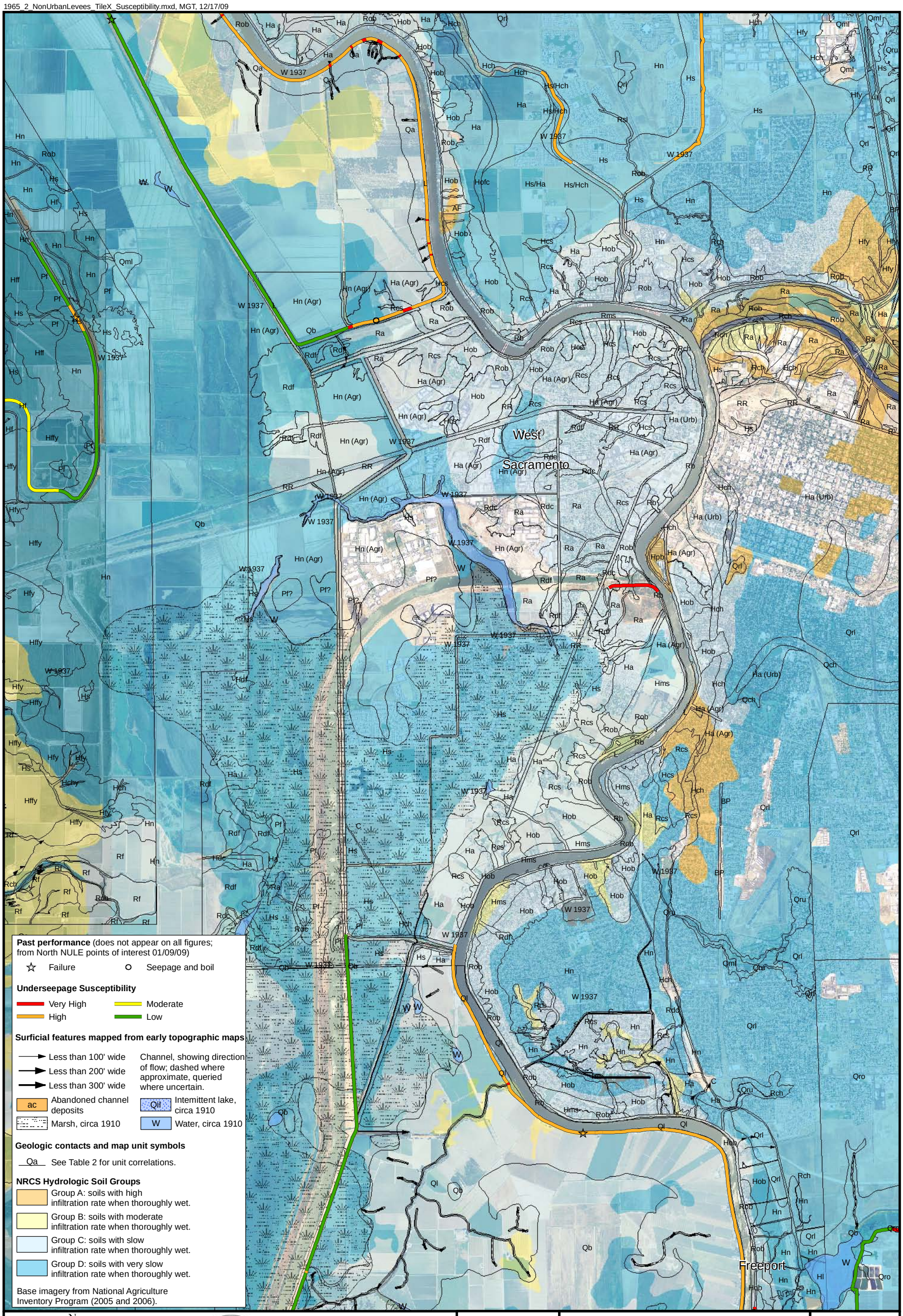
URS in association with: WLA William Lettis & Associates, Inc.

Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 22

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure

○ Seepage and boil

Underseepage Susceptibility

- Very High
- High
- Moderate
- Low

Surficial features mapped from early topographic maps

- Less than 100' wide
- Less than 200' wide
- Less than 300' wide

Channel, showing direction of flow; dashed where approximate, queried where uncertain.

- ac — Abandoned channel deposits
- Qlf — Intermittent lake, circa 1910
- Marsh, circa 1910
- W — Water, circa 1910

Geologic contacts and map unit symbols

Qa — See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

- Group A: soils with high infiltration rate when thoroughly wet.
- Group B: soils with moderate infiltration rate when thoroughly wet.
- Group C: soils with slow infiltration rate when thoroughly wet.
- Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 23

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

Very High
High
Moderate
Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide
Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac — Abandoned channel deposits
Qil — Intemittent lake, circa 1910
Marsh, circa 1910
W — Water, circa 1910

Geologic contacts and map unit symbols

Qa — See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.
Group B: soils with moderate infiltration rate when thoroughly wet.
Group C: soils with slow infiltration rate when thoroughly wet.
Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

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Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

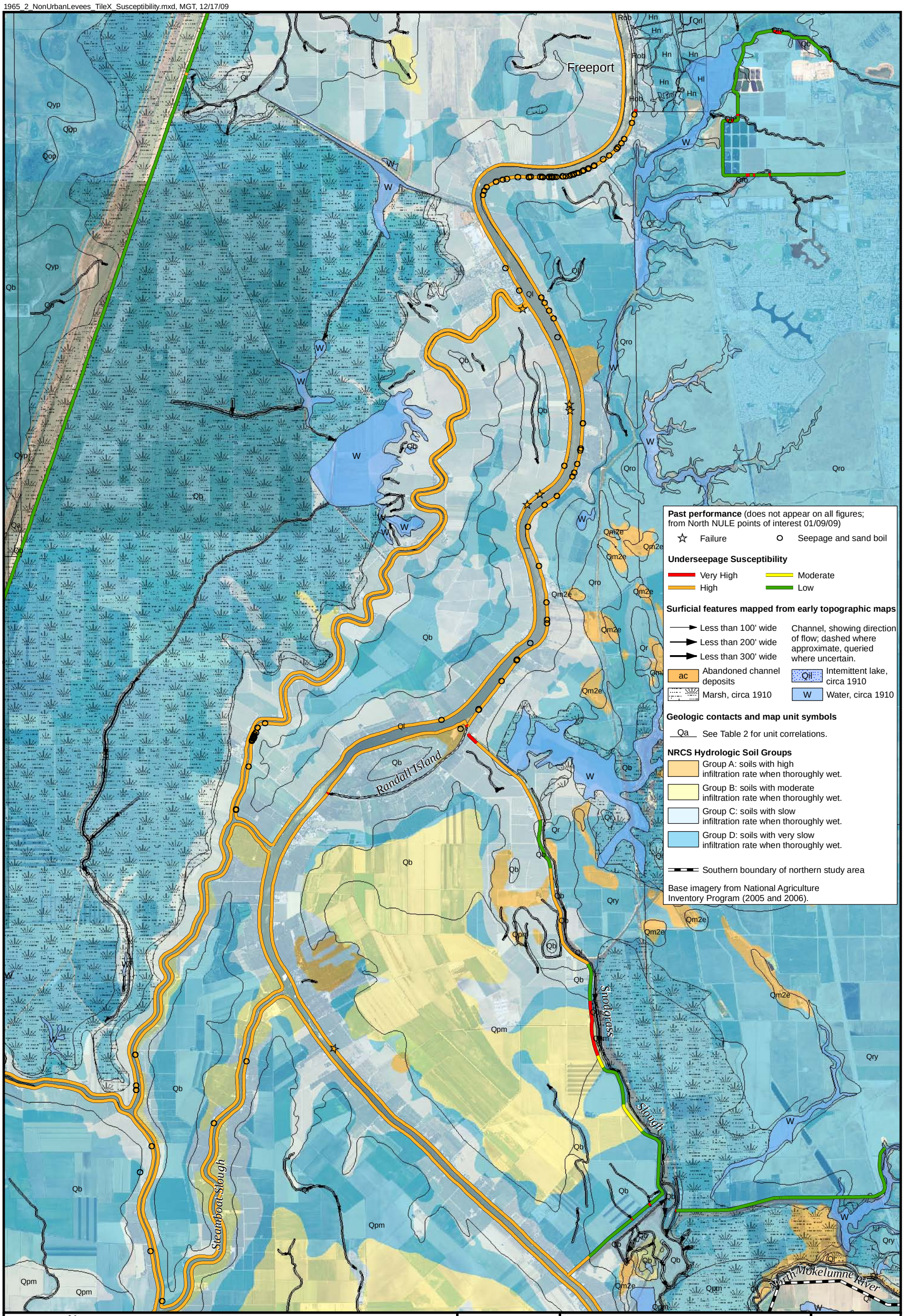
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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 24

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 25

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and sand boil

Underseepage Susceptibility

Very High
High
Moderate
Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide
Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac Abandoned channel deposits
Qil Intemittent lake, circa 1910
Marsh, circa 1910
W Water, circa 1910

Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.
Group B: soils with moderate infiltration rate when thoroughly wet.
Group C: soils with slow infiltration rate when thoroughly wet.
Group D: soils with very slow infiltration rate when thoroughly wet.

Southern boundary of northern study area

Base imagery from National Agriculture Inventory Program (2005 and 2006).

Rio Vista

Steamboat-Slou

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Division of Flood Management
Levee Evaluations Branch

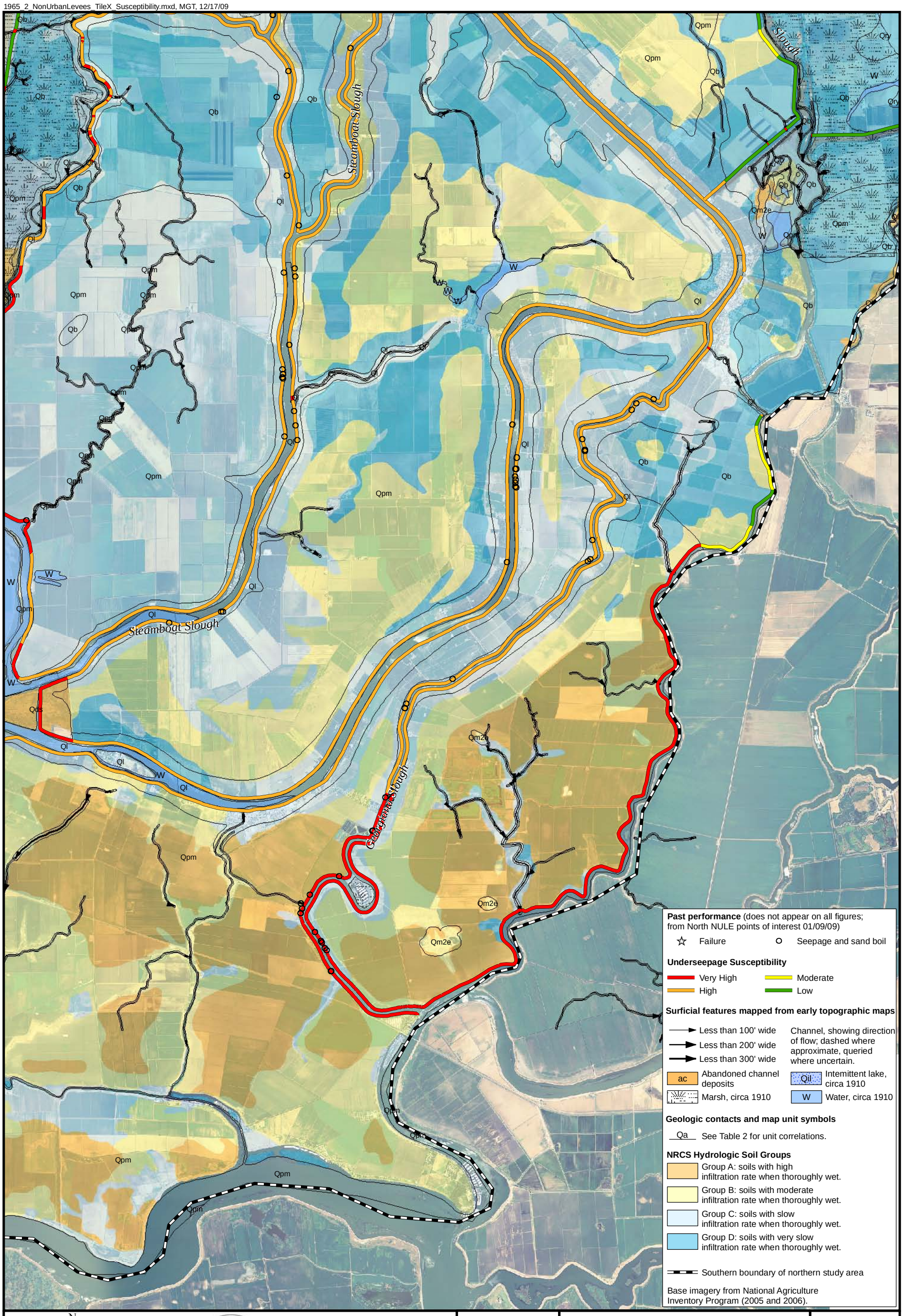
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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 26

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



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Levee Evaluations Branch

URS

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WLA

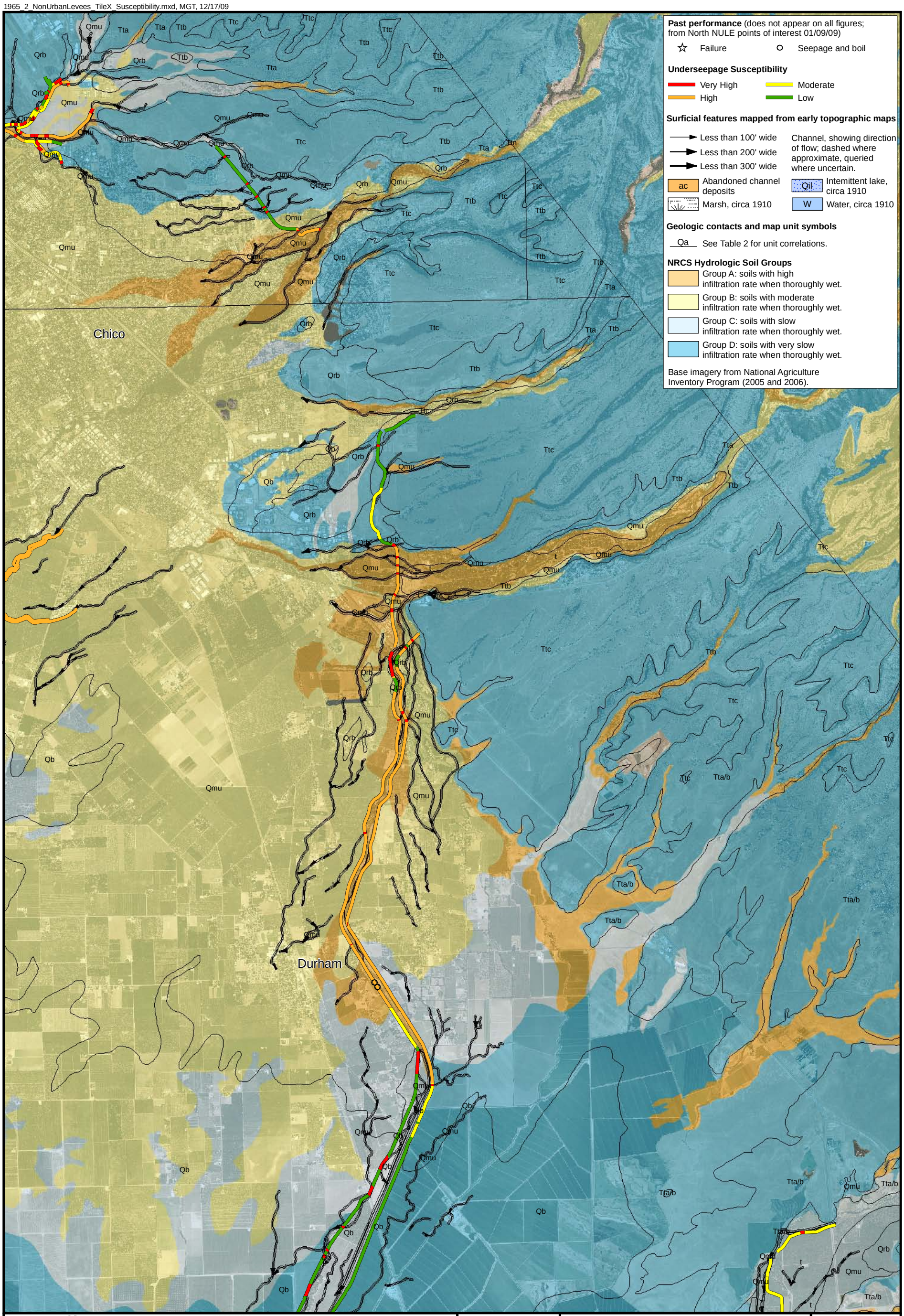
William Lettis & Associates, Inc.

Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 27

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

- Very High
- High
- Moderate
- Low

Surficial features mapped from early topographic maps

- Less than 100' wide
- Less than 200' wide
- Less than 300' wide

Channel, showing direction of flow; dashed where approximate, queried where uncertain.

- ac — Abandoned channel deposits
- Qil — Intermittent lake, circa 1910
- Marsh, circa 1910
- W — Water, circa 1910

Geologic contacts and map unit symbols

Qa — See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

- Group A: soils with high infiltration rate when thoroughly wet.
- Group B: soils with moderate infiltration rate when thoroughly wet.
- Group C: soils with slow infiltration rate when thoroughly wet.
- Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

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Department of Water Resources
Division of Flood Management
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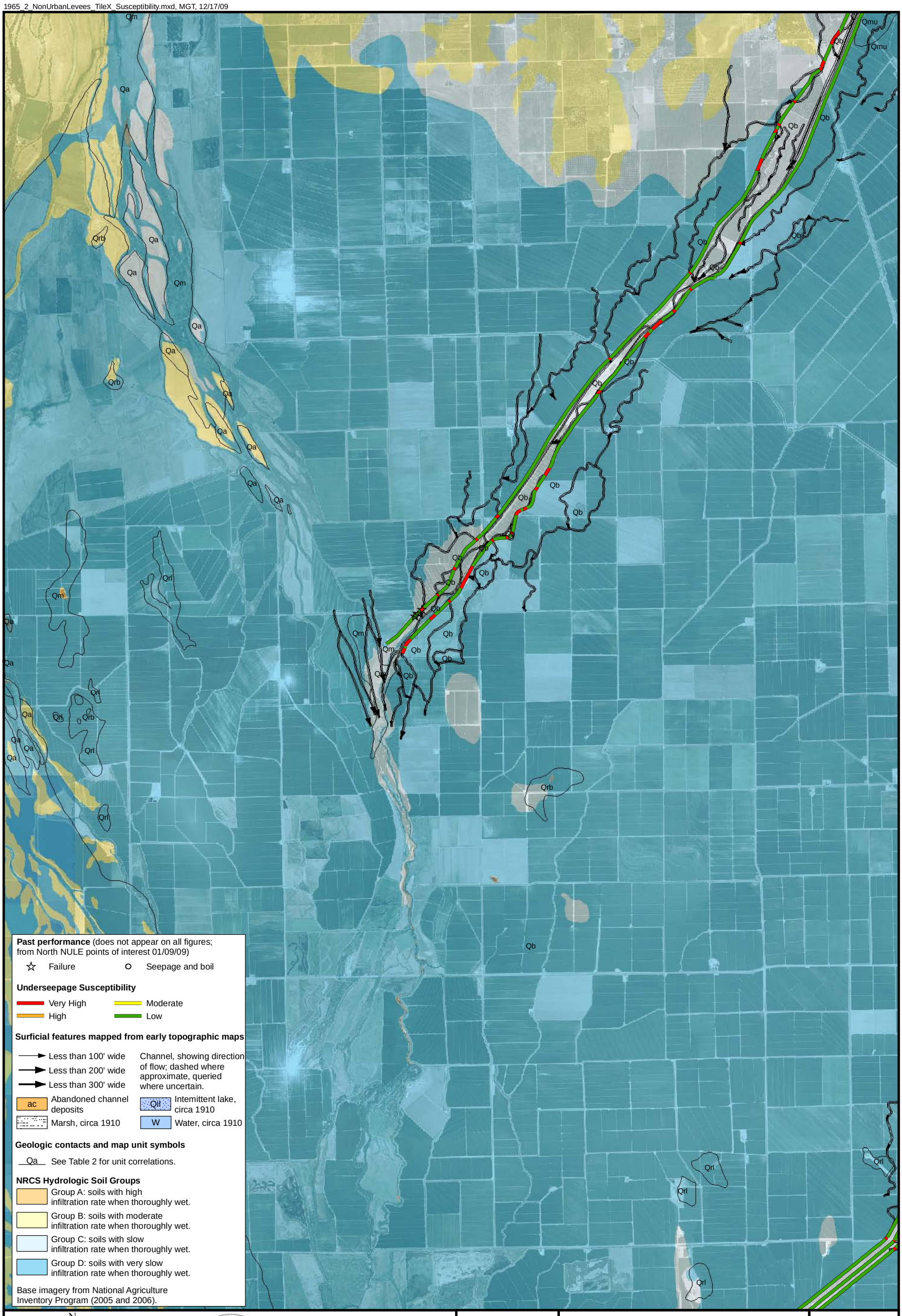
URS in association with: WLA William Lettis & Associates, Inc.

Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 28

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09


Qm
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Qa
Qa
Qm
Qa
Qa
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Qa
Qa
Qa
Qa
Qb
Qmu
Qmu
Qb
Qb
Qb

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Richvale

Biggs

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure

○ Seepage and boil

Underseepage Susceptibility

- Very High
- High
- Moderate
- Low

Surficial features mapped from early topographic maps

- Less than 100' wide
- Less than 200' wide
- Less than 300' wide

Channel, showing direction of flow; dashed where approximate, queried where uncertain.

- ac — Abandoned channel deposits
- Qil — Intermittent lake, circa 1910
- Marsh, circa 1910
- W — Water, circa 1910

Geologic contacts and map unit symbols

Qa — See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

- Group A: soils with high infiltration rate when thoroughly wet.
- Group B: soils with moderate infiltration rate when thoroughly wet.
- Group C: soils with slow infiltration rate when thoroughly wet.
- Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

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Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

URS

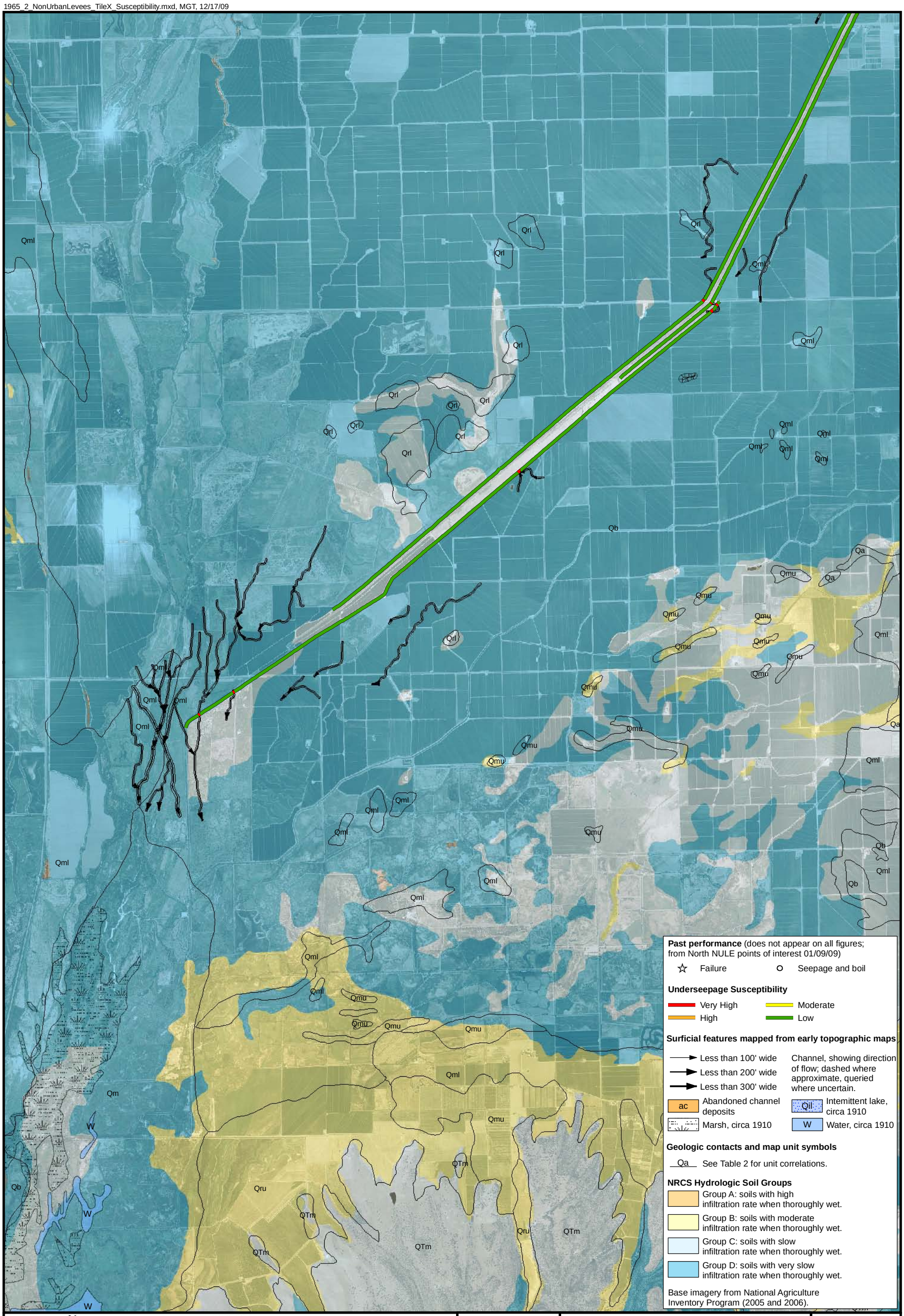
in association with: WLA William Lettis & Associates, Inc.

Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 30

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09



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Levee Evaluations Branch

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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 31

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

- Very High
- High
- Moderate
- Low

Surficial features mapped from early topographic maps

- Less than 100' wide
- Less than 200' wide
- Less than 300' wide

Channel, showing direction of flow; dashed where approximate, queried where uncertain.

- ac — Abandoned channel deposits
- Qit — Intermittent lake, circa 1910
- Marsh, circa 1910
- W — Water, circa 1910

Geologic contacts and map unit symbols

Qa — See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

- Group A: soils with high infiltration rate when thoroughly wet.
- Group B: soils with moderate infiltration rate when thoroughly wet.
- Group C: soils with slow infiltration rate when thoroughly wet.
- Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 32

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

Very High Moderate
High Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide
Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac Abandoned channel deposits
Qil Intermittent lake, circa 1910
Marsh, circa 1910
W Water, circa 1910

Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.
Group B: soils with moderate infiltration rate when thoroughly wet.
Group C: soils with slow infiltration rate when thoroughly wet.
Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

Wheatland

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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 33

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

Very High
High
Moderate
Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide
Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac Abandoned channel deposits
Qil Intemittent lake, circa 1910
Marsh, circa 1910
W Water, circa 1910

Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.
Group B: soils with moderate infiltration rate when thoroughly wet.
Group C: soils with slow infiltration rate when thoroughly wet.
Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

Nicolaus

Nelson Slough

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Levee Evaluations Branch

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Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 34

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

Very High Moderate
High Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide
Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac Abandoned channel deposits
Qil Intemittent lake, circa 1910
Marsh, circa 1910
W Water, circa 1910

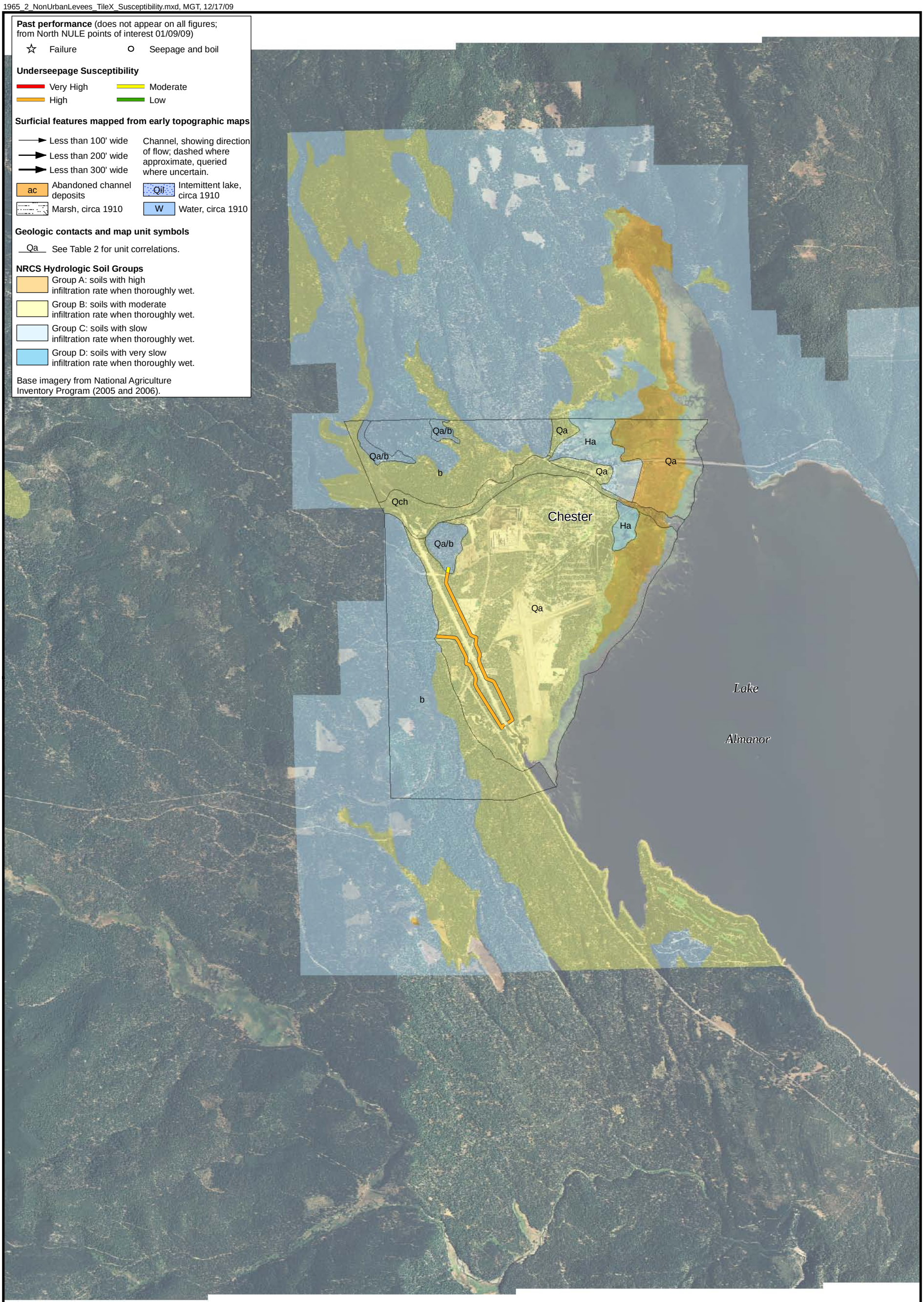
Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.
Group B: soils with moderate infiltration rate when thoroughly wet.
Group C: soils with slow infiltration rate when thoroughly wet.
Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).



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Department of Water Resources
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Levee Evaluations Branch

URS
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William Lettis & Associates, Inc.

Underseepage Susceptibility Map

North Non-Urban Levee Evaluations

Figure 35

1965_2_NonUrbanLevees_TileX_Susceptibility.mxd, MGT, 12/17/09

Past performance (does not appear on all figures; from North NULE points of interest 01/09/09)

☆ Failure ○ Seepage and boil

Underseepage Susceptibility

Very High Moderate
High Low

Surficial features mapped from early topographic maps

Less than 100' wide
Less than 200' wide
Less than 300' wide
Channel, showing direction of flow; dashed where approximate, queried where uncertain.

ac Abandoned channel deposits
Qil Intemittent lake, circa 1910
Marsh, circa 1910
W Water, circa 1910

Geologic contacts and map unit symbols

Qa See Table 2 for unit correlations.

NRCS Hydrologic Soil Groups

Group A: soils with high infiltration rate when thoroughly wet.
Group B: soils with moderate infiltration rate when thoroughly wet.
Group C: soils with slow infiltration rate when thoroughly wet.
Group D: soils with very slow infiltration rate when thoroughly wet.

Base imagery from National Agriculture Inventory Program (2005 and 2006).

Qal
Qla
br
Hob
Qt
Upper Lake
Tule Lake
Hs 1916
Rla 1916
Rsl
Clear Lake

N
0 0.5 1
mi
1:62,500

Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

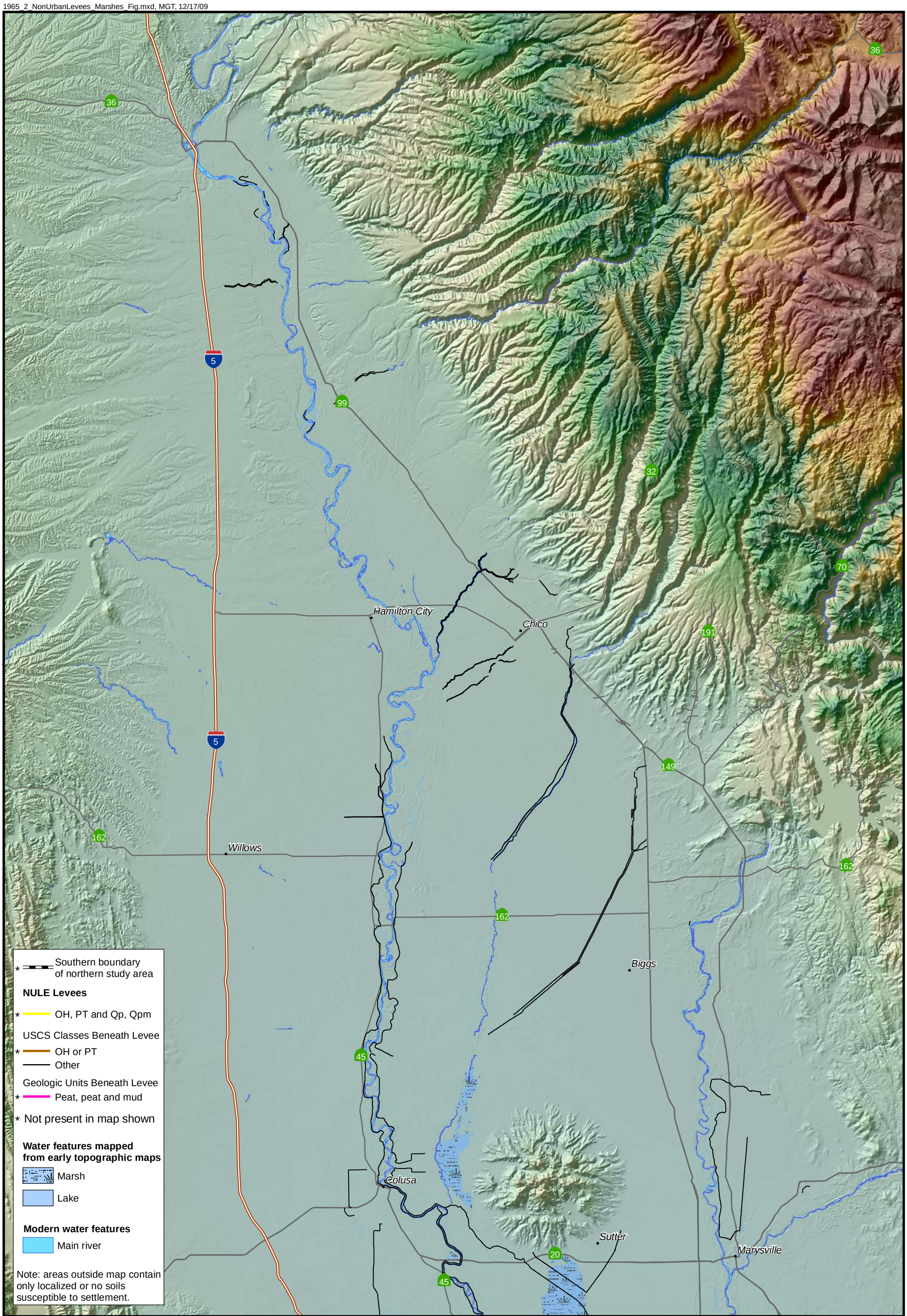
URS
in association with:
WLA
William Lettis & Associates, Inc.

Underseepage Susceptibility Map

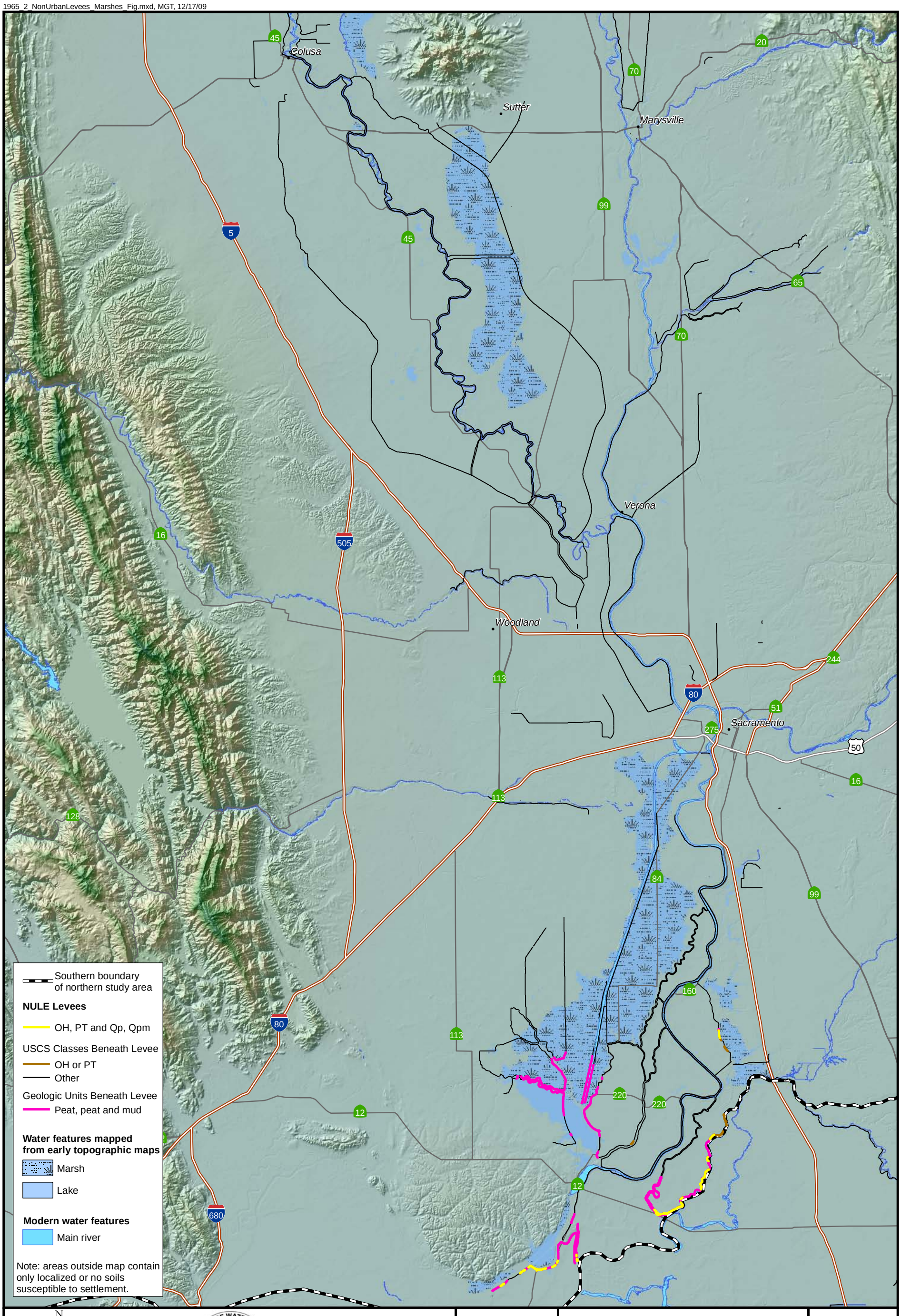
North Non-Urban Levee Evaluations

Figure 36

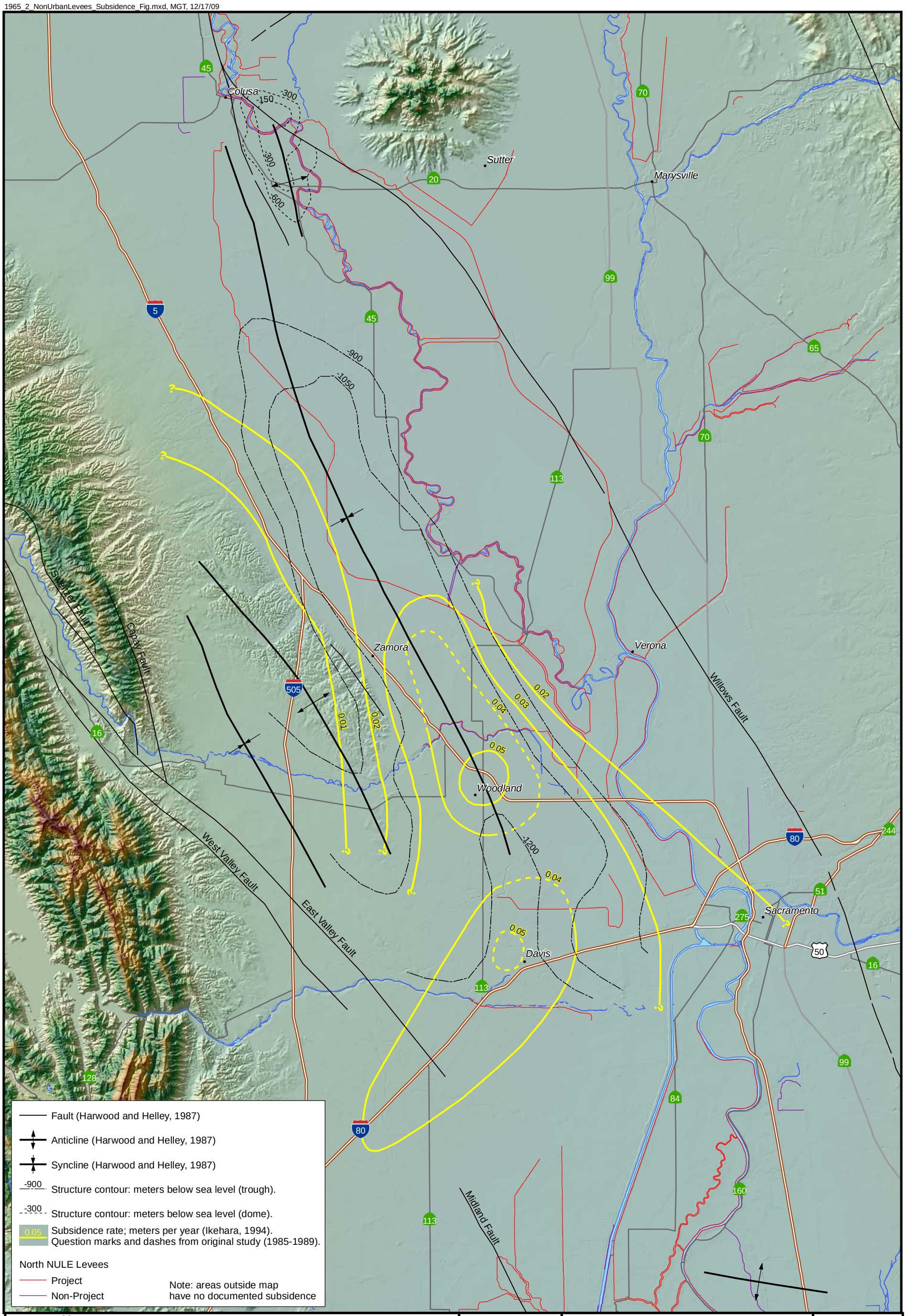
1965_2_NonUrbanLevees_Marshes_Fig.mxd, MGT, 12/17/09



1965_2_NonUrbanLevees_Marshes_Fig.mxd, MGT, 12/17/09



1965_2_NonUrbanLevees_Subsidence_Fig.mxd, MGT, 12/17/09



Department of Water Resources
Division of Flood Management
Levee Evaluations Branch

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Map of Subsidence with Structural Geologic Features

North Non-Urban Levee Evaluations

Figure 38

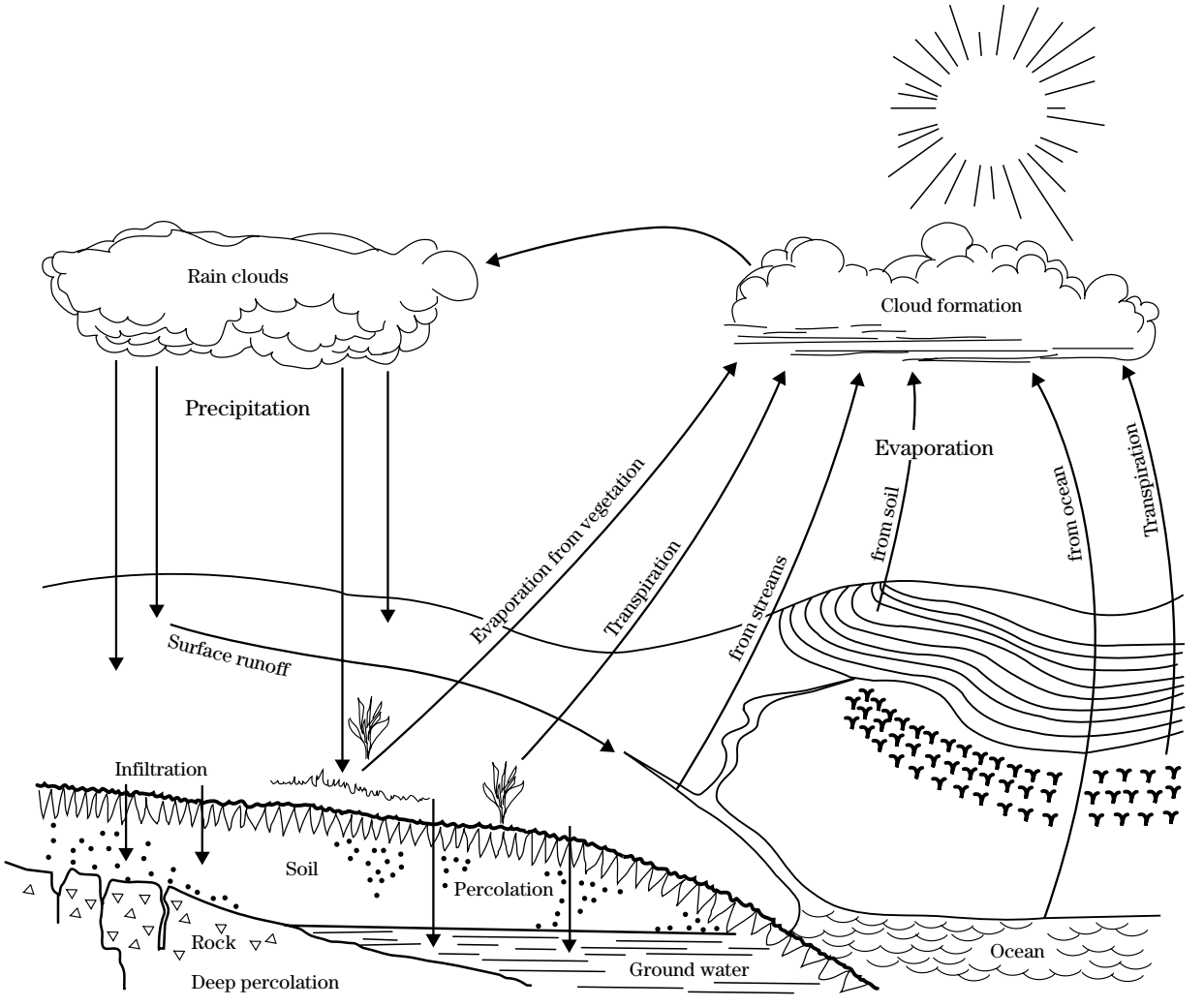
APPENDIX A

United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

Part 630 Hydrology
National Engineering Handbook

Chapter 7 Hydrologic Soil Groups



(210–VI–NEH, May 2007)

Issued May 2007

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(210–VI–NEH, 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 re-defined, 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

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630.0701	**Hydrologic soil groups**	**7–1**
630.0702	**Disturbed soils**	**7–5**
630.0703	**References**	**7–5**

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Chapter 7 Hydrologic Soil Groups

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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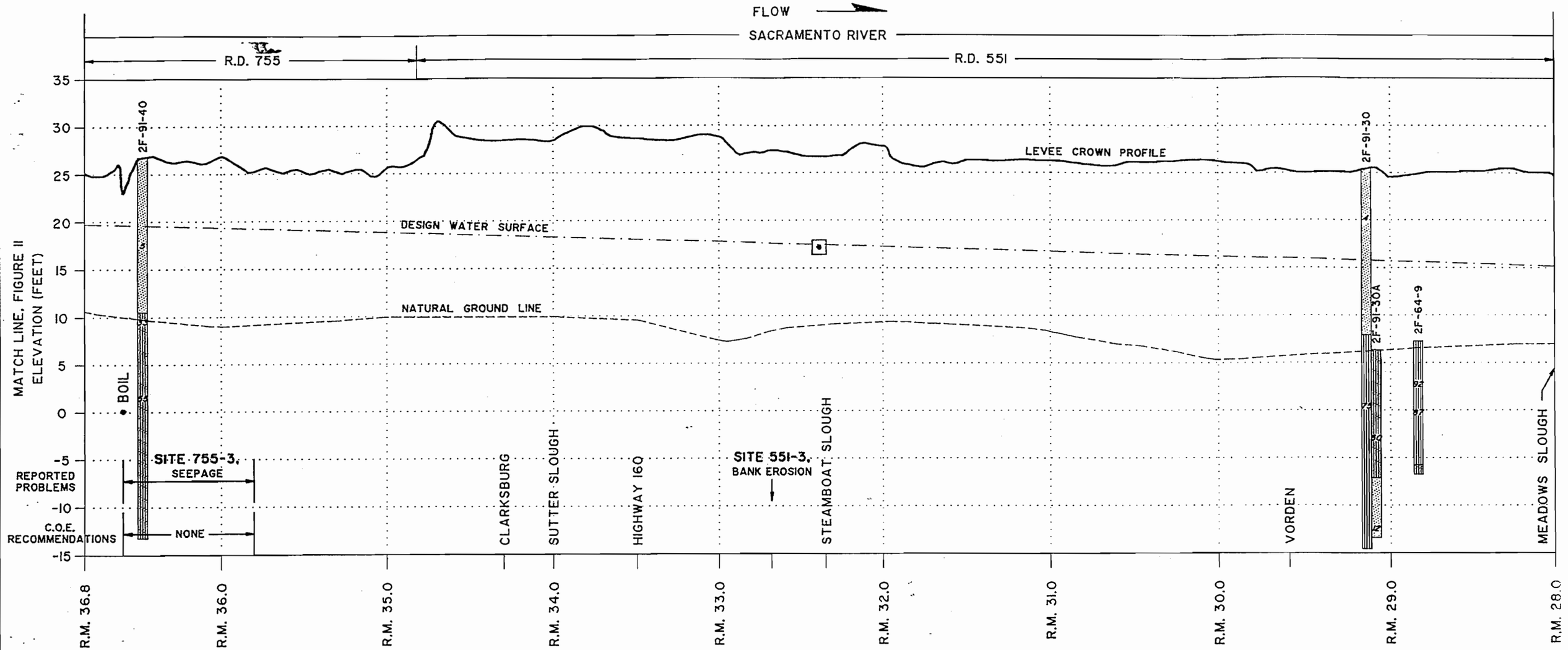
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Appendix D

Historic Boring Logs

www.geiconsultants.com

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



SCALE: 1" = 3000'

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
- 1986 BOIL LOCATION
- 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
SACRAMENTO RIVER
LEFT BANK - R.M. 28.0 TO 36.8

SACRAMENTO DISTRICT, CORPS OF ENGINEERS

PREPARED BY: D. RICKETTS
DRAWN BY: R. IWASA
FEBRUARY 1993

FIGURE 12



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 175 lbs.
DRILLING DATES:
1" HOLES — JAN. 31, 1958 TO MAY 14, 1958
2" HOLES — FEB. 11, 1958 TO APRIL 15, 1958

LEGEND

- M 116 DRY (WET) 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 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

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SALINITY CONTROL BARRIER INVESTIGATION

SUBSURFACE EXPLORATION ON PIERSON TRACT
PLAN AND PROFILE OF BORINGS

SCALE AS SHOWN

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF DESIGN AND CONSTRUCTION
PROJECT GEOLOGY BRANCH

DRILLING AND SAMPLING LOG

DELTA FACILITIES

PERIPHERAL CANAL

HOLE NO. PCA 2-1

ELEV.

FEATURE Hood to Mokelumne River — DEPTH 49.0'

LOCATION — COUNTY Sacramento

LOGGED BY G. Chase - M. Oropeza — DATE DRILLED 9/1-2/1966 — WATER LEVEL 9-2-66 6.6'

DRILLING CO. C. Corder — DRILLER T. Johnson - J. Willingham — DRILL RIG Failing 1500

Hole #1 - Cored with Pitcher core barrel, 3" I.D.
Drove standard penetrometer using 140# hammer with 30" drop.
Hole #2 - Pushed or drove DWR 2-1/2" I.D. sampler
Drilled with 4-5/8" drag bit.
1/ - Sample number and field density (PCF)
* Liner samples for U.S. Bureau of Reclamation - Denver office.

ELEV. (DEPTH)	CLASS.	DESCRIPTION Field Identification	1/ SAMPLE NUMBER #1	#2	MODE #2	#1	REMARKS #1	#2
(0.0)	ML-CL	0.0-2.0 SILTY CLAY: Dry; slow to very slow dilatancy; slight plasticity; dark olive-gray.	PB-1		RD	SD	Augered from 0.0-1.0'	
							Pushed 1.0-3.5' Recovered 76%	
		2.0-47.5 SANDY SILT: Dry; quick dilatancy; no plasticity; loose (dry); 30-40% fine-grained sand; dark yellowish-brown.		L-1B 115.2#		P		Pushed 2.0-4.0'
				L-1C* 113.1#	P		Pushed 3.5-6.0'	
				L-1D 102.6#				Pushed 4.0-5.2' 4.0-5.2'
(4.0)	ML			L-2D 111.1#	P	P		
							Drove 6.0-7.5' 4/.5 5/.5 5/.5	
		7.5' Core moist.			RD	DR	No water at 7.5'.	
(8.0)			PB-2	L-3B 119.7#			Cored 7.5-10.0' Recovered 52%	Pushed 8.0-10.0'
				L-3C 123.1#	P	RD		
				L-3D* 126.7#				
		10.0-10.6' Silty sand; 30% nonplastic fines.					Cored 10.0-12.5' Recovered 80%	Pushed 10.0-11.0'
	SM			L-4D 122.1#	P			
	ML				RD	RD		
(12.0)								

DRILLING AND SAMPLING LOG

FEATURE Hood to Mokelumne River HOLE NO. PCA 2-1

ELEV. (DEPTH)	CLASS.	DESCRIPTION Field Identification	SAMPLE NUMBER #1	SAMPLE NUMBER #2	MODE #2	MODE #1	REMARKS #1	REMARKS #2
(12.0)		2.0-47.5 SANDY SILT: Contd.	PB-2		RD	RD	Drove 12.5-14.0' 3/.5 3/.5 4/.5	
		14.0-20.5' Scattered roots				DR	Cored 14.0-16.5' Recovered 100%	
		14.0' Dark greenish-gray			RD	RD		
(16.0)				L-5B 124.4#				Pushed 16.0-18.0'
				L-5C 122.1#	P		Cored 16.5-19.0' Recovered 92%	
				L-5D* 123.6#		RD		
					P			Pushed 18.0-19.0' No recovery
	ML		PB-3				Drove 19.0-20.5' 1/.5 1.5/.5 1/.5	
(20.0)						DR	Cored 20.5-23.0' Recovered 96%	
					RD			
						RD		Pushed 22.0-24.0'
				L-6B 125#				
				L-6C 122.1#	P		Cored 23.0-25.5' Recovered 100%	
				L-6D* 122.9#				
(24.0)			PB-4			RD		Pushed 24.0-25.2'
				L-7D 122.1#	P			
			No Core				Drove 25.5-27.0' 1/.5 1.5/.5 3.5/.5	
	ML?					DR	*Settled (No core)	
					RD		Cored 27.0-29.5' Recovered 68%	
(28.0)						RD		
	ML		PB-4					Pushed 29.0-31.0'
				L-8B 126.4#	P		Cored 29.5-32.0' Recovered 80%	
				L-8C 124.4#		RD		

DWR 885 (2)

SHEET 2 OF 4

DRILLING AND SAMPLING LOG

FEATURE Hood to Mokelumne River HOLE NO. FCA 2-1

ELEV. (DEPTH)	CLASS.	DESCRIPTION Field Identification	SAMPLE #1 NUMBER #2	MODE #2 #1	REMARKS #1	REMARKS #2
(30.0)	ML	2.0-47.5 SANDY SILT: Contd.	L-8C L-8D* 124.5#	P		
			PB-4	RD		Pushed 31.0-32.0'
		31.5-32.0 Silty sand; 30% non-plastic fines.	L-9D 128.7#	P		
	SM	32.0-33.5' Fine-grained sand 20%.			Drove 32.0-33.5 1/.5 1/.5 2/.5	
				DR		
					Cored 33.5-36.0' Recovered 80%	
(34.0)				RD		
				RD		
	ML				Cored 36.0-38.5'	
			PB-5			Pushed 37.0-39.0' (No sample)
				HD		
(38.0)				P	Drove 38.5-40.0' .5/.5 .5/.5 1.5/.5	
				RD		
				DR	Cored 40.0-42.5' Recovery 80%	Drove 40.0-42.0' 4/.5 3/.5 2/.5 4/.5
		40.9-41.7' Silty sand; 30-40% nonplastic fines.	L-10B* 126.9#			
	SM	40.9-47.5' Scattered beads of fines (up to 1/2"), possibly clay.	L-10C 128.4#	DR		
			L-10D 124.9#			
(42.0)			PB-6			
					Cored 42.5-45.0' Recovery 96%	Drove 42.0-43.5' 1/.5 1/.5 1/.5 (No sample)
	ML			DR		
				RD		Pushed 44.0-46.0'
		44.5-47.5' Slight plasticity; darker greenish-gray.	L-11C 121.4#	P	Drove 45.0-46.5' 2/.5 3/.5 6/.5	
			No Core			
	ML?		L-11D* 125.6#			
(46.0)				DR	(No core)	Pushed 46.0-48.0'
	ML				Cored 46.5-49.0' Recovered 100%	
			PB-6	P		
			L-12C 123.7#			
		47.5-49.0 CLAY TO SANDY CLAY: Wet; slow dilatancy; medium plasticity; 10-20% fine-grained sand; firm to stiff; dark greenish-gray.	L-12D 124.7#			
	CL		PB-7	RD		

DWR 885 (2)

DRILLING AND SAMPLING LOG

FEATURE Hood to Mokelumne River HOLE NO. HCA 2-1

ELEV. (DEPTH)	CLASS.	DESCRIPTION Field Identification	SAMPLE NUMBER #1	SAMPLE NUMBER #2	MODE #2	MODE #1	REMARKS #1	REMARKS #2
(48.0)	CL	47.5-49.0 CLAY: Contd. Sand decreasing with depth	PB-7			RD	Bottomed Hole #1 at 49.0' Set 50.0' of downspout.	Bottomed Hole #2 at 48.0'. Backfilled hole; site marked by 4 x 4" pole
(49.0)								

DWR 865 (2)

SHEET 4 OF 4

Overwater Boring along Courtland NULE Segment 126

Staten Island Vent Shaft 1

Staten Island Launch Shaft

Lost Slough

Mokelumne River

Existing Ground Surface

Existing Ground Surface

DCR-DH-011
GS Elev. 3.772 ft
Completed 10/29/2009

DCRA-DH-002
GS Elev. 10 ft
Completed 10/24/2010

DCA-DH-003
GS Elev. -4.40 ft
Completed 10/28/2009

DCRA-DH-006
GS Elev. 7.8 ft
Completed 10/28/2010

MAIN TUNNEL

MAIN TUNNEL

MAIN TUNNEL

Mathchline: See Figure 9-4c

Mathchline: See Figure 9-4e

TD Elev. -222.73 ft

TD Elev. -211.50 ft

TD Elev. -204.40 ft

TD Elev. -215.20 ft

ELEVATION, Feet (NAVD 88)

ELEVATION, Feet (NAVD 88)

DISTANCE ALONG ALIGNMENT, thousand feet

NOTES:
1. For definition of Unified Soil Classification System abbreviations, consult ASTM D2487.
2. Consult geotechnical data report for Pipeline/Tunnel Option (draft April 2013) for complete boring logs and subsurface data.

Vertical Scale 40.00 ft/in.

Horizontal Scale 4000.00 ft/in.

Sources: DWR 2009-2012 Geotechnical Data Reports; California Department of Water Resources 2015.

BDCP EIR/EIS (12-17-2013) TM

Figure 9-4d
Geologic Borehole Logs in the Vicinity of Proposed Tunnels

Appendix B

PRESENTATION OF SITE INVESTIGATION RESULTS

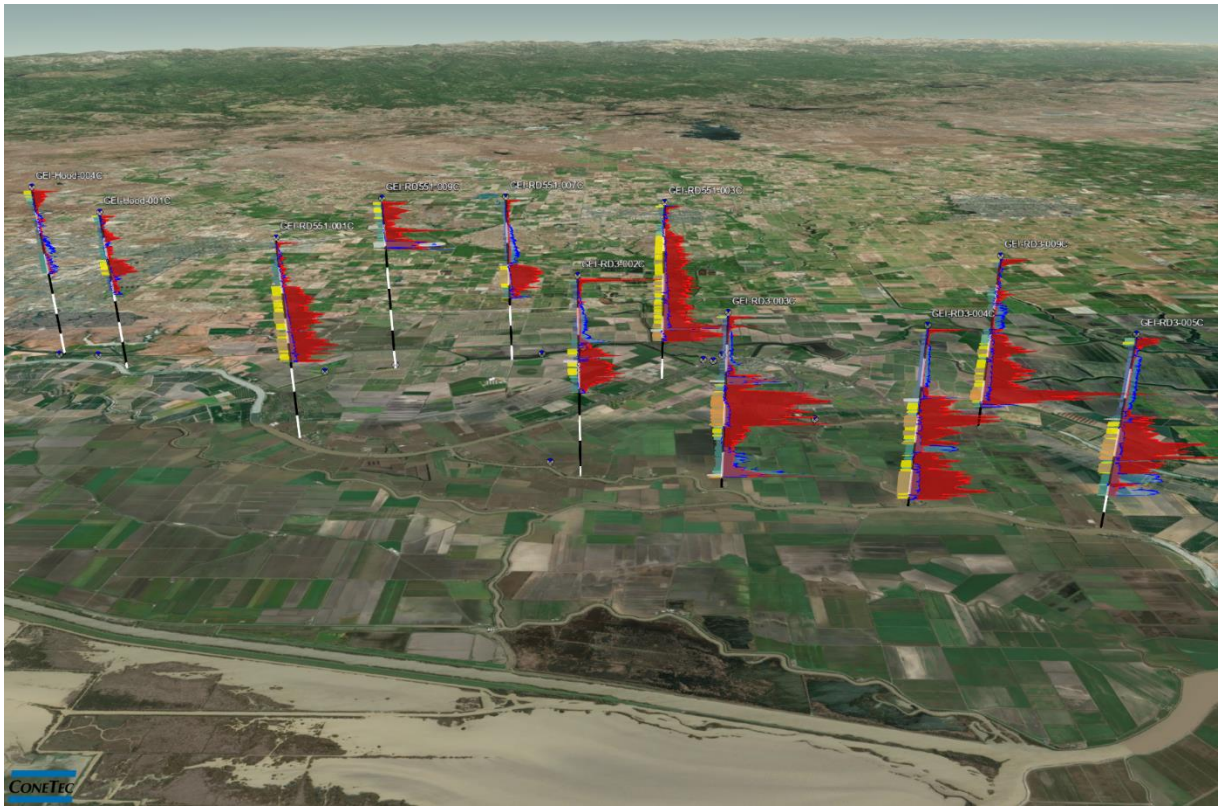
Small Communities

Prepared for:

GEI Consultants

ConeTec Job No: 19-56124

Project Start Date: 19-Aug-2019
Project End Date: 28-Aug-2019
Report Date: 05-Sep-2019



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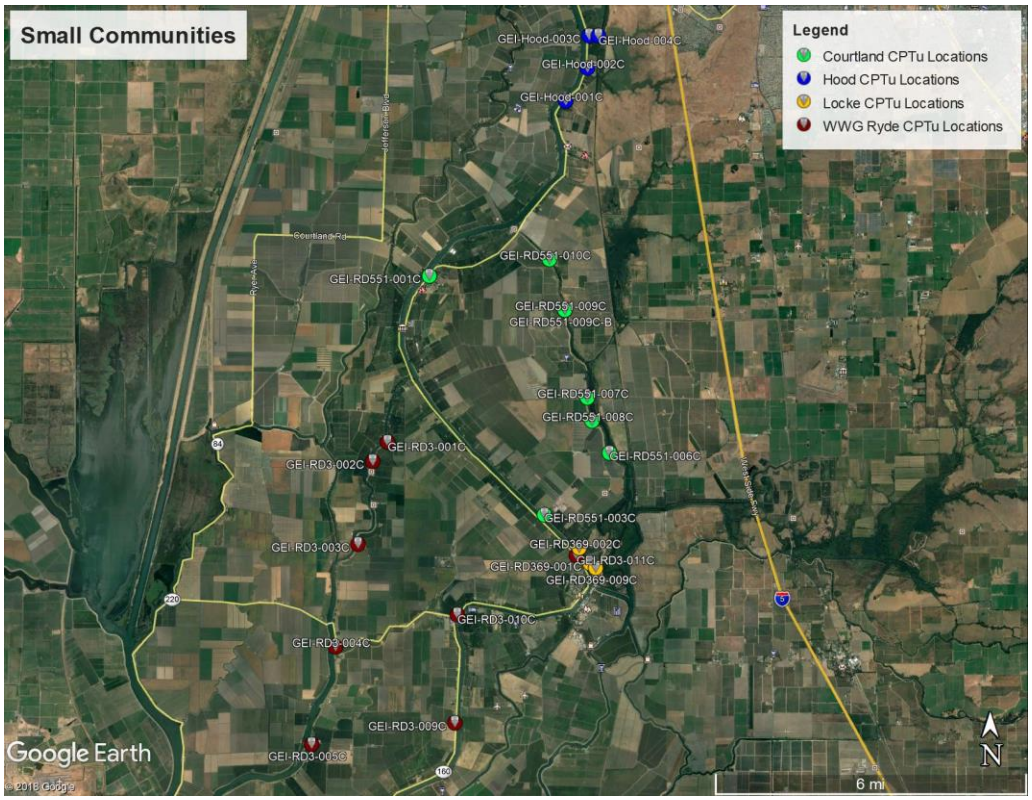
Introduction

The enclosed report presents the results of the site investigation program conducted by ConeTec Inc. for GEI Consultants of Oakland, CA. The program consisted of cone penetration testing (CPTu) at twenty-two (22) locations, with one (1) re-push. Soil samples were collected at all locations with the CPT piston sampler.

Project Information

Project	
Client	GEI Consultants
Project	Small Communities
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)
391:T1500F15U500	391	15	225	1500	15	500
499:T1500F15U500	499	15	225	1500	15	1000
The CPT Summary shows which cone was used on each sounding.						

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	Standard plots with expanded scales, 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". 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.

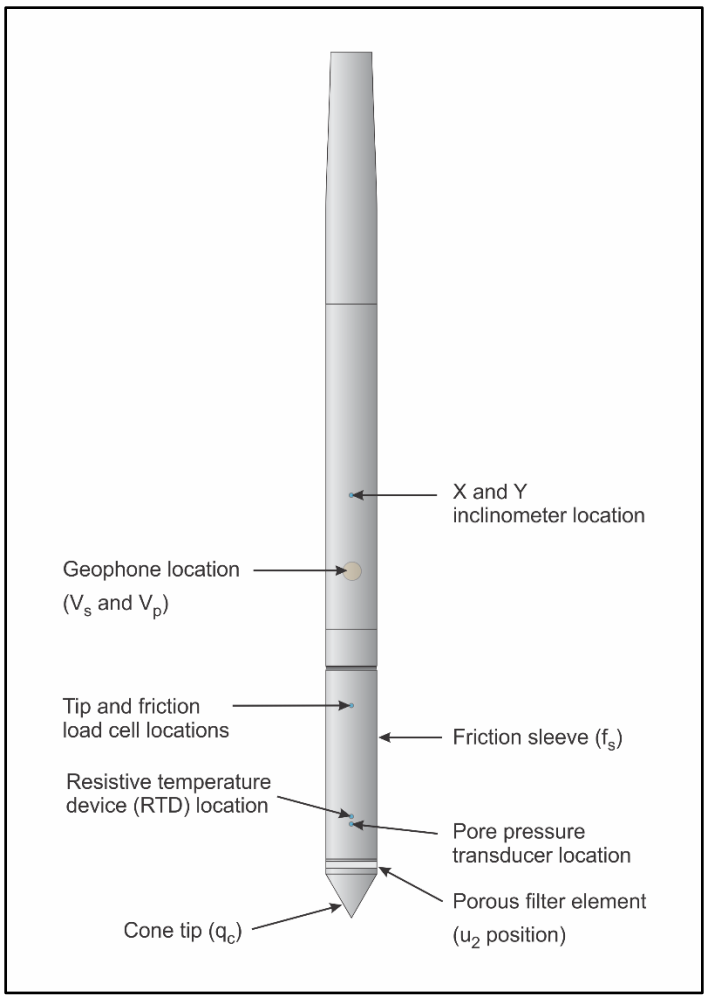


Figure CPTu. Piezocone Penetrometer (15 cm^2)

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 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 behaviour type based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behaviour 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):

$$q_t = q_c + (1\text{-}a) \bullet u_2$$

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).

References

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.

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., 2009, “Interpretation of cone penetration tests – a unified approach”, Canadian Geotechnical Journal, Volume 46: 1337-1355. DOI: 10.1139/T09-065.

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).

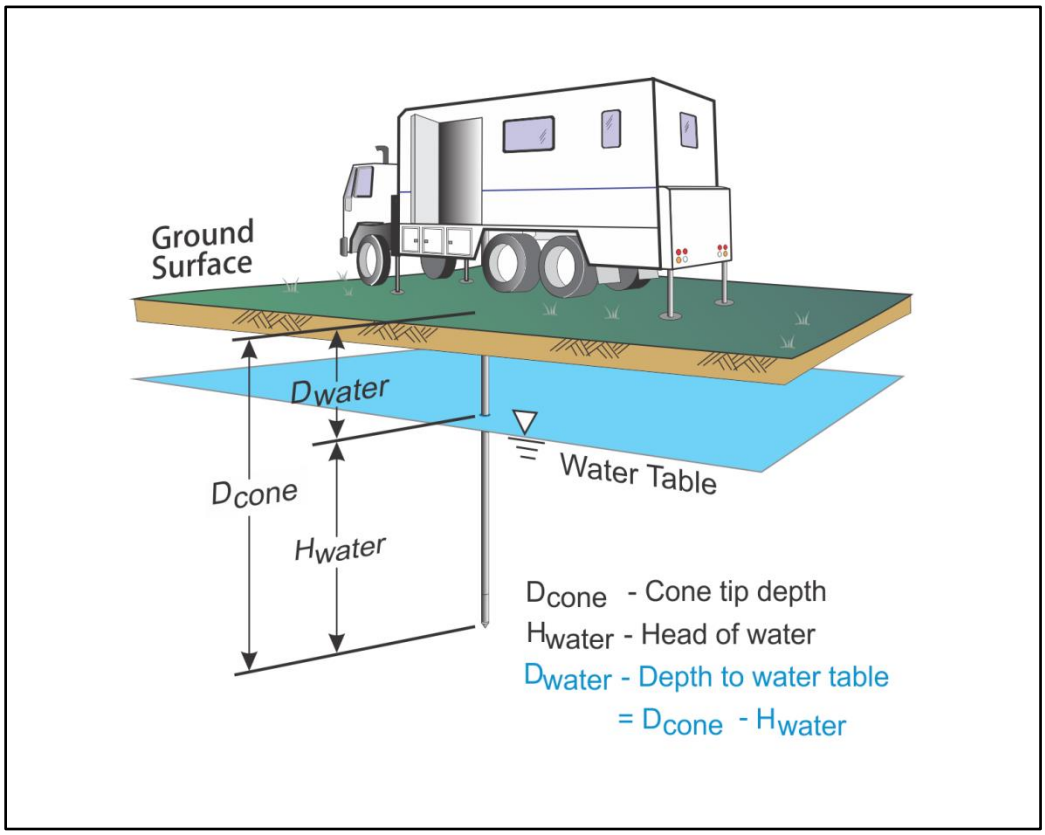


Figure PPD-1. Pore pressure dissipation test setup

Pore pressure dissipation data can be interpreted to provide estimates of ground water conditions, permeability, consolidation characteristics and soil behaviour.

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.

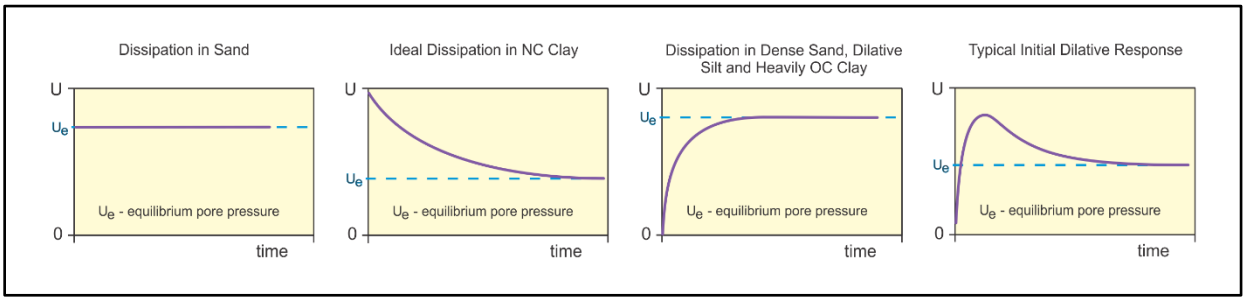


Figure PPD-2. Pore pressure dissipation curve examples

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.

References

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.

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.

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.

The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Standard Cone Penetration Test Plots with Expanded Range
- 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
Start Date:	19-Aug-2019
End Date:	28-Aug-2019

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-RD551-001C	19-56124_CP-RD551-001C	21-Aug-2019	499:T1500F15U1000	6.3	77.84	4243731	625142	25	
GEI-RD551-003C	19-56124_CP-RD551-002C	28-Aug-2019	391:T1500F15U500	4.9	101.05	4236431	628823	25	
GEI-RD551-006C	19-56124_CP-RD551-006C	20-Aug-2019	499:T1500F15U1000	32.0	101.13	4238370	630808	25	
GEI-RD551-007C	19-56124_CP-RD551-007C	20-Aug-2019	499:T1500F15U1000	28.4	75.62	4240059	630097	21	
GEI-RD551-008C	19-56124_CP-RD551-008C	20-Aug-2019	499:T1500F15U1000	32.7	101.30	4239347	630254	21	
GEI-RD551-009C	19-56124_CP-RD551-009C	19-Aug-2019	391:T1500F15U500	34.5	35.52	4242747	629356	24	6, 7
GEI-RD551-009C-B	19-56124_CP-RD551-009C-B	19-Aug-2019	499:T1500F15U1000	34.5	71.36	4242747	629356	24	

Job No:	19-56124
Client:	GEI Consultants
Project:	Small Communities
Start Date:	19-Aug-2019
End Date:	28-Aug-2019

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-RD551-010C	19-56124_CP-RD551-010C	19-Aug-2019	391:T1500F15U500	32.1	75.70	4244298	628854	31	

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.
4. The assumed phreatic surface was based on the pore pressure dissipation test at GEI-Hood-002C.
5. The assumed phreatic surface was based on the pore pressure dissipation test at GEI-RD3-009C.
6. The assumed phreatic surface was based on the pore pressure dissipation test at GEI-RD551-010C.
7. Maxed out the pore pressure sensor on the cone. Switched to high pore pressure cone offset and re-pushed location.

Job No:	19-56124
Client:	GEI Consultants
Project:	Small Communities
Start Date:	21-Oct-2019
End Date:	01-Nov-2019

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-RD551-002C	19-56124_CP-RD551-002C	31-Oct-2019	448:T1500F15U500	9.6	75.05	4240067	625213	16	

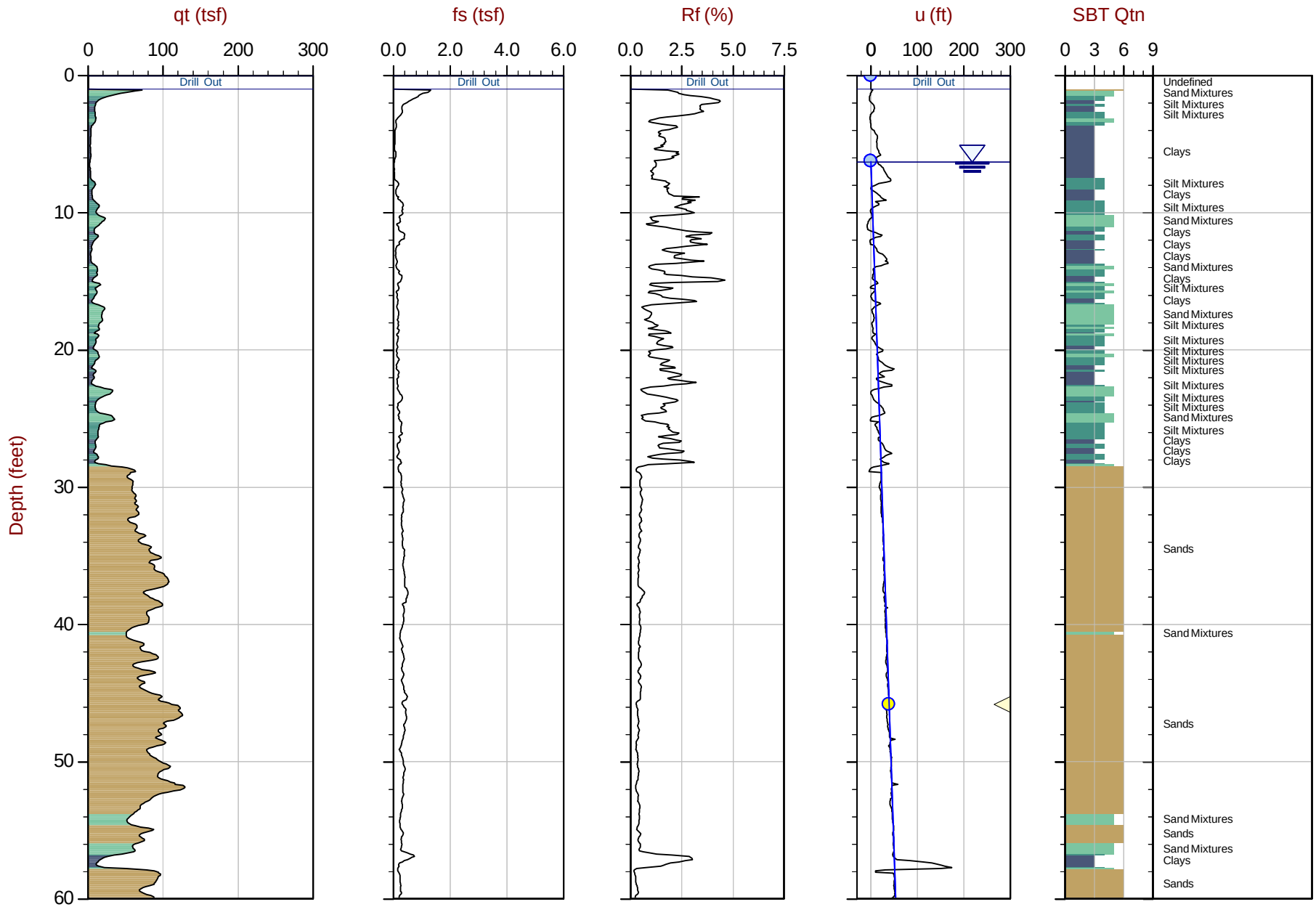
1. The assumed phreatic surface was based on the results of the shallowest pore pressure dissipation test performed within the sounding. Hydrostatic conditions were assumed for the calculated parameters.
2. The coordinates were acquired using consumer grade GPS equipment, datum: WGS 1984 / UTM Zone 10 North.
3. Elevations are refrenced to the ground surface and are derived from Google Earth Elevation for the recorded coordinates.
4. The assumed phreatic surface was based on dynamic pore pressure and the pore pressure dissipation tests at nearby soundings.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-21 08:07
Site: Courtland

Sounding: GEI-RD551-001C
Cone: 499:T1500F15U1K



Max Depth: 23.725 m / 77.84 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-001C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4243731m E: 625142m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

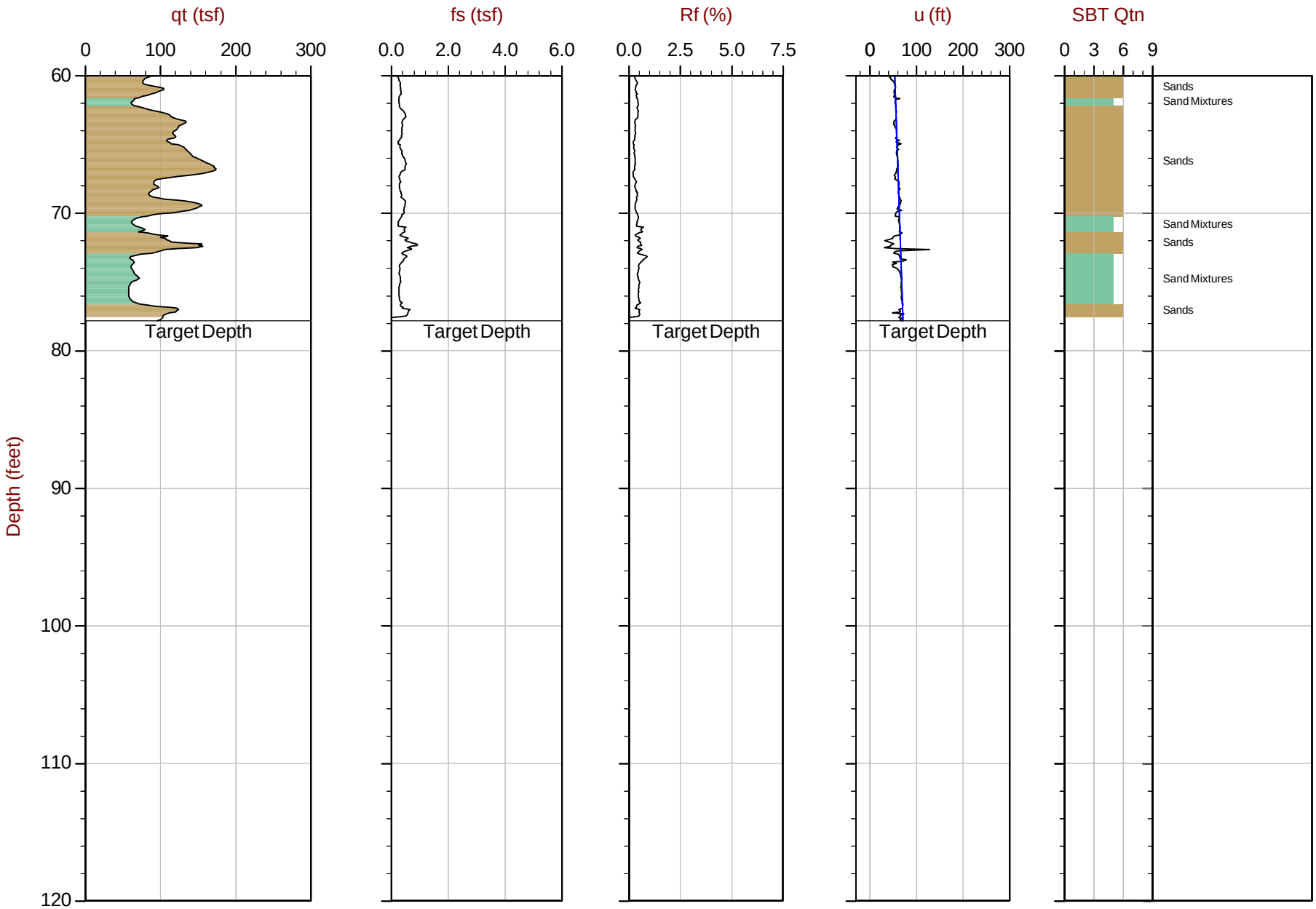
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-21 08:07
Site: Courtland

Sounding: GEI-RD551-001C
Cone: 499:T1500F15U1K



Max Depth: 23.725 m / 77.84 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-001C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4243731m E: 625142m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

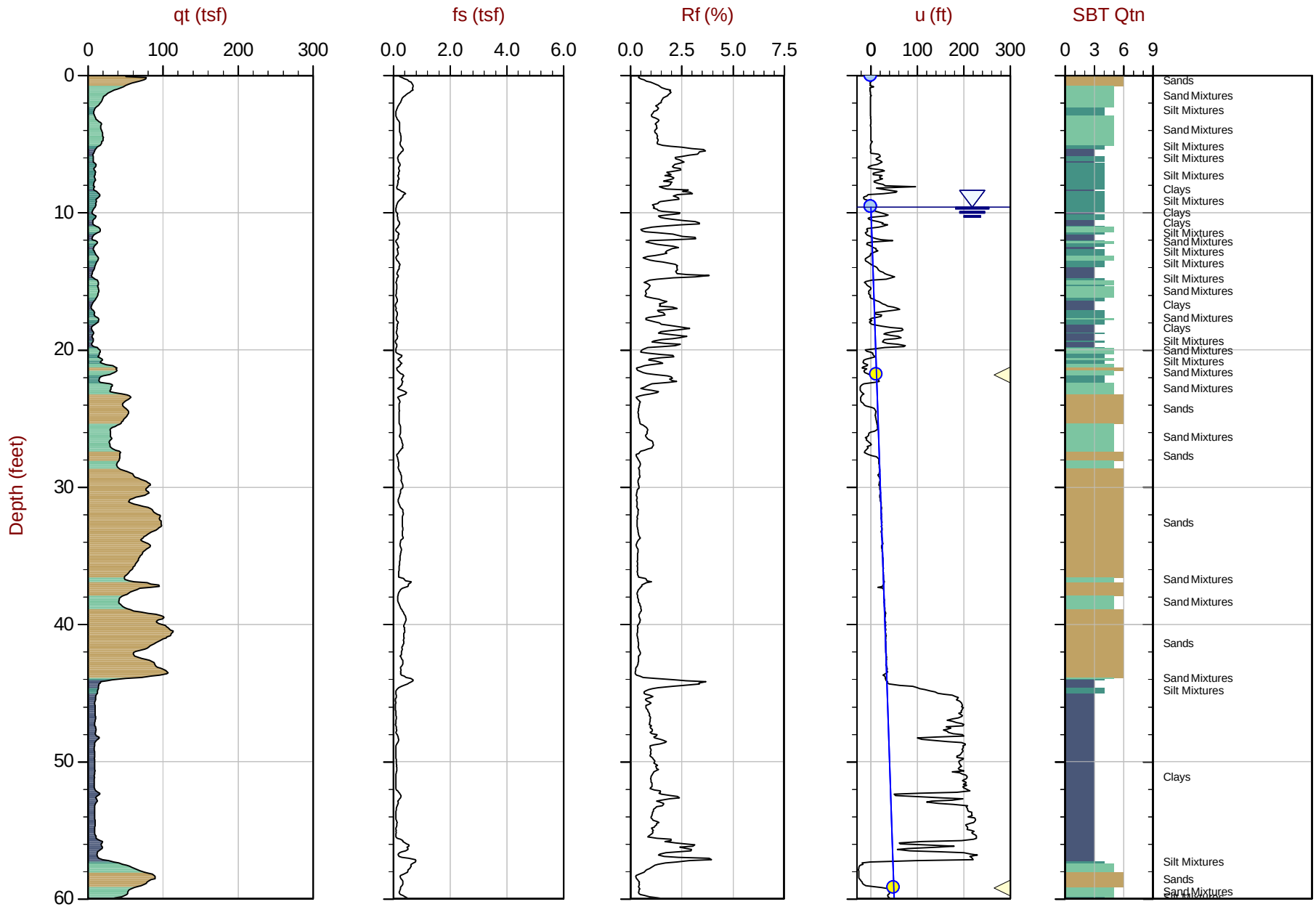
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-10-31 08:48
Site: Courtland

Sounding: GEI-RD551-002C
Cone: 448:T1500F15U500



Max Depth: 22.875 m / 75.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-002C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4240067m E: 625213m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

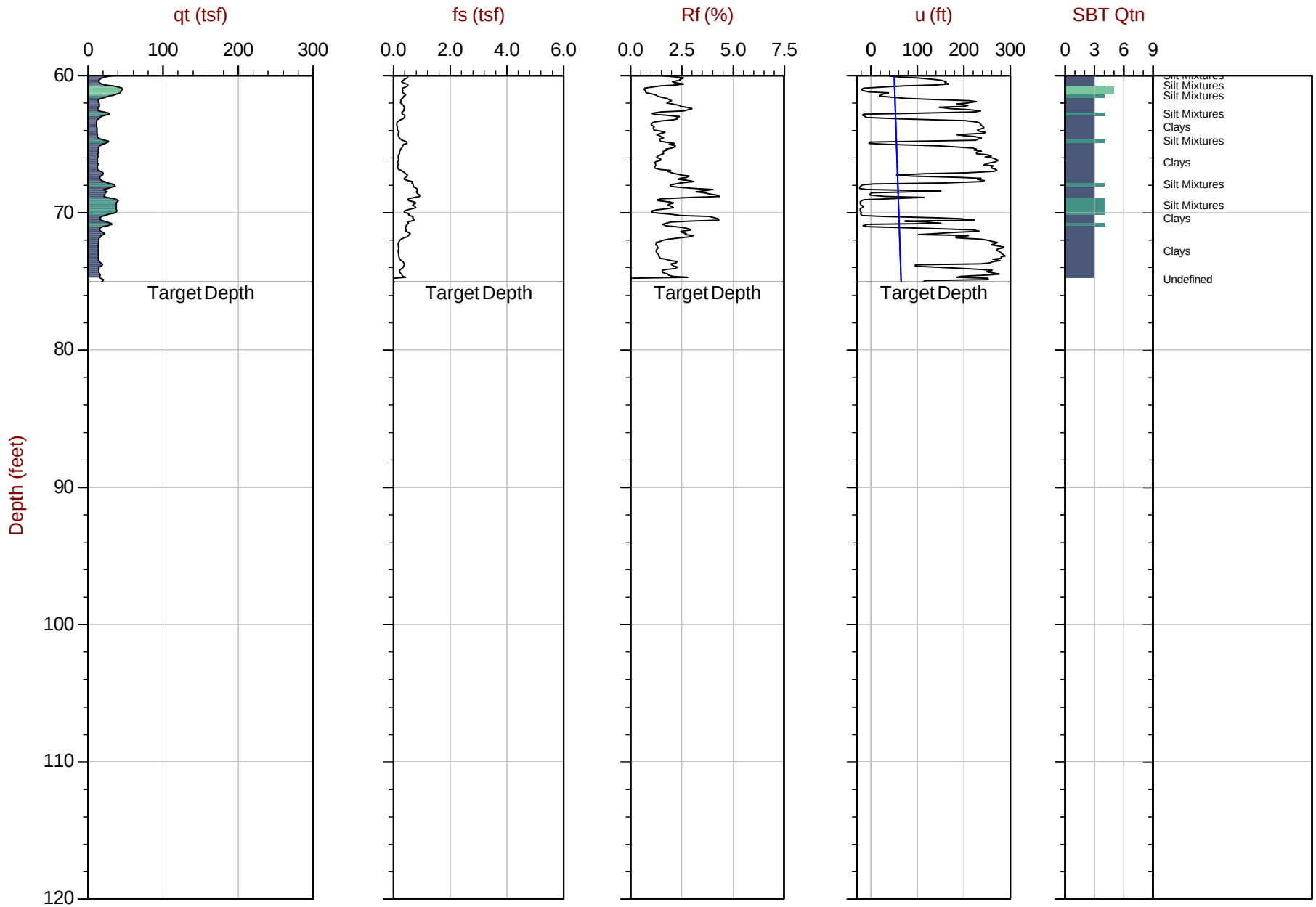
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-10-31 08:48
Site: Courtland

Sounding: GEI-RD551-002C
Cone: 448:T1500F15U500



Max Depth: 22.875 m / 75.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-002C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4240067m E: 625213m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

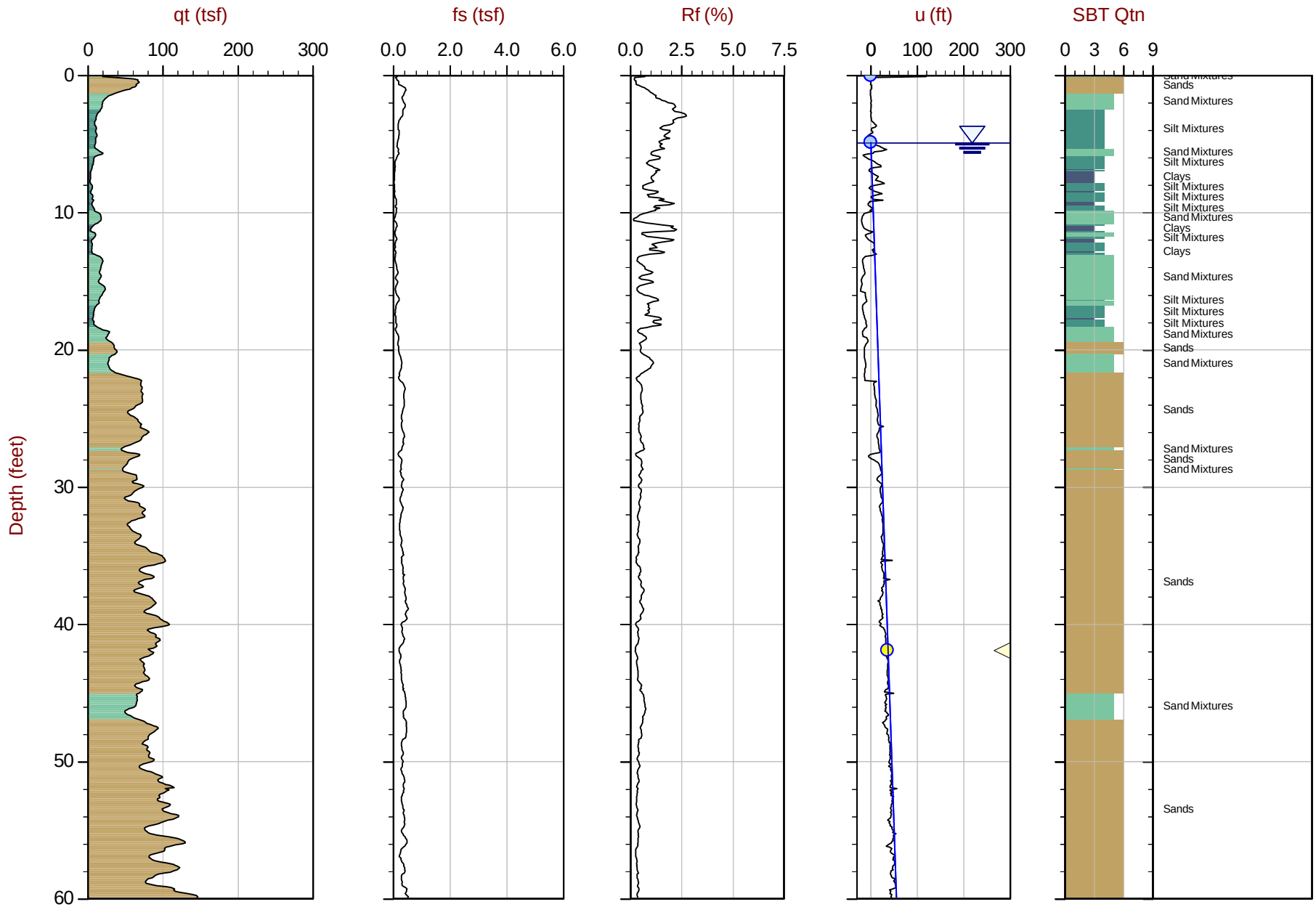
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-28 13:16
Site: Courtland

Sounding: GEI-RD551-003C
Cone: 391:T1500F15U500



Max Depth: 30.800 m / 101.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-003C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4236431m E: 628823m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

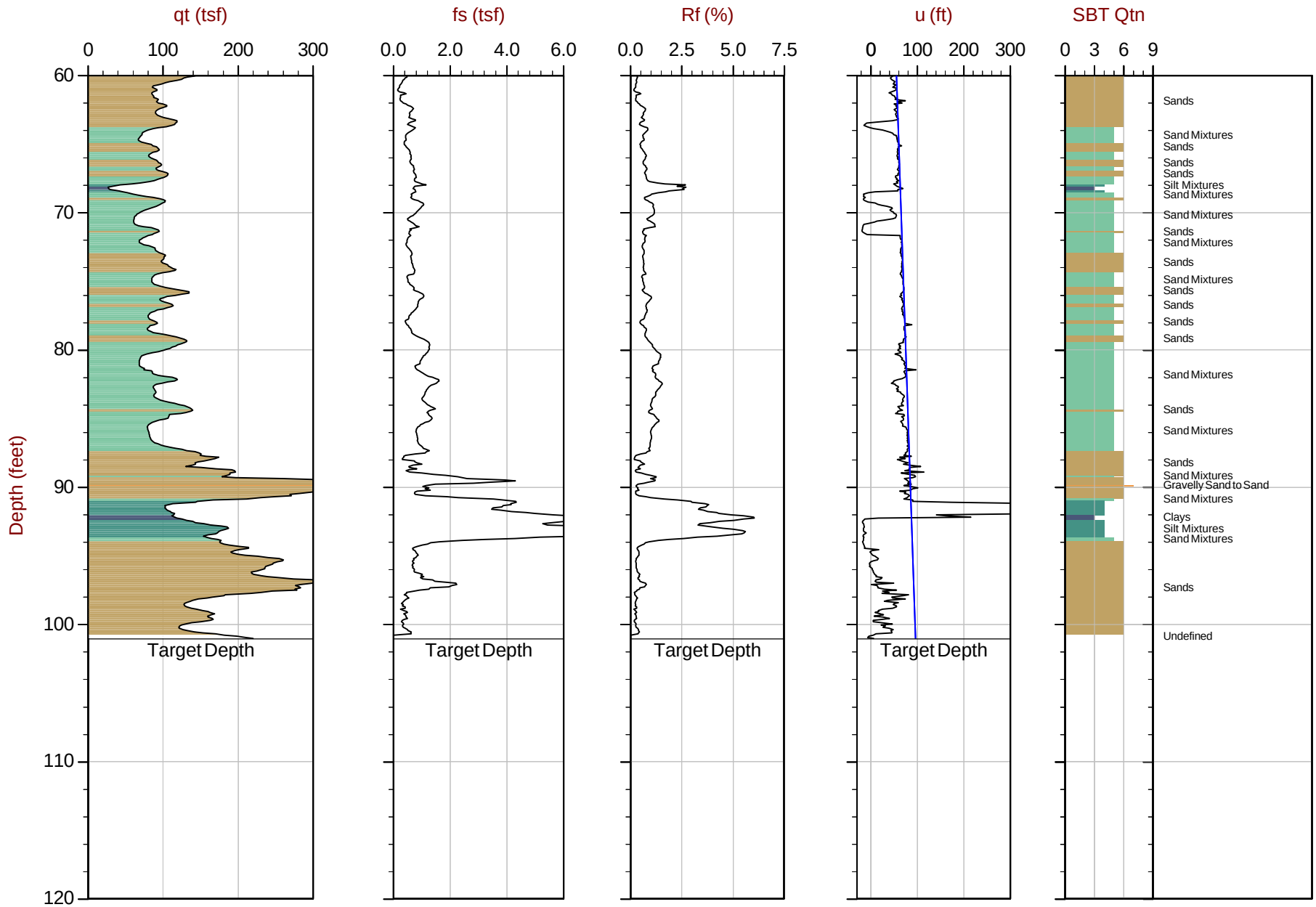
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CONETEC

GEI

Job No: 19-56124
Date: 2019-08-28 13:16
Site: Courtland

Sounding: GEI-RD551-003C
Cone: 391:T1500F15U500



Max Depth: 30.800 m / 101.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-003C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4236431m E: 628823m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

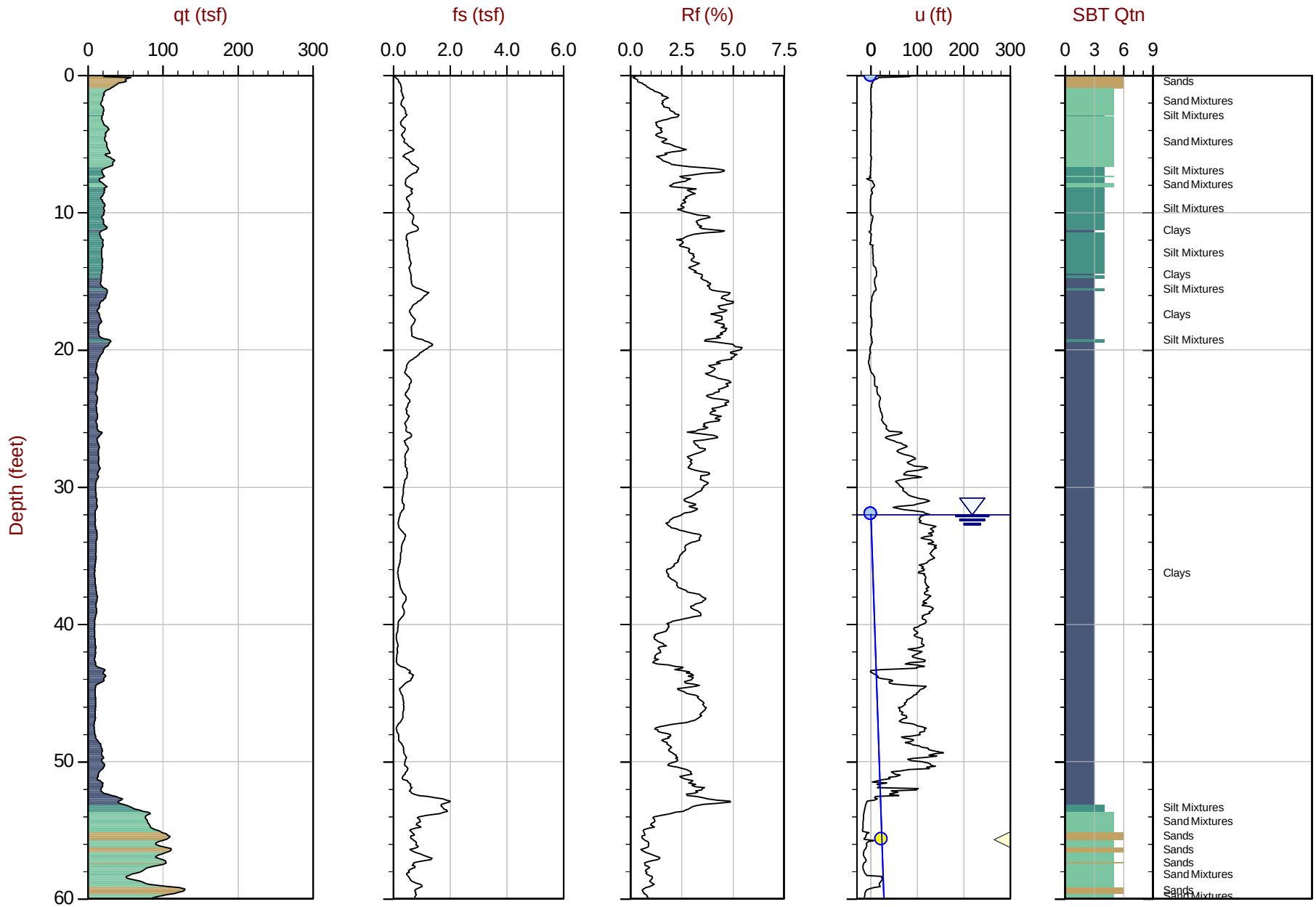
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 14:43
Site: Courtland

Sounding: GEI-RD551-006C
Cone: 499:T1500F15U1K



Max Depth: 30.825 m / 101.13 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-006C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4238370m E: 630808m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

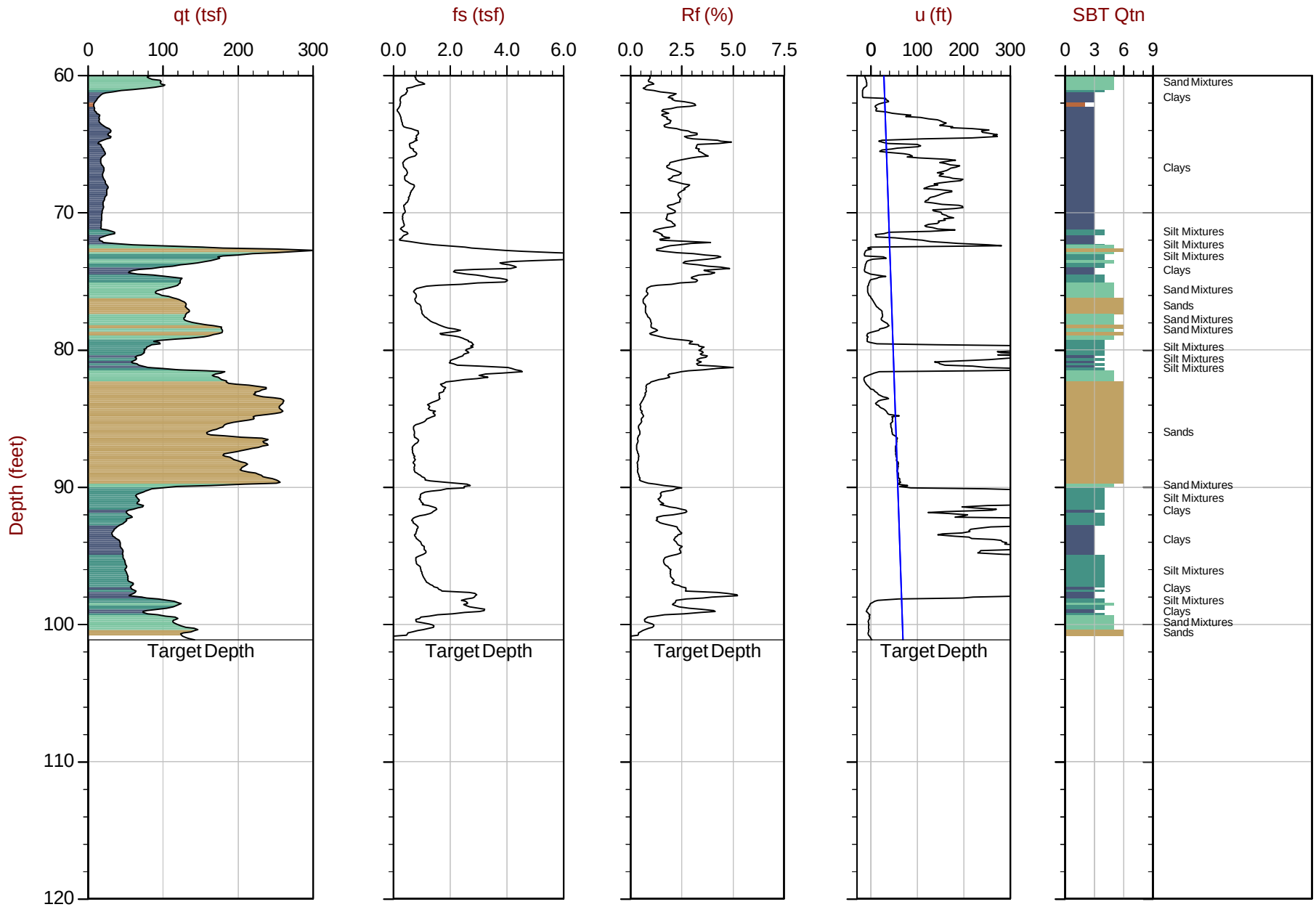
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 14:43
Site: Courtland

Sounding: GEI-RD551-006C
Cone: 499:T1500F15U1K



Max Depth: 30.825 m / 101.13 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-006C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4238370m E: 630808m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

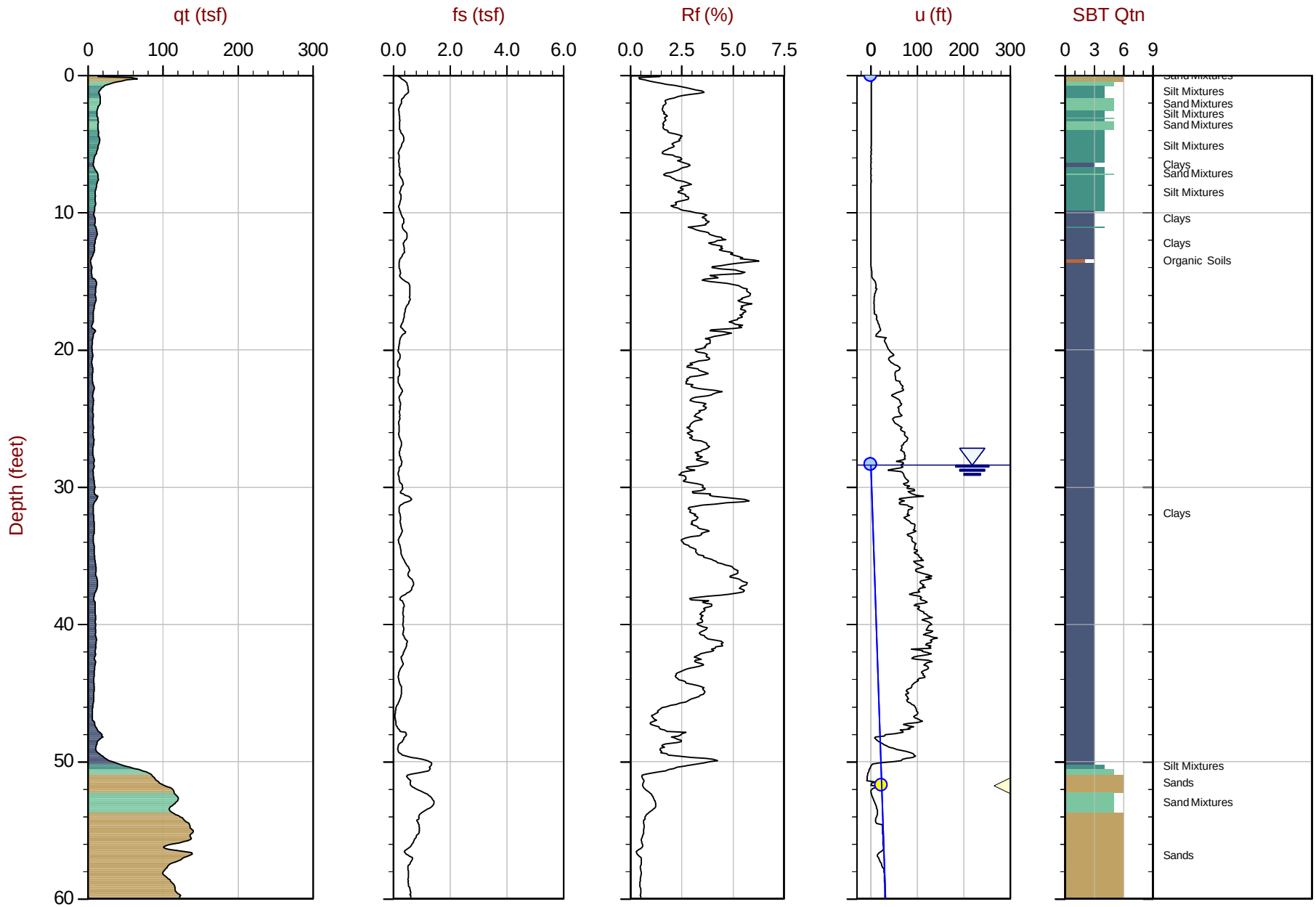
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 08:01
Site: Courtland

Sounding: GEI-RD551-007C
Cone: 499:T1500F15U1K



Max Depth: 23.050 m / 75.62 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-007C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4240059m E: 630097m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

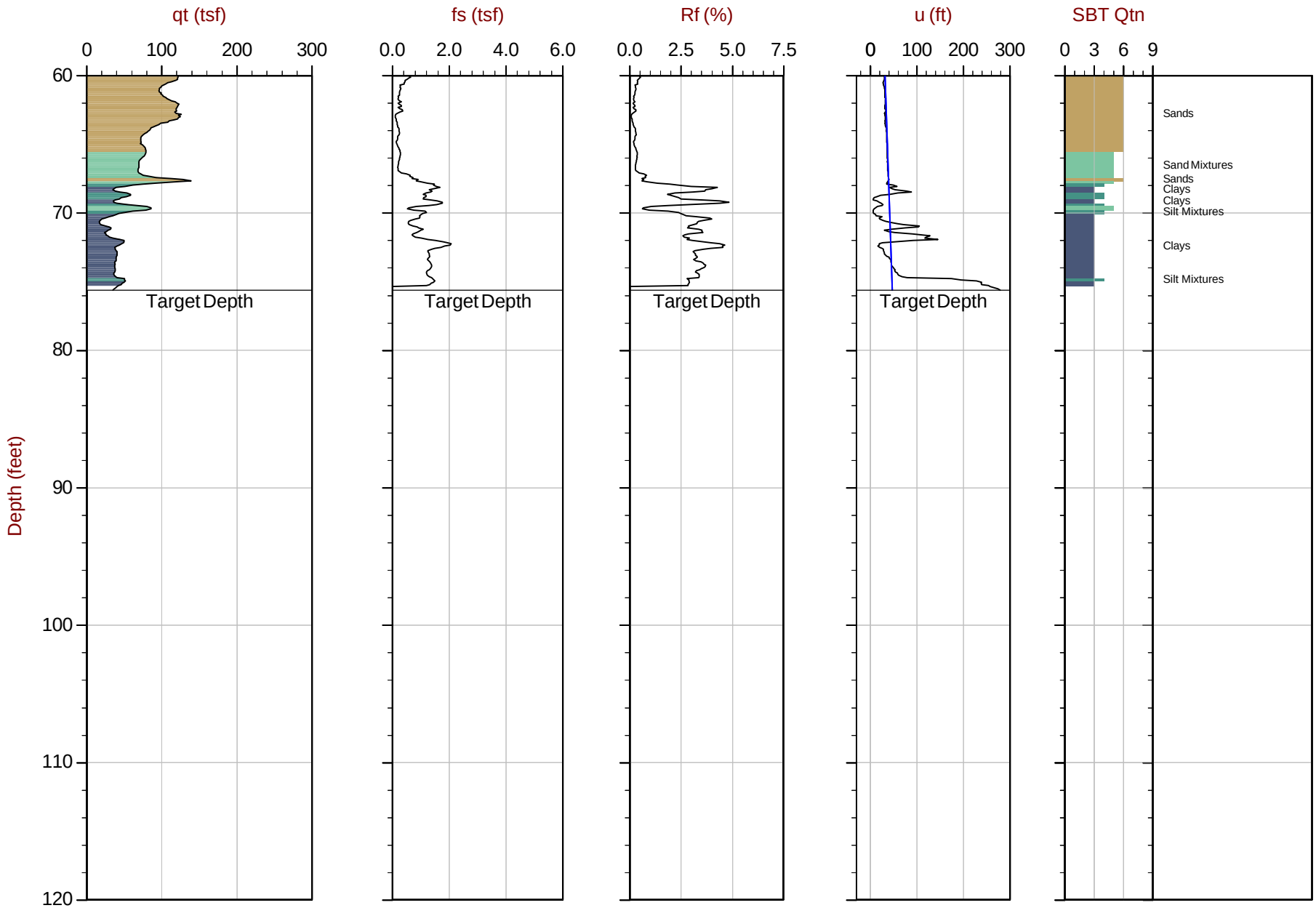
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 08:01
Site: Courtland

Sounding: GEI-RD551-007C
Cone: 499:T1500F15U1K



Max Depth: 23.050 m / 75.62 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-007C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4240059m E: 630097m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

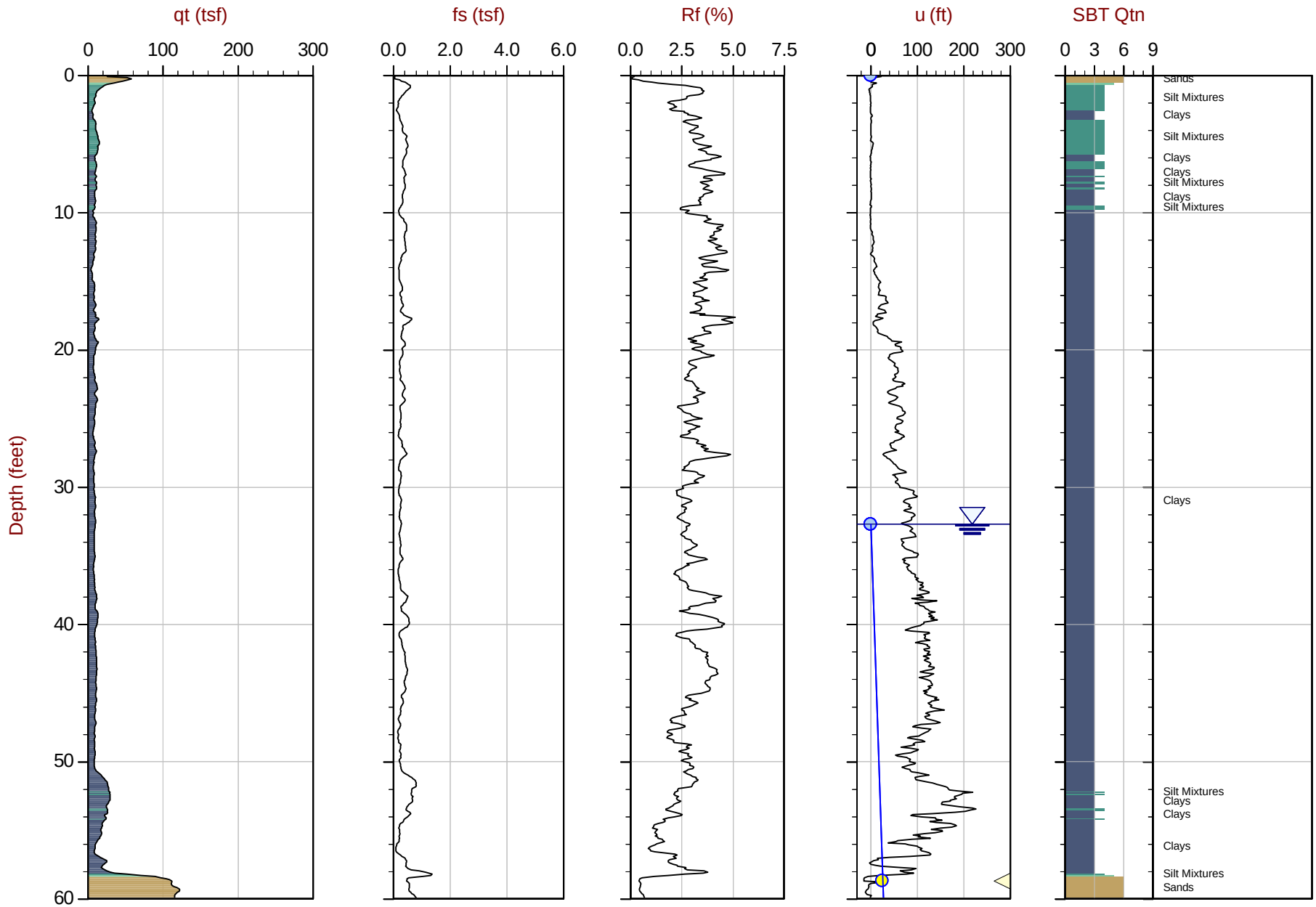
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 11:32
Site: Courtland

Sounding: GEI-RD551-008C
Cone: 499:T1500F15U1K



Max Depth: 30.875 m / 101.29 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-008C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4239347m E: 630254m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

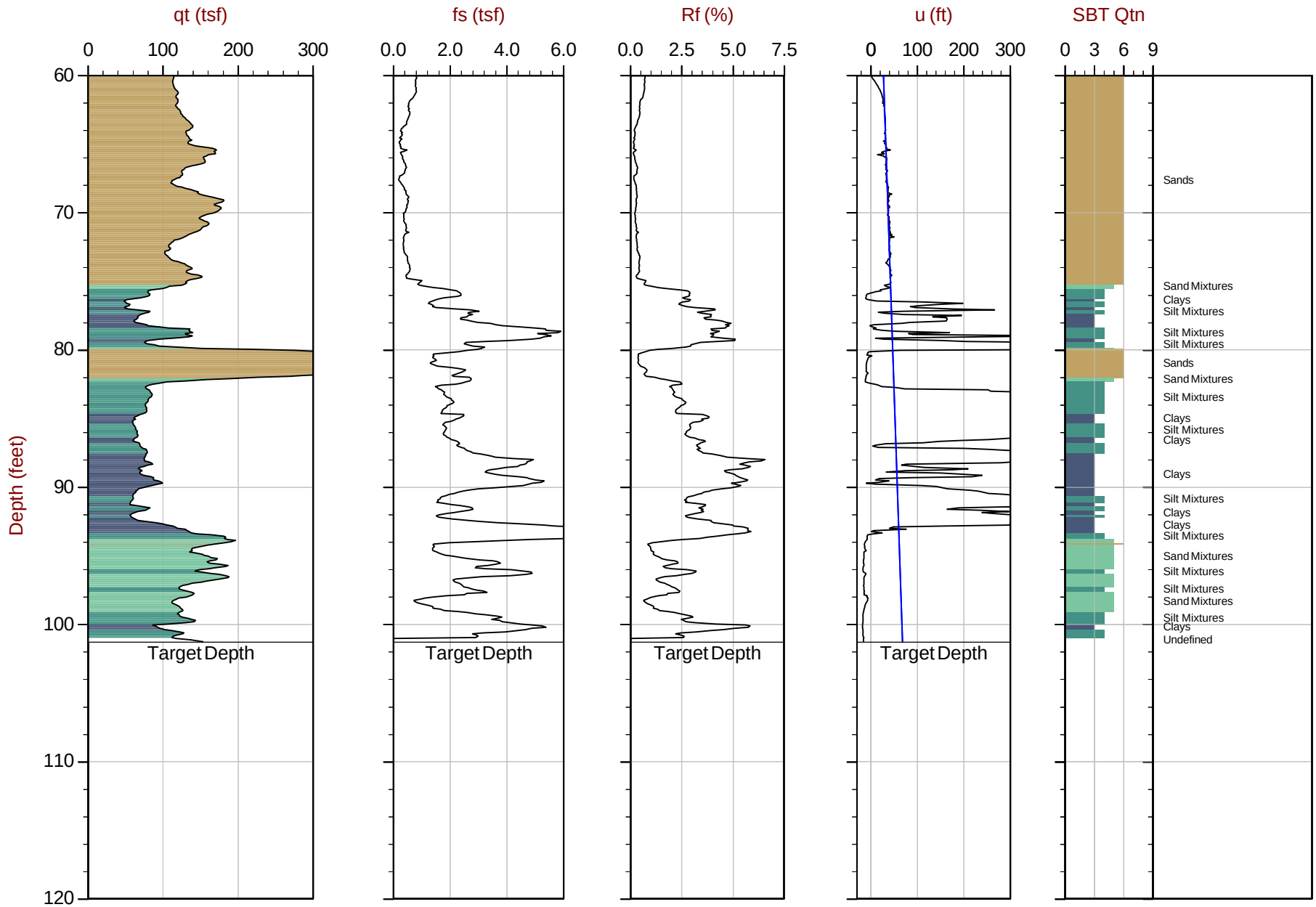
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CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 11:32
Site: Courtland

Sounding: GEI-RD551-008C
Cone: 499:T1500F15U1K



Max Depth: 30.875 m / 101.29 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-008C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4239347m E: 630254m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

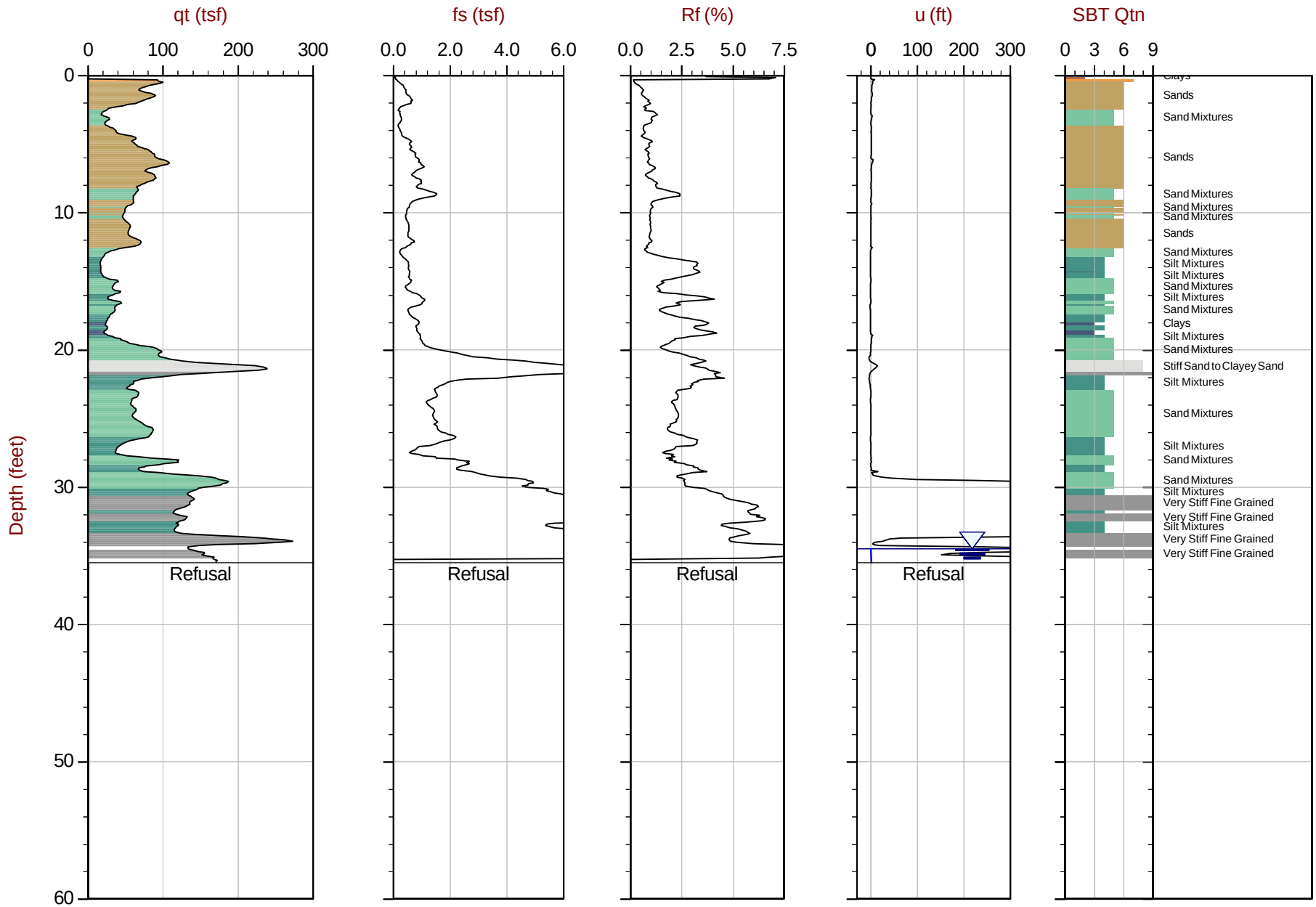
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 13:50
Site: Courtland

Sounding: GEI-RD551-009C
Cone: 391:T1500F15U500



Max Depth: 10.825 m / 35.51 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-009C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4242747m E: 629356m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

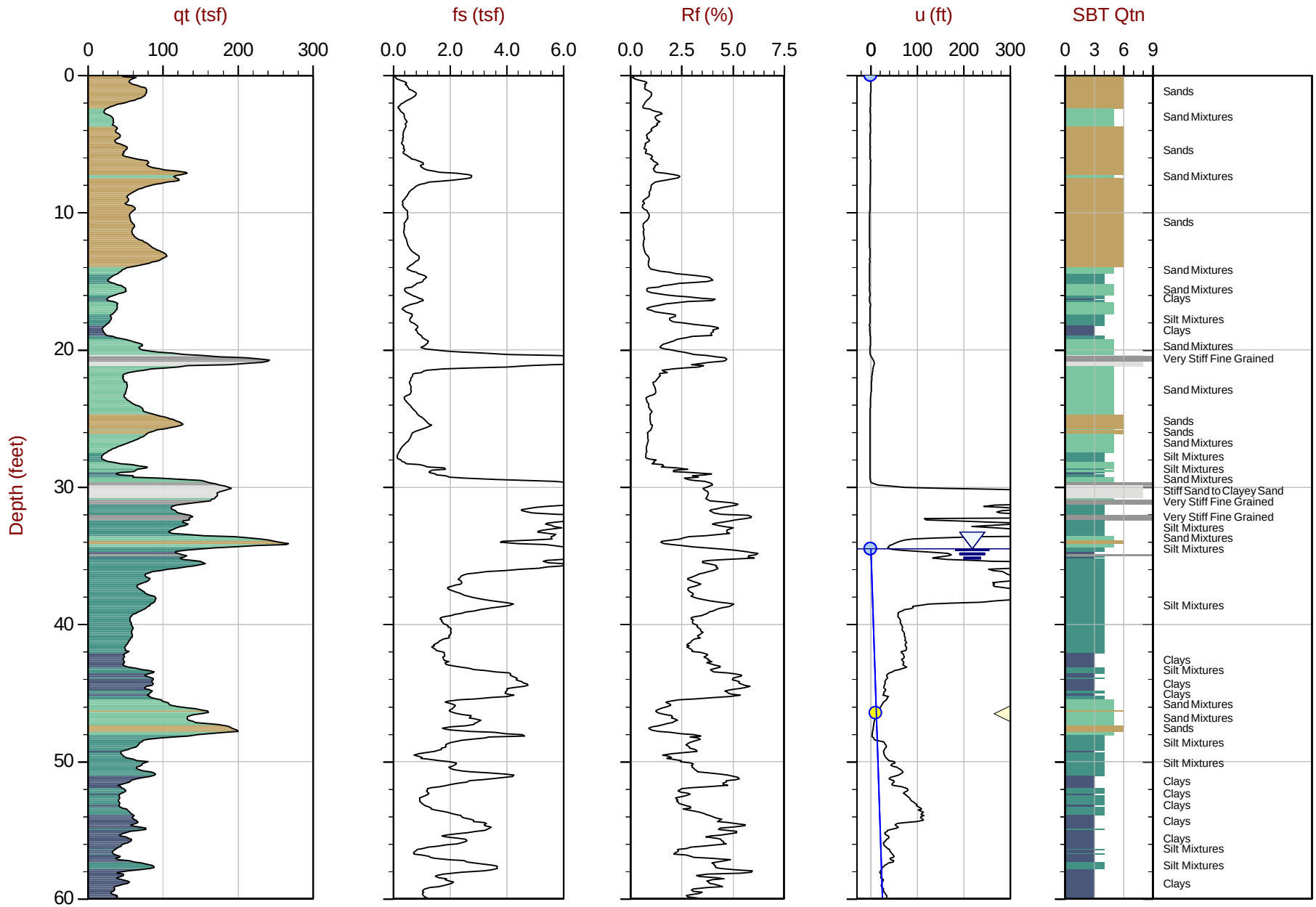
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 14:35
Site: Courtland

Sounding: GEI-RD551-009C-B
Cone: 499:T1500F15U1K



Max Depth: 21.750 m / 71.36 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-009C-B.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4242747m E: 629356m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

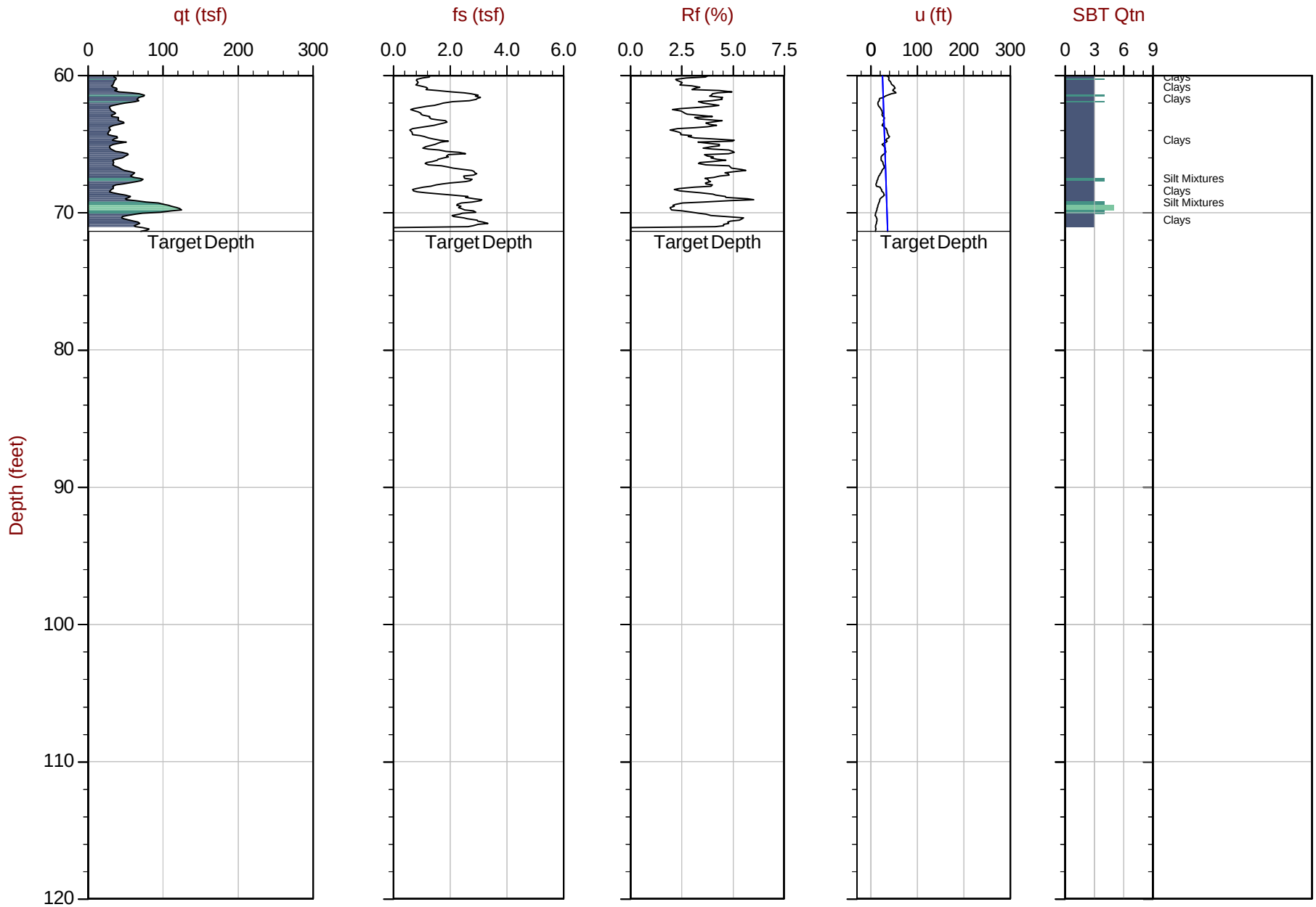
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 14:35
Site: Courtland

Sounding: GEI-RD551-009C-B
Cone: 499:T1500F15U1K



Max Depth: 21.750 m / 71.36 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-009C-B.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4242747m E: 629356m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

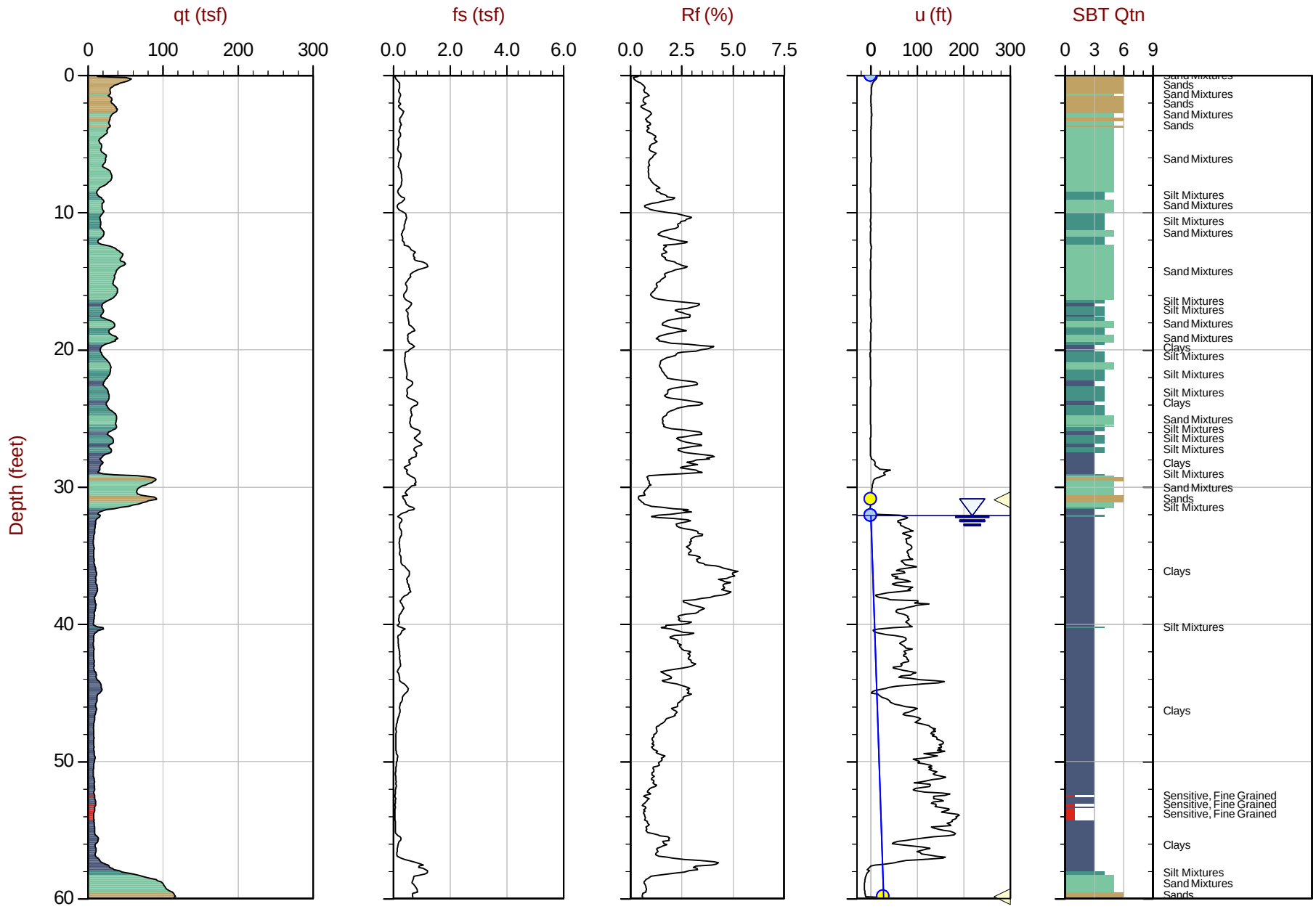
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 09:06
Site: Courtland

Sounding: GEI-RD551-010C
Cone: 391:T1500F15U500



Max Depth: 23.075 m / 75.70 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-010C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4244298m E: 628854m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

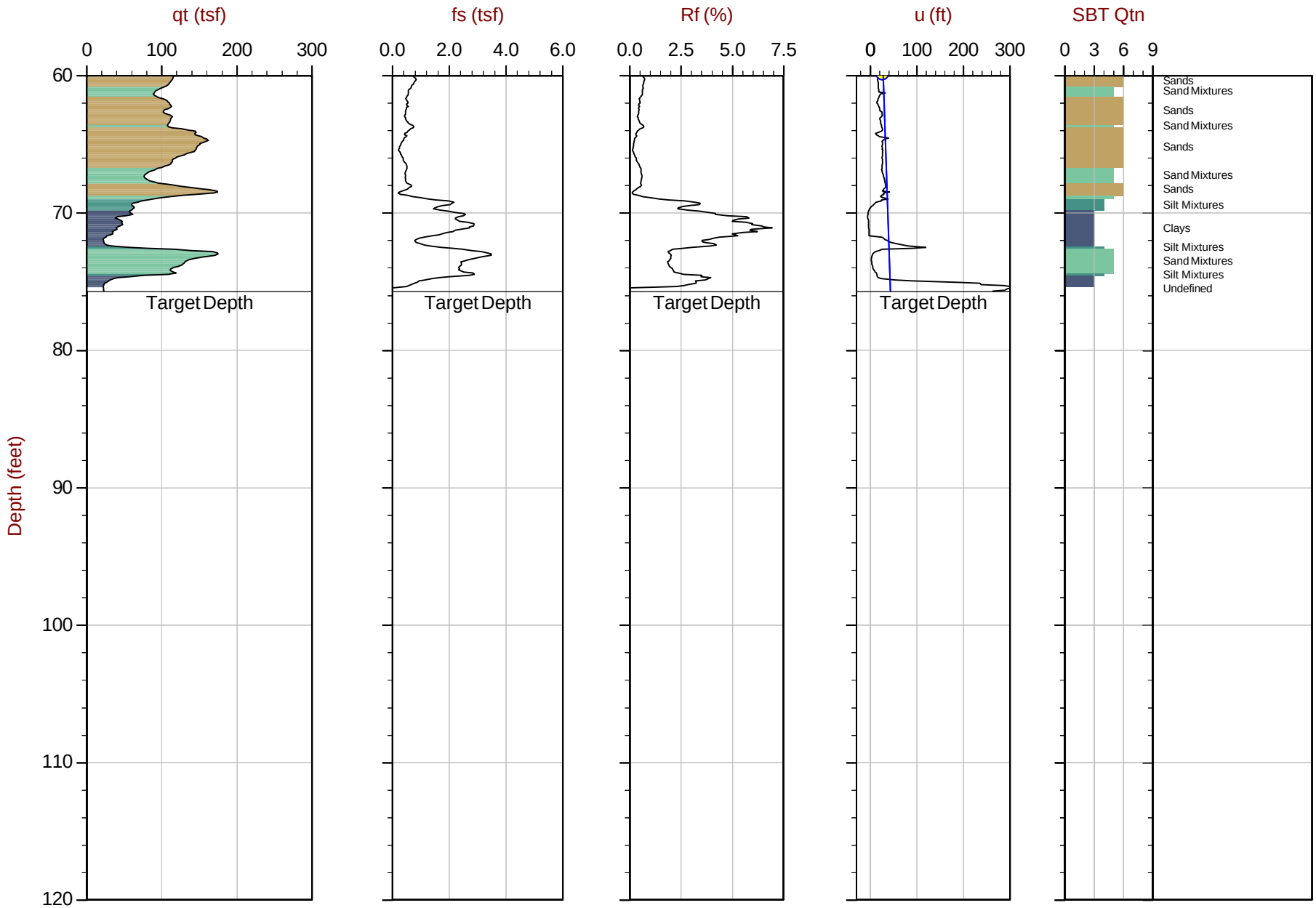
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 09:06
Site: Courtland

Sounding: GEI-RD551-010C
Cone: 391:T1500F15U500



Max Depth: 23.075 m / 75.70 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-010C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4244298m E: 628854m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Standard Cone Penetration Test Plots with Expanded Range

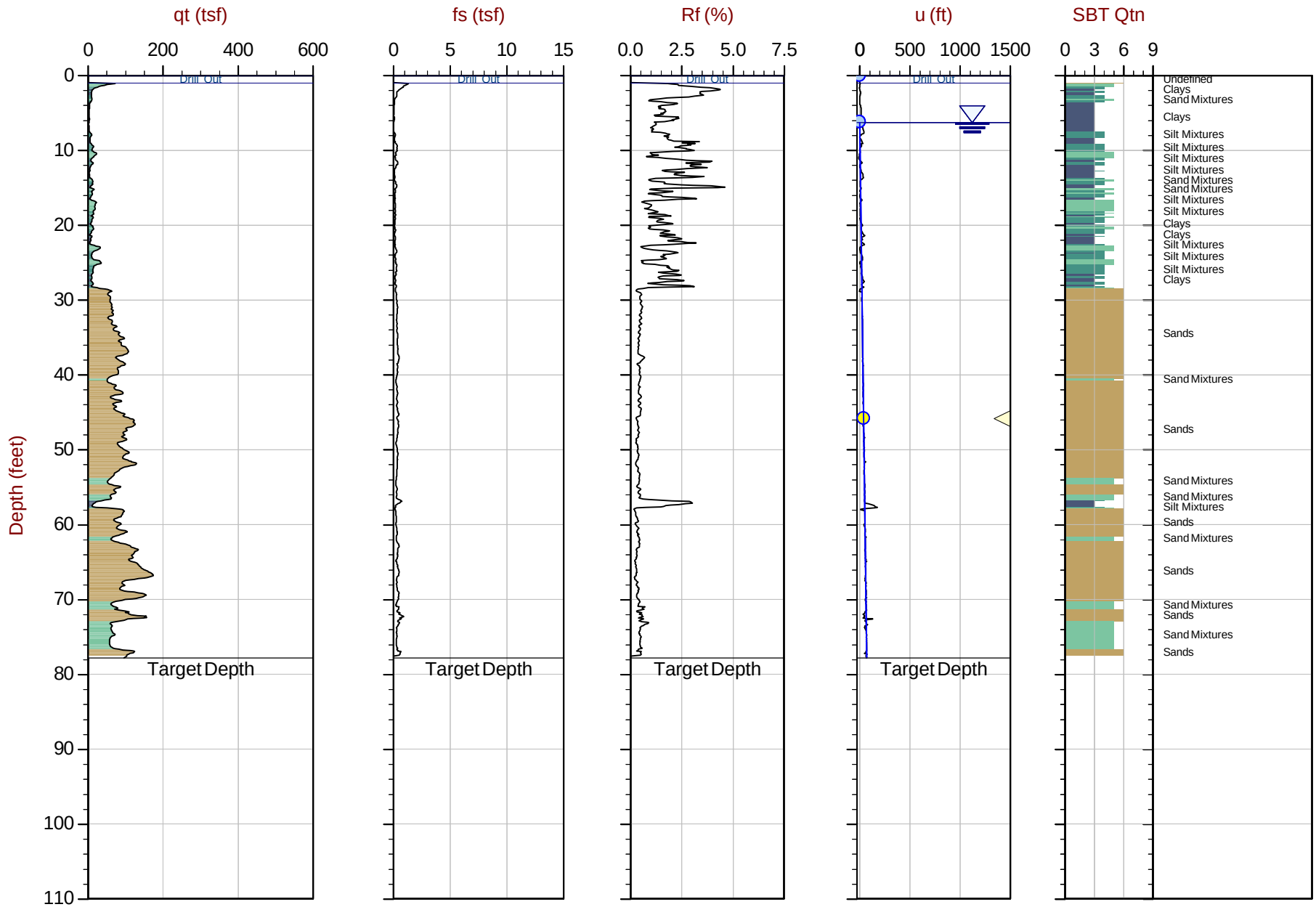
CONETEC

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-21 08:07
Site: Courtland

Sounding: GEI-RD551-001C
Cone: 499:T1500F15U1K



Max Depth: 23.725 m / 77.84 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-001C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4243731m E: 625142m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

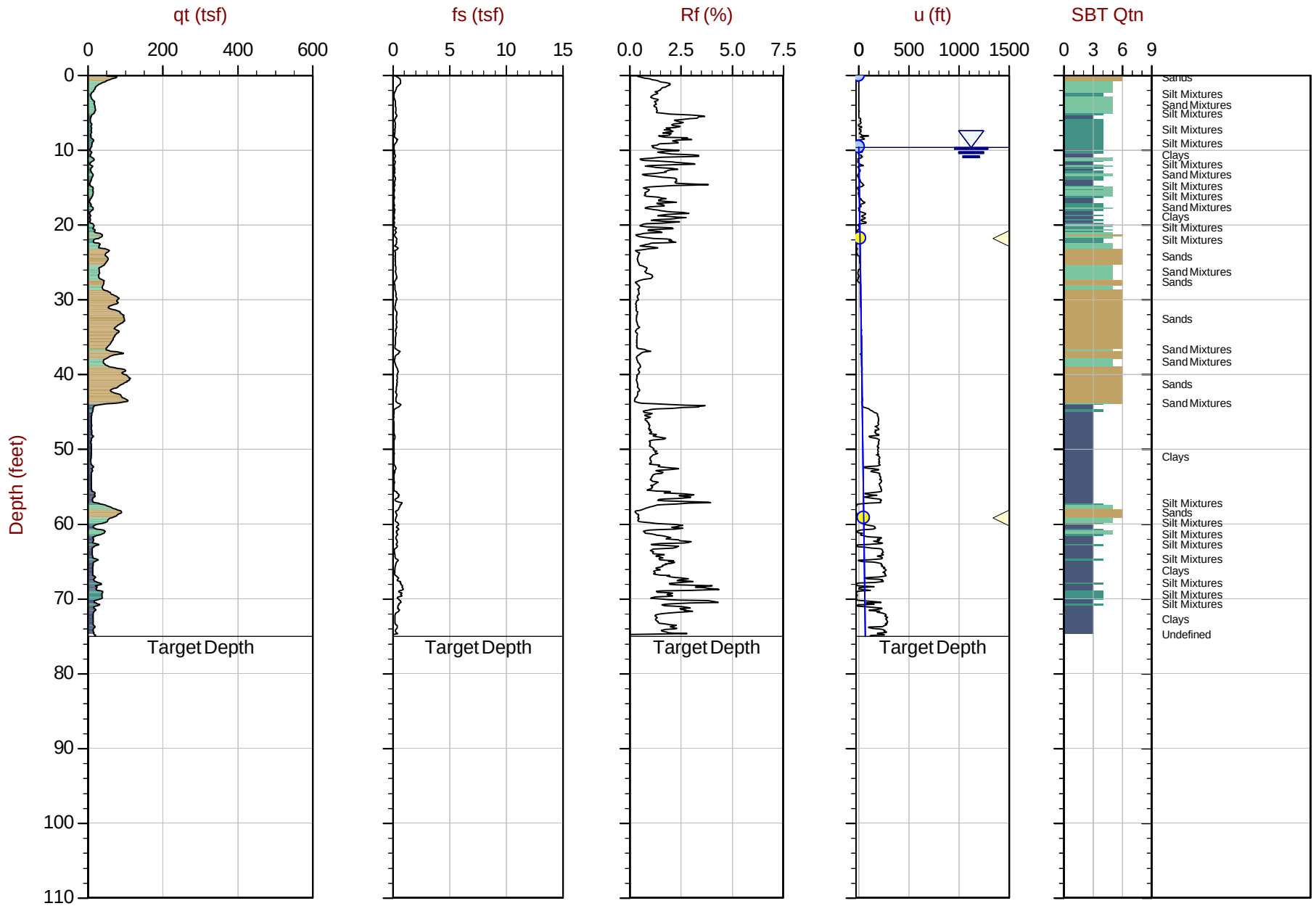
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CONETEC

GEI

Job No: 19-56124
Date: 2019-10-31 08:48
Site: Courtland

Sounding: GEI-RD551-002C
Cone: 448:T1500F15U500



Max Depth: 22.875 m / 75.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-002C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4240067m E: 625213m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

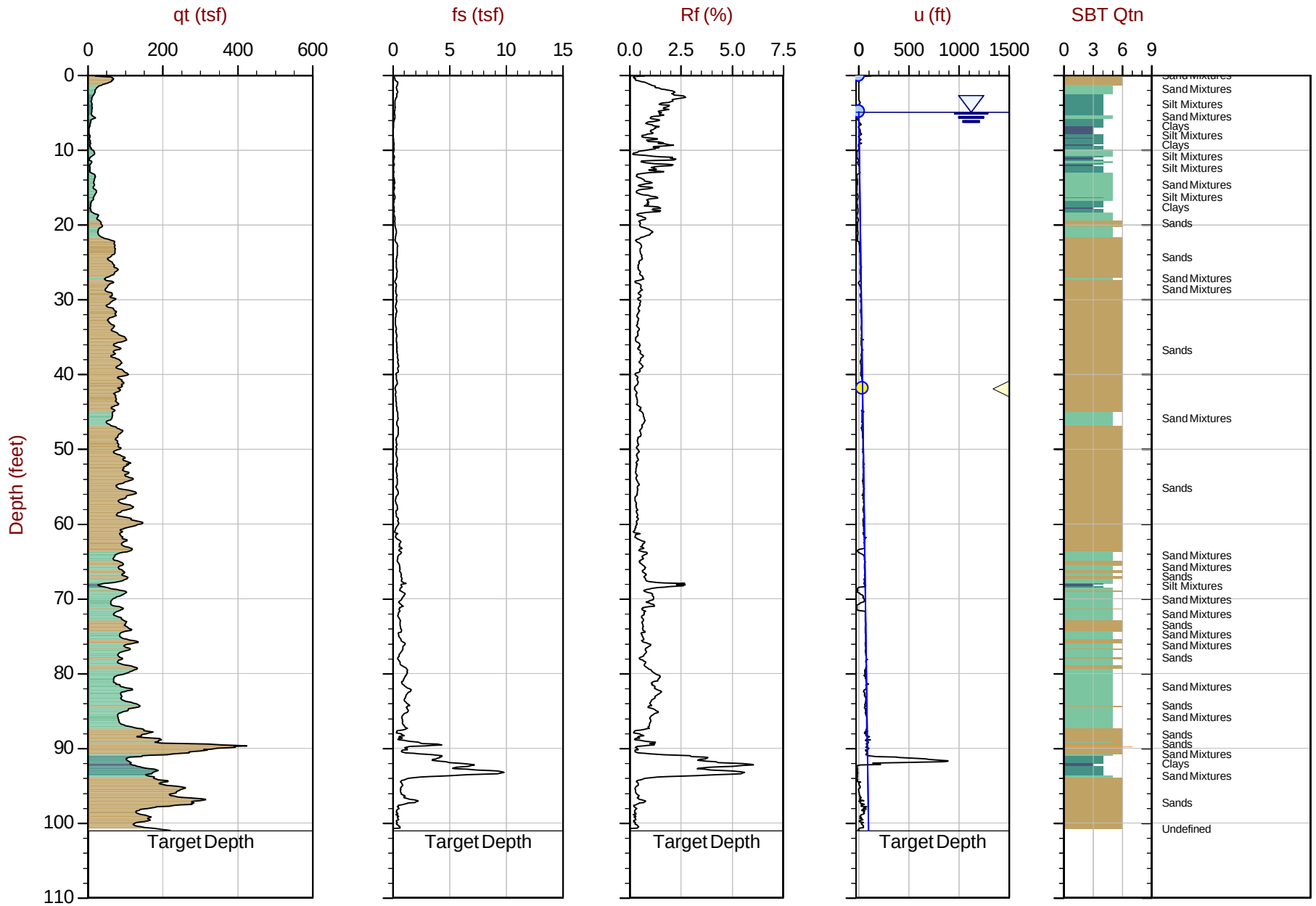
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CONETEC

GEI

Job No: 19-56124
Date: 2019-08-28 13:16
Site: Courtland

Sounding: GEI-RD551-003C
Cone: 391:T1500F15U500



Max Depth: 30.800 m / 101.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-003C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4236431m E: 628823m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

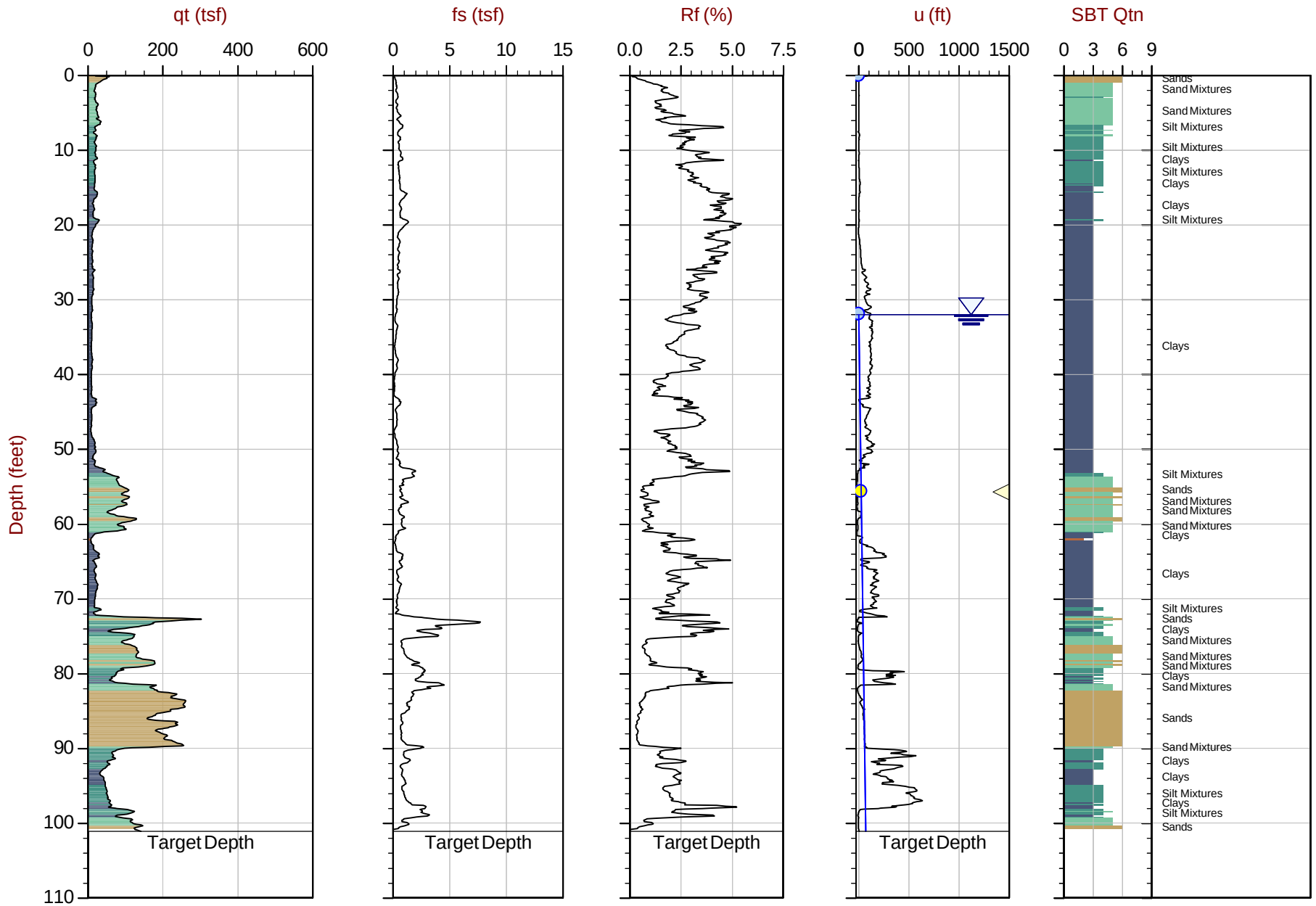
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 14:43
Site: Courtland

Sounding: GEI-RD551-006C
Cone: 499:T1500F15U1K



Max Depth: 30.825 m / 101.13 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-006C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4238370m E: 630808m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

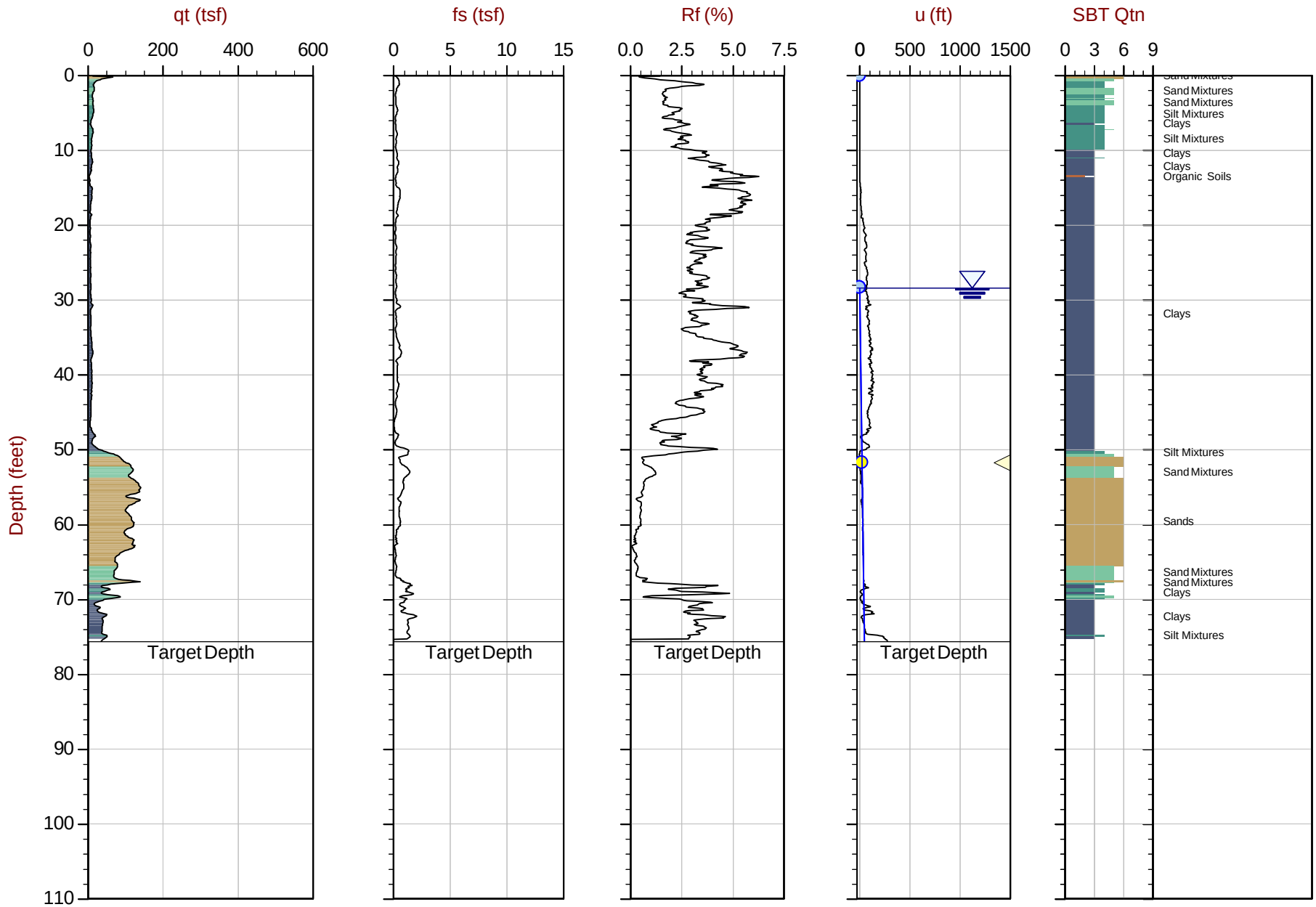
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CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 08:01
Site: Courtland

Sounding: GEI-RD551-007C
Cone: 499:T1500F15U1K



Max Depth: 23.050 m / 75.62 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-007C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4240059m E: 630097m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

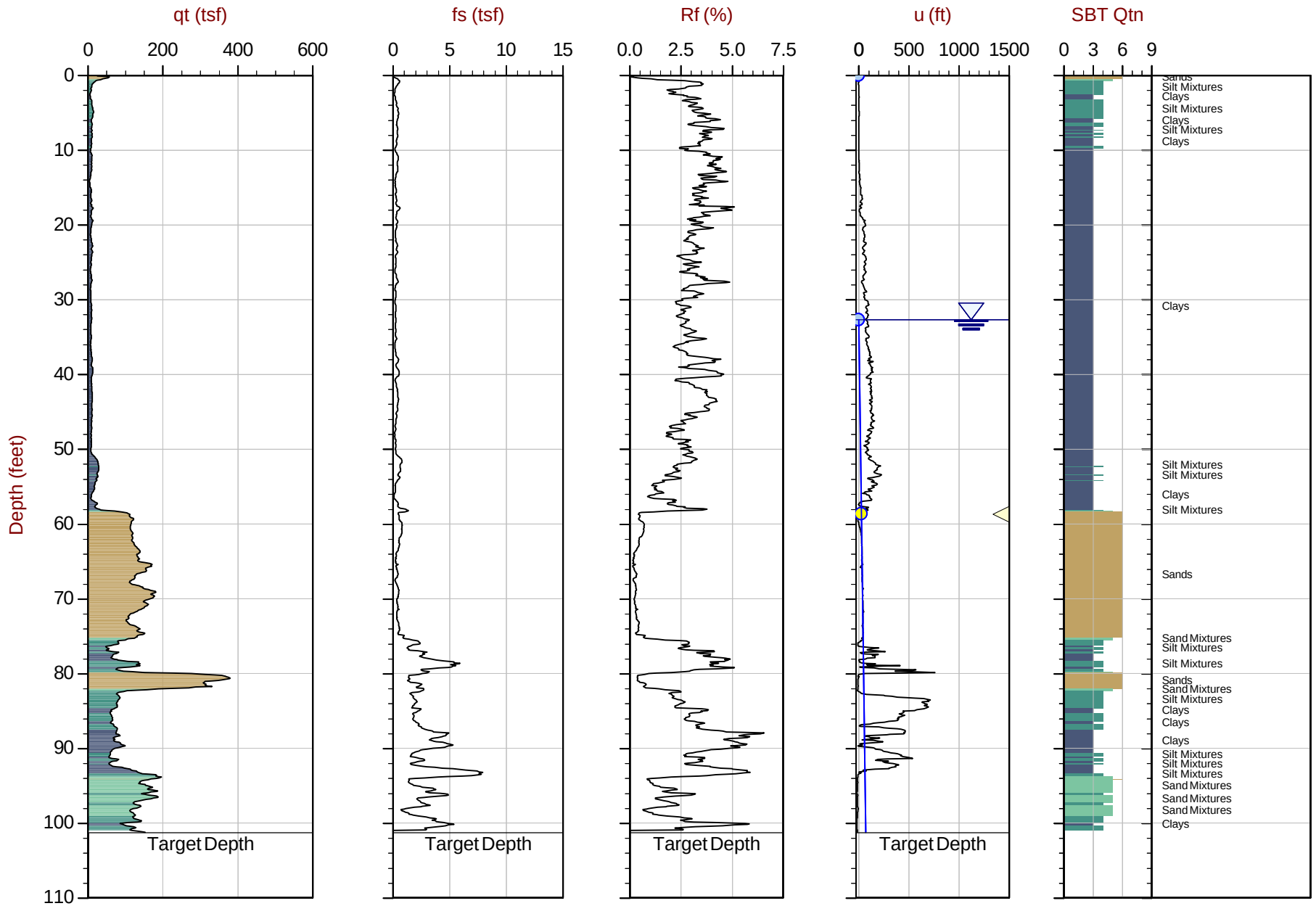
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 11:32
Site: Courtland

Sounding: GEI-RD551-008C
Cone: 499:T1500F15U1K



Max Depth: 30.875 m / 101.29 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-008C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4239347m E: 630254m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

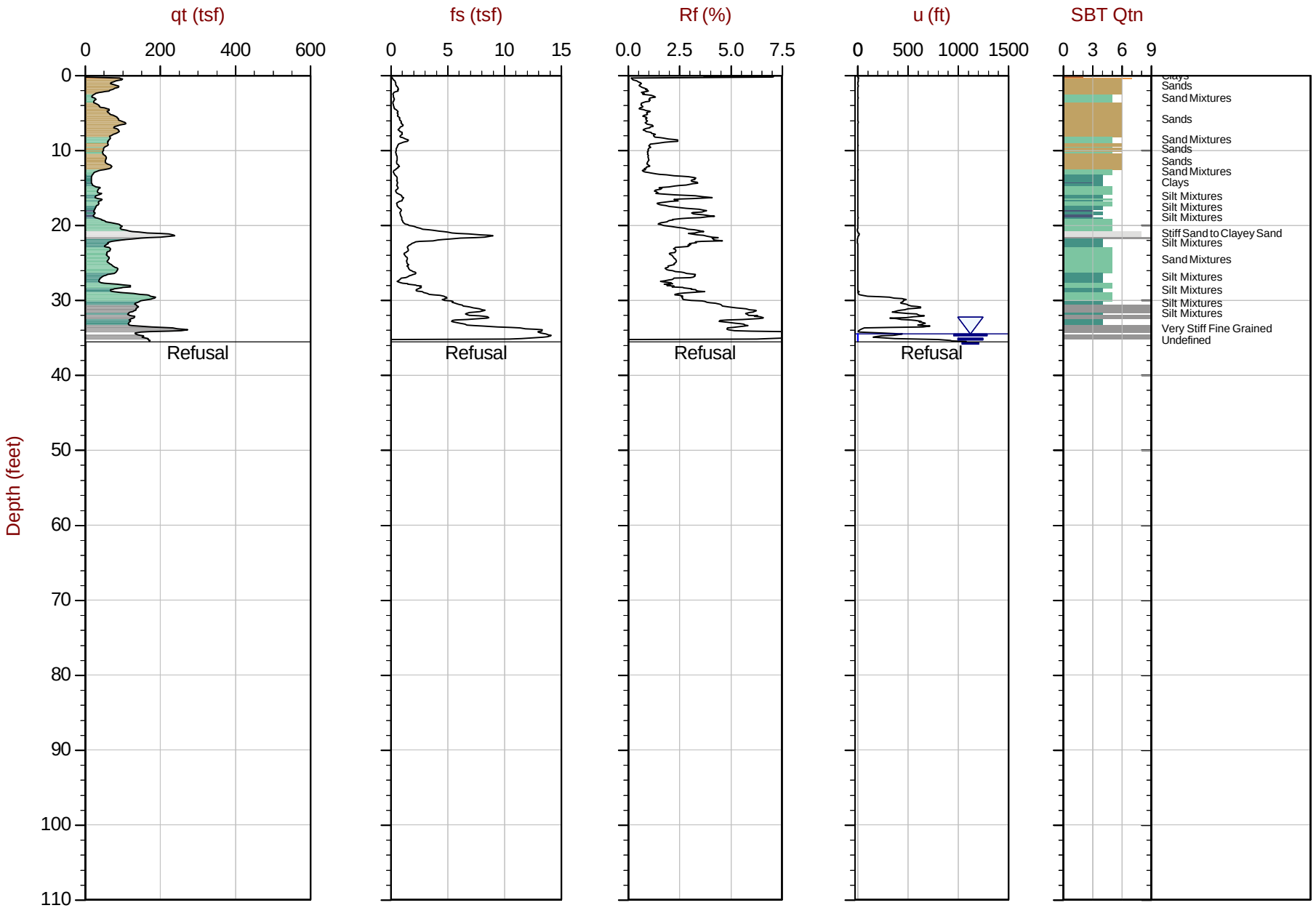
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CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 13:50
Site: Courtland

Sounding: GEI-RD551-009C
Cone: 391:T1500F15U500



Max Depth: 10.825 m / 35.51 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-009C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4242747m E: 629356m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

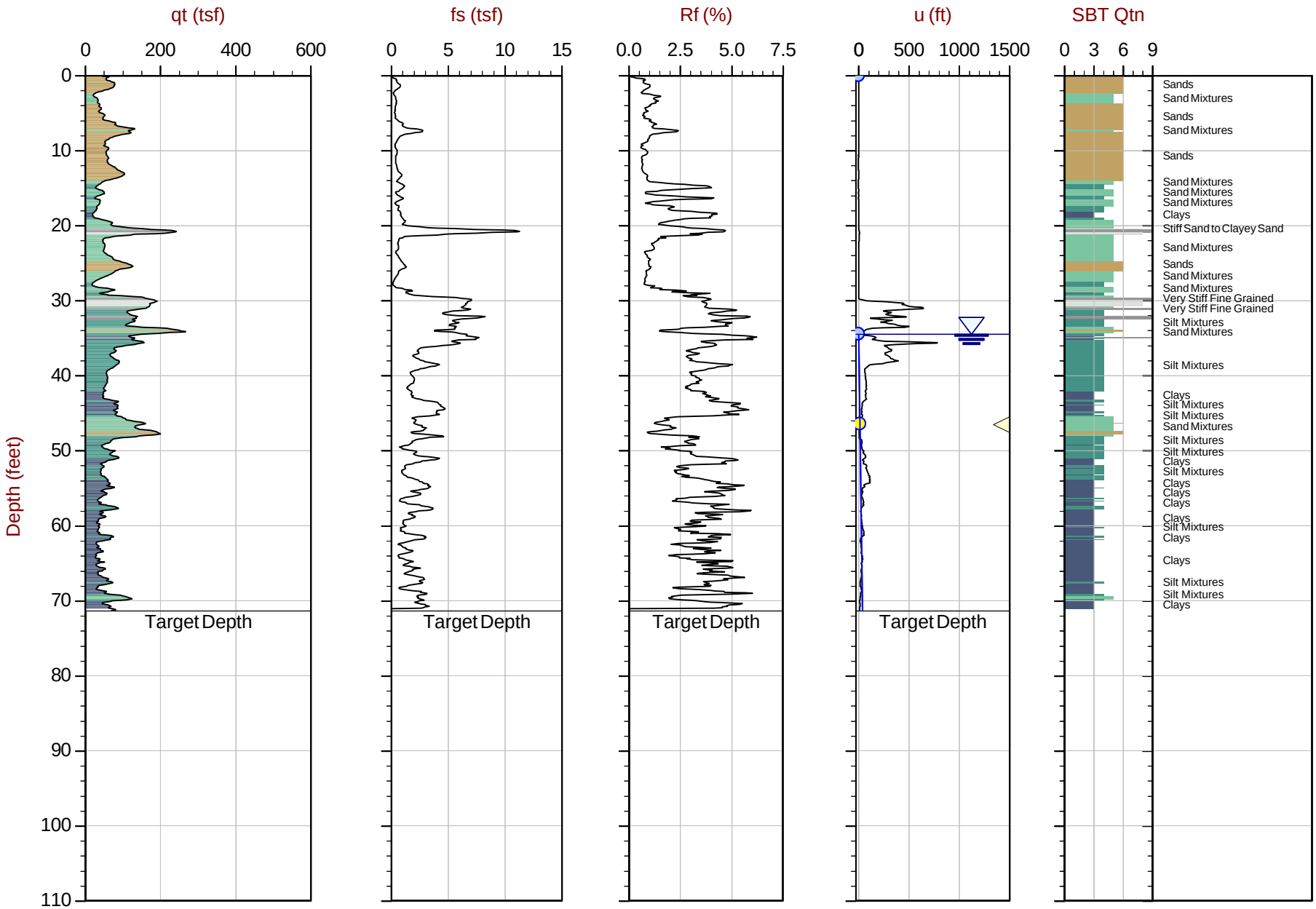
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 14:35
Site: Courtland

Sounding: GEI-RD551-009C-B
Cone: 499:T1500F15U1K



Max Depth: 21.750 m / 71.36 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-009C-B.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4242747m E: 629356m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

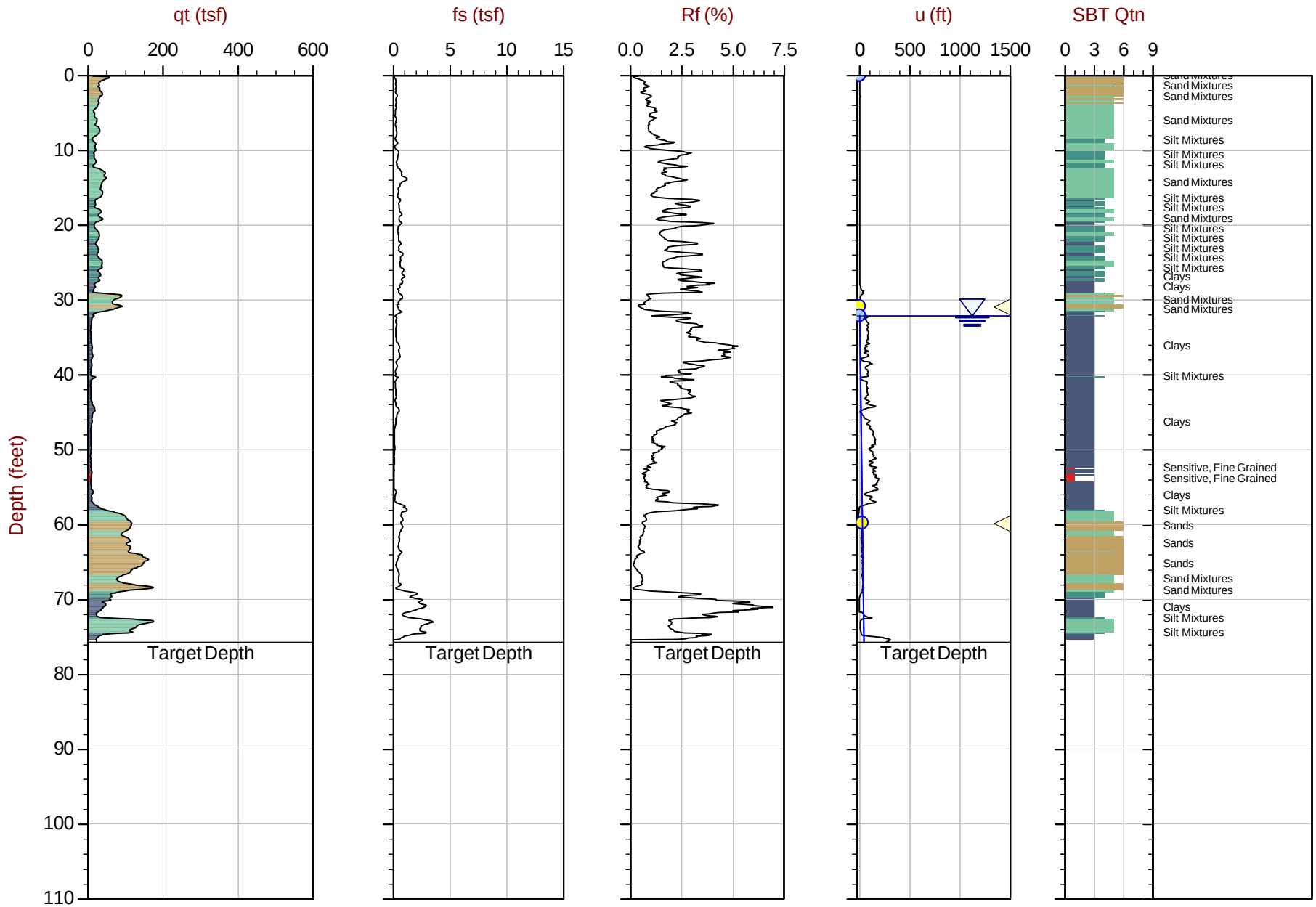
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 09:06
Site: Courtland

Sounding: GEI-RD551-010C
Cone: 391:T1500F15U500



Max Depth: 23.075 m / 75.70 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-010C.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4244298m E: 628854m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

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

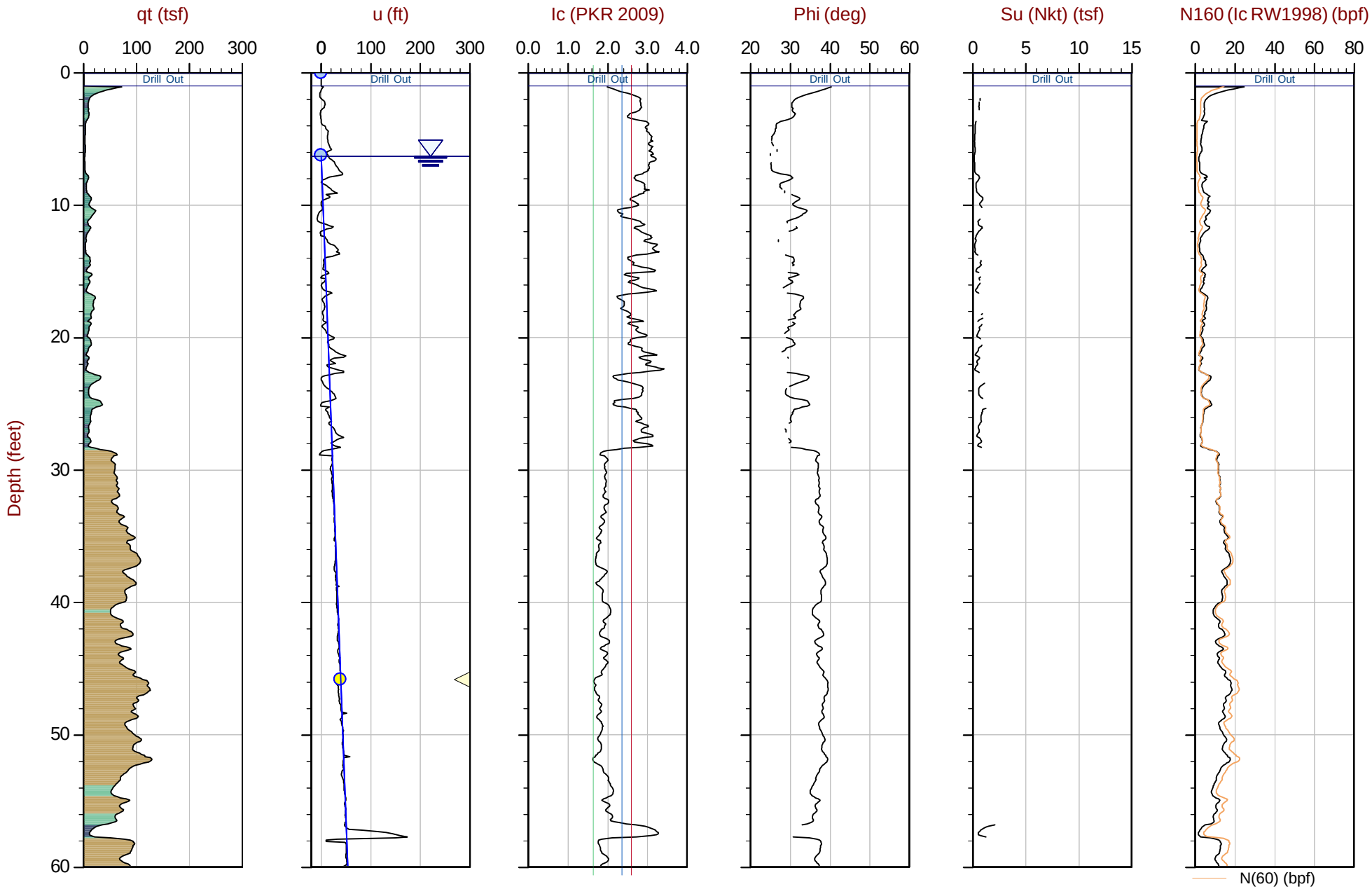
CONETEC

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-21 08:07
Site: Courtland

Sounding: GEI-RD551-001C
Cone: 499:T1500F15U1K



Max Depth: 23.725 m / 77.84 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-001C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4243731m E: 625142m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

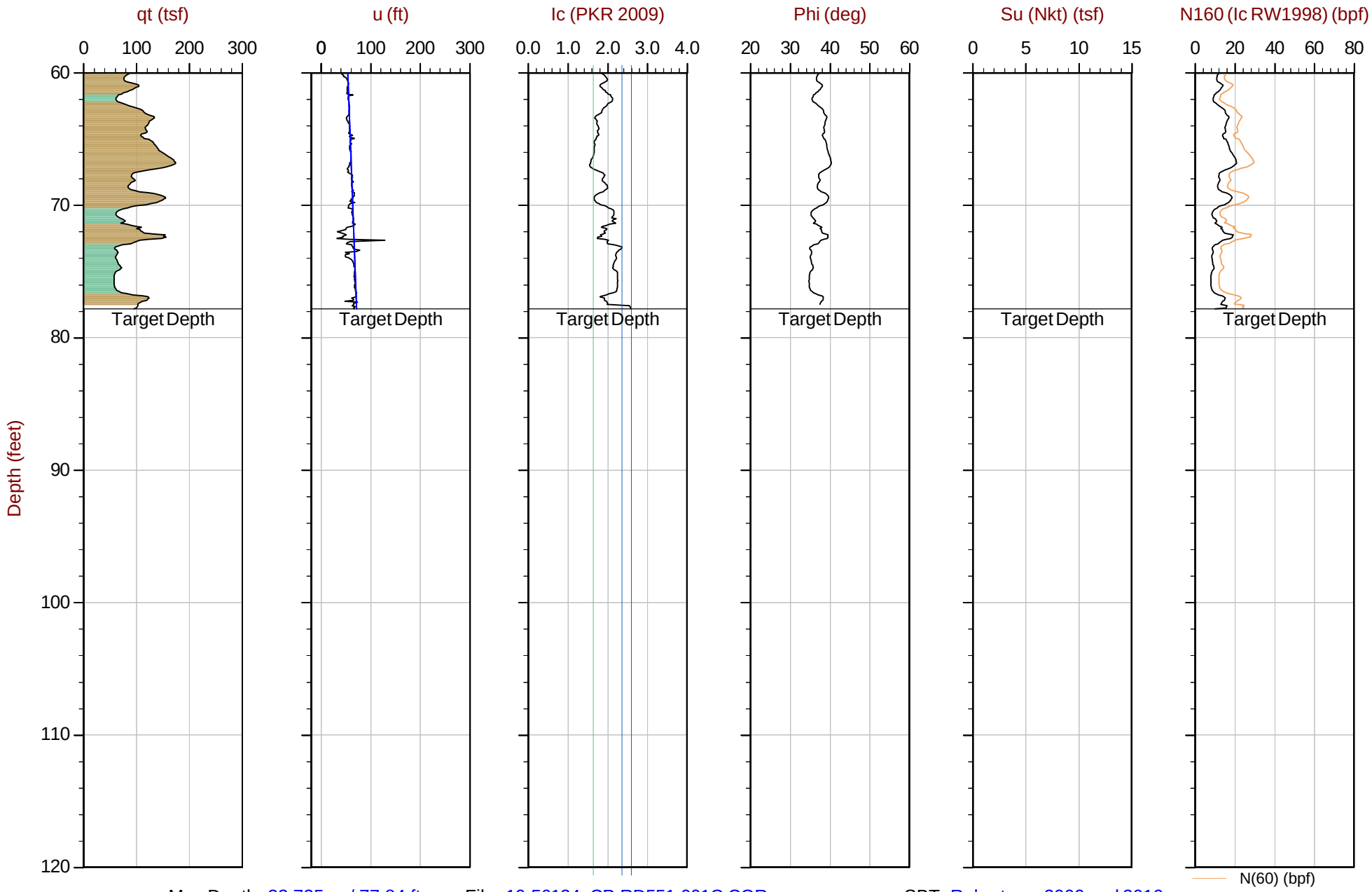
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-21 08:07
Site: Courtland

Sounding: GEI-RD551-001C
Cone: 499:T1500F15U1K



Max Depth: 23.725 m / 77.84 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-001C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4243731m E: 625142m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

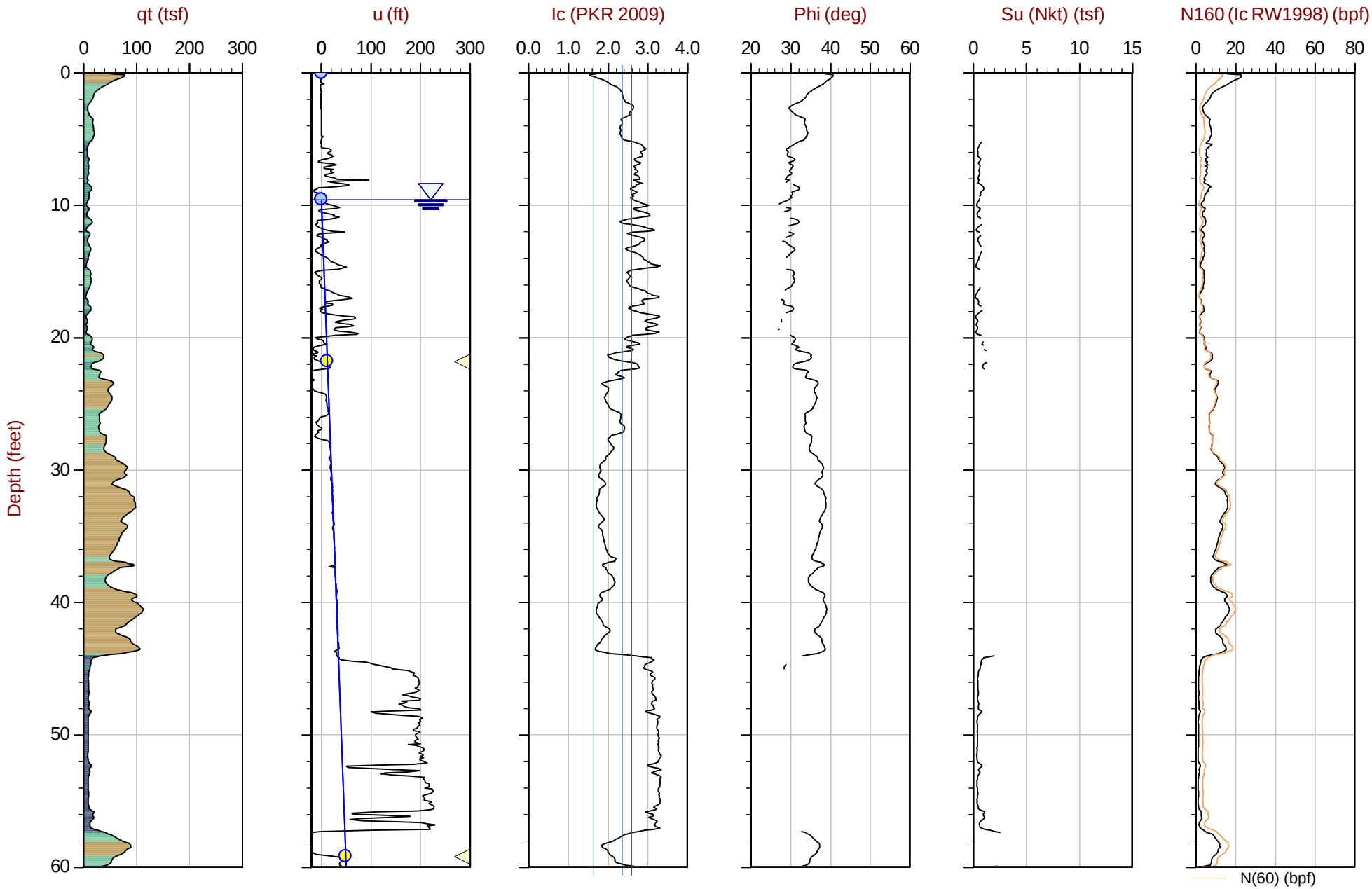
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-10-31 08:48
Site: Courtland

Sounding: GEI-RD551-002C
Cone: 448:T1500F15U500



Max Depth: 22.875 m / 75.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-002C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4240067m E: 625213m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

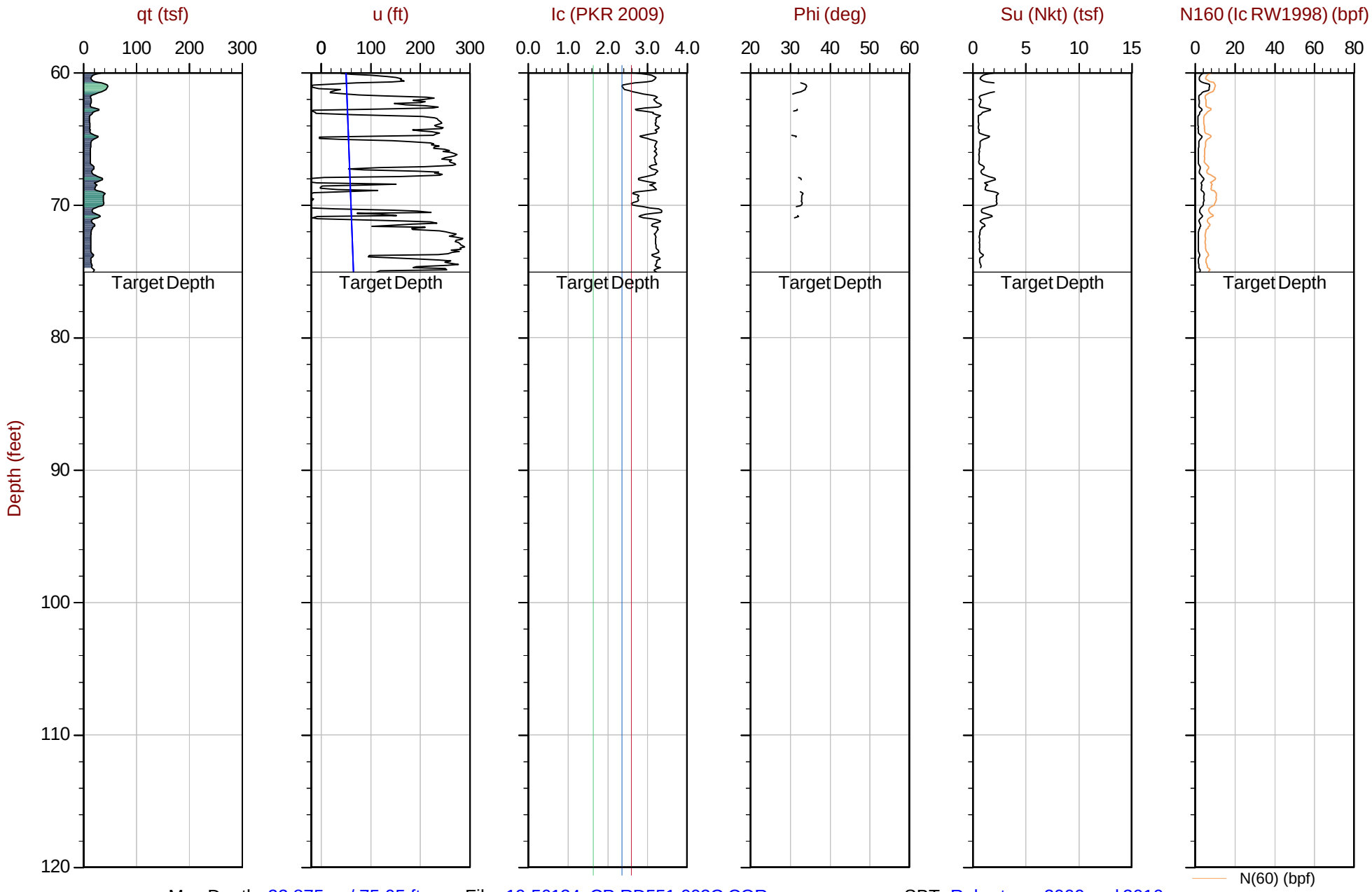
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-10-31 08:48
Site: Courtland

Sounding: GEI-RD551-002C
Cone: 448:T1500F15U500



Max Depth: 22.875 m / 75.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-002C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4240067m E: 625213m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

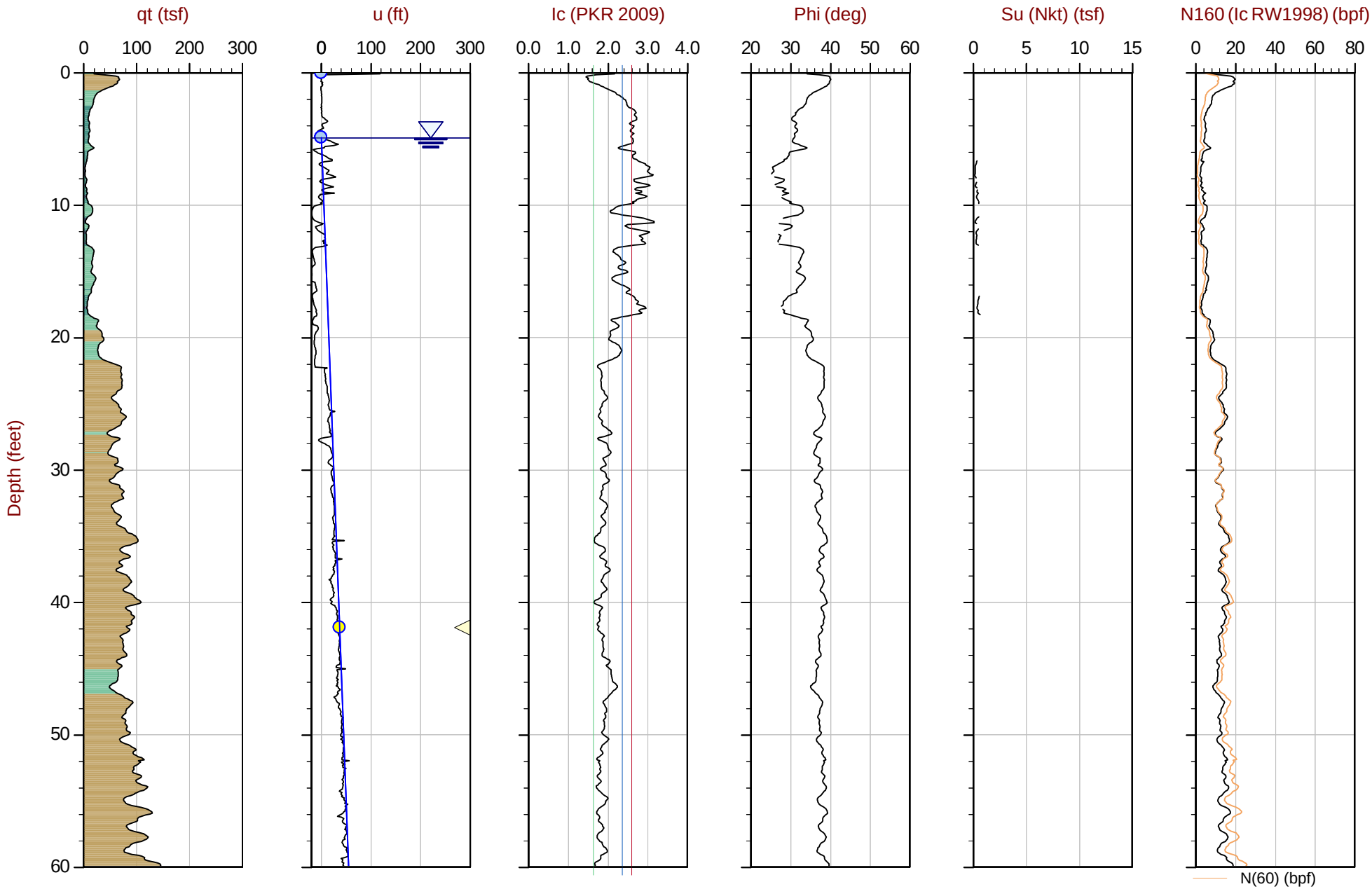
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-28 13:16
Site: Courtland

Sounding: GEI-RD551-003C
Cone: 391:T1500F15U500



Max Depth: 30.800 m / 101.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-003C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4236431m E: 628823m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

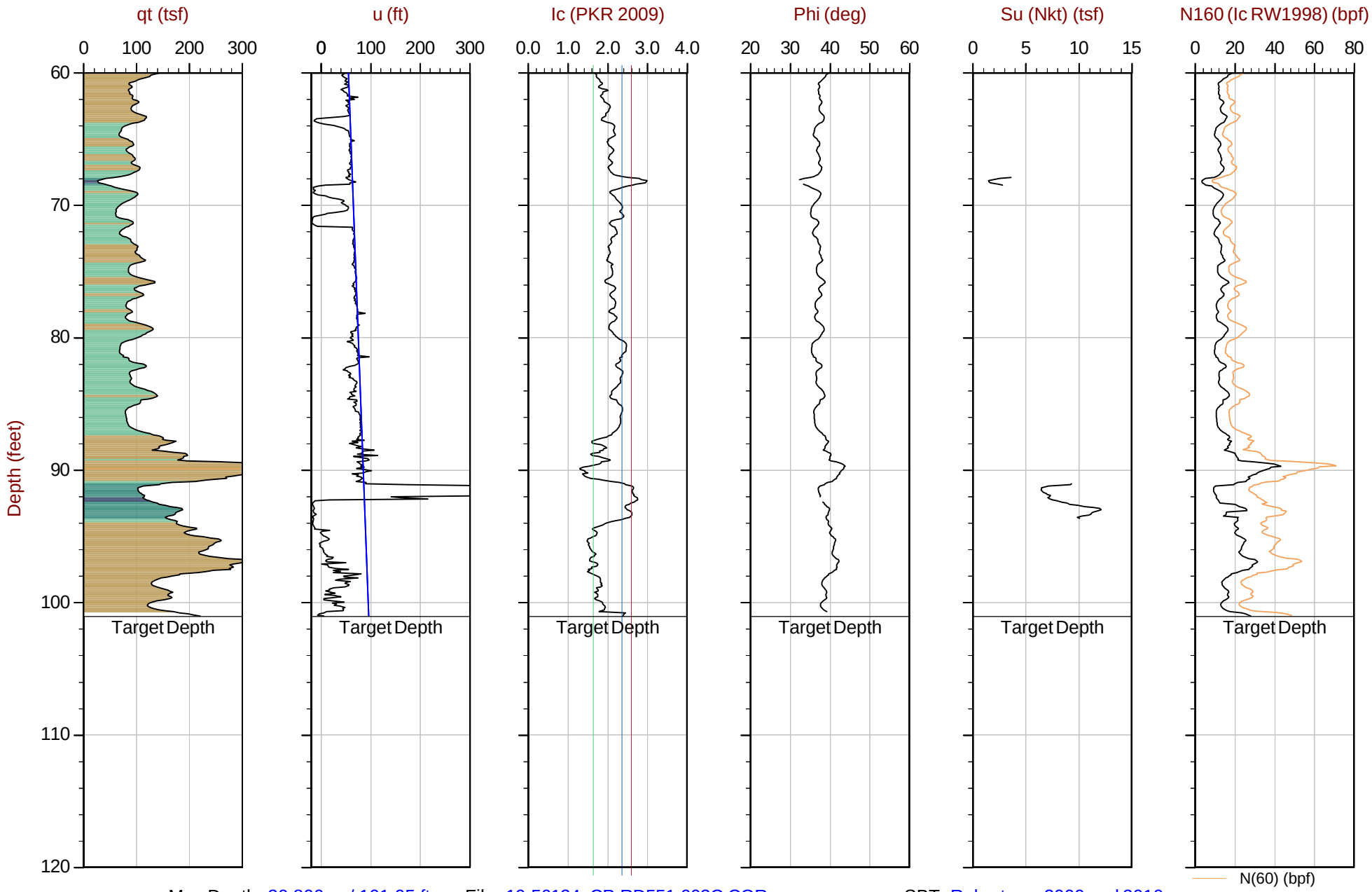
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-28 13:16
Site: Courtland

Sounding: GEI-RD551-003C
Cone: 391:T1500F15U500



Max Depth: 30.800 m / 101.05 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-003C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4236431m E: 628823m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

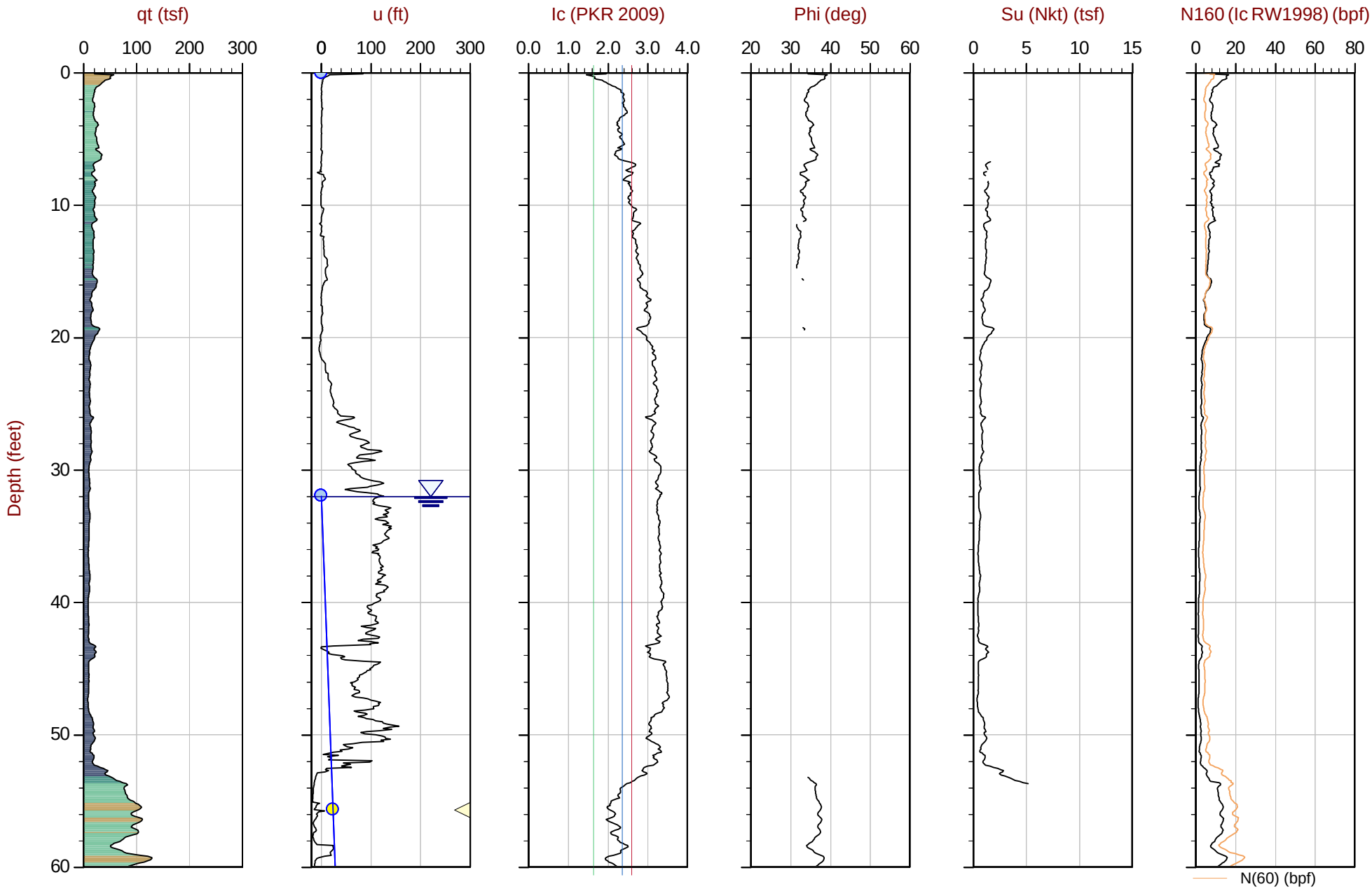
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 14:43
Site: Courtland

Sounding: GEI-RD551-006C
Cone: 499:T1500F15U1K



Max Depth: 30.825 m / 101.13 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-006C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4238370m E: 630808m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

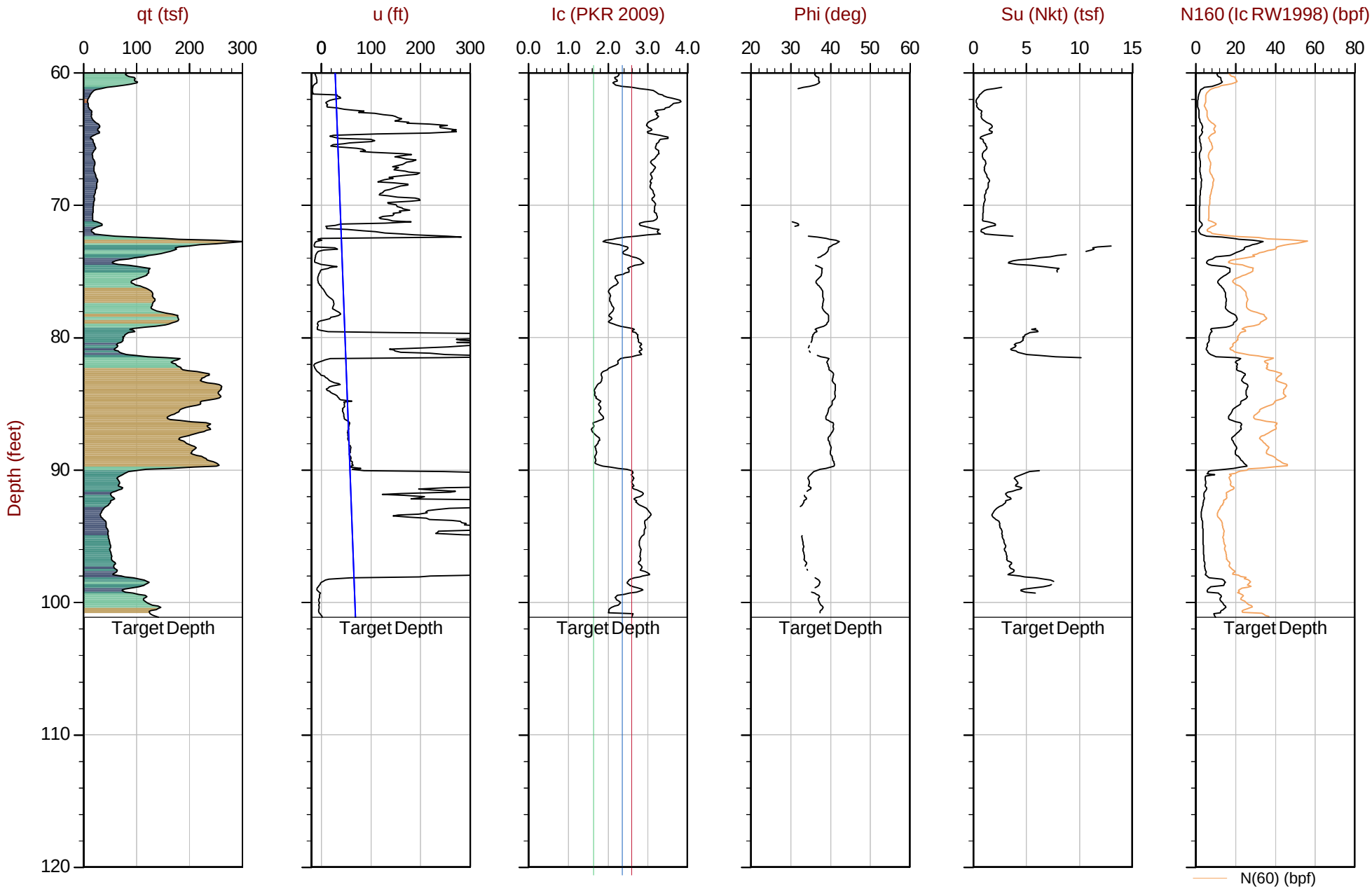
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 14:43
Site: Courtland

Sounding: GEI-RD551-006C
Cone: 499:T1500F15U1K



Max Depth: 30.825 m / 101.13 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-006C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4238370m E: 630808m

Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

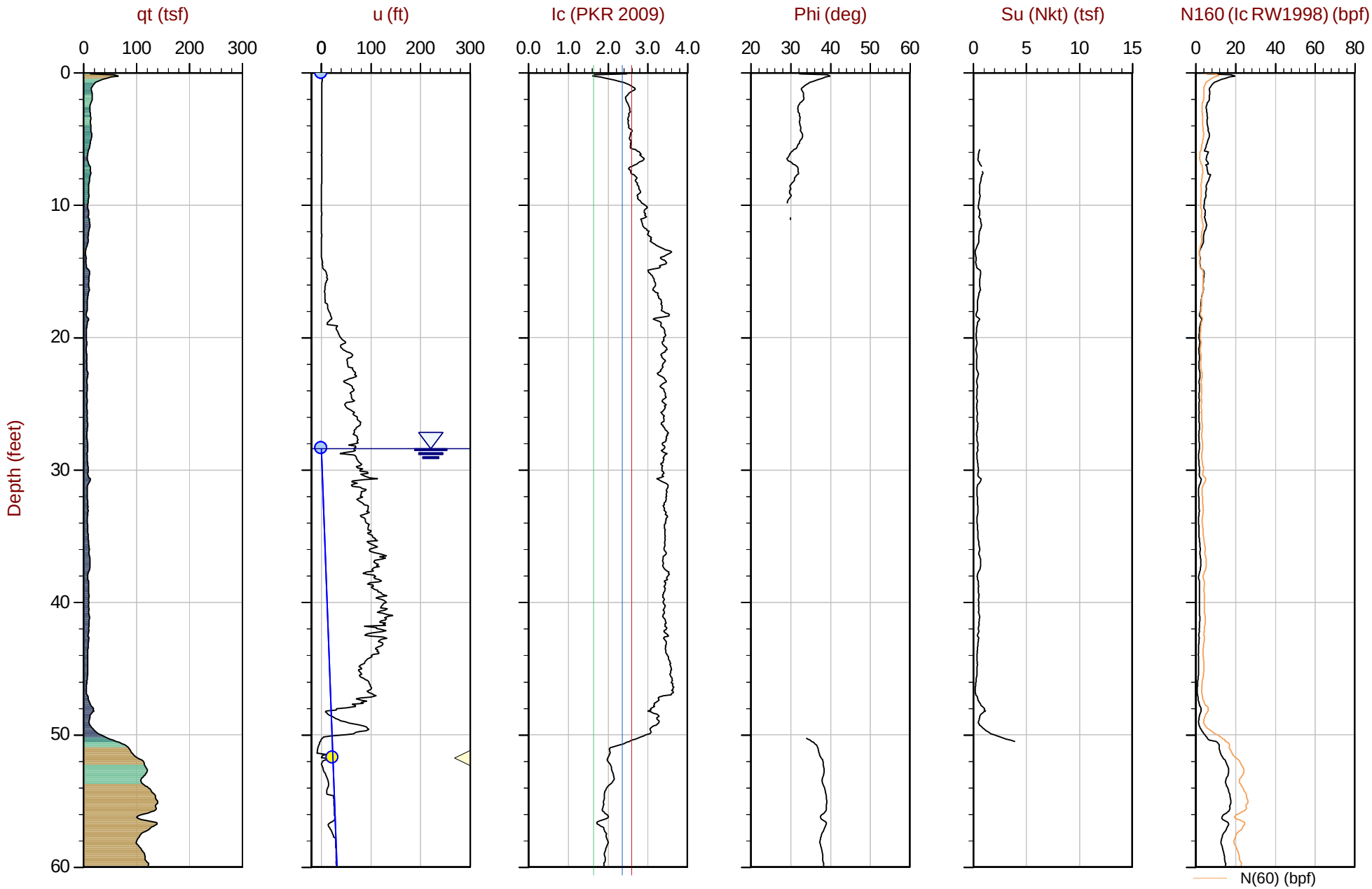
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 08:01
Site: Courtland

Sounding: GEI-RD551-007C
Cone: 499:T1500F15U1K



Max Depth: 23.050 m / 75.62 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-007C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4240059m E: 630097m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

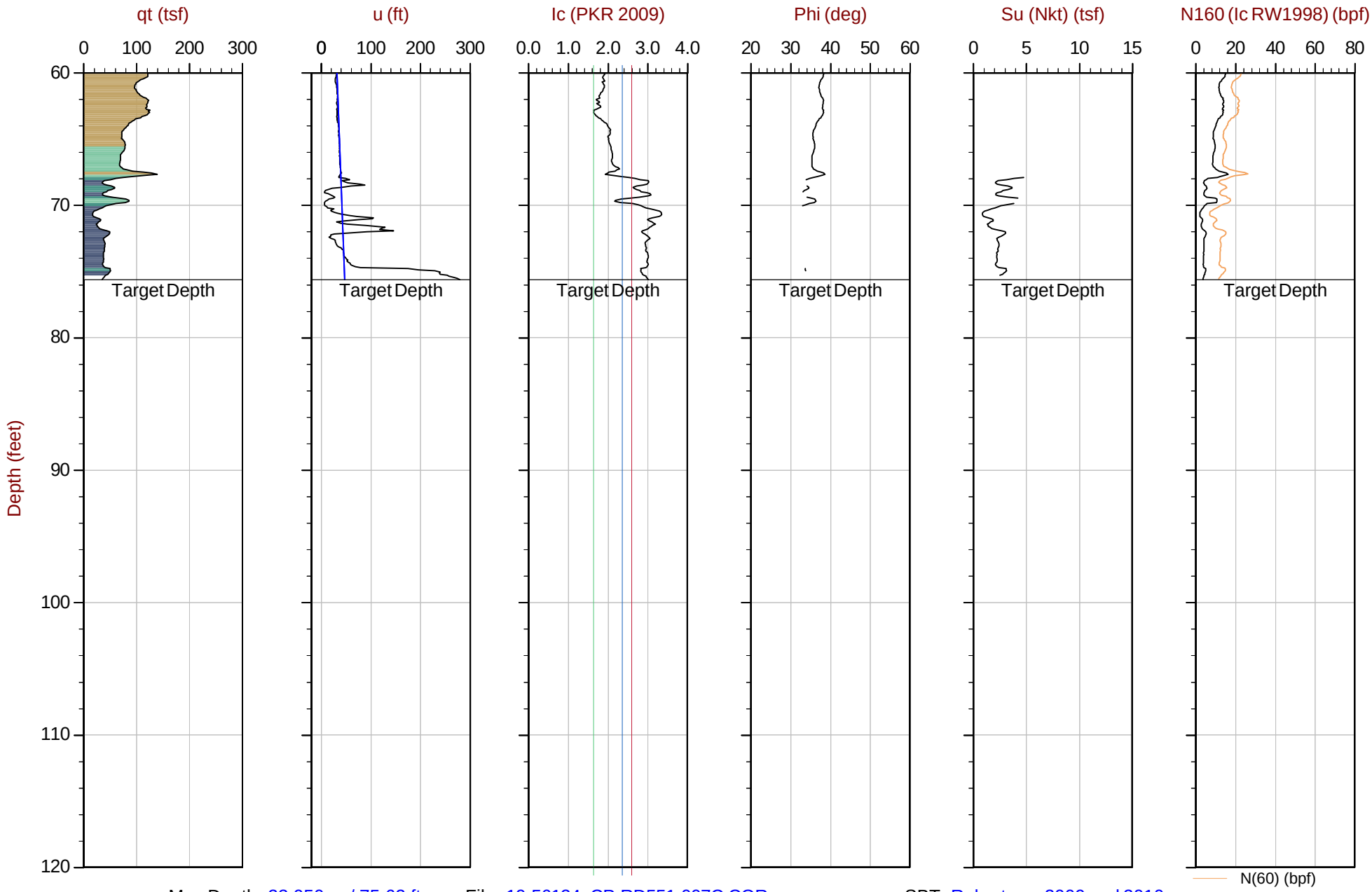
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 08:01
Site: Courtland

Sounding: GEI-RD551-007C
Cone: 499:T1500F15U1K



Max Depth: 23.050 m / 75.62 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-007C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4240059m E: 630097m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

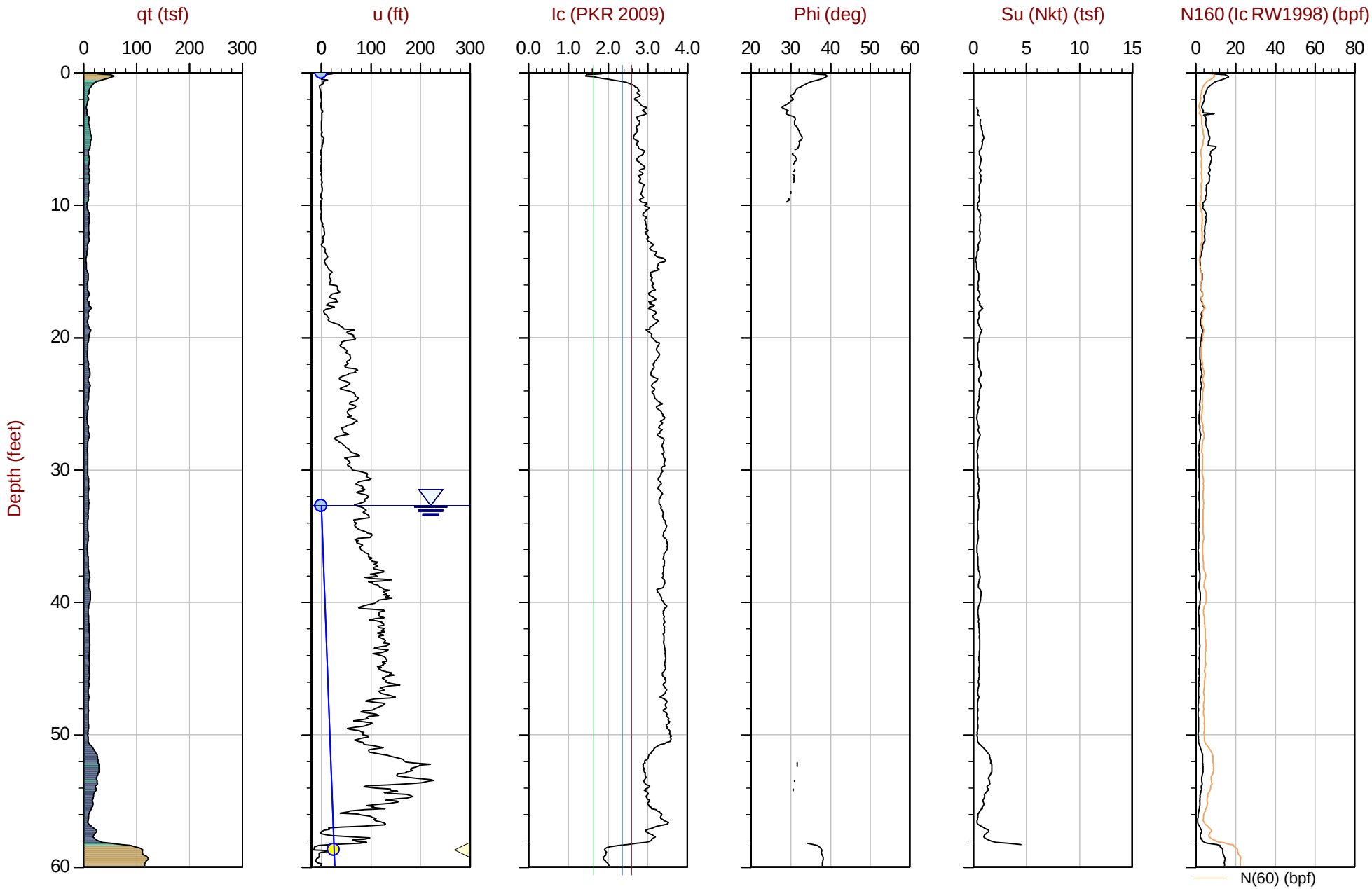
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 11:32
Site: Courtland

Sounding: GEI-RD551-008C
Cone: 499:T1500F15U1K



Max Depth: 30.875 m / 101.29 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-008C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4239347m E: 630254m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

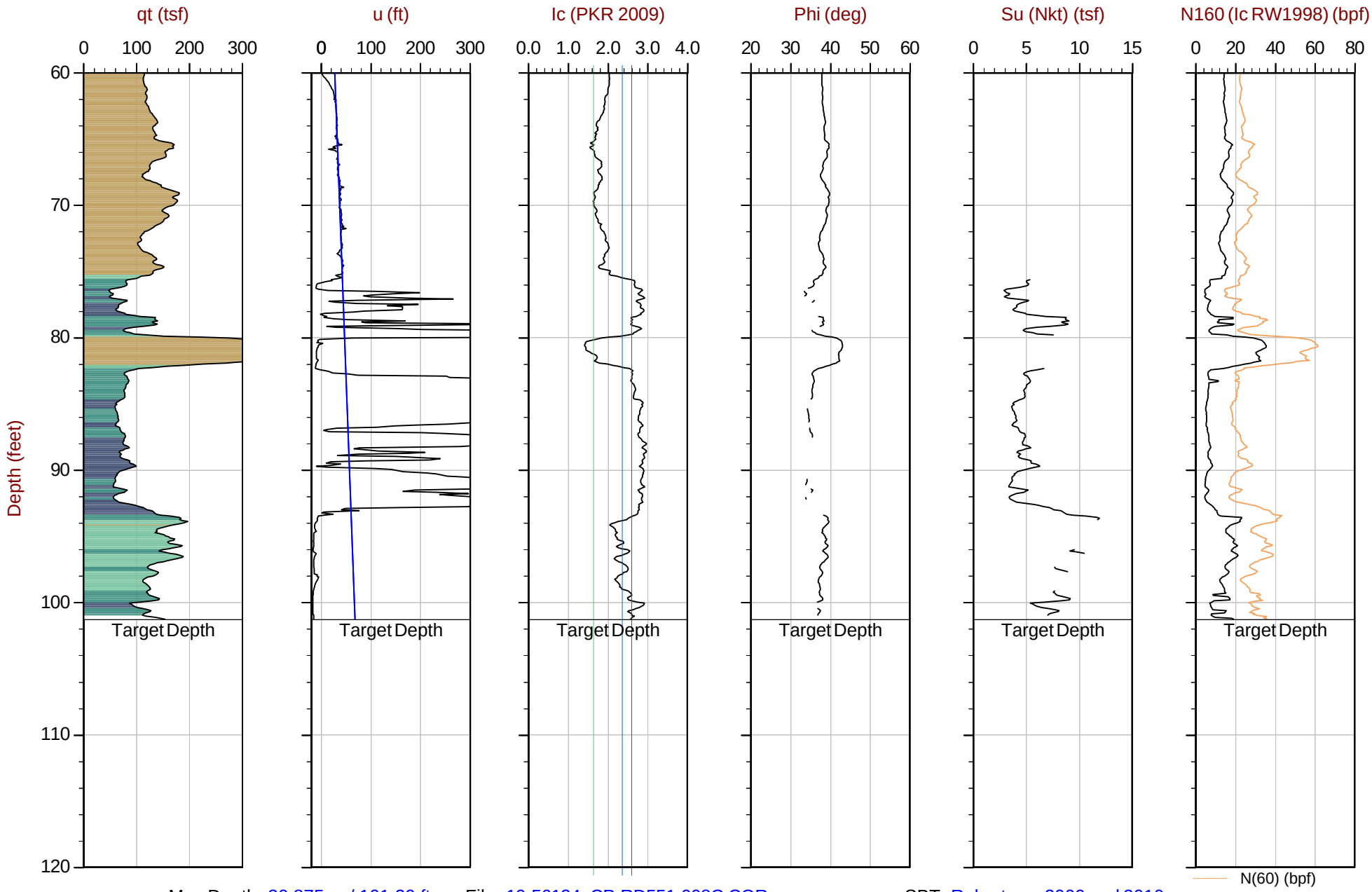
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-20 11:32
Site: Courtland

Sounding: GEI-RD551-008C
Cone: 499:T1500F15U1K



Max Depth: 30.875 m / 101.29 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-008C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4239347m E: 630254m

Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

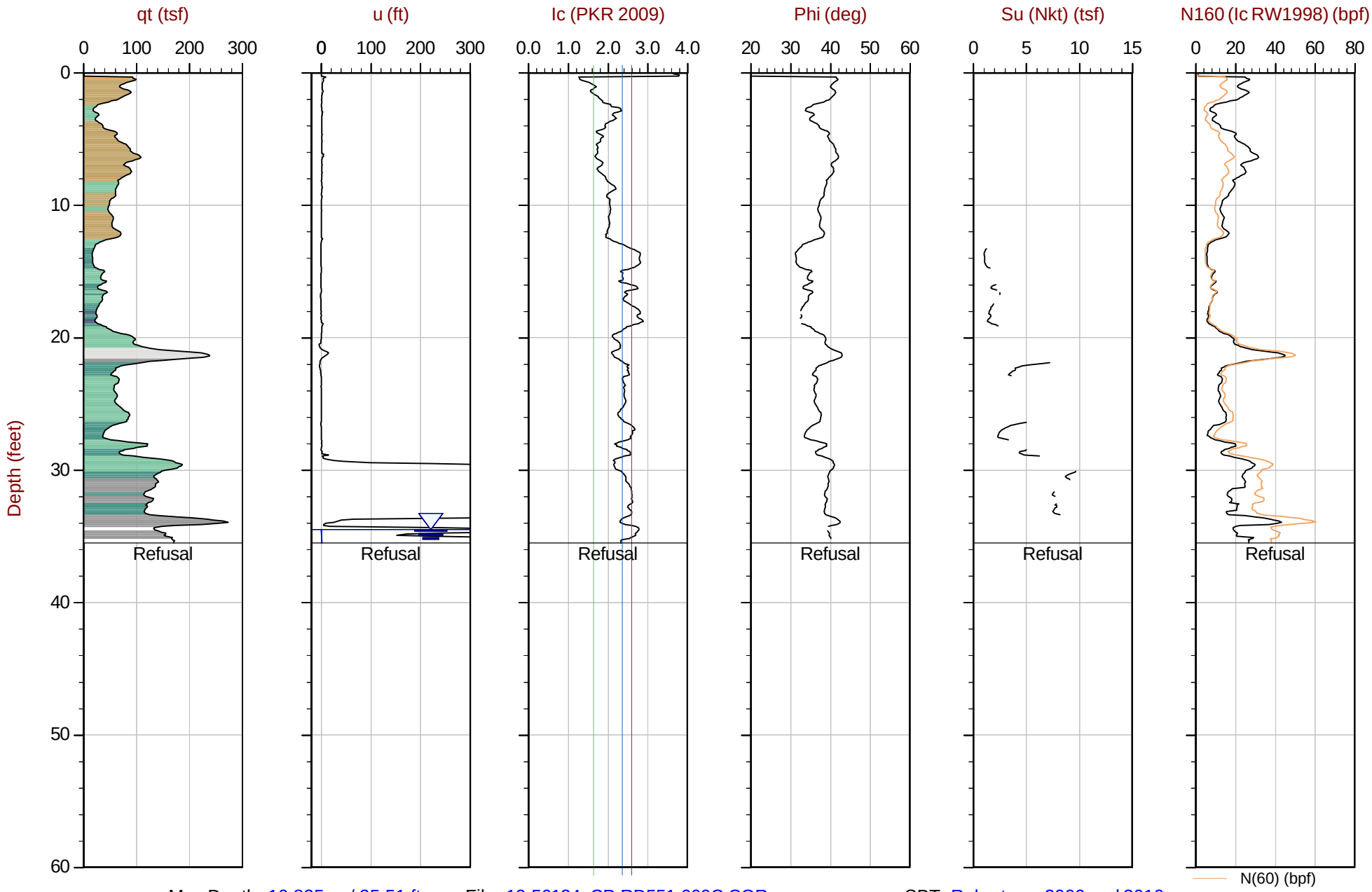
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 13:50
Site: Courtland

Sounding: GEI-RD551-009C
Cone: 391:T1500F15U500



Max Depth: 10.825 m / 35.51 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-009C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4242747m E: 629356m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

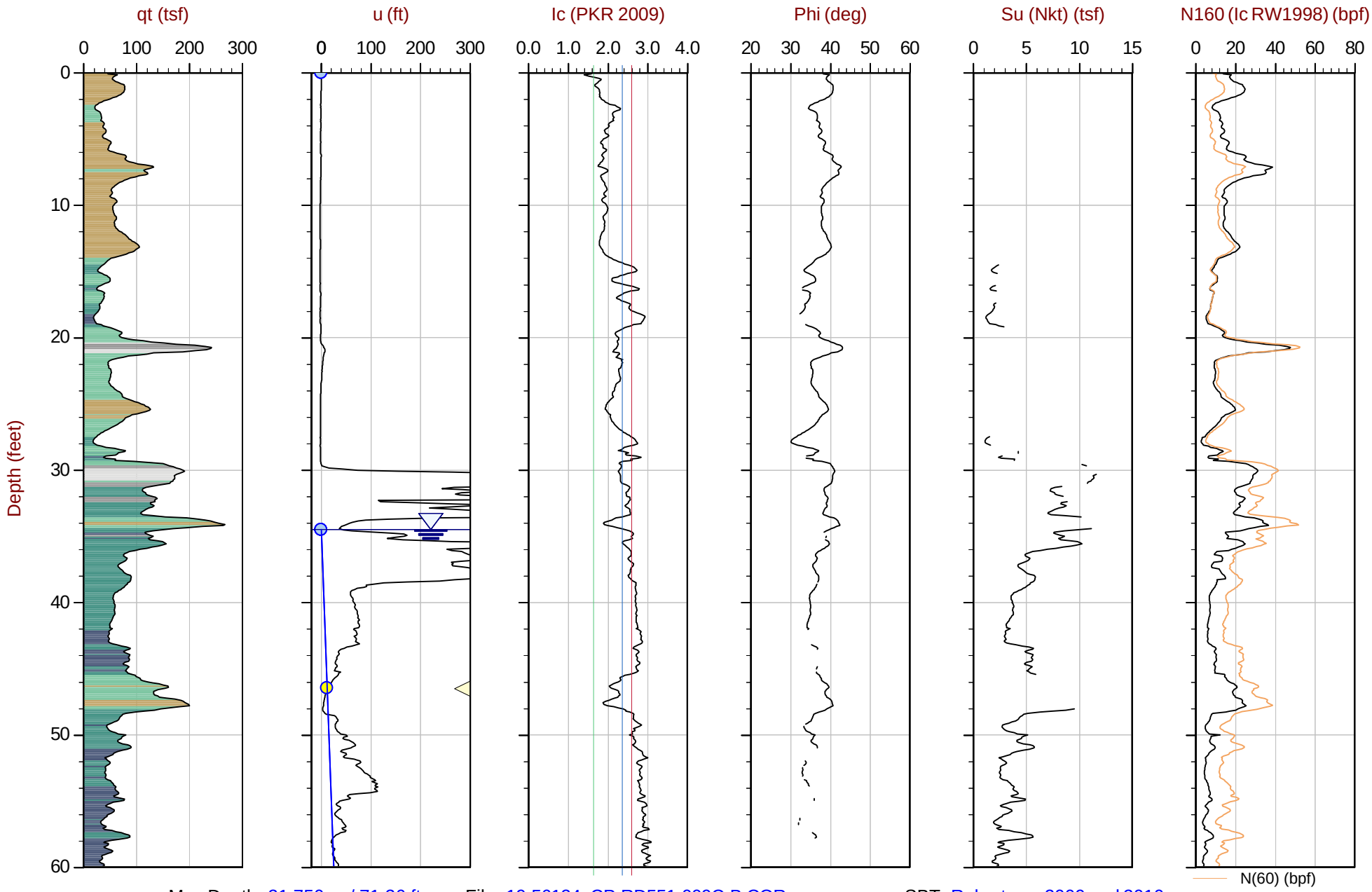
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 14:35
Site: Courtland

Sounding: GEI-RD551-009C-B
Cone: 499:T1500F15U1K



Max Depth: 21.750 m / 71.36 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-009C-B.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4242747m E: 629356m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

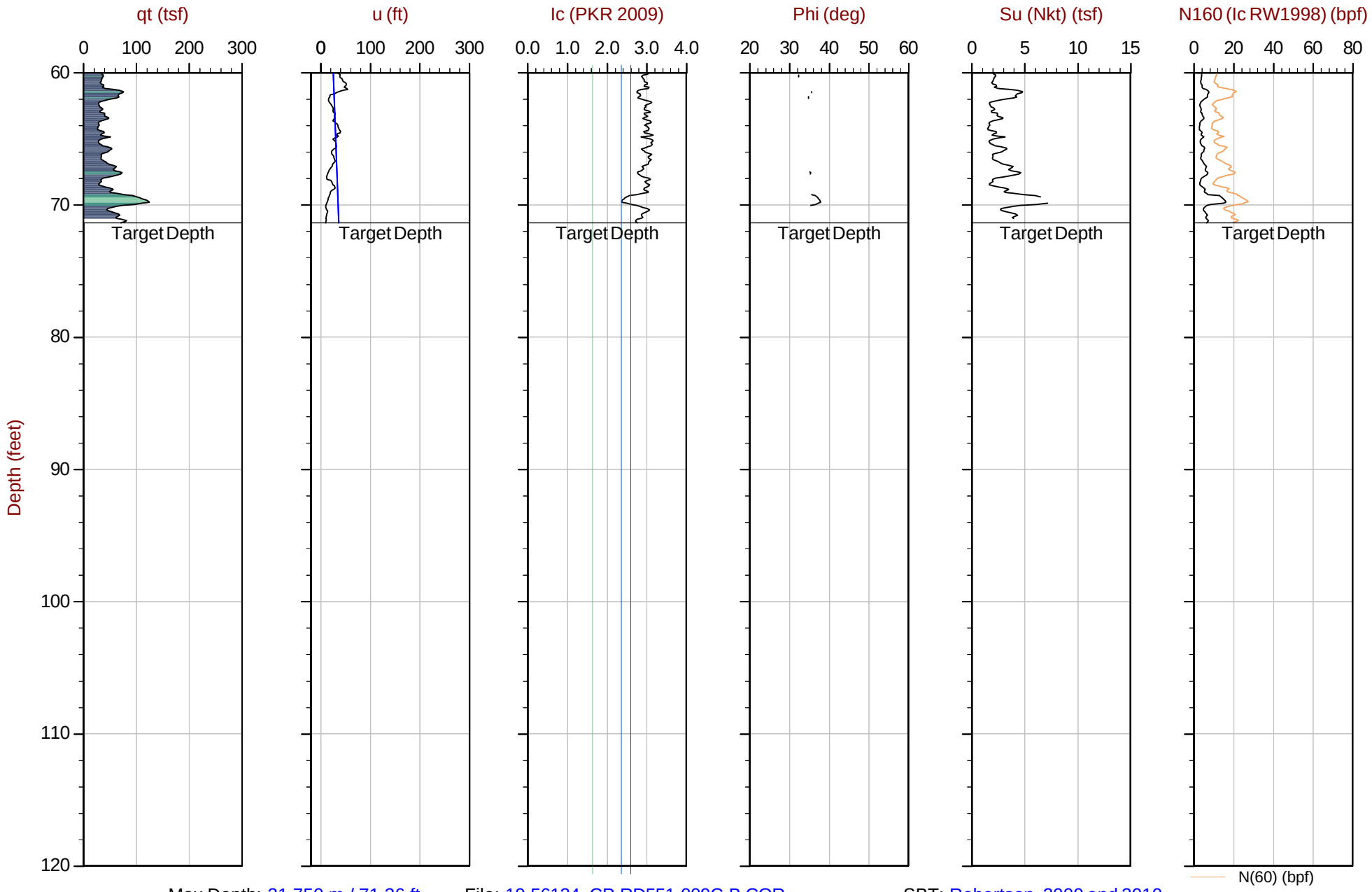
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CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 14:35
Site: Courtland

Sounding: GEI-RD551-009C-B
Cone: 499:T1500F15U1K



Max Depth: 21.750 m / 71.36 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-009C-B.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4242747m E: 629356m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

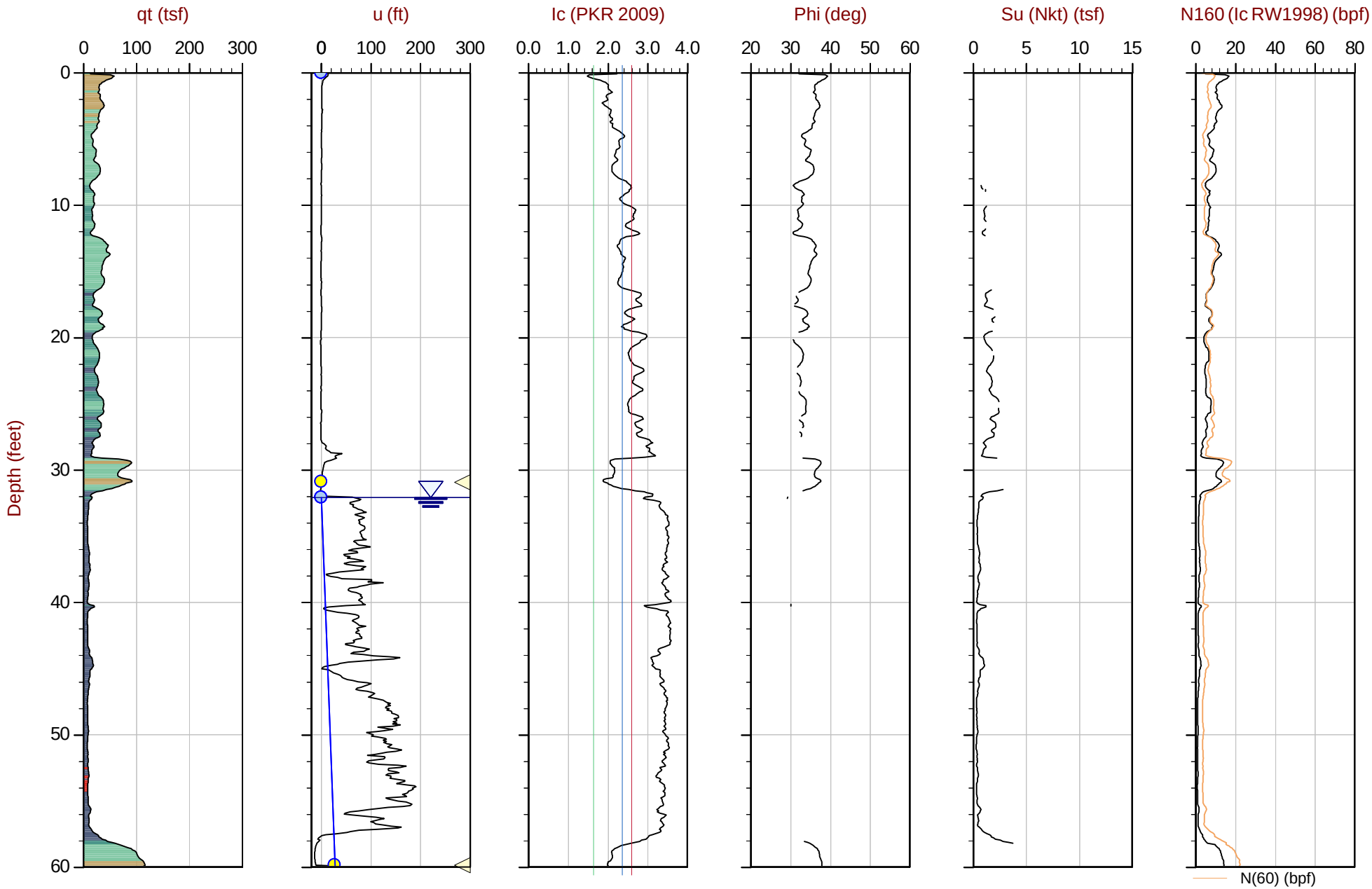
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 09:06
Site: Courtland

Sounding: GEI-RD551-010C
Cone: 391:T1500F15U500



Max Depth: 23.075 m / 75.70 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-010C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4244298m E: 628854m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

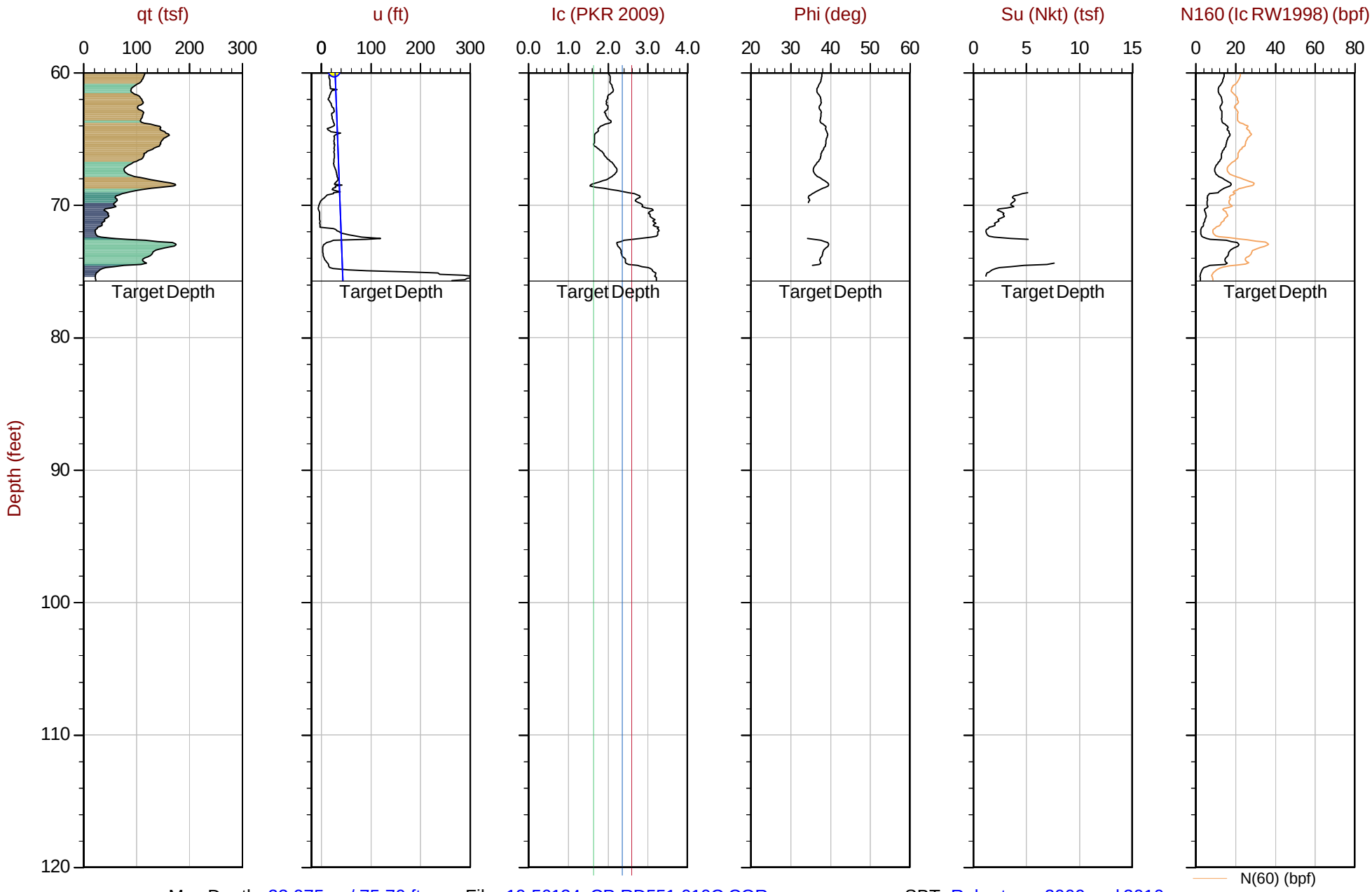
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CONETEC

GEI

Job No: 19-56124
Date: 2019-08-19 09:06
Site: Courtland

Sounding: GEI-RD551-010C
Cone: 391:T1500F15U500



Max Depth: 23.075 m / 75.70 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 19-56124_CP-RD551-010C.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4244298m E: 628854m

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

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

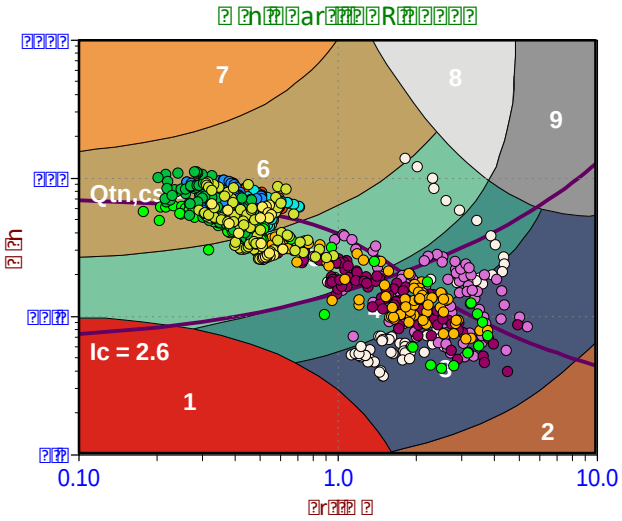
CONETEC

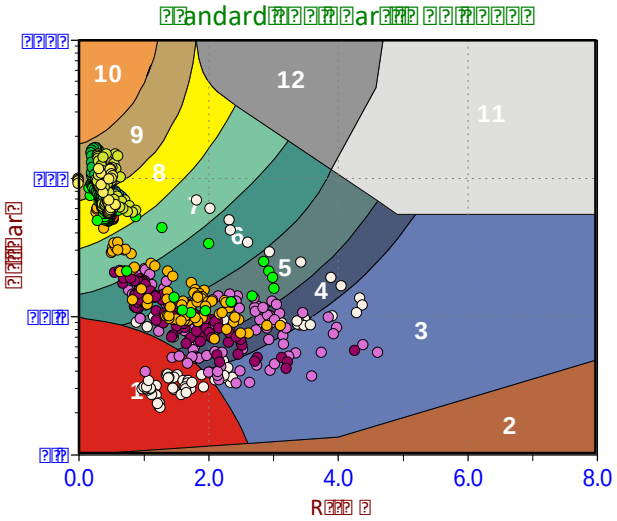
CONETEC

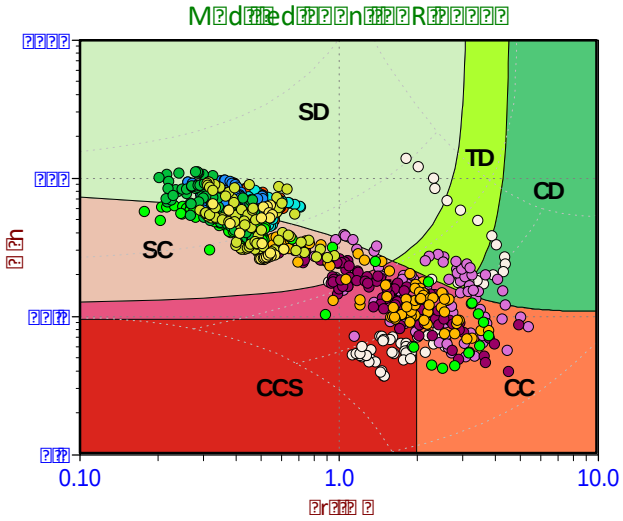
GEI

Job No: 19-56124
Date: 2019-08-21 08:07
Site: Courtland

Sounding: GEI-RD551-001C
Cone: 499:T1500F15U1K







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

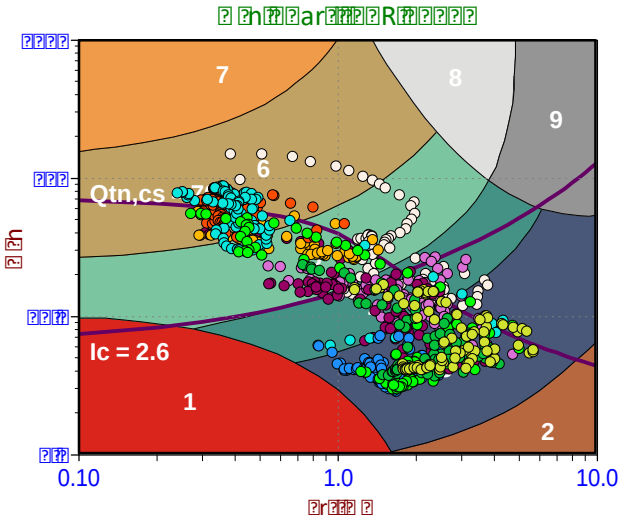
Legend
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

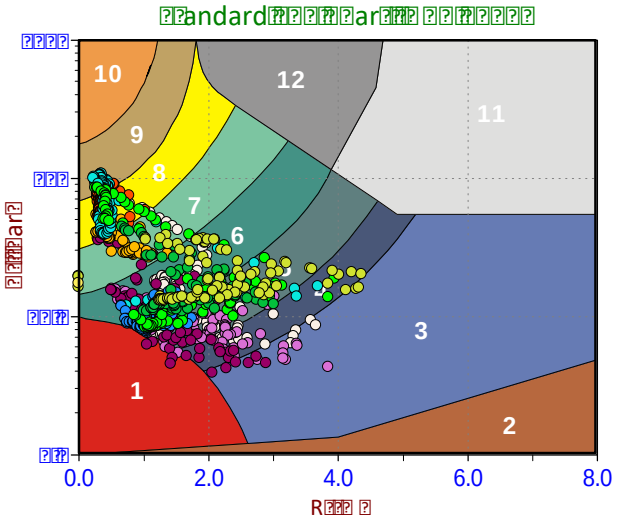
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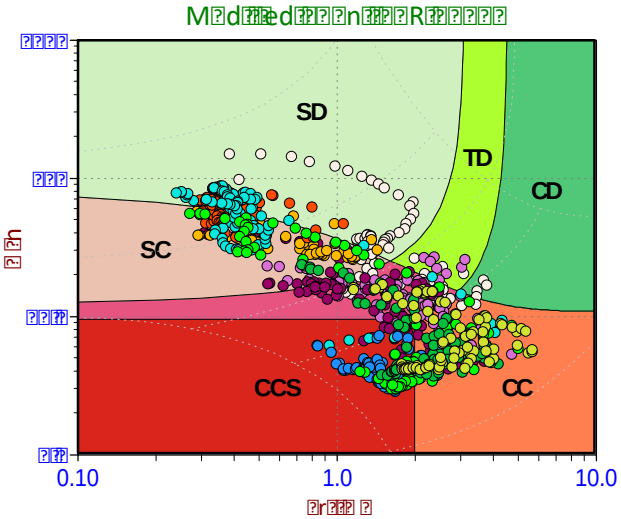
GEI

Job No: 19-56124
Date: 2019-10-31 08:48
Site: Courtland

Sounding: GEI-RD551-002C
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

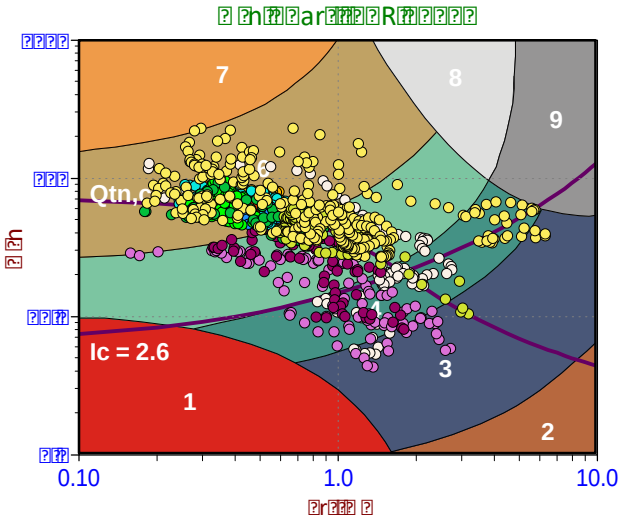
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

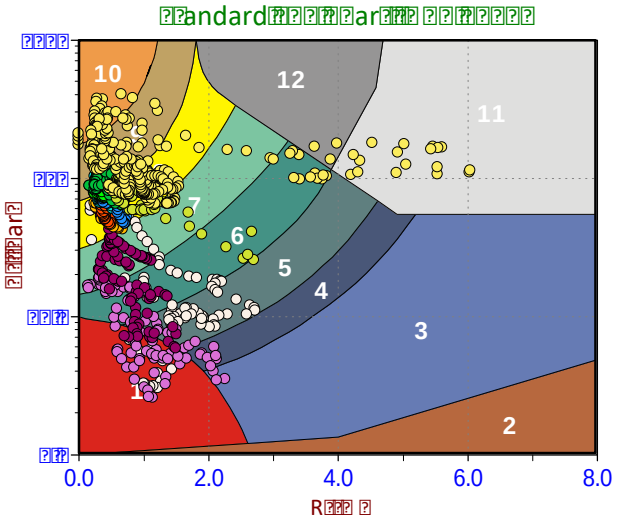
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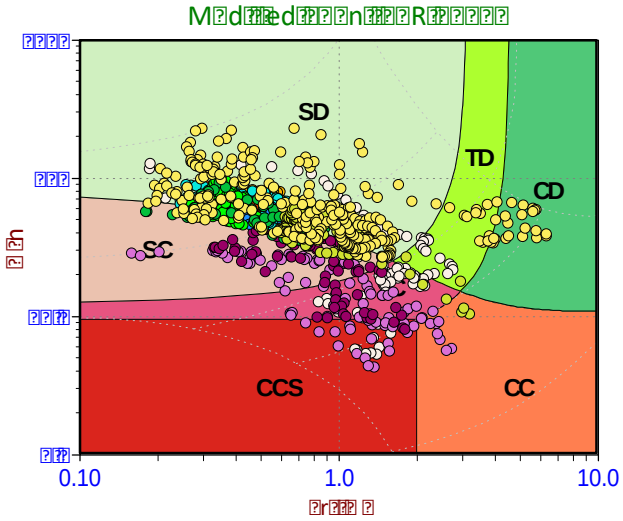
GEI

Job No: 19-56124
Date: 2019-08-28 13:16
Site: Courtland

Sounding: GEI-RD551-003C
Cone: 391: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

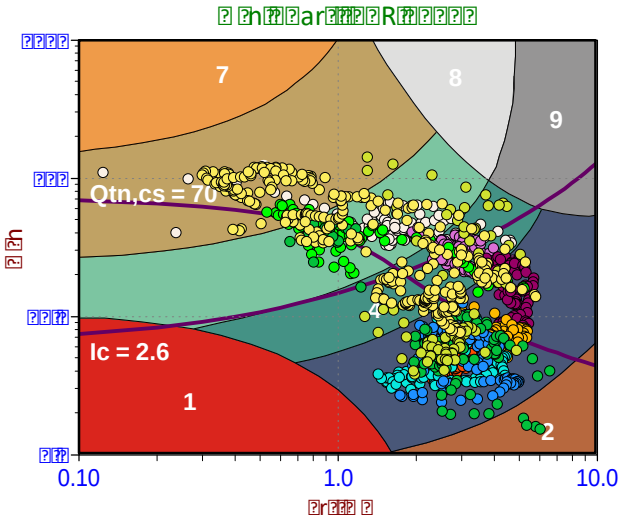
Legend
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

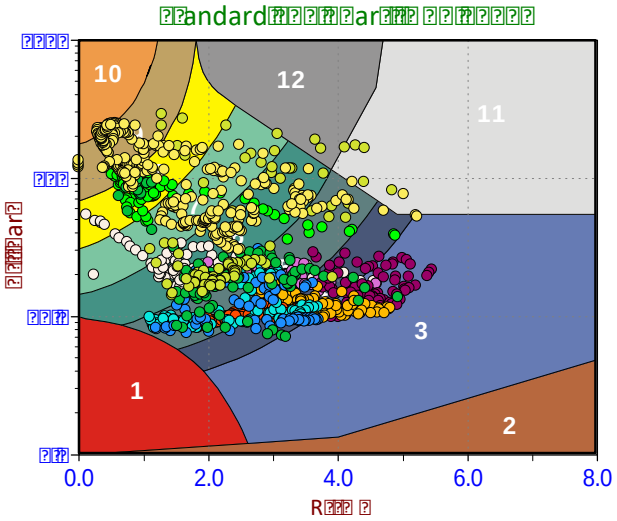
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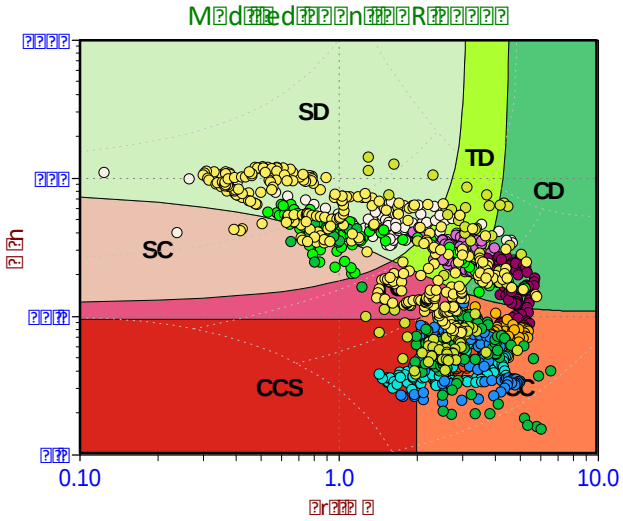
GEI

Job No: 19-56124
Date: 2019-08-20 14:43
Site: Courtland

Sounding: GEI-RD551-006C
Cone: 499:T1500F15U1K







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

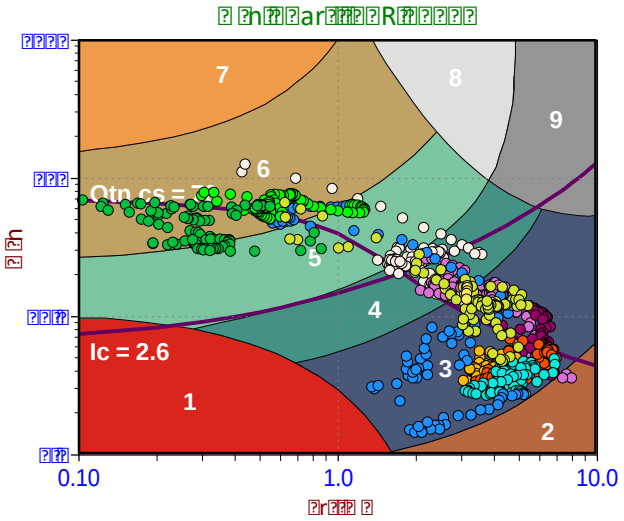
Legend
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

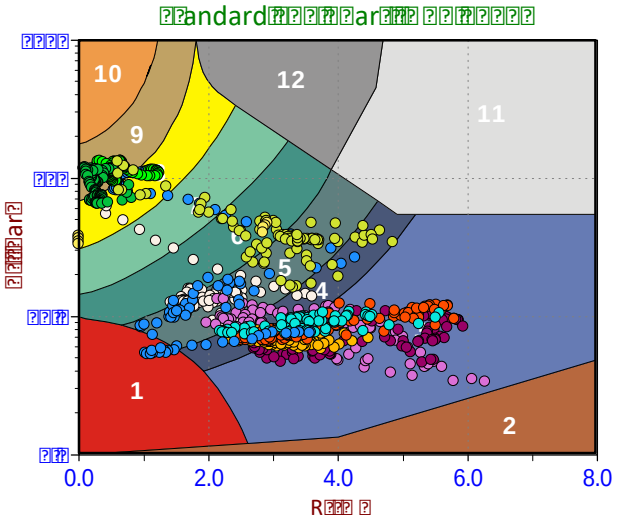
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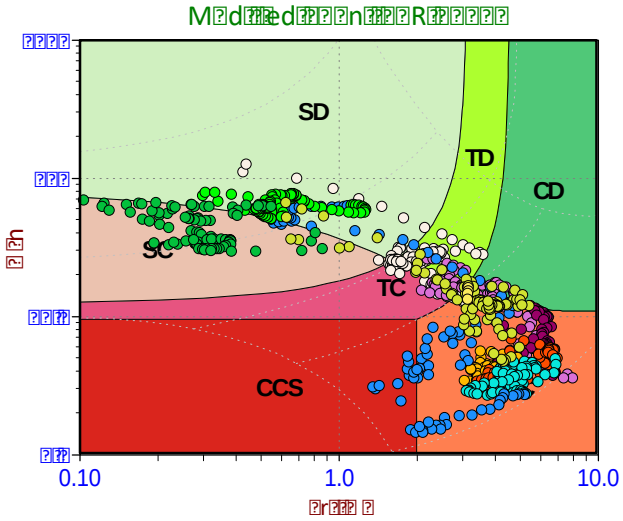
GEI

Job No: 19-56124
Date: 2019-08-20 08:01
Site: Courtland

Sounding: GEI-RD551-007C
Cone: 499:T1500F15U1K







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

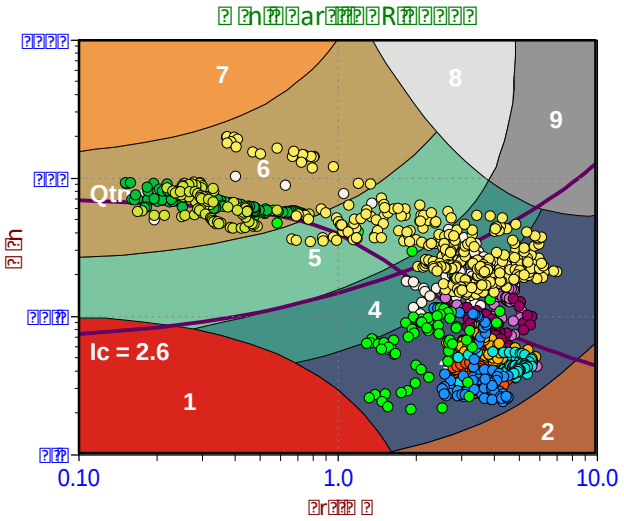
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

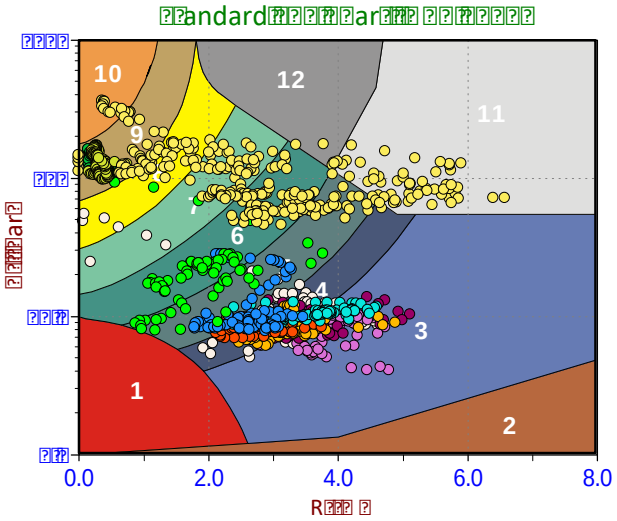
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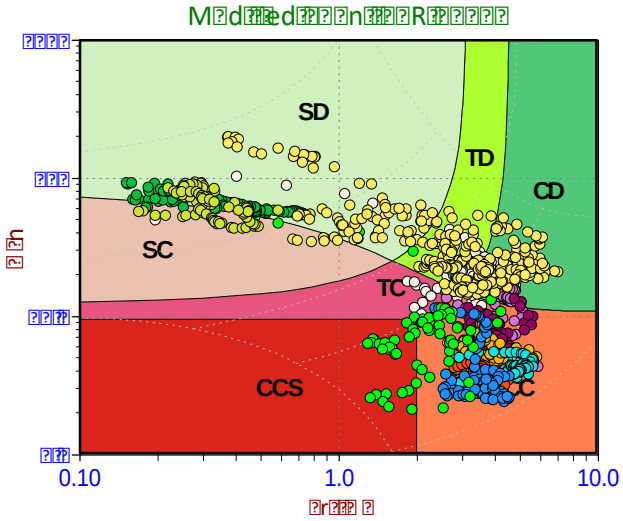
GEI

Job No: 19-56124
Date: 2019-08-20 11:32
Site: Courtland

Sounding: GEI-RD551-008C
Cone: 499:T1500F15U1K







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

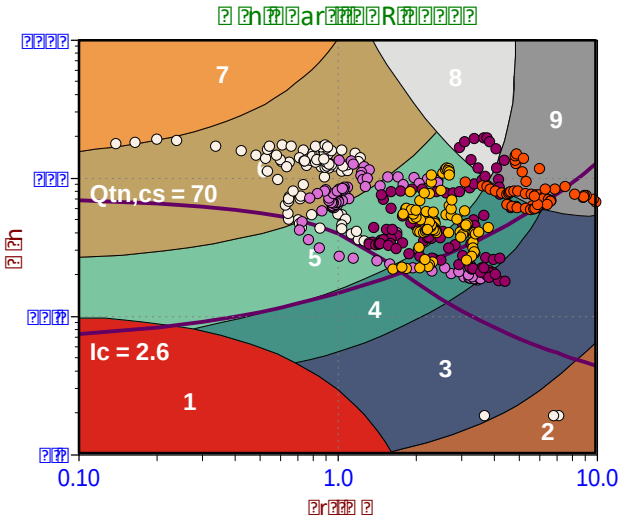
Legend
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

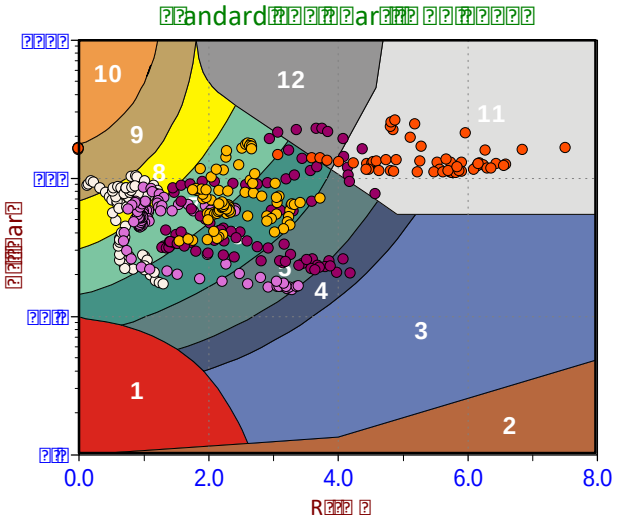
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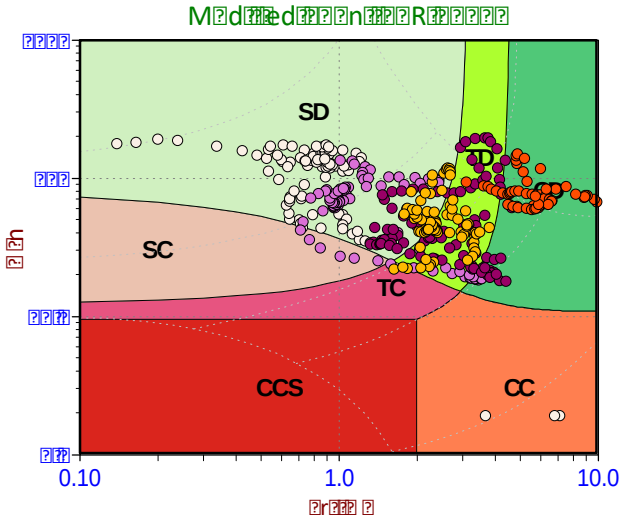
GEI

Job No: 19-56124
Date: 2019-08-19 13:50
Site: Courtland

Sounding: GEI-RD551-009C
Cone: 391: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

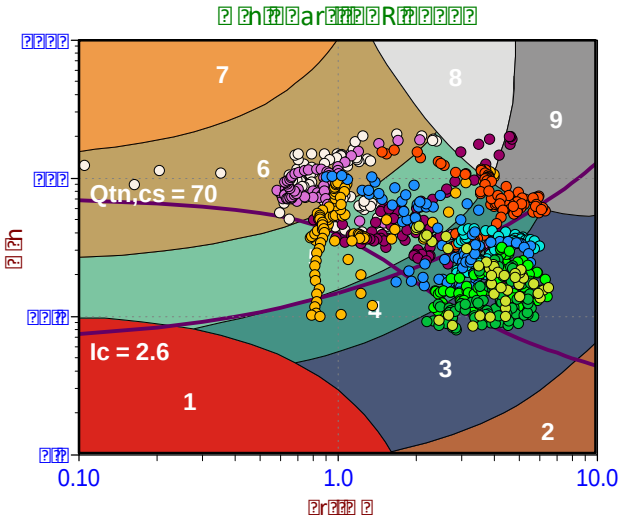
Legend
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

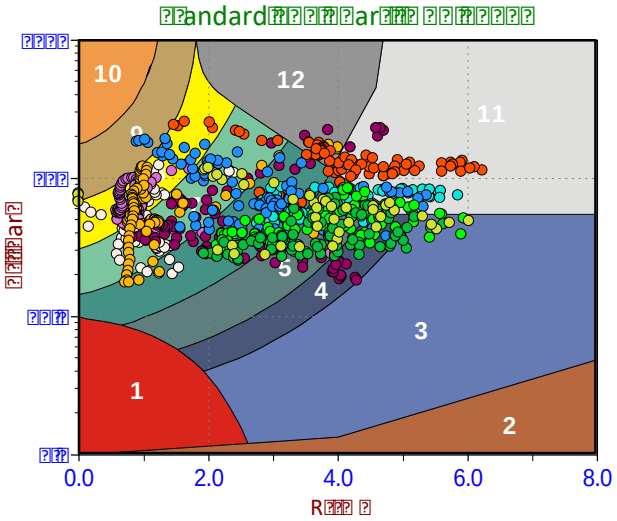
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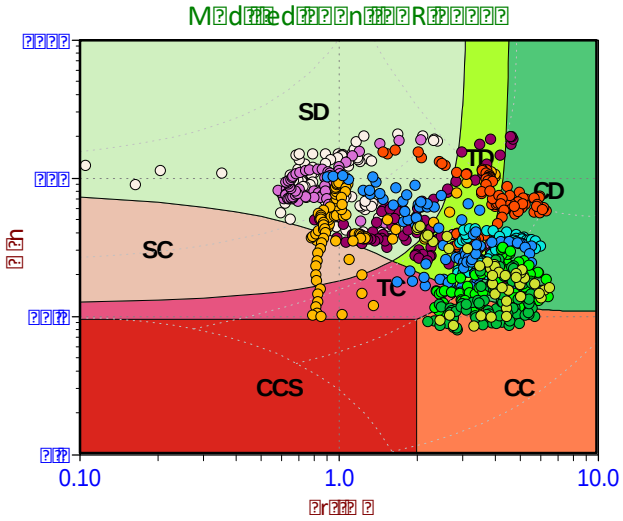
GEI

Job No: 19-56124
Date: 2019-08-19 14:35
Site: Courtland

Sounding: GEI-RD551-009C-B
Cone: 499:T1500F15U1K







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

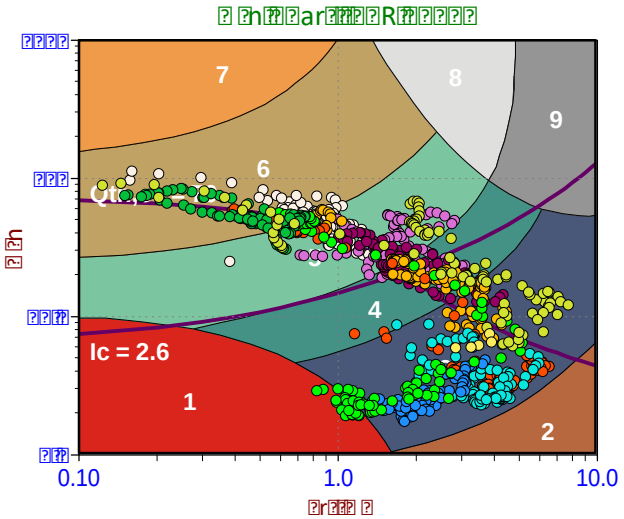
Legend
- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)

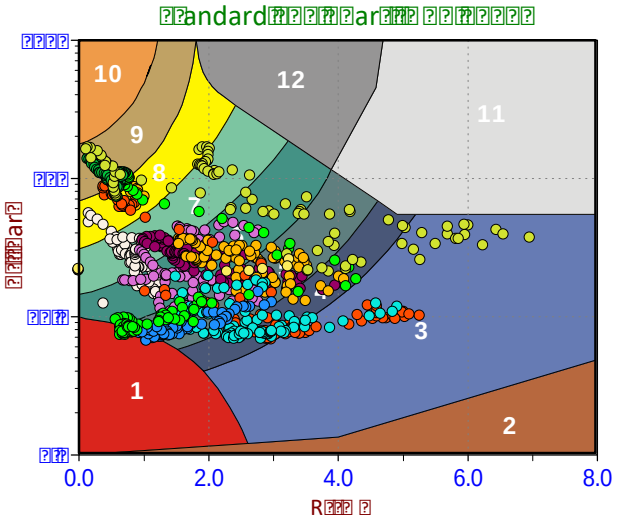
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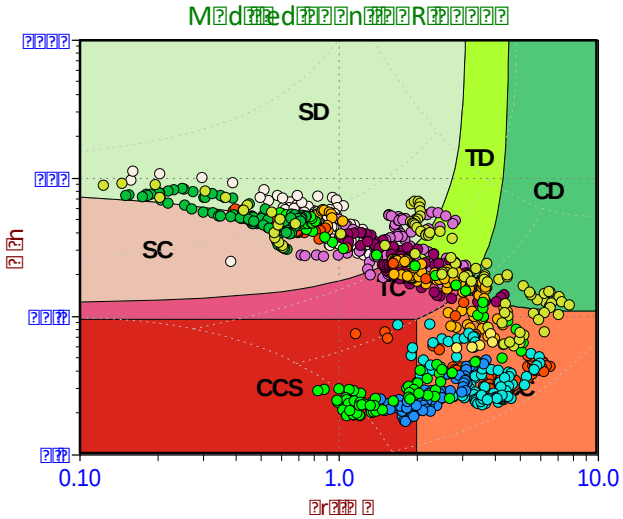
GEI

Job No: 19-56124
Date: 2019-08-19 09:06
Site: Courtland

Sounding: GEI-RD551-010C
Cone: 391: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)

Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

Job No:	19-56124
Client:	GEI Consultants
Project:	Small Communities
Start Date:	19-Aug-2019
End Date:	28-Aug-2019

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-RD551-001C	19-56124_CP-RD551-001C	15	455	45.85	39.6	6.3
GEI-RD551-003C	19-56124_CP-RD551-003C	15	305	41.91	37.0	4.9
GEI-RD551-006C	19-56124_CP-RD551-006C	15	310	55.69	23.7	32.0
GEI-RD551-007C	19-56124_CP-RD551-007C	15	490	51.75	23.4	28.4
GEI-RD551-008C	19-56124_CP-RD551-008C	15	395	58.73	26.0	32.7
GEI-RD551-009C-B	19-56124_CP-RD551-009C-B	15	620	46.51	12.0	34.5
GEI-RD551-010C	19-56124_CP-RD551-010C	15	195	30.92	0.0	30.9
GEI-RD551-010C	19-56124_CP-RD551-010C	15	360	59.87	27.8	32.1

Job No:	19-56124
Client:	GEI Consultants
Project:	Small Communities
Start Date:	21-Oct-2019
End Date:	01-Nov-2019

CPTu PORE PRESSURE DISSIPATION SUMMARY

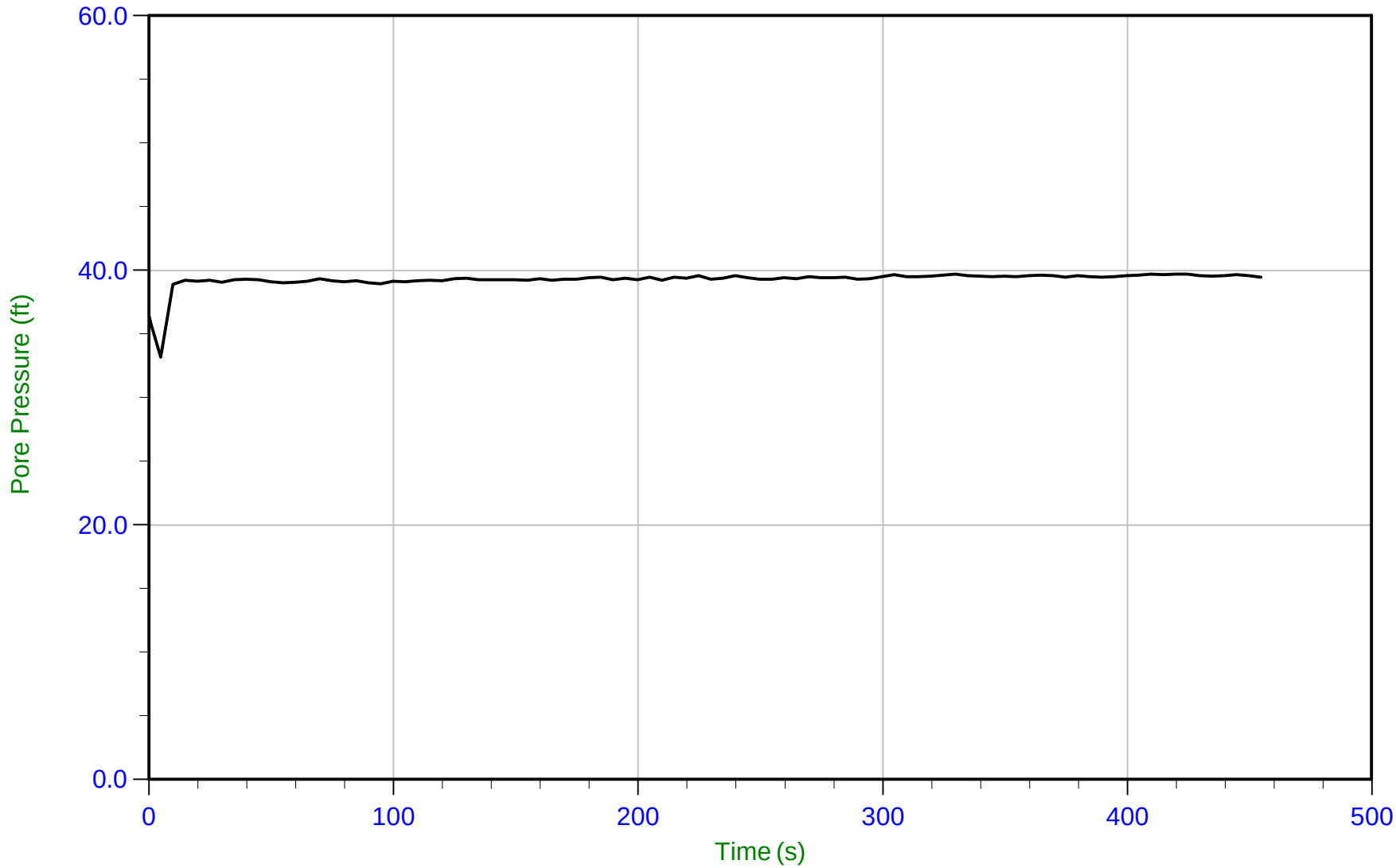
Sounding ID	File Name	Cone Area (cm^2)	Duration (s)	Test Depth (ft)	Estimated Equilibrium Pore Pressure U_{eq} (ft)	Calculated Phreatic Surface (ft)
GEI-RD551-002C	19-56124_CP-RD551-002C	15	300	21.82	12.2	9.6
GEI-RD551-002C	19-56124_CP-RD551-002C	15	300	59.22	49.0	10.2

CONETEC

GEI

Job No: 19-56124
Date: 08/21/2019 08:07
Site: Courtland

Sounding: GEI-RD551-001C
Cone: 499:T1500F15U1K Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-RD551-001C.PPD
Depth: 13.975 m / 45.849 ft
Duration: 455.0 s

u Min: 33.2 ft
u Max: 39.7 ft
u Final: 39.5 ft

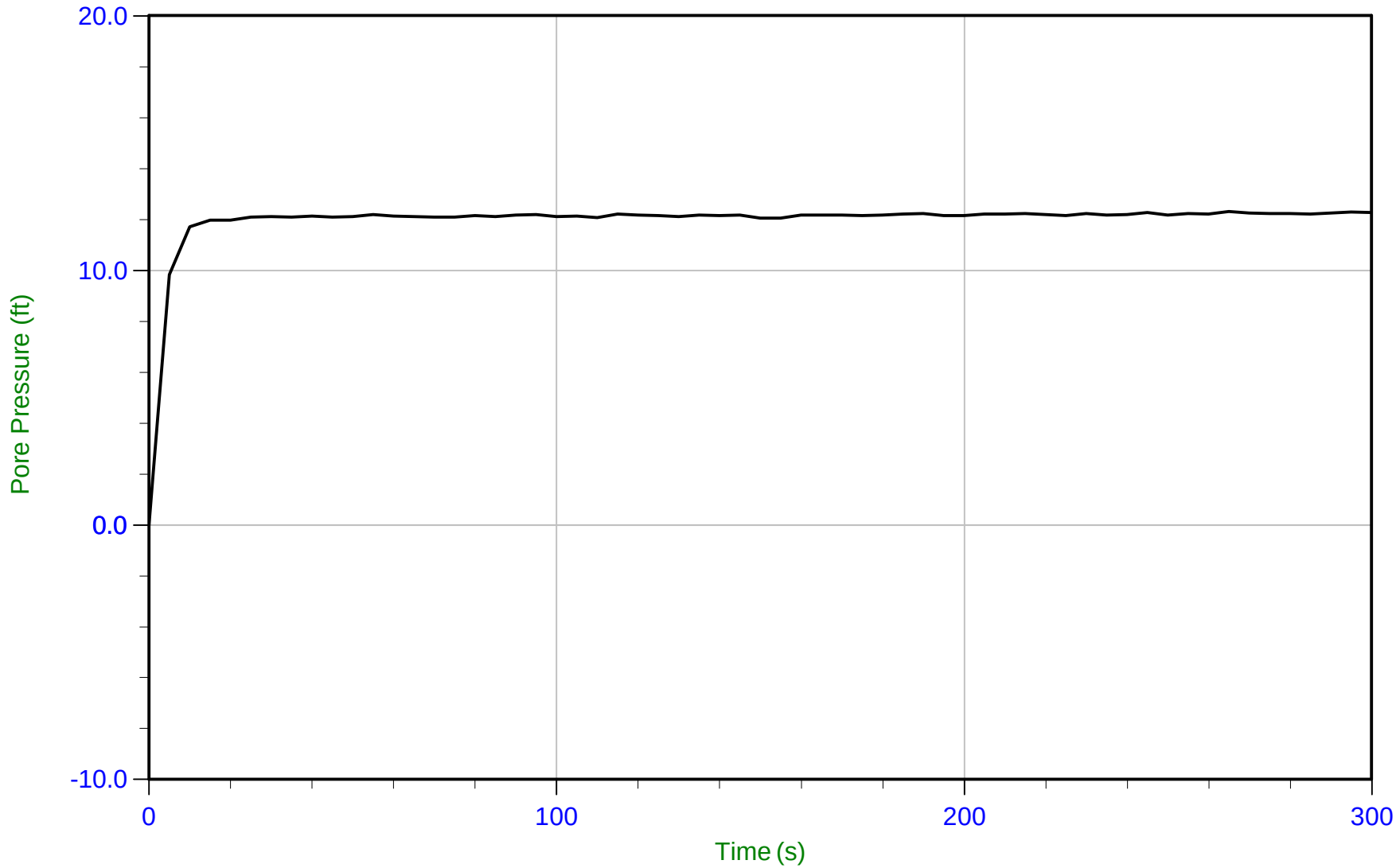
WT: 1.908 m / 6.260 ft
Ueq: 39.6 ft

CONETEC

GEI

Job No: 19-56124
Date: 10/31/2019 08:48
Site: Courtland

Sounding: GEI-RD551-002C
Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-RD551-002C.PPF
Depth: 6.650 m / 21.817 ft
Duration: 300.0 s

u Min: -0.0 ft
u Max: 12.3 ft
u Final: 12.3 ft

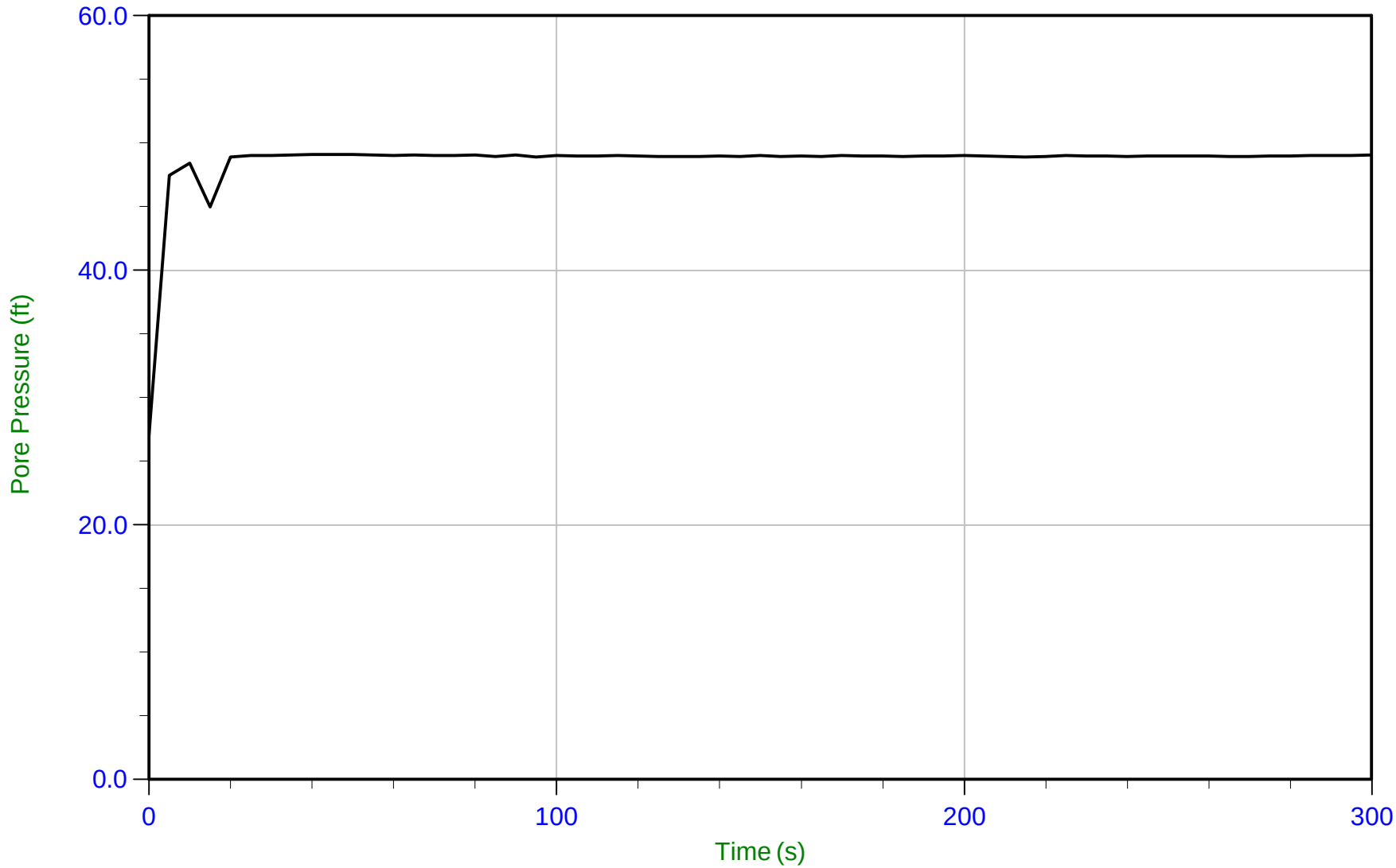
WT: 2.919 m / 9.577 ft
Ueq: 12.2 ft

CONETEC

GEI

Job No: 19-56124
Date: 10/31/2019 08:48
Site: Courtland

Sounding: GEI-RD551-002C
Cone: 448:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-RD551-002C.PPF
Depth: 18.050 m / 59.218 ft
Duration: 300.0 s

u Min: 27.0 ft
u Max: 49.1 ft
u Final: 49.0 ft

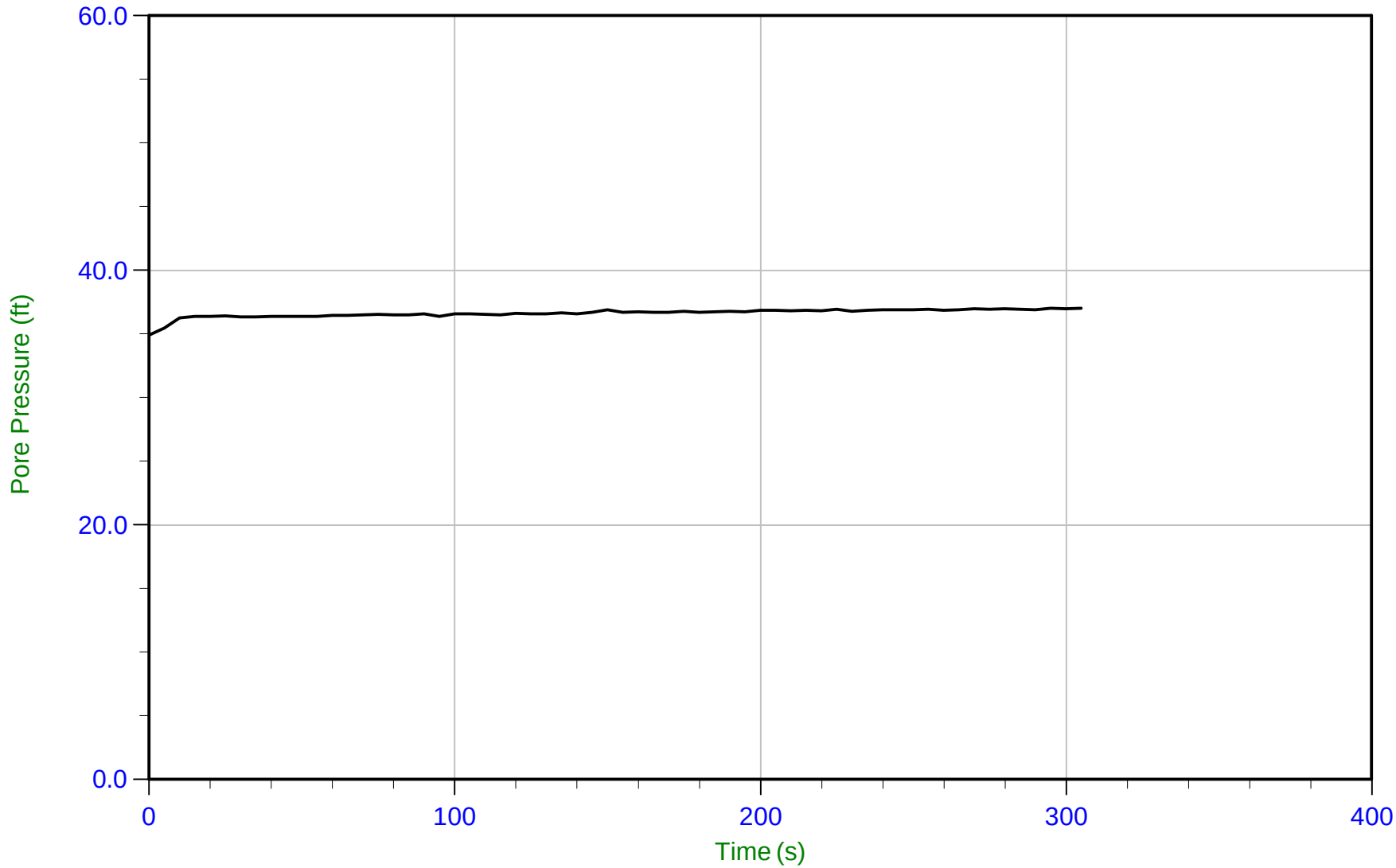
WT: 3.100 m / 10.171 ft
Ueq: 49.0 ft

CONETEC

GEI

Job No: 19-56124
Date: 08/28/2019 13:16
Site: Courtland

Sounding: GEI-RD551-003C
Cone: 391:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-RD551-003C.PPD
Depth: 12.775 m / 41.912 ft
Duration: 305.0 s

u Min: 34.9 ft
u Max: 37.0 ft
u Final: 37.0 ft

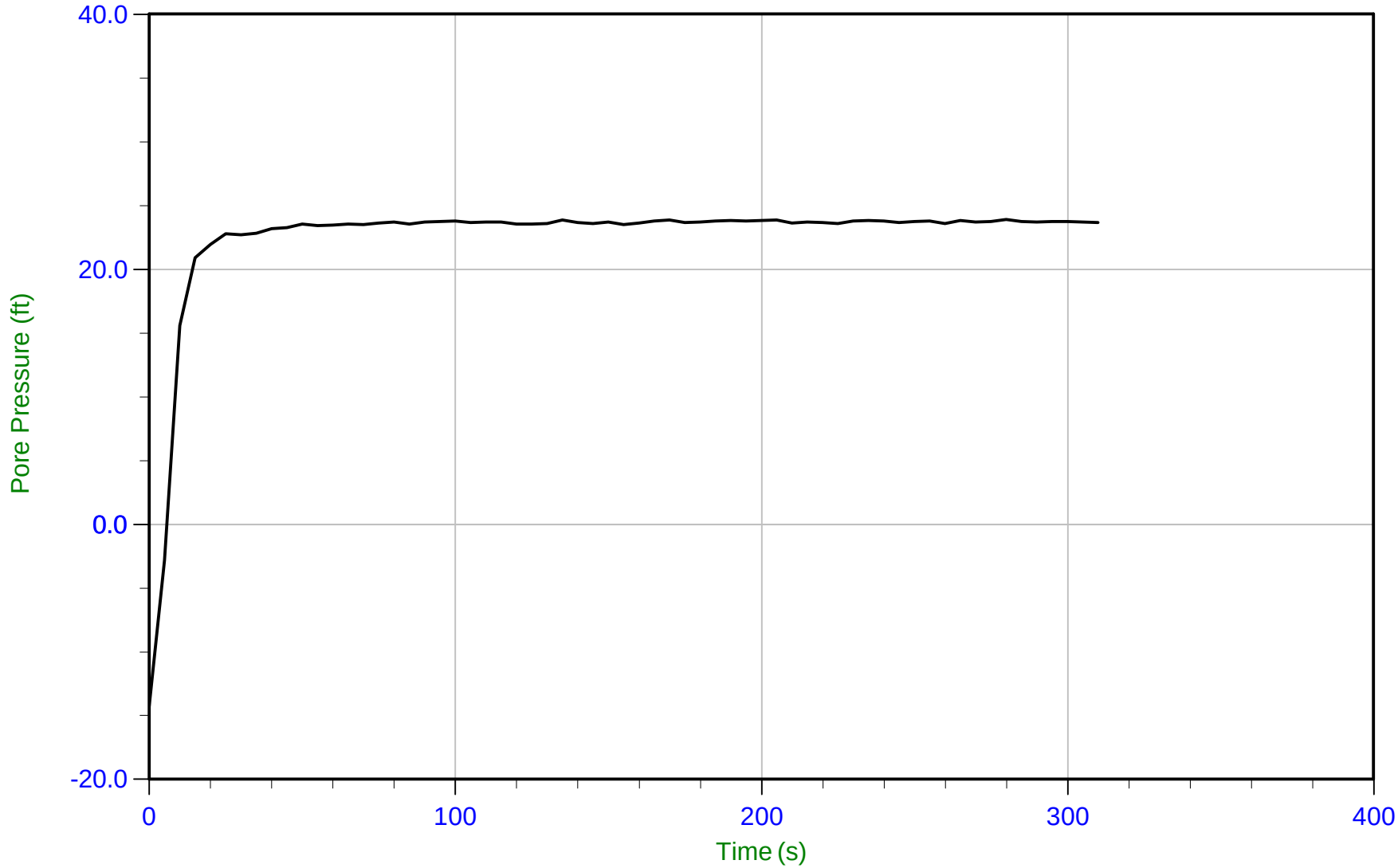
WT: 1.493 m / 4.898 ft
Ueq: 37.0 ft

CONETEC

GEI

Job No: 19-56124
Date: 08/20/2019 14:43
Site: Courtland

Sounding: GEI-RD551-006C
Cone: 499:T1500F15U1K Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-RD551-006C.PPD
Depth: 16.975 m / 55.692 ft
Duration: 310.0 s

u Min: -14.3 ft
u Max: 23.9 ft
u Final: 23.6 ft

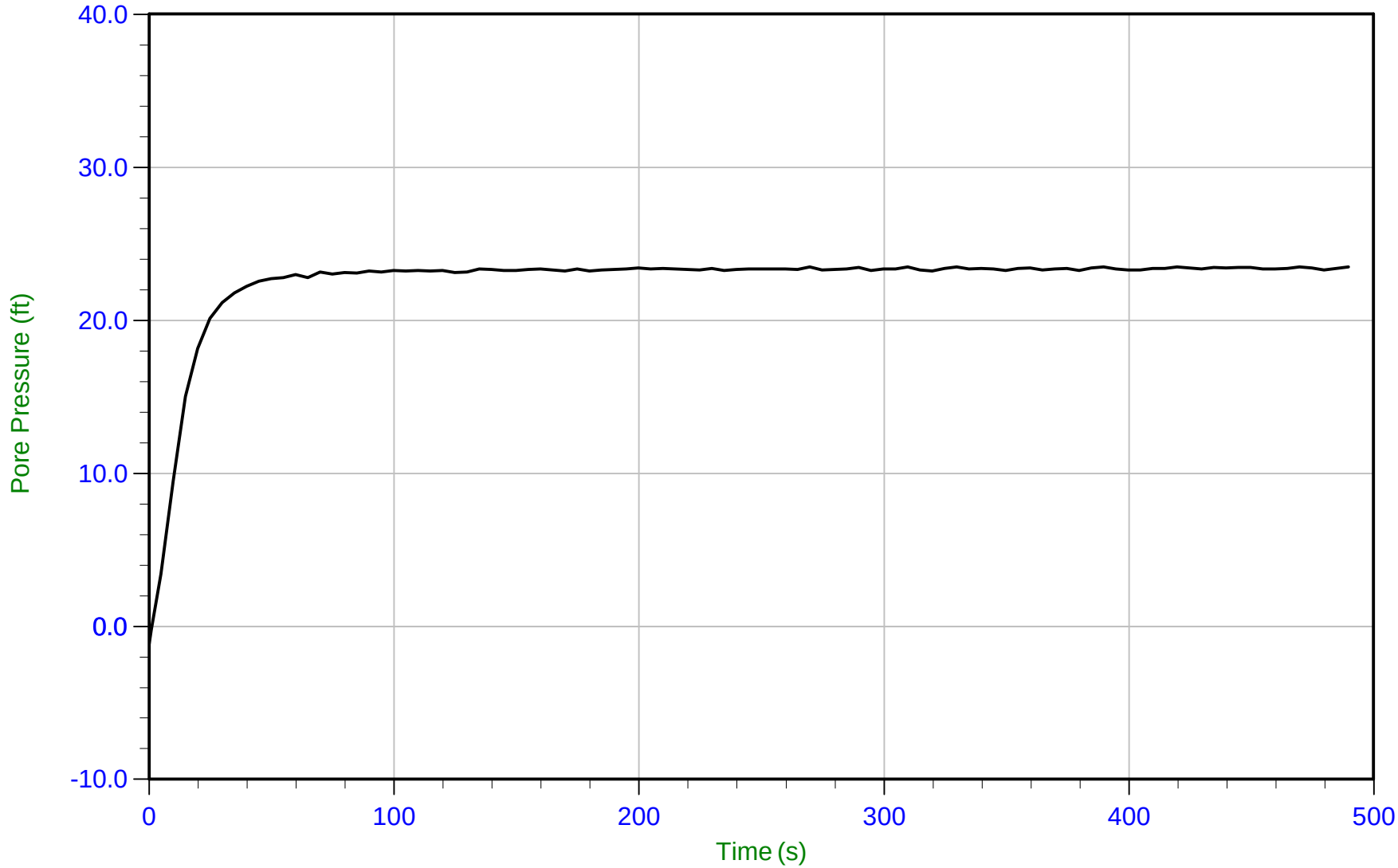
WT: 9.739 m / 31.952 ft
Ueq: 23.7 ft

CONETEC

GEI

Job No: 19-56124
Date: 08/20/2019 08:01
Site: Courtland

Sounding: GEI-RD551-007C
Cone: 499:T1500F15U1K Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-RD551-007C.PPD
Depth: 15.775 m / 51.755 ft
Duration: 490.0 s

u Min: -1.2 ft
u Max: 23.5 ft
u Final: 23.5 ft

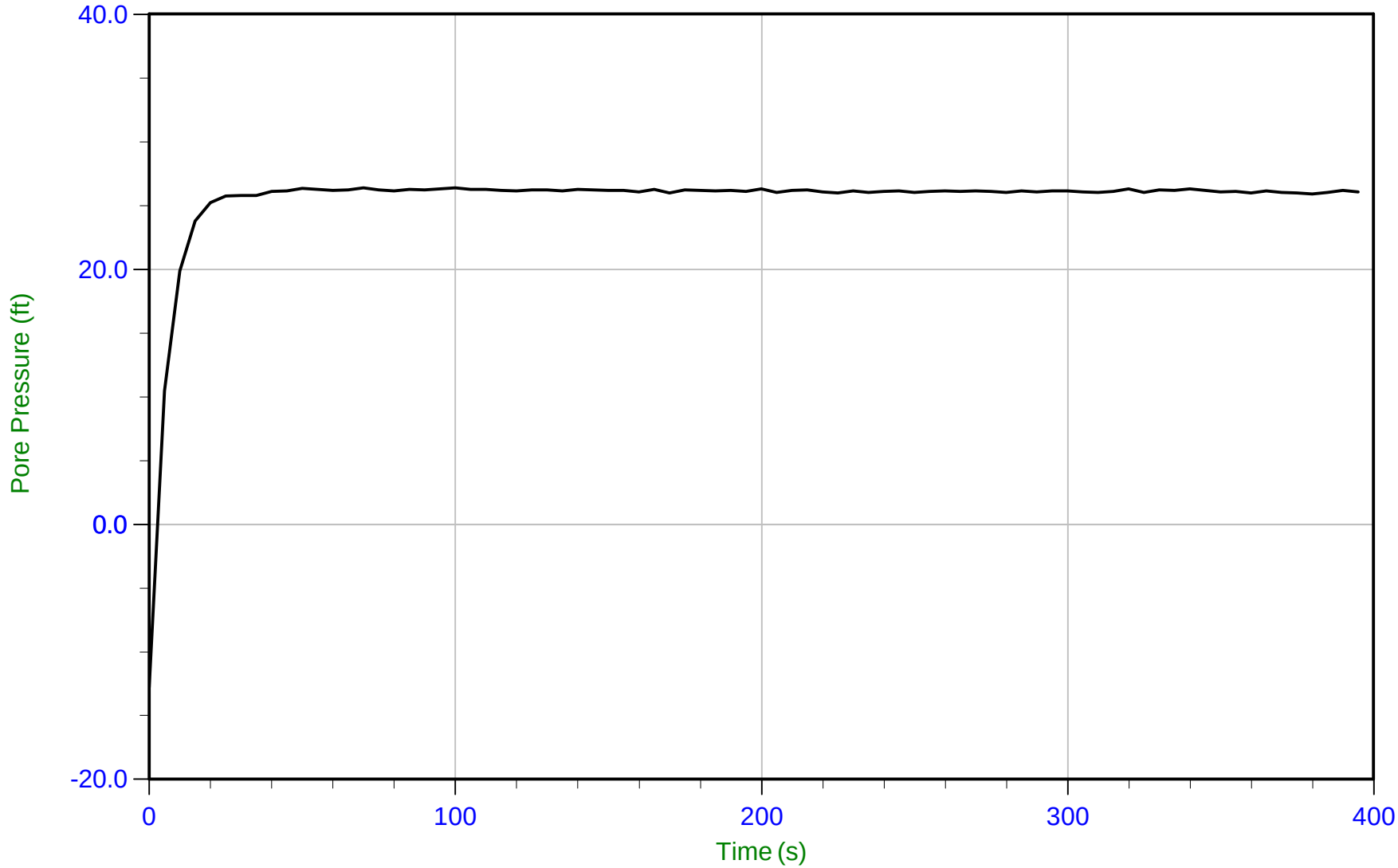
WT: 8.646 m / 28.366 ft
Ueq: 23.4 ft

CONETEC

GEI

Job No: 19-56124
Date: 08/20/2019 11:32
Site: Courtland

Sounding: GEI-RD551-008C
Cone: 499:T1500F15U1K Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-RD551-008C.PPD
Depth: 17.900 m / 58.726 ft
Duration: 395.0 s

u Min: -12.8 ft
u Max: 26.4 ft
u Final: 26.0 ft

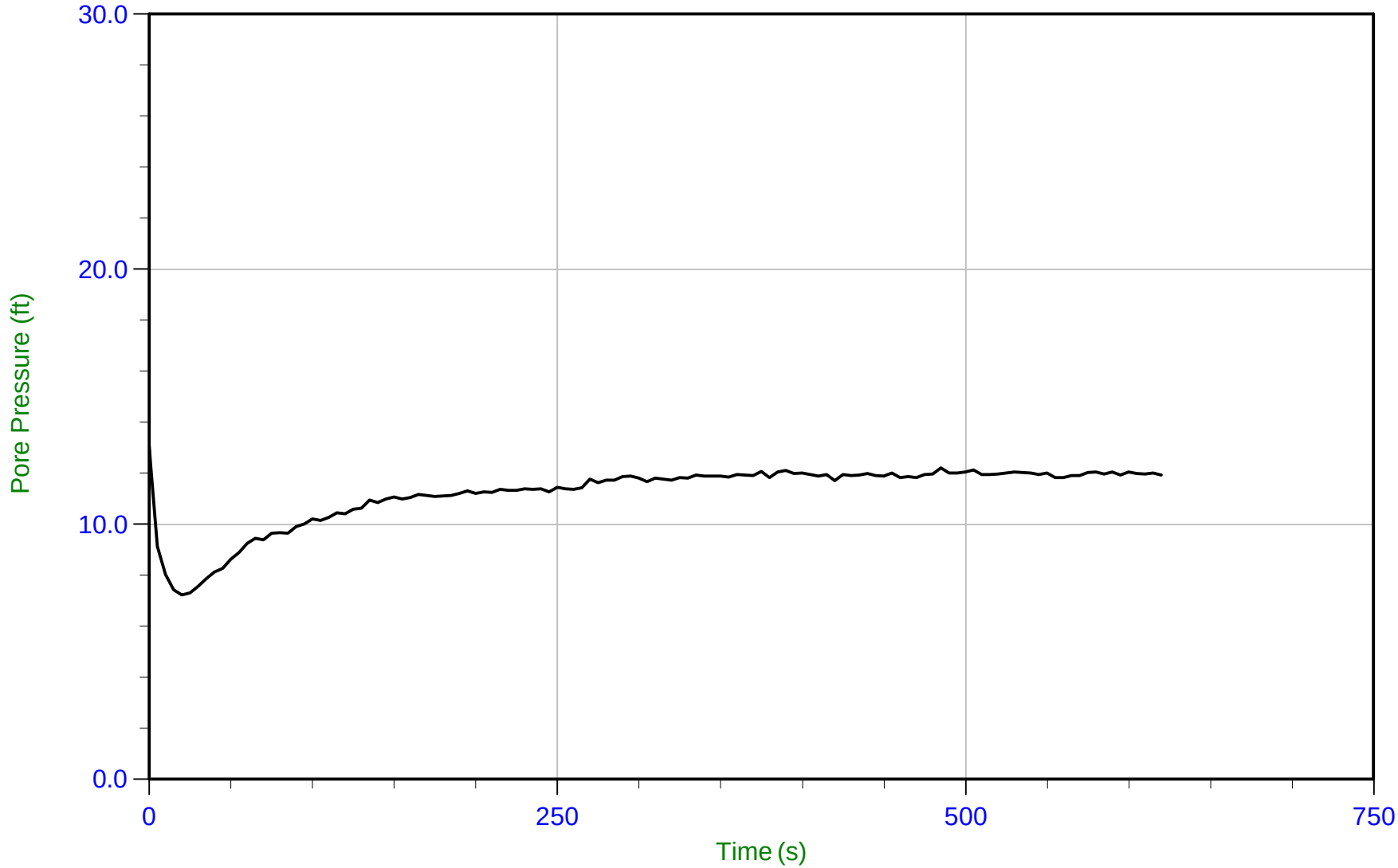
WT: 9.981 m / 32.746 ft
Ueq: 26.0 ft

CONETEC

GEI

Job No: 19-56124
Date: 08/19/2019 14:35
Site: Courtland

Sounding: GEI-RD551-009C-B
Cone: 499:T1500F15U1K Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-RD551-009C-B.PPD
Depth: 14.175 m / 46.505 ft
Duration: 620.0 s

u Min: 7.2 ft
u Max: 13.1 ft
u Final: 11.9 ft

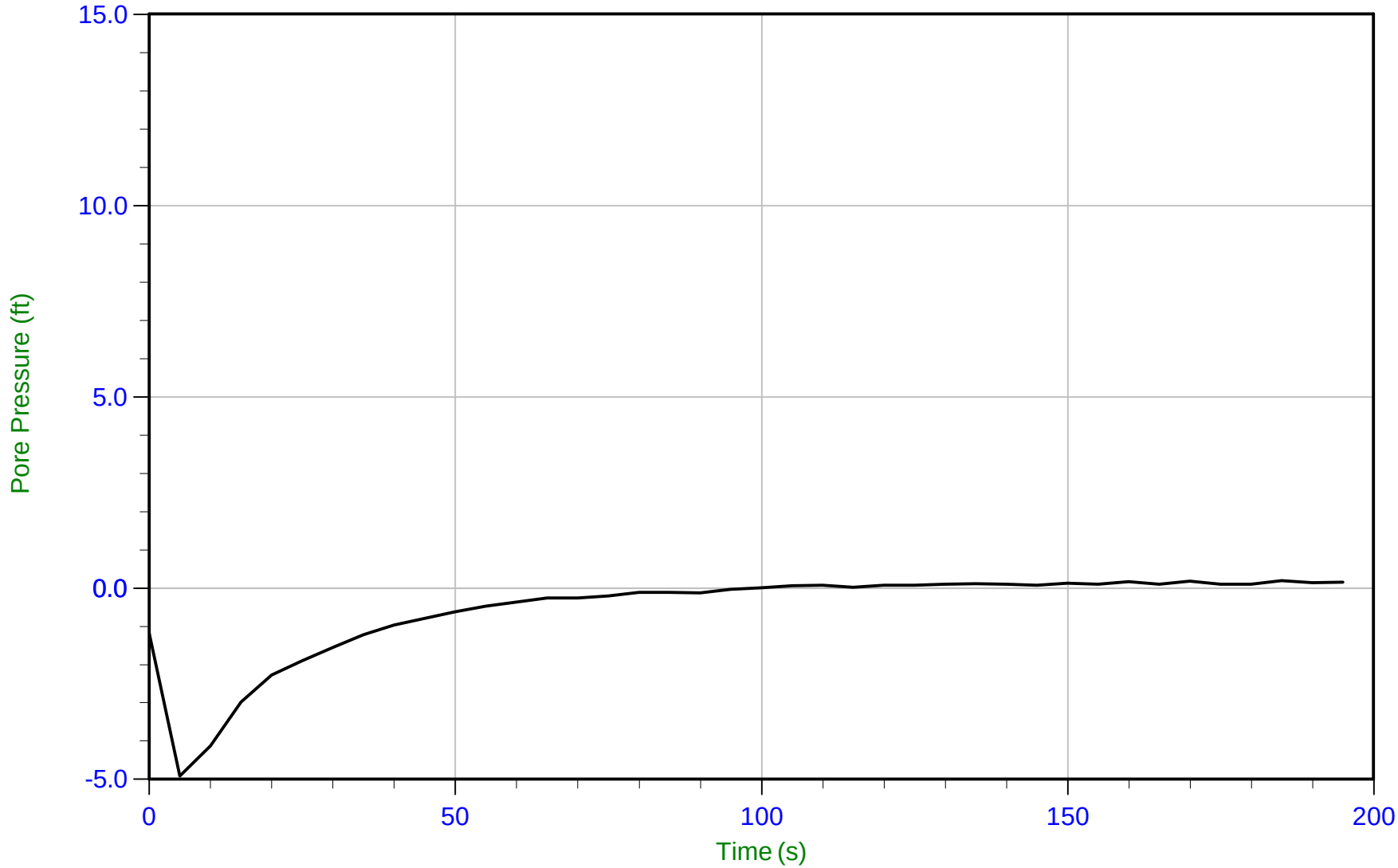
WT: 10.525 m / 34.530 ft
Ueq: 12.0 ft

CONETEC

GEI

Job No: 19-56124
Date: 08/19/2019 09:06
Site: Courtland

Sounding: GEI-RD551-010C
Cone: 391:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-RD551-010C.PPD
Depth: 9.425 m / 30.922 ft
Duration: 195.0 s

u Min: -4.9 ft
u Max: 0.2 ft
u Final: 0.2 ft

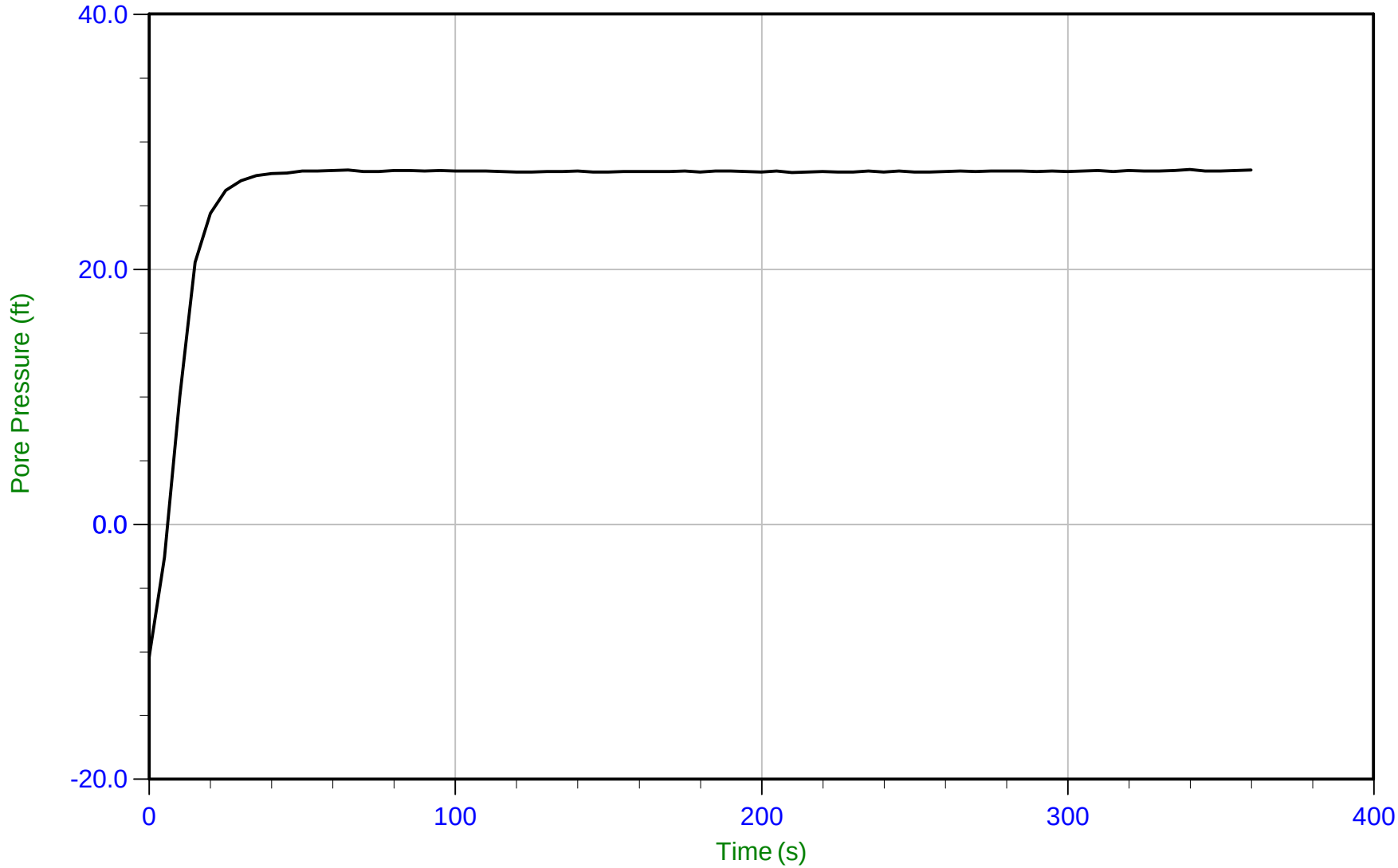
WT: 9.422 m / 30.912 ft
Ueq: 0.0 ft

CONETEC

GEI

Job No: 19-56124
Date: 08/19/2019 09:06
Site: Courtland

Sounding: GEI-RD551-010C
Cone: 391:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 19-56124_CP-RD551-010C.PPD
Depth: 18.250 m / 59.875 ft
Duration: 360.0 s

u Min: -10.4 ft
u Max: 27.8 ft
u Final: 27.8 ft

WT: 9.789 m / 32.116 ft
Ueq: 27.8 ft

Soil Sample Summary

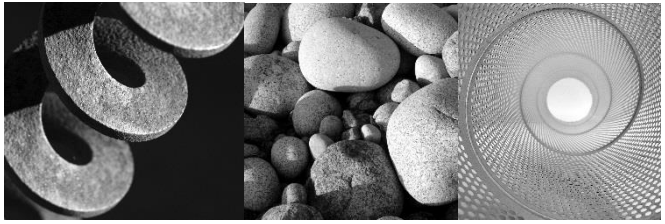
Job No:	19-56124
Client:	GEI Consultants
Project:	Small Communities
Start Date:	19-Aug-2019
End Date:	28-Aug-2019

SOIL SAMPLE SUMMARY

Sounding ID	Sample Intervals (ft)	Sampling Date	Northing[1] (m)	Easting[1] (m)	Elevation[2] (ft.)	Samples Taken[3]	Refer to Notation Number
GEI-RD551-001C	4.0 - 7.0 19.0 - 23.0 30.0 - 33.0	21-Aug-2019	4243731	625142	25	11	
GEI-RD551-003C	1.0 - 3.0 6.0 - 8.0 23.0 -25.0	28-Aug-2019	4236431	628823	25	6	
GEI-RD551-006C	10.0 - 12.0 23.0 - 25.0 32.0 - 34.0	20-Aug-2019	4238370	630808	25	6	
GEI-RD551-007C	5.0 - 7.0 19.0 - 21.0	20-Aug-2019	4240059	630097	21	4	
GEI-RD551-008C	10. - 12.0 26.0 - 28.0	20-Aug-2019	4239347	630254	21	4	
GEI-RD551-009C	9.0 - 11.0 17.0 - 19.0 24.0 - 26.0 29.0 - 31.0	19-Aug-2019	4242747	629356	24	8	
GEI-RD551-010C	9.0 - 11.0 19.0 - 21.0 29.0 - 31.0 39.0 - 41.0	19-Aug-2019	4244298	628854	31	8	

1. The coordinates were acquired using consumer grade GPS equipment, datum: WGS 1984 / UTM Zone 10 North.
2. Elevations are refrenced to the ground surface and are derived from Google Earth Elevation for the recorded coordinates.
3. Refers to the number of 12 inch samples taken.
4. No recovery, hand augered to 3 feet to collect sample

Appendix C



GEI Consultants

Consulting
Engineers and
Scientists

Geotechnical Exploration Work Plan

Sacramento County Small Community of Courtland

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: July 2019
Project No. 1800758

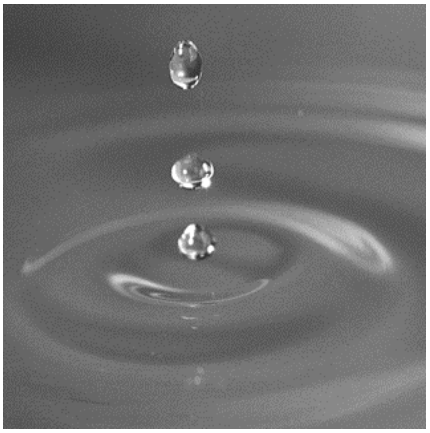


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Abbreviations and Acronyms

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 Sacramento County (County) in DWR's Small Community Flood Risk Reduction Program (Project) for the community of Courtland. Courtland is located approximately 25 miles south of Sacramento (Figure 1). The levees protecting this community are constructed along the left bank of the Sacramento River (California Department of Water Resources [DWR] Non-Urban Levee Evaluation [NULE] Segments 126 and 131), and the right banks of Meadows Slough (NULE Segment 1040) and Snodgrass Slough (NULE Segment 1041), as shown on Figure 1. These levees encompass two Reclamation Districts (RDs), RD 755 at the northern, upstream end and RD 551.

Exploratory borings were previously performed along Sacramento River levee left bank and Snodgrass Slough levee right bank, but are widely spaced and were drilled between the 1950's and 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 August 19, 2019 and be completed by August 22, 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:
    - 3 CPTs landward of the landside toe of the Sacramento River left bank;
    - 2 CPTs on the levee crown of Meadows Slough right bank;
    - 5 CPTs on the levee crown of Snodgrass Slough right bank;
- 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 3 levee segments encompassing the Community of Courtland. The Sacramento River left bank levees near Courtland (NULE Segments 126 and 131) extends approximately 8.6 miles along Sacramento River near the northerly extension of Snodgrass Slough at the upstream end to the confluence of the Sacramento River and Meadows Slough at the southern, downstream end. These NULE levee segments are SPFC levees. The northern, upstream 1.8 miles are part of the RD 755 levee system, and the remaining 6.8 miles are part of the RD 551 levee system. The Meadows Slough right bank levee (NULE Segment 1040) is a Non-SPFC levee that is a part of the RD 551 levee system. It is approximately 1.4 miles long, extending from the confluence of Snodgrass Slough and Meadows Slough westward towards the Sacramento River. The western end of Meadows Slough does not connect to the Sacramento River and is affected by the backwater conditions. The Snodgrass Slough

right bank levee (NULE Segment 1041) is a Non-SPFC levee that is a part of the RD 551 levee system. It is about 5.9 miles long and extends from the upstream end near Sacramento River southward to the confluence with Meadows Slough. This levee system protects an area of approximately 9,000 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 16 known investigations along the entire leveed perimeter of RD 551 and RD 755, a distance of approximately 16 miles. The boring locations are shown on Figure 2. The borings are derived mainly from DWR's 1958 Salinity Control Barrier Investigations (12 borings), but also from USACE's Sacramento River Flood Control System Evaluation for the Lower Sacramento Area (4 borings). Available log information for 15 of the 16 explorations is limited to profiles without detailed material descriptions. The Salinity Control Barrier Investigation profile for 11 of the borings includes some index test laboratory results but detailed results are not available. No laboratory testing was identified for the other 5 explorations. Profiles of these historic explorations are in Appendix A.

The locations of the identified historic explorations by others are shown for reference in Figure 2, along with the proposed GEI explorations.

1.3.1 Foundation Conditions

Geomorphology mapping developed for the DWR NULE project (Figure 3) indicates the levees along the Sacramento River and Meadow Slough primarily overlie historical overbank deposits (Rob) likely consisting of interbedded sand, silt, and clay deposited during high-stage flow, overtopping channel banks. Localized areas of historical crevasse splay deposits (Rcs) 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 available DWR NULE geomorphology mapping for Snodgrass Slough is less detailed but indicates that the northern half of the levee segment overlies natural levee deposits and the southern half overlies flood basin deposits. The natural levee deposits likely consistent of interbedded silt, sand, and clay. The soils in the floodplain deposits are likely finer-grained, consisting primarily of silt and clay. Peat deposits are mapped beneath the levee in the surficial geology mapping over an approximately 0.7-mile extent, starting approximately 1.75 miles upstream from the confluence with Meadows Slough. This mapped peat deposits extent is within the 1.4-mile section of subsidence that has been referred to as "the Peat Section," as it is likely comprised of dredged peat materials on peat foundation. This area was documented to have settled 2 to 3 feet between 1907 and 1913 and was raised in 1913.

Existing subsurface data from the 16 known investigations indicate the levee has a fine-grained blanket layer that varies in thickness from no blanket to a blanket thickness of 30 feet or thicker below ground surface underlain by a pervious aquifer, but were generally not deep enough to confirm the depth to a deeper aquiclude layer.

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 10 CPTs are planned along the Sacramento River right (eastern) bank landside toe, Meadows Slough right (northern) bank crown, and Snodgrass Slough right (western) bank crown. A summary of the exploration locations and types is below:

Planned Explorations:

- Sacramento River left bank, NULE Segment 126 - 3 CPTs
- Meadows Slough right bank, NULE Segment 1040 - 2 CPTs
- Snodgrass Slough right bank, NULE Segment 1041 - 5 CPTs

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 or track-mounted 20- to 30-ton capacity cone apparatus in general accordance with ASTM D5778. The typical track-mounted CPT operation includes the track-mounted CPT rig, a 2-axle supply/water support truck with trailer, and a personal vehicle for the field personnel. 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 40 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 typically range between 70-100 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 boring location becomes too soft to mobilize a CPT truck or track rig, 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 Geocon Consultants, Inc. (Geocon) in their Rancho Cordova, 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.
- Preparation of a draft gINT log.
- 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.
- Final draft logs in gINT format will be reviewed by the Project Manager and any necessary final adjustments will be made prior to delivery to the County.

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 Courtland Community Levee Evaluation Project. Rather, field personnel will explain that Sacramento County consultants are inspecting and documenting the subsurface conditions along the Sacramento River, Meadows Slough, and Snodgrass 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

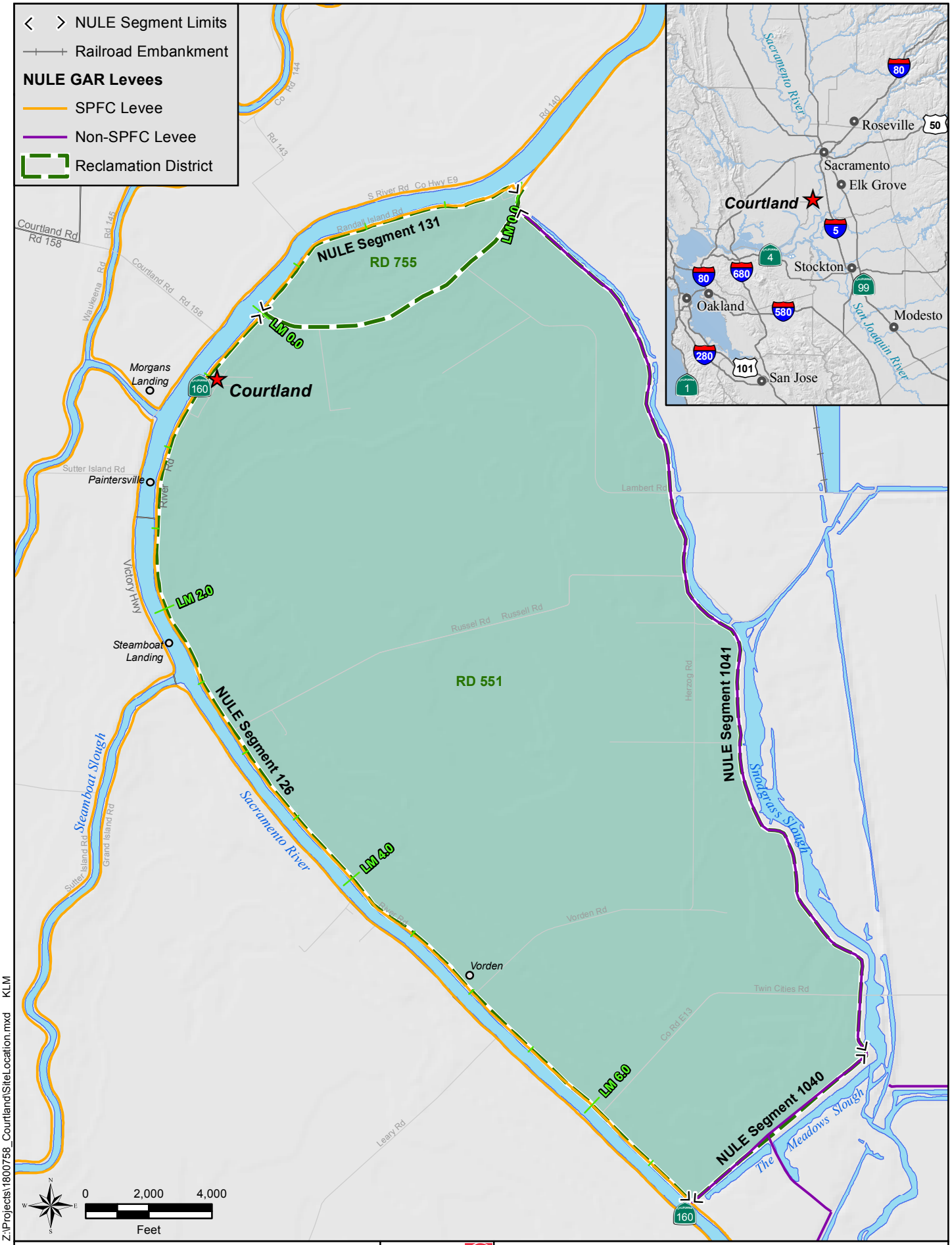
Table 1. Summary of Subsurface Explorations - Courtland

Exploration ID	Latitude	Longitude	USA Ticket #	Parcel APN	Location of Exploration	Approximate Landside Levee Height	Proposed Exploration Depth (ft)
GEI_RD551_001C	38.332934	-121.568177	X922003171	132-0190-027	Landside Toe	19	76
GEI_RD551_002C	38.300010	-121.568022		146-0060-038	Landside Toe	18	72
GEI_RD551_003C	38.266500	-121.527400	X922500772	146-0100-076	Landside Toe	17	68
GEI_RD551_004C	38.26649128	-121.5064347	X922001956	146-0100-084	Crown	25	100
GEI_RD551_005C	38.26977883	-121.5011943		146-0100-084	Crown	25	100
GEI_RD551_006C	38.28376067	-121.5044545	X922002518	146-0070-008	Crown	24	96
GEI_RD551_007C	38.299046	-121.512290	X922500831	146-0070-001	Crown	19	76
GEI_RD551_008C	38.30311315	-121.5124431		146-0030-037	Crown	19	76
GEI_RD551_009C	38.32345252	-121.5199862	X922002573	132-0200-005	Crown	17	68
GEI_RD551_010C	38.33736205	-121.5253532	X922002589	132-0210-032	Crown	19	76

Table 2. List of Contacts

Name	Role	Organization	Mailing Address	Email Address	Telephone	Cellular Telephone
Autumn Eberhardt	Regional Health & Safety Officer	GEI	2868 Prospect Park Drive, Suite 400, Rancho Cordova, 95670	AEberhardt@geiconsultants.com	(916) 631-4525	(631) 481-5094
Jeff Twitchell	Project Manager	GEI	180 Grand Avenue, Suite 1410 Oakland, CA 94612	jtwitchell@geiconsultants.com	(916) 631-4555	(916) 990-2569
Graham Bradner	Project Geologist	GEI	2868 Prospect Park Drive, Suite 310, Rancho Cordova, 95670	GBradner@geiconsultants.com	(916) 631-4577	(916) 709-3833
Nichole Tollefson	Project Engineer	GEI	2868 Prospect Park Drive, Suite 400, Rancho Cordova, 95670	ntollefson@geiconsultants.com	(916) 631-4590	(916) 580-7030
Emily Pappalardo	Project Engineer	MBK	455 University Ave #100, Sacramento, CA 95825	pappalardo@mbkengineers.com	(916) 456-4400	(916) 205-0770
Nicole Cholewinski	Field Geologist	GEI	2868 Prospect Park Drive, Suite 310, Rancho Cordova, 95670	ncholewinski@geiconsultants.com	(916) 631-4584	(803) 524-1060
John Rogie	CPT Manager	ConeTec	820 Aladdin Avenue, San Leandro, CA 94577	jrogie@conetec.com	(510) 357-3677	(650) 346-1490
Clayton Bartholomew	CPT Manager	ConeTec	820 Aladdin Avenue, San Leandro, CA 94577	cbartholomew@conetec.com	(510) 357-3677	(925) 849-2989
David VonAsper	Grout Inspector	County of Sacramento	10590 Armstrong Ave, Suite A, Mather, CA 95655	To Schedule: (916) 875-8524	(916) 875-8467	(916) 591-2679

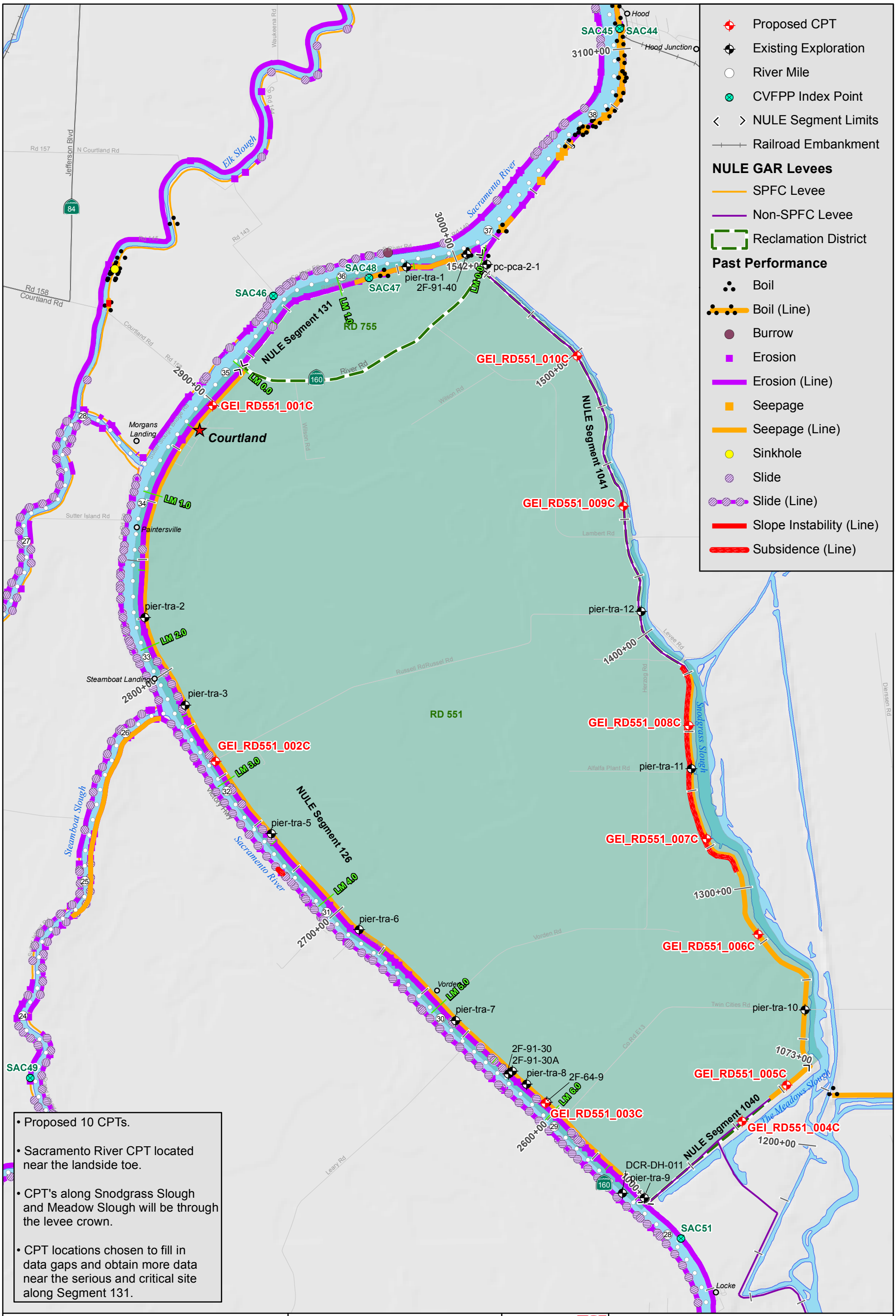
Figures



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10-Apr-2018

Small Communities Flood Risk Reduction Program	GEI Consultants	COMMUNITY OF COURTLAND
County of Sacramento		APRIL 2018 FIGURE 1


Proposed CPT
Existing Exploration
River Mile
CVFPP Index Point
NULE Segment Limits
Railroad Embankment
NULE GAR Levees
SPFC Levee
Non-SPFC Levee
Reclamation District
Past Performance
Boil
Boil (Line)
Burrow
Erosion
Erosion (Line)
Seepage
Seepage (Line)
Sinkhole
Slide
Slide (Line)
Slope Instability (Line)
Subsidence (Line)
SAC45
SAC44
Hood
Hood Junction
3100+00
SAC48
SAC47
SAC46
pier-tra-1
2F-91-40
1542+00
pc-pca-2-1
3000+00
Sacramento River
Elk Slough
Jefferson Blvd
Rd 157
N Courtland Rd
Rd 158
Courtland Rd
Waukeena Rd
Co Rd 144
Rd 143
Rd 145
Rd 140
S River Rd
84
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
160
LM 0.0
LM 1.0
LM 2.0
LM 3.0
LM 4.0
LM 5.0
LM 6.0
LM 7.0
NULE Segment 131
NULE Segment 126
NULE Segment 1041
NULE Segment 1040
RD 755
RD 551
River Rd
2900+00
2800+00
2700+00
2600+00
1500+00
1400+00
1300+00
1200+00
1100+00
1073+00
GEI_RD551_010C
GEI_RD551_001C
GEI_RD551_009C
GEI_RD551_002C
GEI_RD551_008C
GEI_RD551_007C
GEI_RD551_006C
GEI_RD551_005C
GEI_RD551_003C
GEI_RD551_004C
Courtland
Morgans Landing
Paintersville
Steamboat Landing
Vorden
Locke
pier-tra-2
pier-tra-3
pier-tra-5
pier-tra-6
pier-tra-7
pier-tra-8
pier-tra-9
pier-tra-10
pier-tra-11
pier-tra-12
2F-91-30
2F-91-30A
2F-64-9
DCR-DH-011
SAC49
SAC51
Sutter Island Rd
Sutter Slough Bridge Rd
Wilson Rd
Lambert Rd
Russell RdRussel Rd
Levee Rd
Herzog Rd
Alfalfa Plant Rd
Dierssen Rd
Co Rd E13
Twin Cities Rd
Vorden Rd
Leary Rd
Steamboat Slough
Snodgrass Slough
The Meadows Slough
Victory Hwy
• Proposed 10 CPTs.
• Sacramento River CPT located near the landside toe.
• CPT's along Snodgrass Slough and Meadow Slough will be through the levee crown.
• CPT locations chosen to fill in data gaps and obtain more data near the serious and critical site along Segment 131.
3,000 1,500 0 3,000
Feet
N
S
E
W
Small Communities
Flood Risk Reduction Program
County of Sacramento
GEI Consultants
PROPOSED EXPLORATIONS AND
PAST PERFORMANCE
COMMUNITY OF COURTLAND
JULY 2019
DRAFT
FIGURE 2
12Jul2019 Z:\Projects\1800758_Courtland\ProposedExplorations_PastPerformance.mxd KLM/RS

- Proposed 12 CPTs.
- Sacramento River CPT located near the landside toe.
- CPT's along Snodgrass Slough and Meadow Slough will be through the levee crown.
- CPT locations chosen to fill in data gaps and obtain more data near the serious and critical site along Segment 131.

Courtland
Paintersville
Morgans Landing
Steamboat Landing
Vorden
Walnut Grove
Locke
Sacramento River
Snodgrass Slough
The Meadows Slough
NULE Segment 131
NULE Segment 126
NULE Segment 1041
NULE Segment 1040
RD 755
RD 551
SAC46
SAC47
SAC51
SAC52
pier-tra-1
pier-tra-2
pier-tra-3
pier-tra-5
pier-tra-6
pier-tra-7
pier-tra-8
pier-tra-9
pier-tra-10
pier-tra-11
pier-tra-12
2F-91-40
2F-91-30
2F-91-30A
2F-64-9
DCR-DH-011
pc-pca-2-1
LM 0.0
LM 2.0
LM 4.0
LM 6.0
3000+00
2900+00
2800+00
2700+00
2600+00
2500+00
2400+00
1542+00
1506+00
1400+00
1300+00
1200+00
1100+00
1073+00
1000+00

Geologic Unit (NULE, Level 2-I)

- Qb, Alluvium of Supratidal Floodplains - Holocene
- Ql, Alluvium of Supratidal Floodplains - Holocene
- Qm2e, Eolian Deposits - Pleistocene
- Qoe, Eolian Deposits - Pleistocene
- Qpm, Peat and Muck - Holocene
- Qr, Alluvial Fans from Glaciated Basins - Riverbank Formation
- Qro, Alluvial Fans from Glaciated Basins - Riverbank Formation
- Qry, Alluvial Fans from Glaciated Basins - Riverbank Formation

Geologic Unit (NULE, Level 2-II)

- W 1937 - Water, circa 1937
- C - Canal
- BP - Borrow Pit
- AF - Artificial fill
- L - Levee
- RR - Railroad embankment
- Rob - Overbank deposits
- Rcs - Crevasse splay deposits
- Rdf - Distributary fan deposits
- Rch - Channel deposits
- Rdc - Distributary channel deposits
- Rsl - Slough deposits
- Hob - Overbank deposits
- Hcs - Crevasse splay deposits
- Hpm - Peat and mud
- Hch - Channel deposits
- Hdc - Distributary channel deposits
- Hsl - Slough deposits
- Hl 1906 - Lacustrine deposits
- Hn - Basin deposits
- Hs 1937 - Marsh deposits
- Qe - Eolian deposits
- Qrl - Riverbank formation; lower member

- Proposed CPT (Location Approximate)
- Existing Exploration
- River Mile
- CVFPP Index Point
- NULE Segment Limits
- Railroad Embankment

NULE GAR Levees

- SPFC Levee
- Non-SPFC Levee
- Reclamation District

Past Performance

- Boil
- Boil (Line)
- Burrow
- Erosion
- Erosion (Line)
- Seepage
- Seepage (Line)
- Sinkhole
- Slide
- Slide (Line)
- Slope Instability (Line)
- Subsidence (Line)

3,000 1,500 0 3,000
Feet

Small Communities Flood Risk Reduction Program

County of Sacramento

GEI Consultants

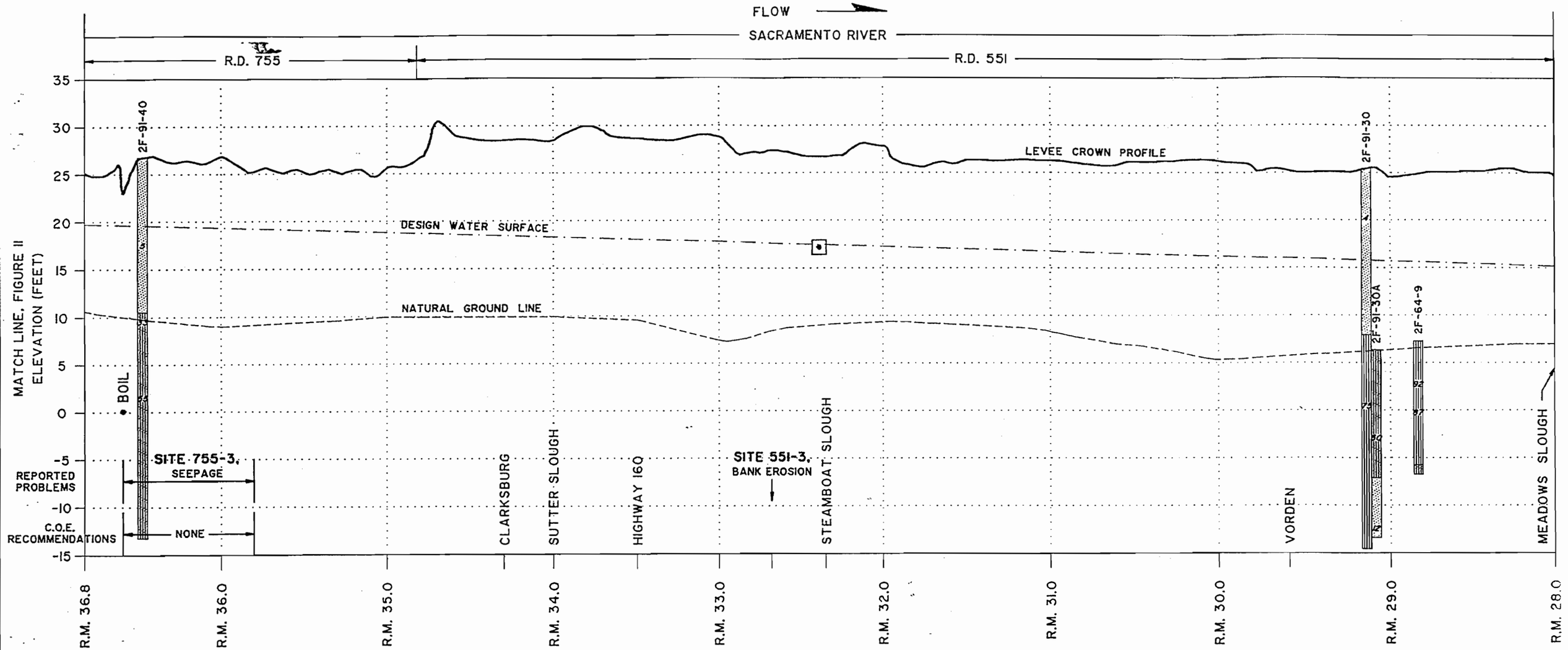
PROPOSED EXPLORATIONS AND PAST PERFORMANCE COMMUNITY OF COURTLAND

MARCH 2019 **DRAFT** FIGURE 3

4Mar2019 Z:\Projects\1800758_Courtland\ProposedExplorations_PastPerformance_geomorphology.mxd KLM/RS

Appendix A

Historic Boring Logs



SCALE: 1" = 3000'

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
- 1986 BOIL LOCATION
- 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
SACRAMENTO RIVER
LEFT BANK - R.M. 28.0 TO 36.8

SACRAMENTO DISTRICT, CORPS OF ENGINEERS

PREPARED BY: D. RICKETTS
DRAWN BY: R. IWASA
FEBRUARY 1993

FIGURE 12



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 175 lbs.
DRILLING DATES:
1" HOLES — JAN. 31, 1958 TO MAY 14, 1958
2" HOLES — FEB. 11, 1958 TO APRIL 15, 1958

LEGEND

- M 116 DRY (WET) 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 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

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SALINITY CONTROL BARRIER INVESTIGATION

SUBSURFACE EXPLORATION ON PIERSON TRACT
PLAN AND PROFILE OF BORINGS

SCALE AS SHOWN

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF DESIGN AND CONSTRUCTION
PROJECT GEOLOGY BRANCH

DRILLING AND SAMPLING LOG

DELTA FACILITIES

PERIPHERAL CANAL

HOLE NO. PCA 2-1

ELEV.

FEATURE Hood to Mokelumne River — DEPTH 49.0'

LOCATION — COUNTY Sacramento

LOGGED BY G. Chase - M. Oropeza — DATE DRILLED 9/1-2/1966 — WATER LEVEL 9-2-66 6.6'

DRILLING CO. C. Corder — DRILLER T. Johnson - J. Willingham — DRILL RIG Failing 1500

Hole #1 - Cored with Pitcher core barrel, 3" I.D.
Drove standard penetrometer using 140# hammer with 30" drop.
Hole #2 - Pushed or drove DWR 2-1/2" I.D. sampler
Drilled with 4-5/8" drag bit.
1/ - Sample number and field density (PCF)
* Liner samples for U.S. Bureau of Reclamation - Denver office.

ELEV. (DEPTH)	CLASS.	DESCRIPTION Field Identification	1/ SAMPLE NUMBER #1	#2	MODE #2	#1	REMARKS #1	#2
(0.0)	ML-CL	0.0-2.0 SILTY CLAY: Dry; slow to very slow dilatancy; slight plasticity; dark olive-gray.	PB-1		RD	SD	Augered from 0.0-1.0'	
							Pushed 1.0-3.5' Recovered 76%	
		2.0-47.5 SANDY SILT: Dry; quick dilatancy; no plasticity; loose (dry); 30-40% fine-grained sand; dark yellowish-brown.		L-1B 115.2#		P		Pushed 2.0-4.0'
				L-1C* 113.1#	P		Pushed 3.5-6.0'	
				L-1D 102.6#				Pushed 4.0-5.2' 4.0-5.2'
(4.0)	ML			L-2D 111.1#	P	P		
							Drove 6.0-7.5' 4/.5 5/.5 5/.5	
		7.5' Core moist.			RD	DR	No water at 7.5'.	
(8.0)			PB-2	L-3B 119.7#			Cored 7.5-10.0' Recovered 52%	Pushed 8.0-10.0'
				L-3C 123.1#	P	RD		
				L-3D* 126.7#				
		10.0-10.6' Silty sand; 30% nonplastic fines.					Cored 10.0-12.5' Recovered 80%	Pushed 10.0-11.0'
	SM			L-4D 122.1#	P			
	ML				RD	RD		
(12.0)								

DRILLING AND SAMPLING LOG

FEATURE Hood to Mokelumne River HOLE NO. PCA 2-1

ELEV. (DEPTH)	CLASS.	DESCRIPTION Field Identification	SAMPLE NUMBER #1	SAMPLE NUMBER #2	MODE #2	MODE #1	REMARKS #1	REMARKS #2
(12.0)		2.0-47.5 SANDY SILT: Contd.	PB-2		RD	RD	Drove 12.5-14.0' 3/.5 3/.5 4/.5	
		14.0-20.5' Scattered roots				DR	Cored 14.0-16.5' Recovered 100%	
		14.0' Dark greenish-gray			RD	RD		
(16.0)				L-5B 124.4#				Pushed 16.0-18.0'
				L-5C 122.1#	P		Cored 16.5-19.0' Recovered 92%	
				L-5D* 123.6#		RD		
					P			Pushed 18.0-19.0' No recovery
	ML		PB-3				Drove 19.0-20.5' 1/.5 1.5/.5 1/.5	
(20.0)						DR	Cored 20.5-23.0' Recovered 96%	
					RD			
						RD		Pushed 22.0-24.0'
				L-6B 125#				
				L-6C 122.1#	P		Cored 23.0-25.5' Recovered 100%	
				L-6D* 122.9#				
(24.0)			PB-4			RD		Pushed 24.0-25.2'
				L-7D 122.1#	P			
			No Core				Drove 25.5-27.0' 1/.5 1.5/.5 3.5/.5	
	ML?					DR	*Settled (No core)	
					RD		Cored 27.0-29.5' Recovered 68%	
(28.0)						RD		
	ML		PB-4					Pushed 29.0-31.0'
				L-8B 126.4#	P		Cored 29.5-32.0' Recovered 80%	
				L-8C 124.4#		RD		

DWR 885 (2)

SHEET 2 OF 4

DRILLING AND SAMPLING LOG

FEATURE Hood to Mokelumne River HOLE NO. FCA 2-1

ELEV. (DEPTH)	CLASS.	DESCRIPTION Field Identification	SAMPLE #1 NUMBER #2	MODE #2 #1	REMARKS #1	REMARKS #2
(30.0)	ML	2.0-47.5 SANDY SILT: Contd.	L-8C L-8D* 124.5#	P		
			PB-4	RD		Pushed 31.0-32.0'
		31.5-32.0 Silty sand; 30% non-plastic fines.	L-9D 128.7#	P		
	SM	32.0-33.5' Fine-grained sand 20%.			Drove 32.0-33.5 1/.5 1/.5 2/.5	
				DR		
					Cored 33.5-36.0' Recovered 80%	
(34.0)				RD		
				RD		
	ML				Cored 36.0-38.5'	
			PB-5			Pushed 37.0-39.0' (No sample)
				HD		
(38.0)				P	Drove 38.5-40.0' .5/.5 .5/.5 1.5/.5	
				RD		
				DR	Cored 40.0-42.5' Recovery 80%	Drove 40.0-42.0' 4/.5 3/.5 2/.5 4/.5
		40.9-41.7' Silty sand; 30-40% nonplastic fines.	L-10B* 126.9#			
	SM	40.9-47.5' Scattered beads of fines (up to 1/2"), possibly clay.	L-10C 128.4#	DR		
			L-10D 124.9#			
(42.0)			PB-6			
					Cored 42.5-45.0' Recovery 96%	Drove 42.0-43.5' 1/.5 1/.5 1/.5 (No sample)
	ML			DR		
				RD		Pushed 44.0-46.0'
		44.5-47.5' Slight plasticity; darker greenish-gray.	L-11C 121.4#	P	Drove 45.0-46.5' 2/.5 3/.5 6/.5	
			No Core			
	ML?		L-11D* 125.6#			
(46.0)				DR	(No core)	Pushed 46.0-48.0'
	ML				Cored 46.5-49.0' Recovered 100%	
			PB-6	P		
			L-12C 123.7#			
		47.5-49.0 CLAY TO SANDY CLAY: Wet; slow dilatancy; medium plasticity; 10-20% fine-grained sand; firm to stiff; dark greenish-gray.	L-12D 124.7#			
	CL		PB-7	RD		

DWR 885 (2)

DRILLING AND SAMPLING LOG

FEATURE Hood to Mokelumne River HOLE NO. HCA 2-1

ELEV. (DEPTH)	CLASS.	DESCRIPTION Field Identification	SAMPLE NUMBER #1	SAMPLE NUMBER #2	MODE #2	MODE #1	REMARKS #1	REMARKS #2
(48.0)	CL	47.5-49.0 CLAY: Contd. Sand decreasing with depth	PB-7			RD	Bottomed Hole #1 at 49.0' Set 50.0' of downspout.	Bottomed Hole #2 at 48.0'. Backfilled hole; site marked by 4 x 4" pole
(49.0)								

DWR 865 (2)

SHEET 4 OF 4

Appendix B

Permits

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

AR 57769

WELL INSPECTION LINE: (916) 875-8524

IS THIS PERMIT FOR A HAZARDOUS SUBSTANCE INVESTIGATION? ☐ YES ☒ NO

FOR OFFICE USE ONLY **EXPEDITED PROCESSING?** ☐ YES ☐ NO

☐ APPROVED ☒ APPROVED W/CONDITIONS (ATTACHED) Below

PERMIT NUMBER(S): 60993

BY: DVA DATE: 8.14.19

DATE RECEIVED: 8-9-19 TOTAL FEE: $426

INITIAL GROUT BY: _____ DATE: _____ RECEIPT NO: 449314 DEPTH TO WATER: _____

FINAL INSPECTION BY: _____ DATE: _____ WELL DEPTH: _____ GROUT DEPTH: _____

DESTRUCTION BY: _____ DATE: _____ GPS: N: 38 W: -121

COMMENTS: Backfill top 5' of each borehole with cleanfill (non-grout)
Delta Levee CPTs RD concurs rec'd on 8.14.19

SITE ADDRESS: See Attached Tables

Job Address:	Nearest Major Cross Street:
Property Owner:	Parcel Number(s): Multiple - see table
Well Contractor: ConeTec	CA License No.: C57 1049248 EXP 1-31-2015
Contractor's Address: 820 Aladdin Ave., San Leandro, CA 94577	510-357-3677
Well/Boring Identification Number(s): See Attached Tables	

TYPE OF WORK: (California C-57 License required unless noted otherwise)

☐ Well construction ☐ Vault box repair (General A or B) ☐ Well destruction **(SUPPLEMENT REQUIRED)**
☐ Pump replacement (or C-61) ☐ Well repair ☒ Exploratory boring (C-57 if water present)
☐ Well inactivation (Owner only) ☐ Pump repair (or C-61) ☒ Other: CPT (Cone Penetration Testing)

INTENDED USE:

☐ Domestic/private ☐ Dewatering ☒ Geotechnical ~~boring~~ exploration using CPT
☐ Irrigation/agricultural ☐ Cathodic protection ☐ Environmental boring
☐ Water/vapor monitoring/extraction ☐ Heat exchange ☐ Other: _____
☐ Public water system: _____
(NAME OF WATER PURVEYOR WITH CONTACT NAME AND TELEPHONE NUMBER)

DRILLING METHOD:

☐ Mud rotary ☐ Air Rotary ☐ Cable tool ☐ Auger ☐ Driven ☒ 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. CASING: Diameter: _____ Depth: _____
Diameter: _____ Depth: _____ CASING: Diameter: _____ Depth: _____
CONDUCTOR: Diameter: _____ Depth: _____ IF STEEL: Gauge: _____ or Thickness: _____
ANNULAR SEAL: Depth: _____ Material: Neat cement grout IF PLASTIC: Type: _____ (Must meet ASTM F-480)
TRANSITION SEAL: Material: _____ MULTIPLE COMPLETION? ☐ Yes **(DIAGRAM REQUIRED)**
COMMENTS: with up to 5% bentonite by weight; addition of bentonite is optional. DVA

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: _____ ☐ Property Owner
PRINTED NAME: Eduardo Cerna Alvarez ☐ Well Contractor
COMPANY: GEI Consultants ☒ Agent **(REQUIRES AUTHORIZATION FORM)**
MAILING ADDRESS: 2868 Prospect Park Dr. Suite 310, Rancho Cordova, CA 95670
PHONE NUMBER: (916) 631-4526 FIELD PHONE: (831) 540-7620

A SITE PLAN MUST BE SUBMITTED WITH EACH APPLICATION.
PERMIT EXPIRES ONE (1) YEAR AFTER DATE APPROVED (UNLESS EXTENDED)

Appendix C

Sub-Consultants License

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

Field Forms

GEI Consultants

DAILY INSPECTION REPORT

CONTRACT: **DATE:** _____

GEI PROJECT # _____
CONTRACTOR: _____ **SHIFT 1 2 3**
INSPECTOR: _____ **TEMPERATURE:** _____**AM** _____**PM**
SUPERINTENDENT: _____ **WEATHER:** **Clear Rain Showers Cloudy**

Crew	No.	Hrs	Crew	No.	Hrs
Foreman			Pipefitter(s)		
Operator(s)			Ironworker(s)		
Laborer(s)			Survey		
Teamster(s)					

(1) Detailed Contractor Activity/Progress: _____

Signature _____

GEI Consultants

DAILY INSPECTION REPORT

CONTRACT: **DATE:** _____

Signature _____

Daily Safety Briefing and Site Visitor Sign-In

Project Number:	**Project Name:**
[1]Date:	**Time:**
Briefing Conducted by:	**Signature:**

This sign-in log documents the tailgate briefing conducted in accordance with the site specific HASP. Personnel who perform work operations on site are required to attend each briefing and to acknowledge receipt of each briefing, daily.

TOPICS COVERED (check all those covered):

☐ Accident Reporting Procedures	☐ General PPE Usage	☐ Site Control	☐ Other:
☐ Cellular Phone Charged w/Service	☐ Heat Stress	☐ Site Emergency Procedures	☐ Other:
☐ Changes to the HASP	☐ Hearing Conservation	☐ Slips, Trips, Falls	☐ Other:
☐ Cold Stress	☐ Lockout/Tagout	☐ Traffic Safety	☐ Other:
☐ Confined Space	☐ Personal Hygiene	☐ Other:	☐ Other:
☐ Decon Procedures	☐ Respiratory Protection	☐ Other:	☐ Other:
☐ Exposure Guidelines	☐ Review of Hazards	☐ Other:	☐ Other:

Daily Safety Topic Description:

Personnel Sign-in List

Printed Name	Signature	Company Name	Time-In	Time-Out

Project Safety Briefing Form

Project Number:	**Project Name:**
Date:	**Time:**
Briefing Conducted by:	**Signature:**

This sign-in log documents that a project specific-briefing was conducted in accordance with the site-specific HASP and GEI's H&S policy. GEI personnel who perform work on site are required to attend this project briefing. Applicable health and safety SOPs and any additional hazards are also required to be reviewed during this briefing. Prior to the start of the project or upon the start of a new on-site project team member, this form must be completed. Please email this completed form to:

SafetyTeam@geiconsultants.com

TOPICS COVERED (check all those covered):			
SOP HS-001 Biological Hazards		SOP HS-025 Manual Lifting	
SOP HS-002 Bloodborne Pathogens		SOP HS -26 Hazard Identification	
SOP HS-003 Container Management		SOP HS-27 Confined Space Entry for Sanitary Sewers	
SOP HS-004 Driver Safety		SOP HS-28 Safe Trailer Use	
SOP HS-005a Electrical Safety		SOP HS-29 Overtime and Fatigue Management	
SOP HS-005b Lockout/Tagout		Accident Reporting Procedures	
SOP HS-006 Excavation/Trenching		Changes to the HASP	
SOP HS-008a Hand Tools (Non-Powered)		Cold Stress	
SOP HS-008b Powered Hand Tools		Confined Space	
SOP HS-009 Hazardous Substances Management		Decon Procedures	
SOP HS-010 Inclement Weather		Exposure Guidelines	
SOP HS-011 Ladders		General PPE Usage	
SOP HS-012 Noise Exposure		Heat Stress	
SOP HS-013 Nuclear Density Gauge		Hearing Conservation	
SOP HS-014 Utility Markout		Lockout/Tagout	
SOP HS-015 Respirator Fit Test		Personal Hygiene	
SOP HS-016 Traffic Hazards		Respiratory Protection	
SOP HS-017 Water Safety		Review of Hazard Evaluation	
SOP HS-018 Working Around Heavy Equipment		Site Control	
SOP HS-019 Rail Safety		Site Emergency Procedures	
SOP HS-020 Aerial Lift		Slips, Trips, Falls	
SOP HS-021 Mobile Equipment		Other (Specify):	
SOP HS-022 Aquatic Ecological Survey/Electrofishing		Other (Specify):	
SOP HS-023 Scaffolding		Other (Specify):	
SOP HS-024 Wilderness Safety		Other (Specify):	

Personnel Sign-in List	
Printed Name	**Signature**

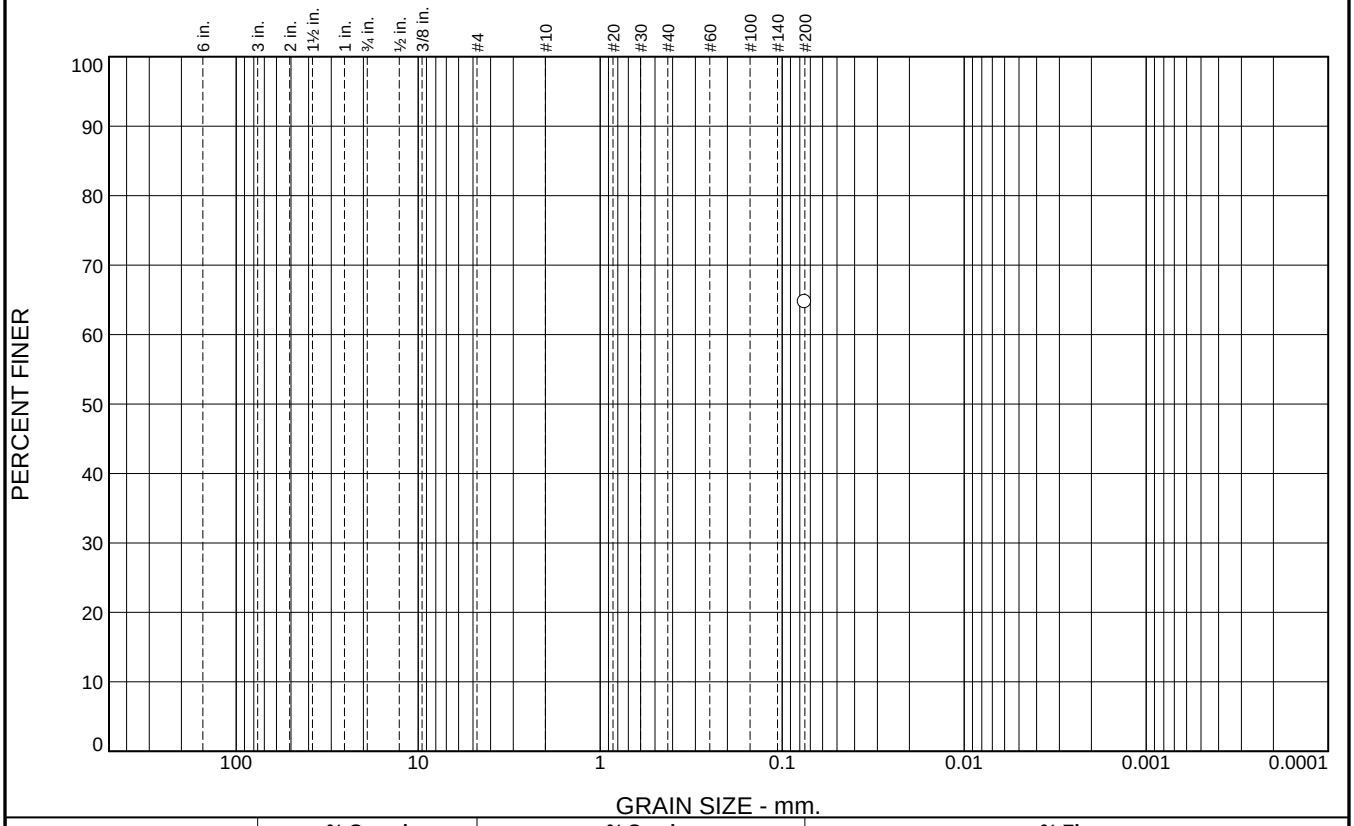
Appendix E

Health and Safety Plan

GEI Consultants

Appendix D

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						64.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	64.7		

* (no specification provided)

Material Description

SANDY lean CLAY, very dark brown

Atterberg Limits

PL= 22 LL= 32 PI= 10

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_RD551_001C **Depth:** 4-5',6-7'
Sample Number: S01,03 A/B **Date:**

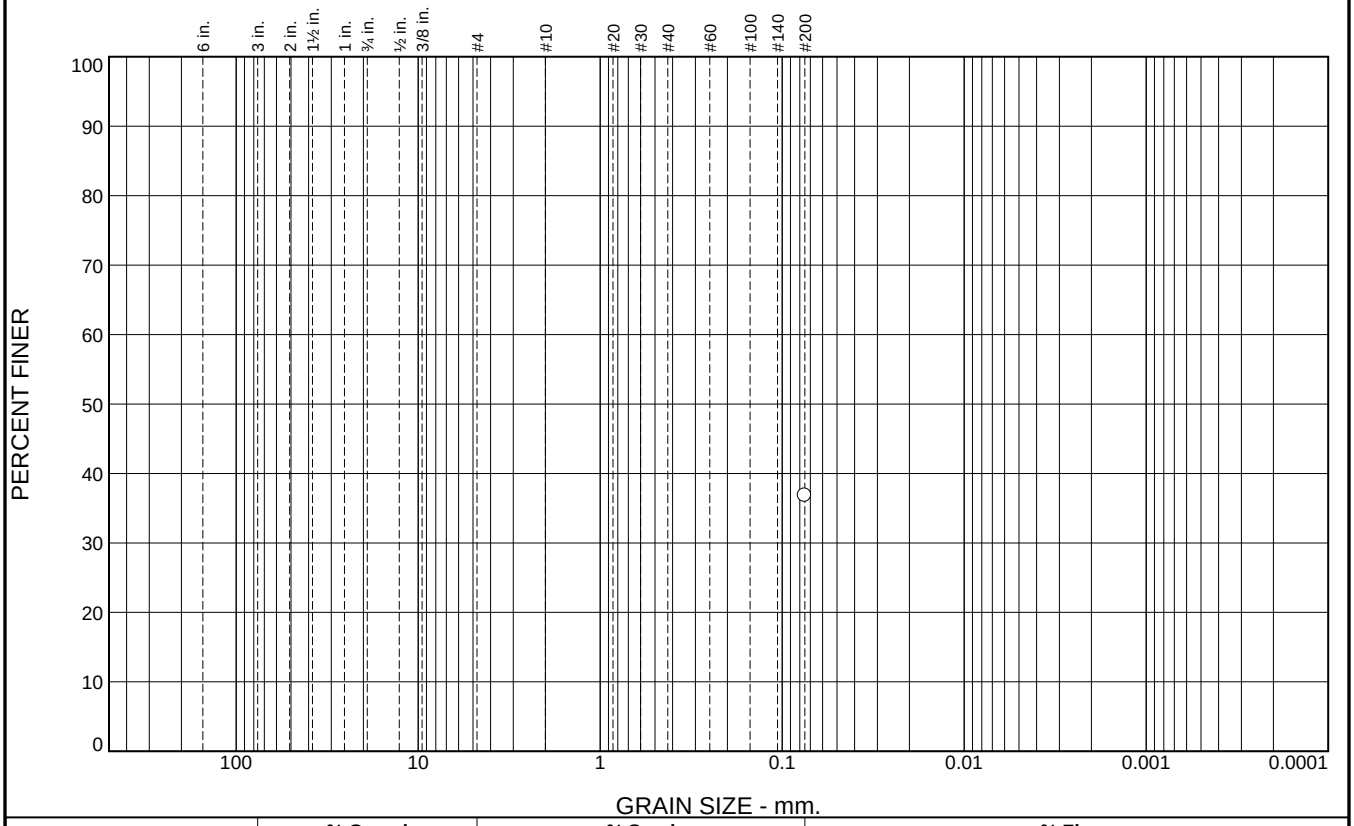
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						36.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	36.8		

* (no specification provided)

Material Description

SILTY SAND, dark olive brown

Atterberg Limits

PL= 25 LL= 25 PI= NP

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_RD551_002C **Depth:** 3.5-5'
Sample Number: S01 **Date:**

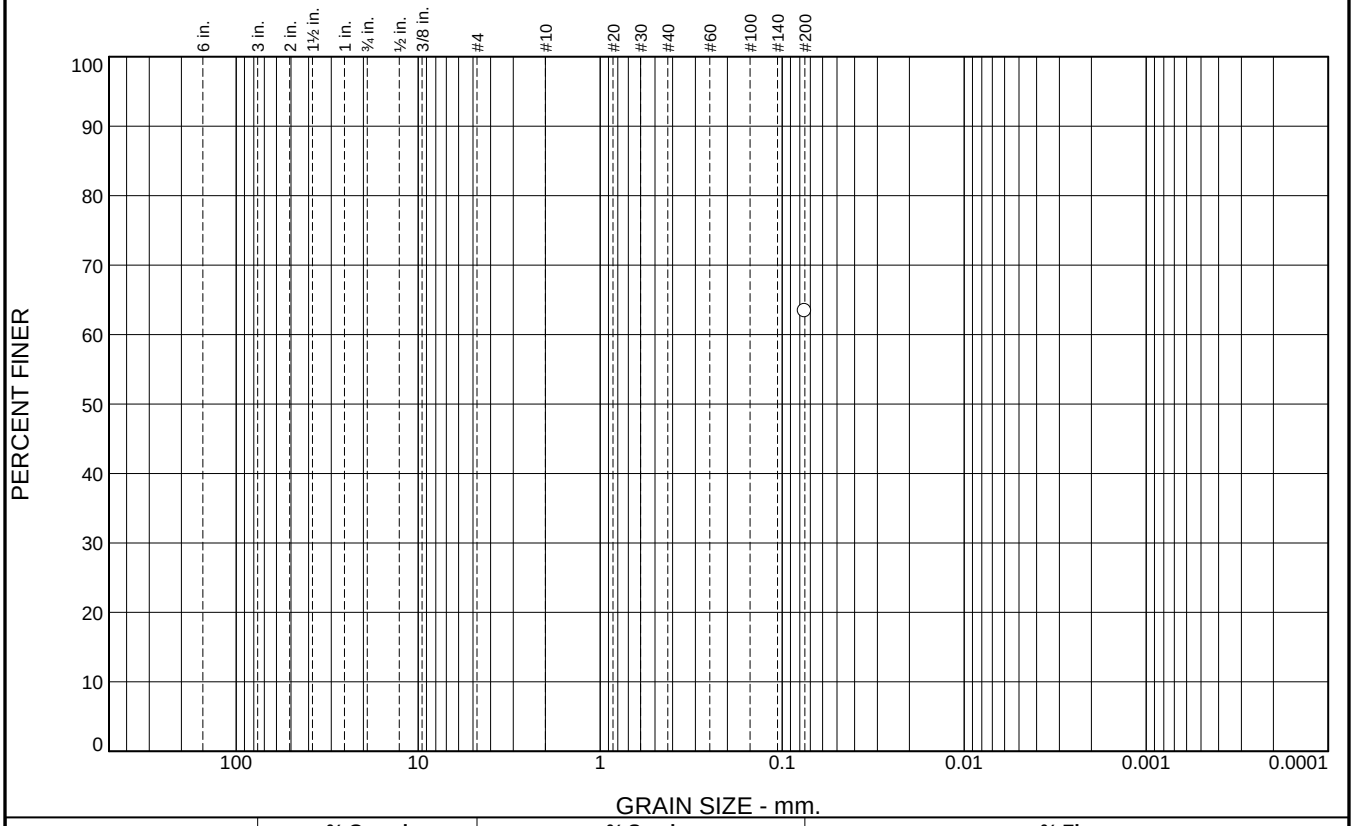
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						63.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	63.4		

* (no specification provided)

Material Description

SANDY SILT, dark olive gray

Atterberg Limits

PL= 24 LL= 30 PI= 6

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= ML AASHTO=

Remarks

Source of Sample: GEI_RD551_002C **Depth:** 8-10'
Sample Number: S02 **Date:**

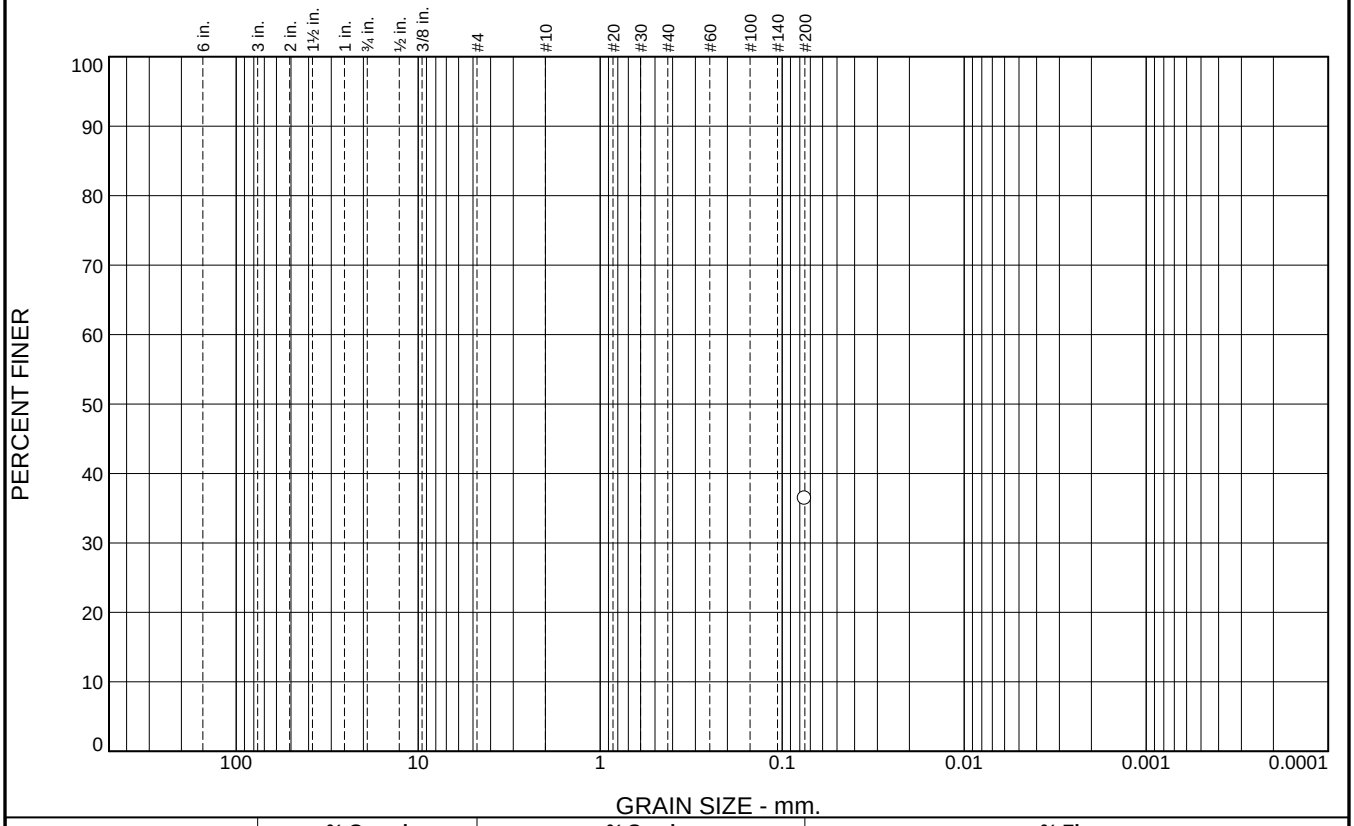
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						36.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	36.4		

* (no specification provided)

Material Description

SILTY SAND, dark gray

Atterberg Limits

PL= NP LL= NP PI= NP

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_RD551_002C **Depth:** 14-18'
Sample Number: S04 **Date:**

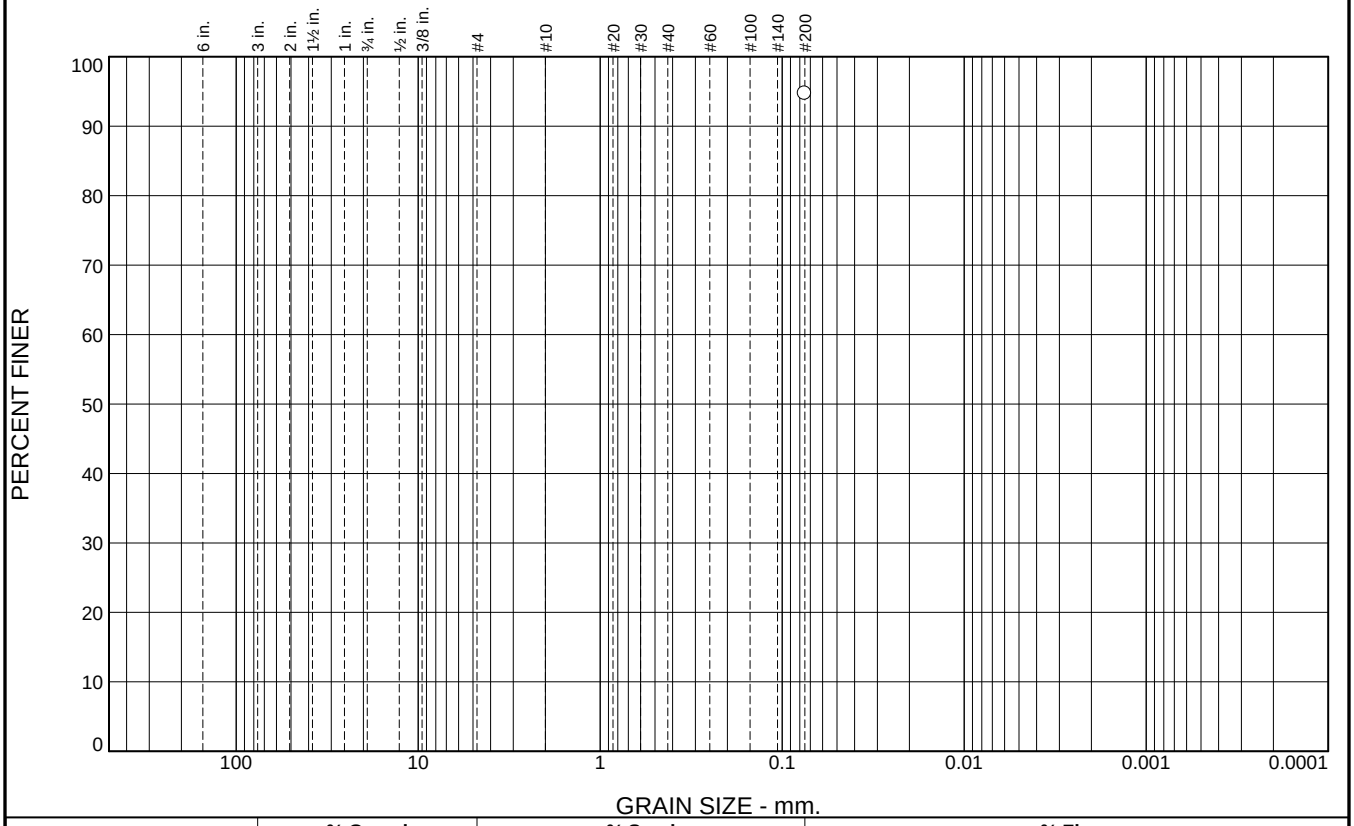
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						94.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	94.7		

* (no specification provided)

Material 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_RD551_003C **Depth:** 1-3'
Sample Number: S01,02 A/B **Date:**

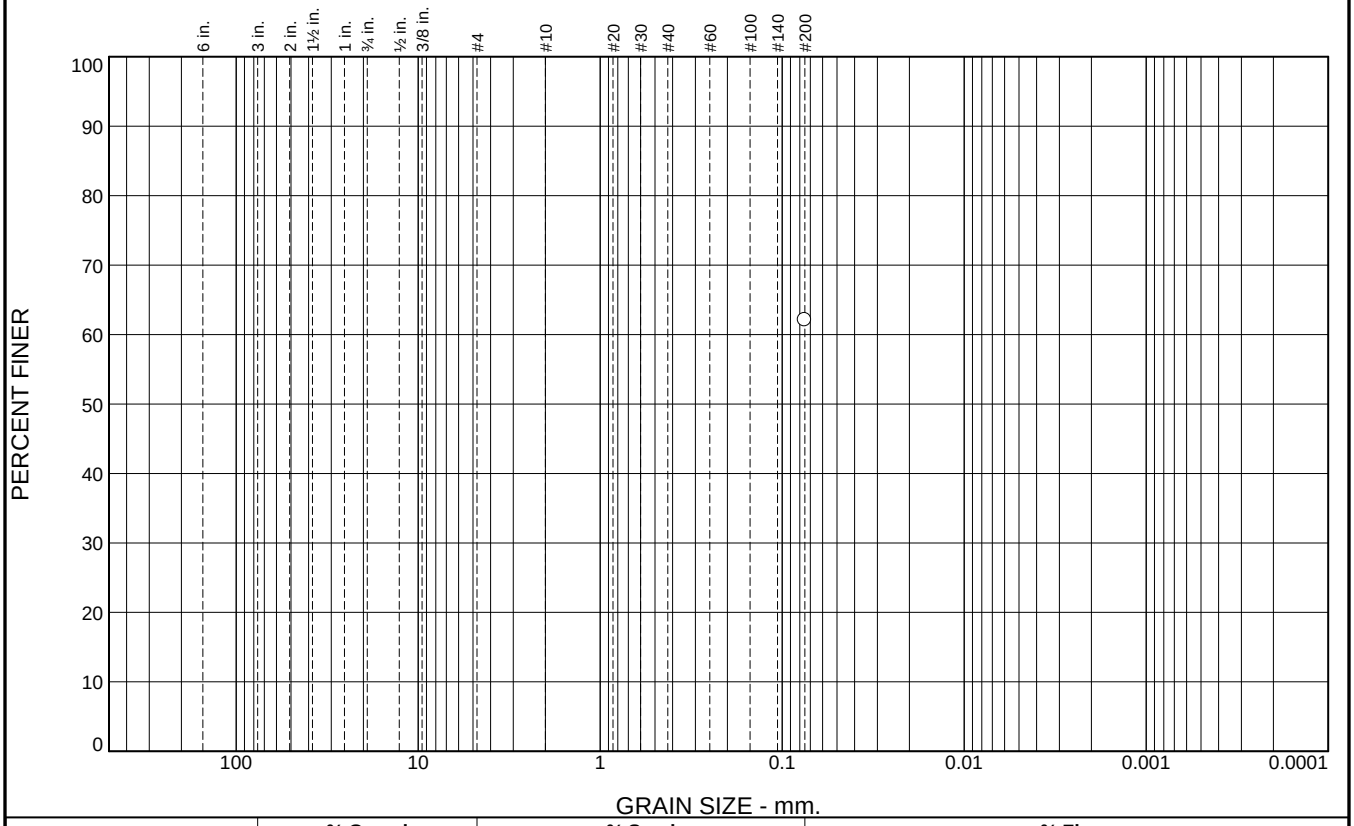
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						62.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	62.1		

* (no specification provided)

Material Description

SANDY SILT, dark olive brown

Atterberg Limits

PL= 24 LL= 32 PI= 8

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= ML AASHTO=

Remarks

Source of Sample: GEI_RD551_003C **Depth:** 6-8'
Sample Number: S03,04 A/B **Date:**

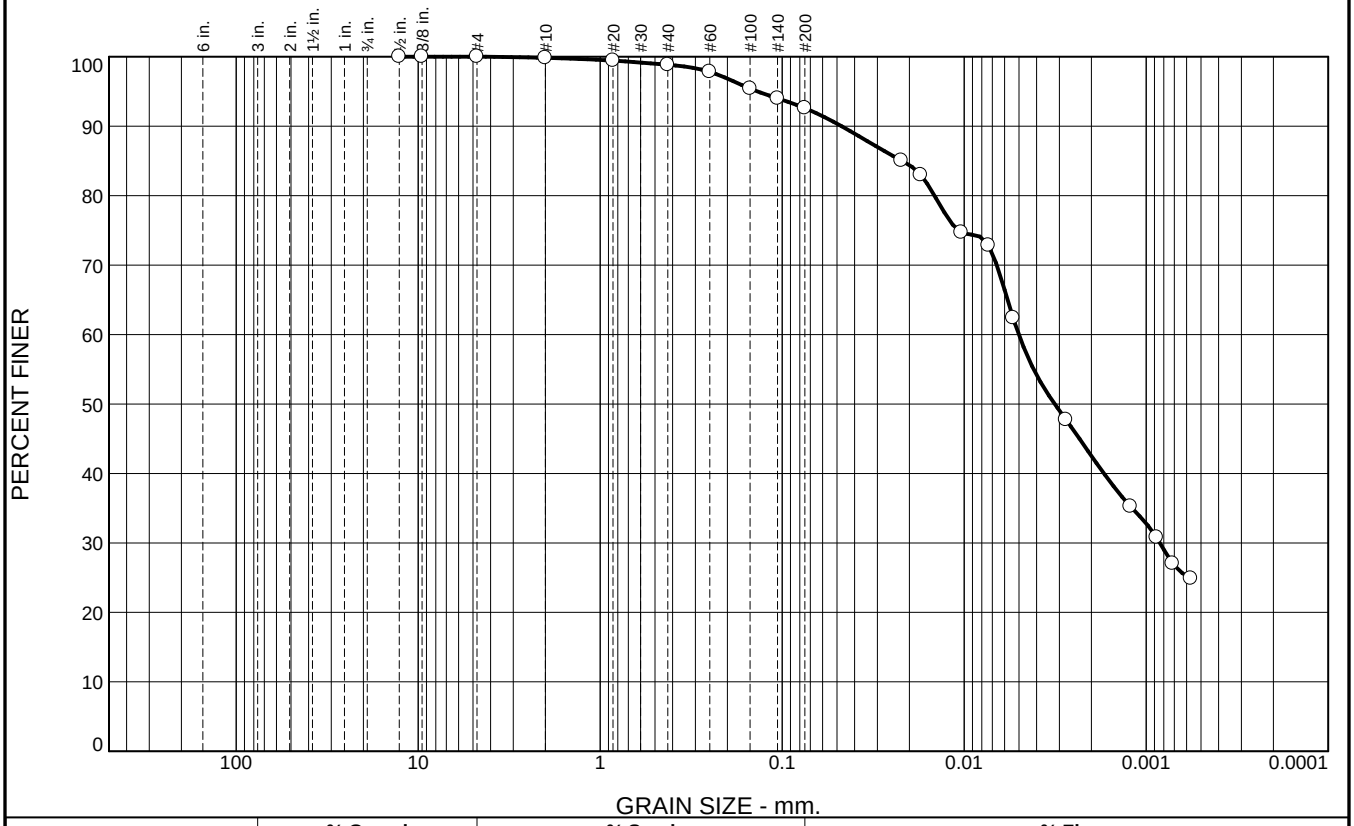
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.2	1.0	6.2	32.7	59.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2"	100.0		
3/8"	100.0		
#4	100.0		
#10	99.8		
#20	99.4		
#40	98.8		
#60	97.8		
#100	95.4		
#140	94.0		
#200	92.6		

* (no specification provided)

Material Description

Fat CLAY, very dark grayish brown

Atterberg Limits

PL= 31 LL= 70 PI= 39

Coefficients

D_{90}= 0.0473 D_{85}= 0.0220 D_{60}= 0.0050
D_{50}= 0.0032 D_{30}= 0.0008 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CH AASHTO= A-7-5(43)

Remarks

Source of Sample: GEI_RD551_006C **Depth:** 10-12'
Sample Number: S01,02 A/B **Date:**

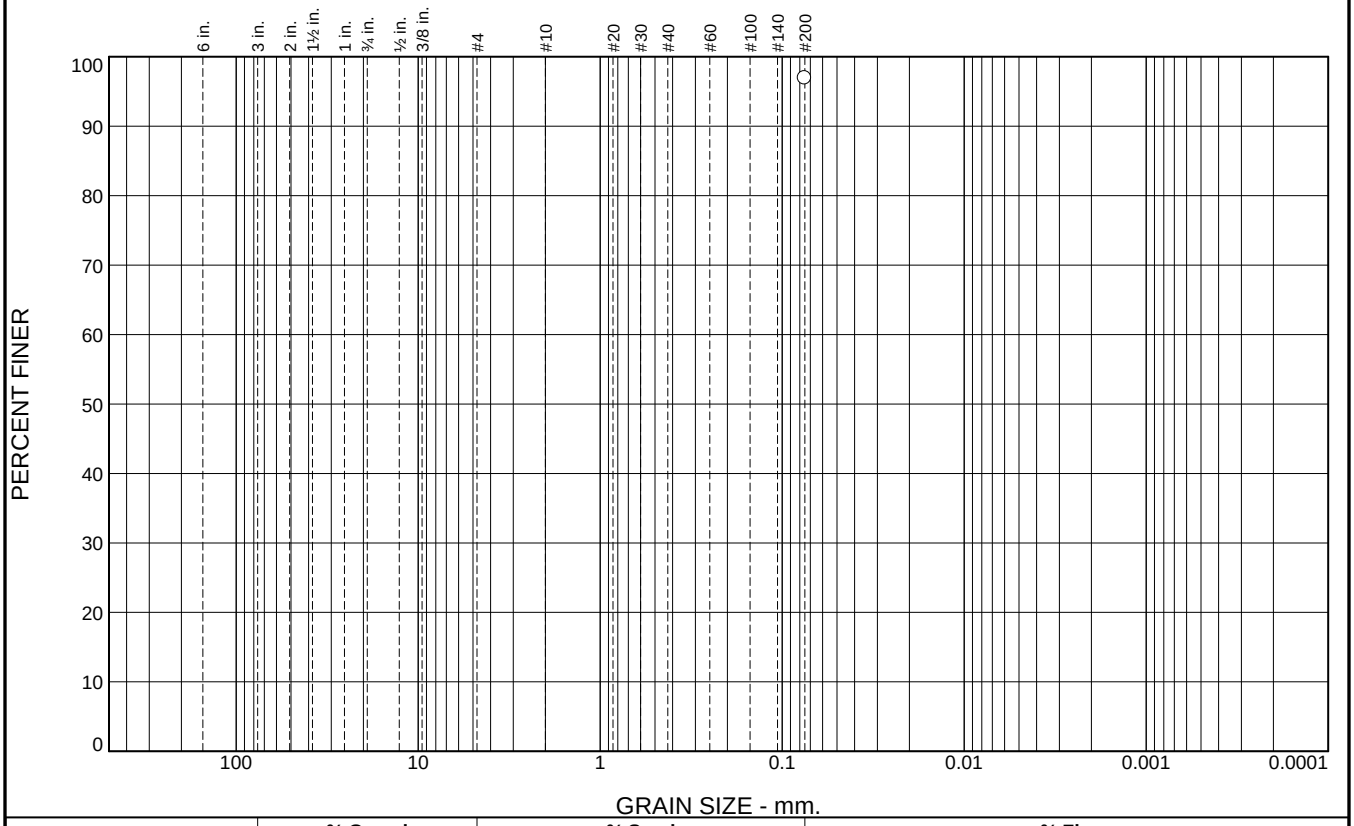
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						96.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	96.9		

* (no specification provided)

Material Description

Fat CLAY, dark grayish brown

Atterberg Limits

PL= 36 LL= 90 PI= 54

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CH AASHTO=

Remarks

Source of Sample: GEI_RD551_006C **Depth:** 23-25'
Sample Number: S03,04 A/B **Date:**

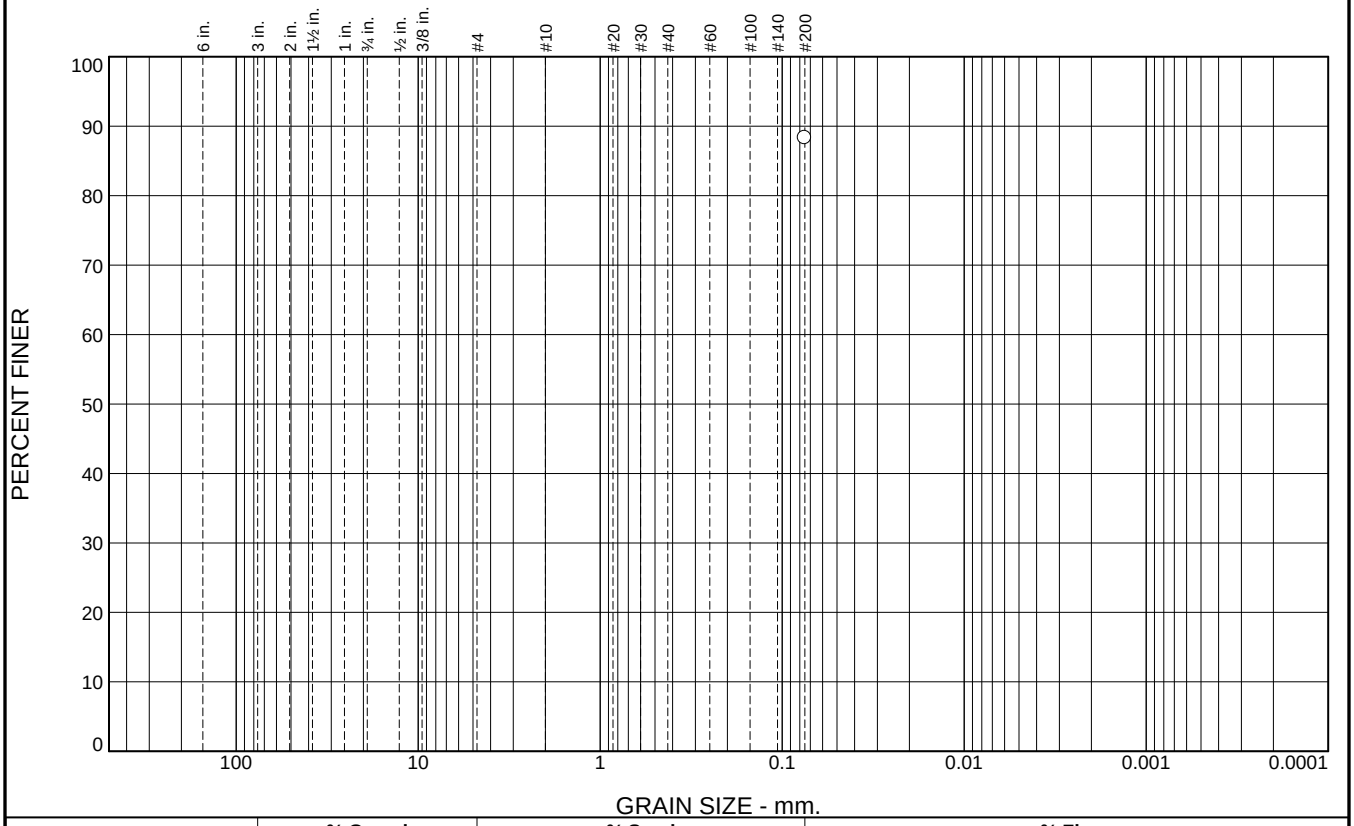
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						88.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	88.3		

* (no specification provided)

Material Description

Elastic SILT, very dark brown

Atterberg Limits

PL= 40 LL= 83 PI= 43

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= MH AASHTO=

Remarks

Source of Sample: GEI_RD551_007C **Depth:** 5-7'
Sample Number: S02,03 A/B **Date:**

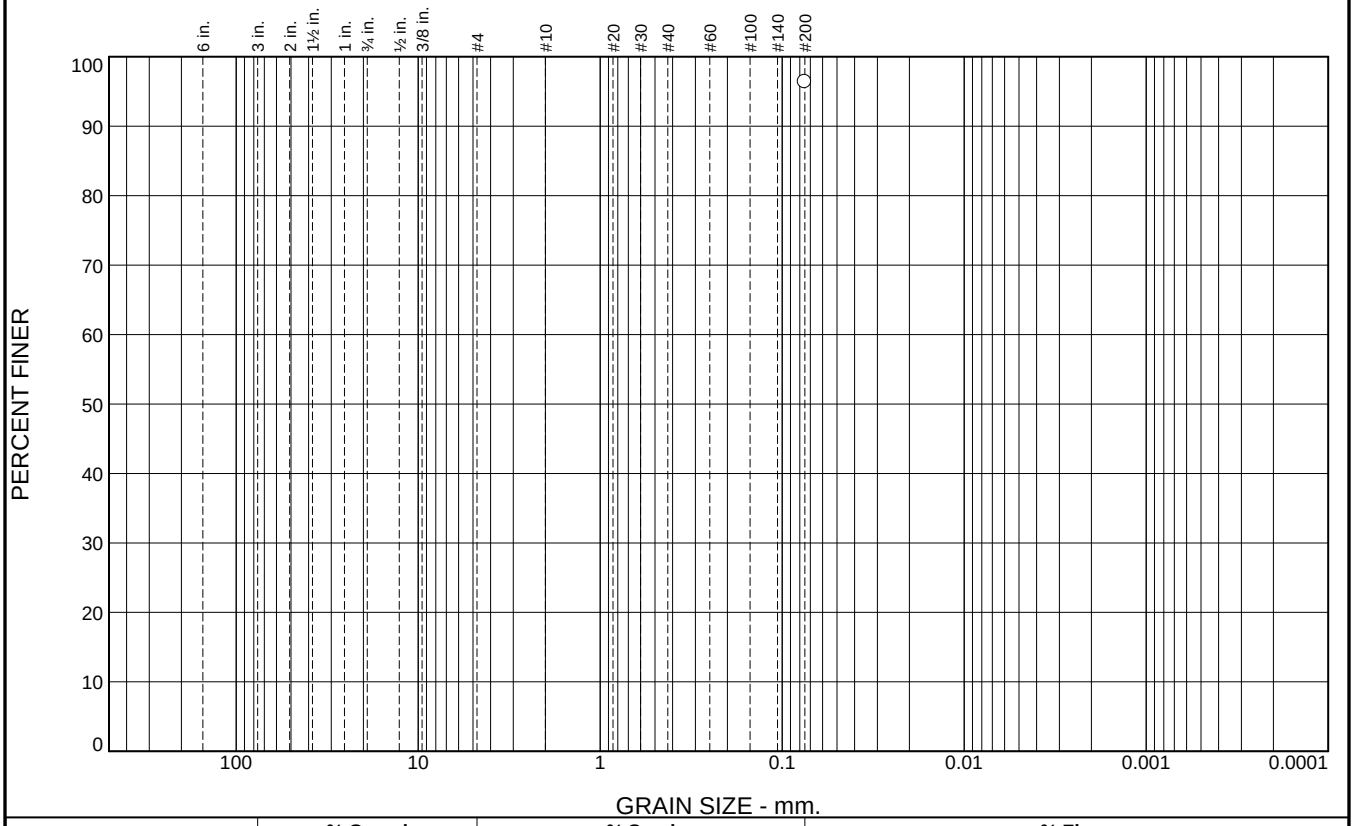
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						96.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	96.4		

* (no specification provided)

Material Description

Elastic SILT, very dark gray

Atterberg Limits

PL= 41 LL= 89 PI= 48

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_RD551_007C **Depth:** 19.5-20',21-22'
Sample Number: S04,06 A/B **Date:**

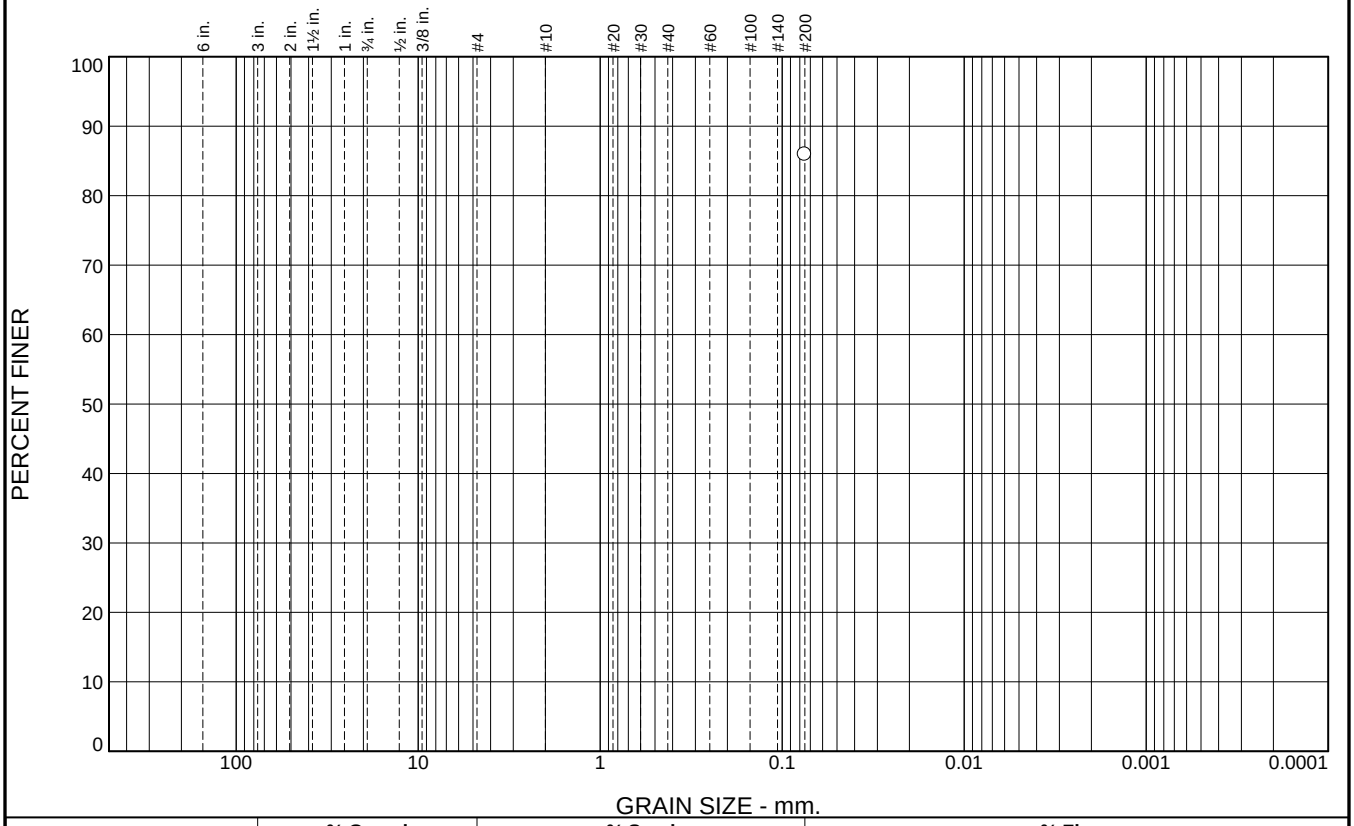
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						85.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	85.9		

* (no specification provided)

Material Description

Elastic SILT, black

Atterberg Limits

PL= 43 LL= 94 PI= 51

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= MH AASHTO=

Remarks

Source of Sample: GEI_RD551_008C **Depth:** 10-12'
Sample Number: S01,02 A/B **Date:**

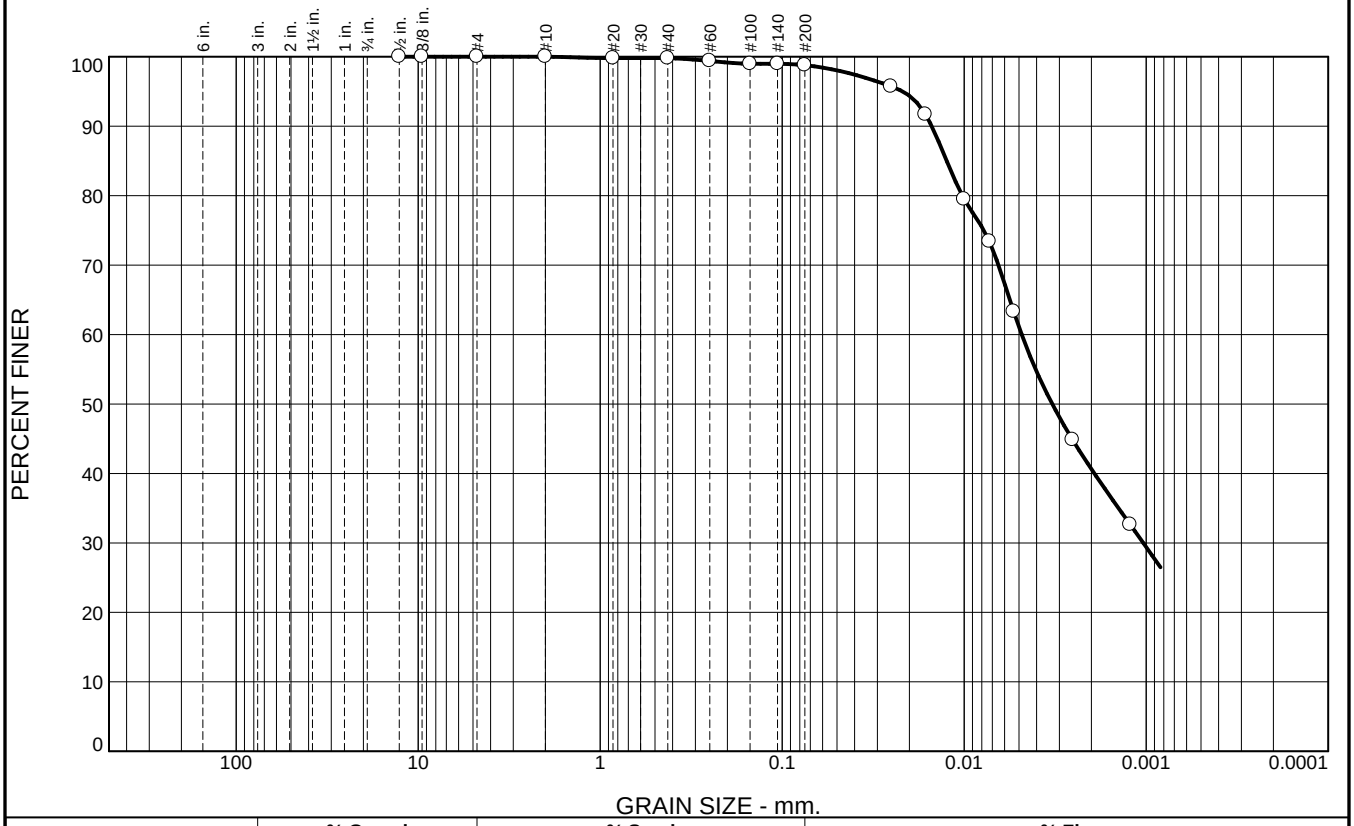
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.2	1.0	37.7	61.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2"	100.0		
3/8"	100.0		
#4	100.0		
#10	100.0		
#20	99.8		
#40	99.8		
#60	99.4		
#100	99.0		
#140	99.0		
#200	98.8		

* (no specification provided)

Material Description

Elastic SILT, very dark gray

Atterberg Limits

PL= 39 LL= 79 PI= 40

Coefficients

D_{90}= 0.0151 D_{85}= 0.0125 D_{60}= 0.0048
D_{50}= 0.0033 D_{30}= 0.0010 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= MH AASHTO= A-7-5(50)

Remarks

Source of Sample: GEI_RD551_008C **Depth:** 27-29'
Sample Number: S04,05 A/B **Date:**

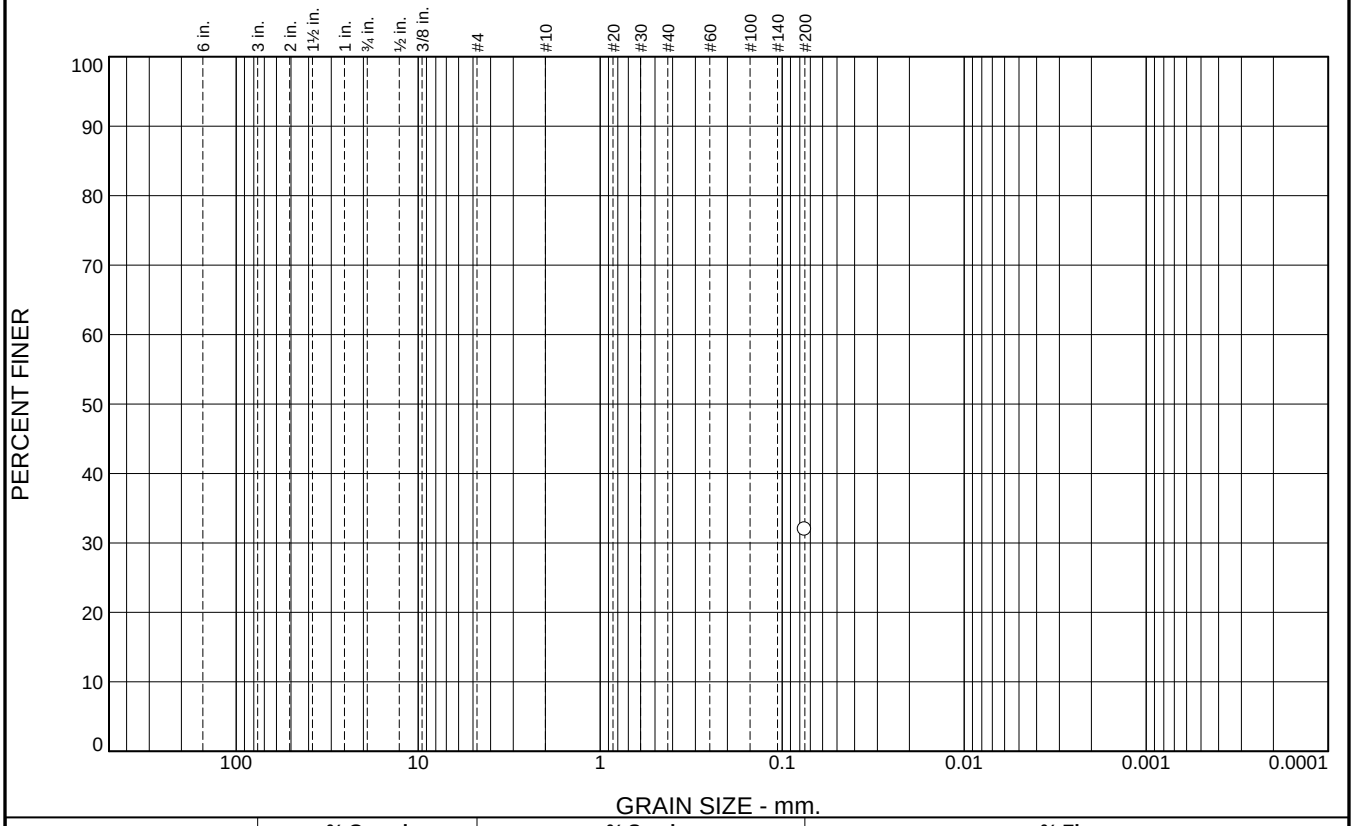
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						32.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	32.0		

* (no specification provided)

Material Description

strong 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_RD551_009C_b **Depth:** 9-11'
Sample Number: S01,02 A/B **Date:**

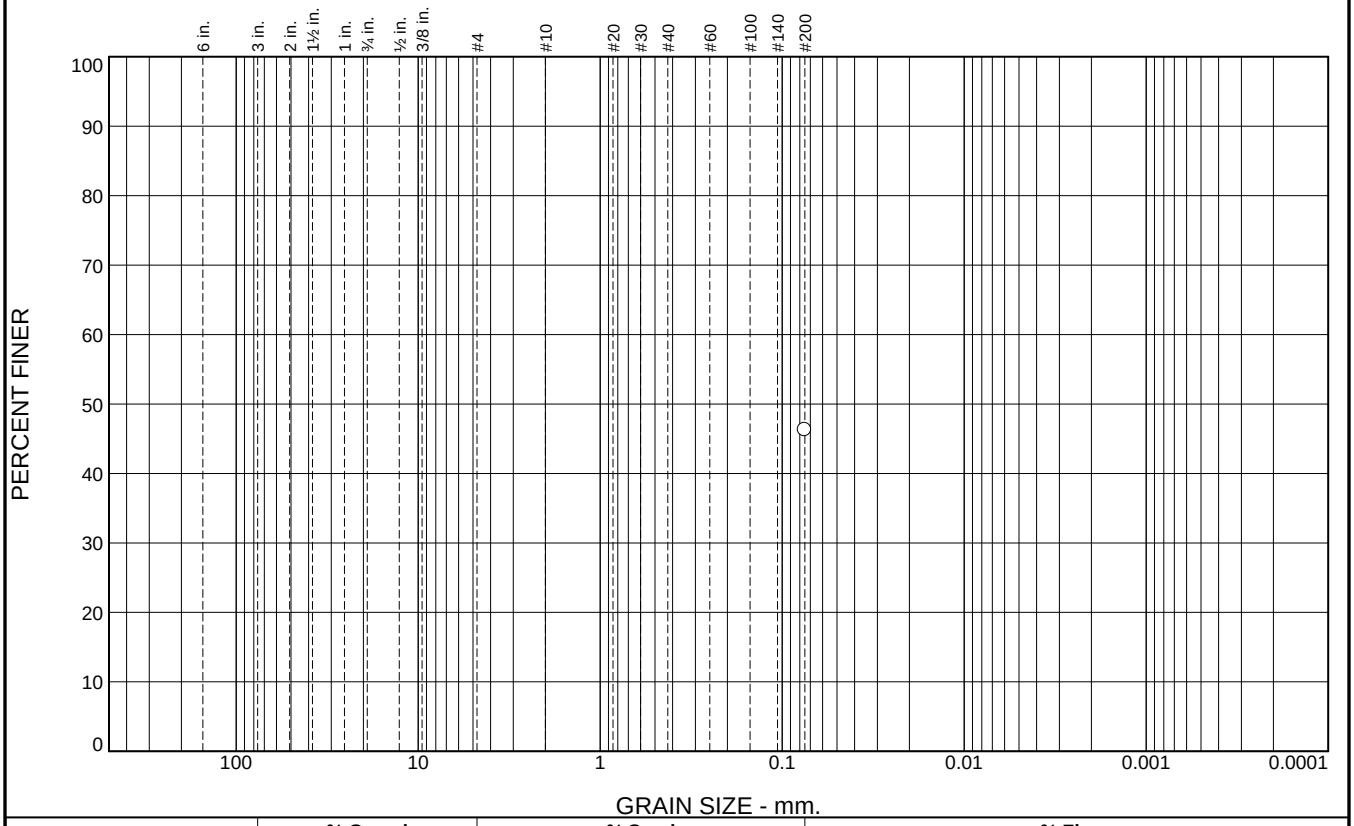
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						46.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	46.3		

* (no specification provided)

Material Description

CLAYEY SAND, very dark brown

Atterberg Limits

PL= 13 LL= 22 PI= 9

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_RD551_009C_b **Depth:** 17-19'
Sample Number: S03,04 A/B **Date:**

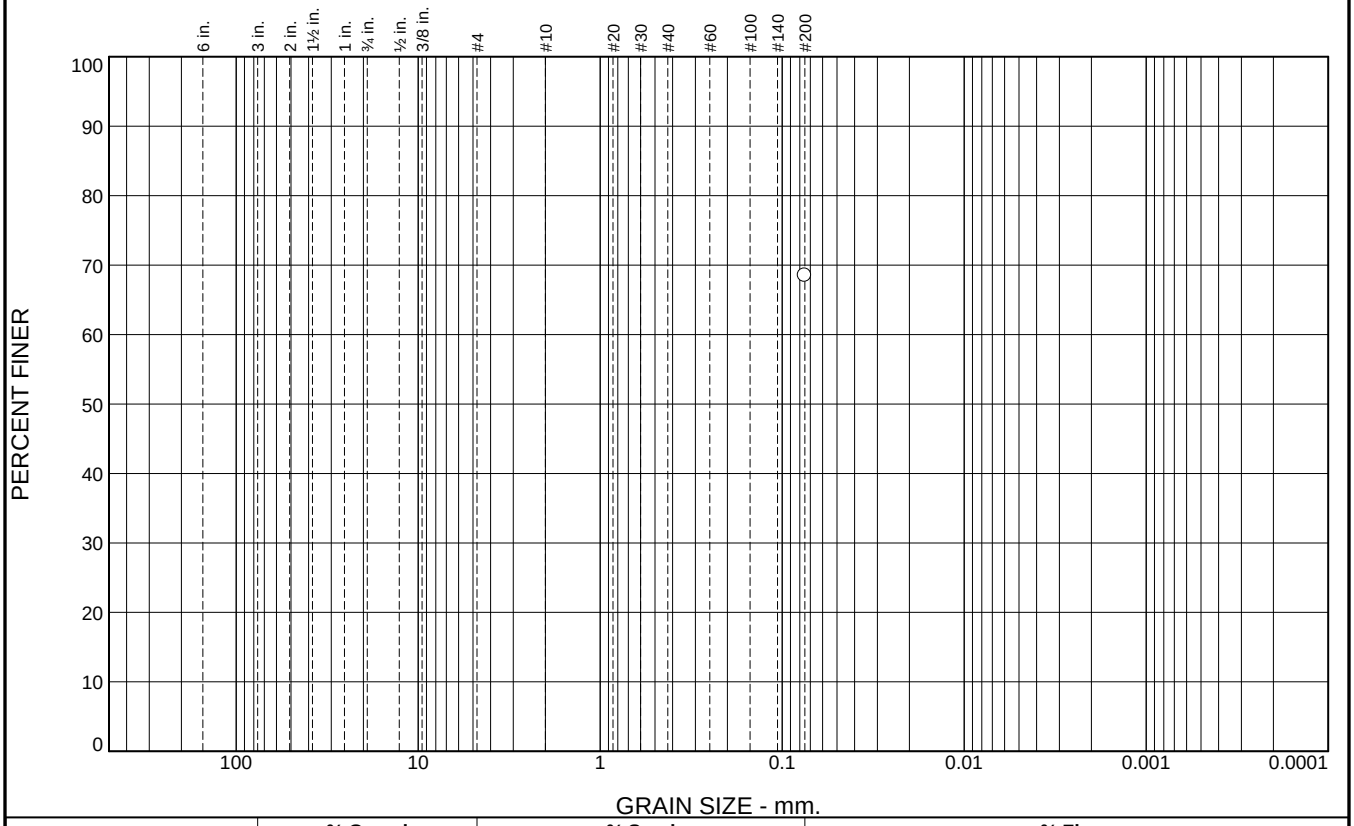
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						68.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	68.5		

* (no specification provided)

Material 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_RD551_010C **Depth:** 9-11'
Sample Number: S01,02 A/B **Date:**

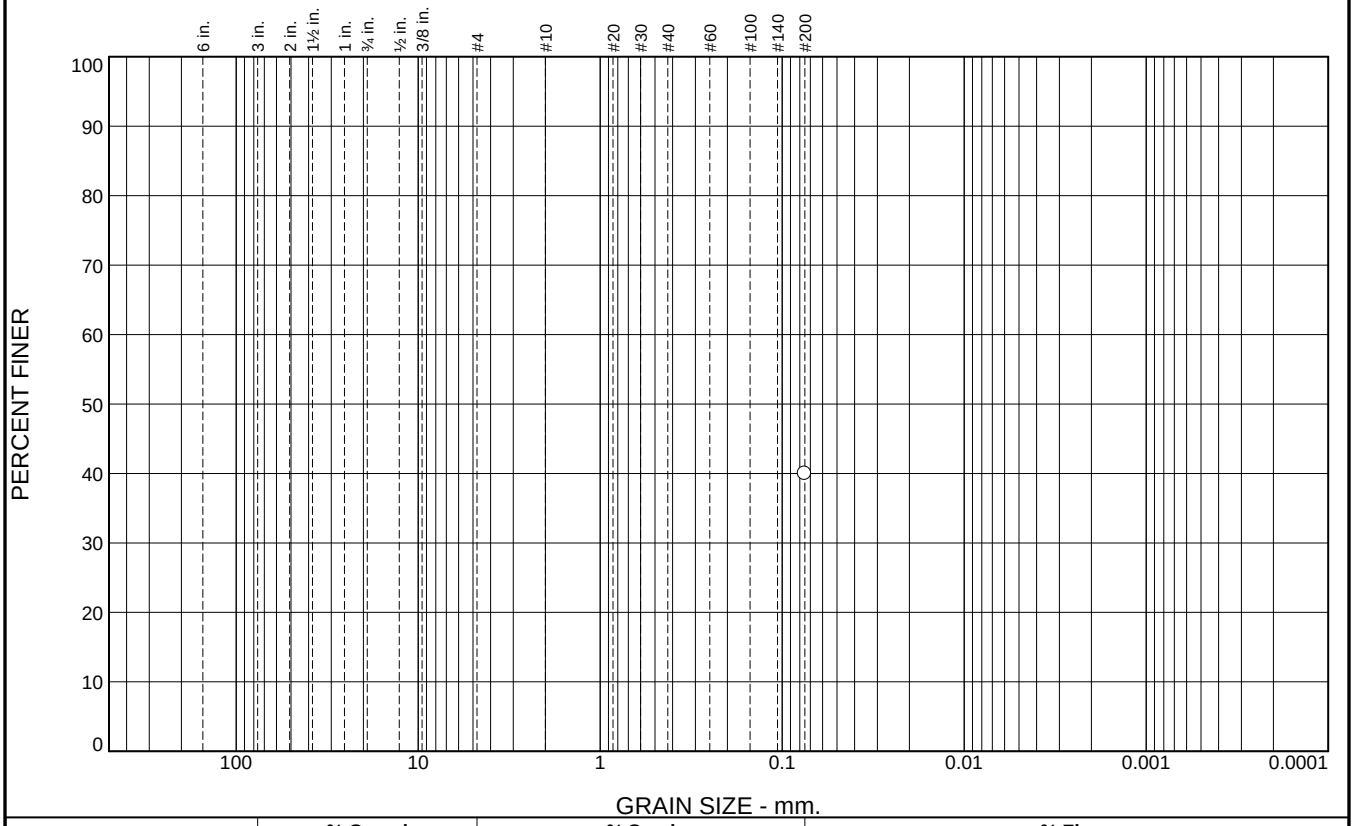
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						40.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	40.0		

* (no specification provided)

Material Description

strong brown & dark red

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_RD551_010C **Depth:** 19-21'
Sample Number: S03,04 A/B **Date:**

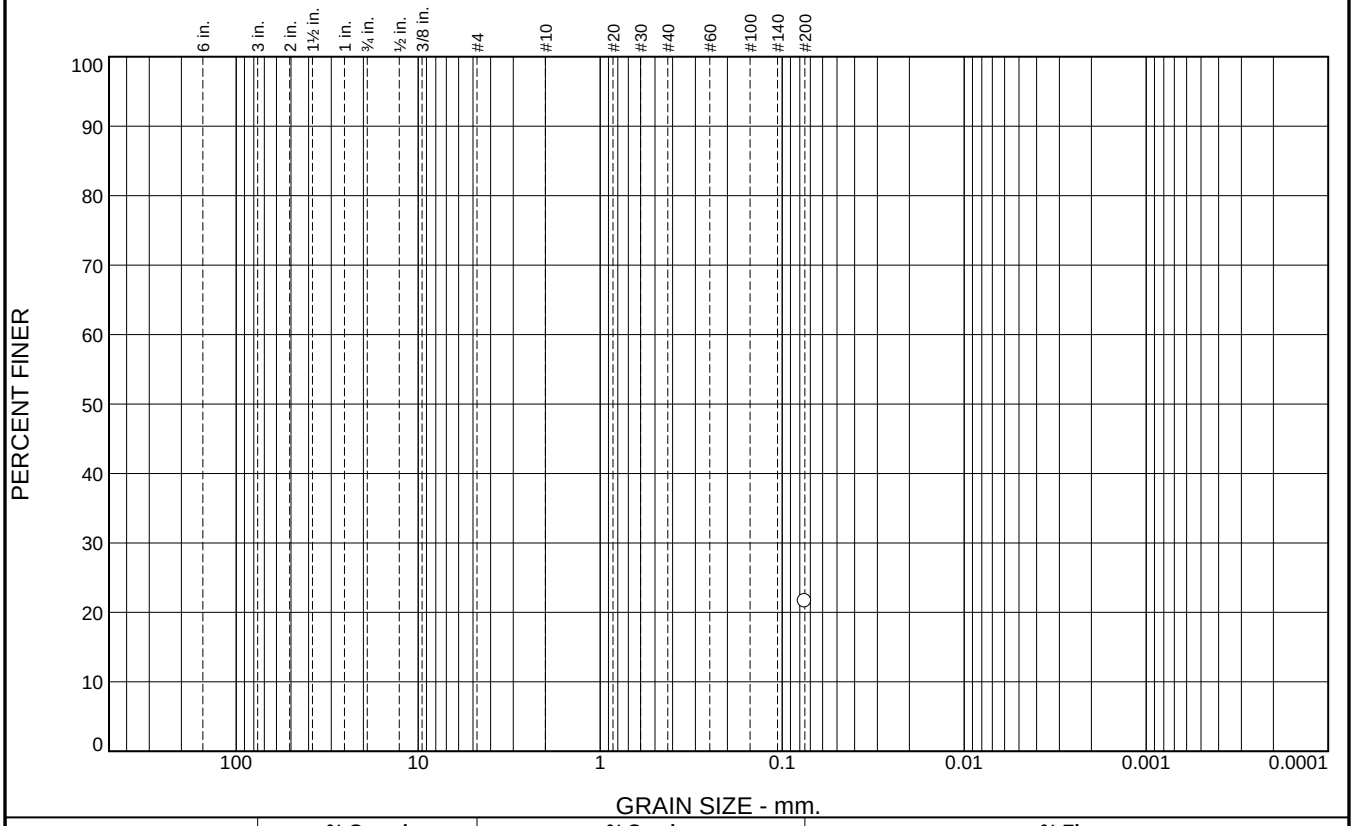
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						21.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	21.6		

* (no specification provided)

Material Description

brown & gray

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_RD551_010C **Depth:** 29.5-31.5'
Sample Number: S05,06 A/B **Date:**

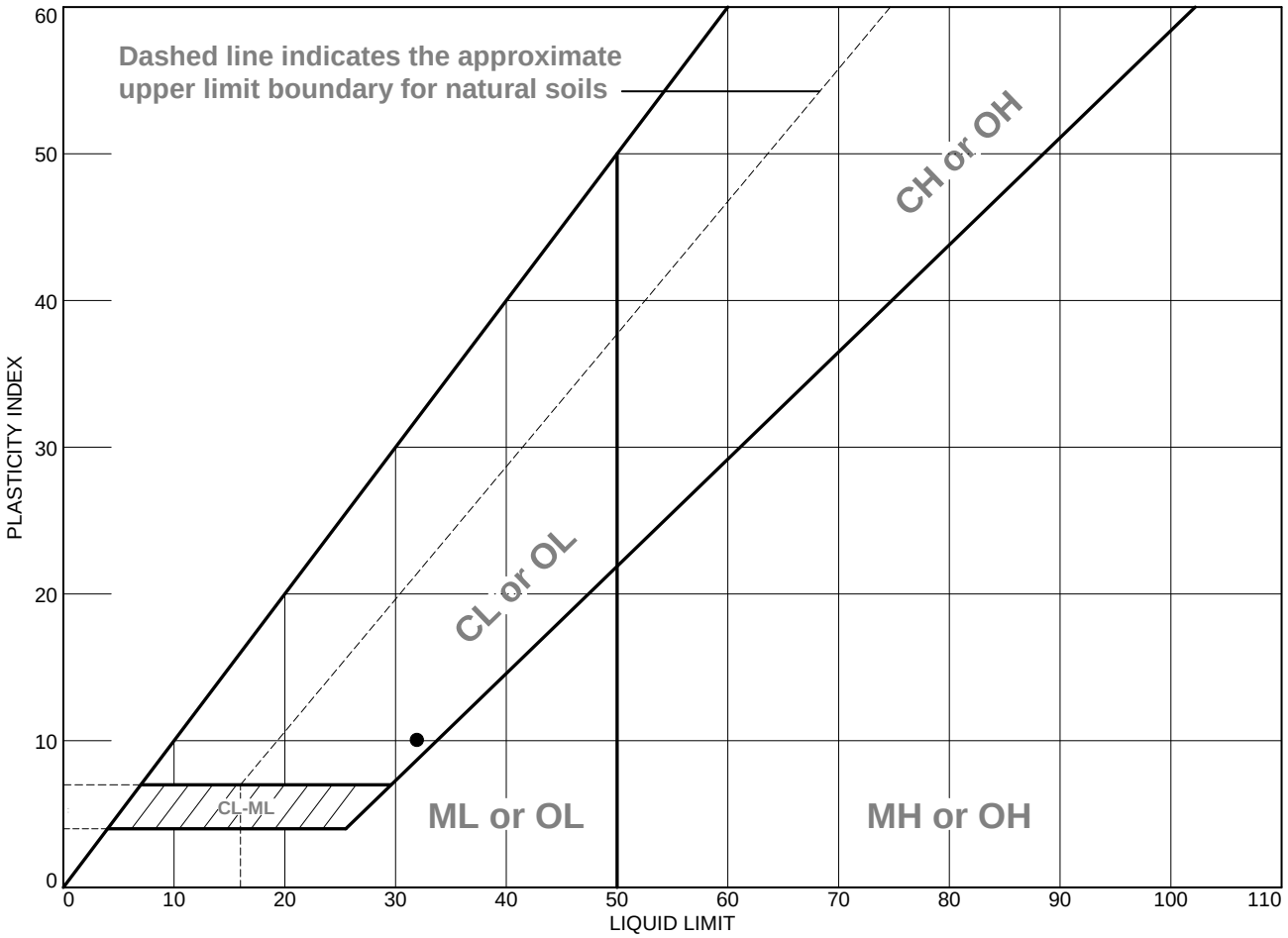
Blackburn Consulting

W. Sacramento, CA

Client: GEI Consultants, Inc.
Project: Small Communities - Courtland (1800758)

Project No: 3755.X 003 **Figure**

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SANDY lean CLAY, very dark brown	32	22	10		64.7	CL

Project No. 3755.X 003 **Client:** GEI Consultants, Inc.

Project: Small Communities - Courtland (1800758)

●**Source:** GEI_RD551_001C **Depth:** 4-5',6-7' **Sample No.:** S01,03 A/B

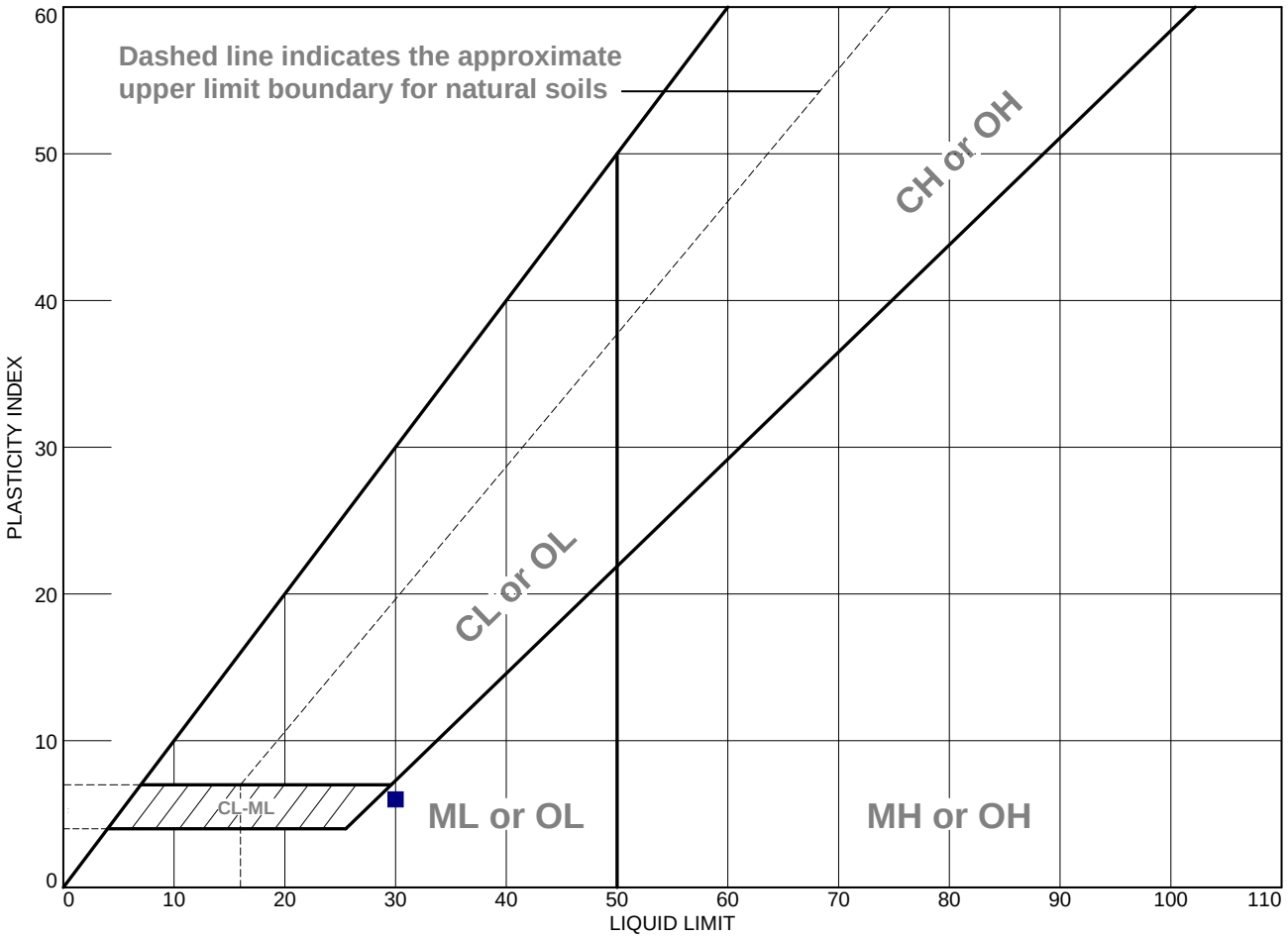
Remarks:

Blackburn Consulting

W. Sacramento, CA

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SILTY SAND, dark olive brown	25	25	NP		36.8	SM
■	SANDY SILT, dark olive gray	30	24	6		63.4	ML
▲	SILTY SAND, dark gray	NP	NP	NP		36.4	SM

Project No. 3755.X 003 **Client:** GEI Consultants, Inc.

Project: Small Communities - Courtland (1800758)

●**Source:** GEI_RD551_002C **Depth:** 3.5-5' **Sample No.:** S01
■**Source:** GEI_RD551_002C **Depth:** 8-10' **Sample No.:** S02
▲**Source:** GEI_RD551_002C **Depth:** 14-18' **Sample No.:** S04

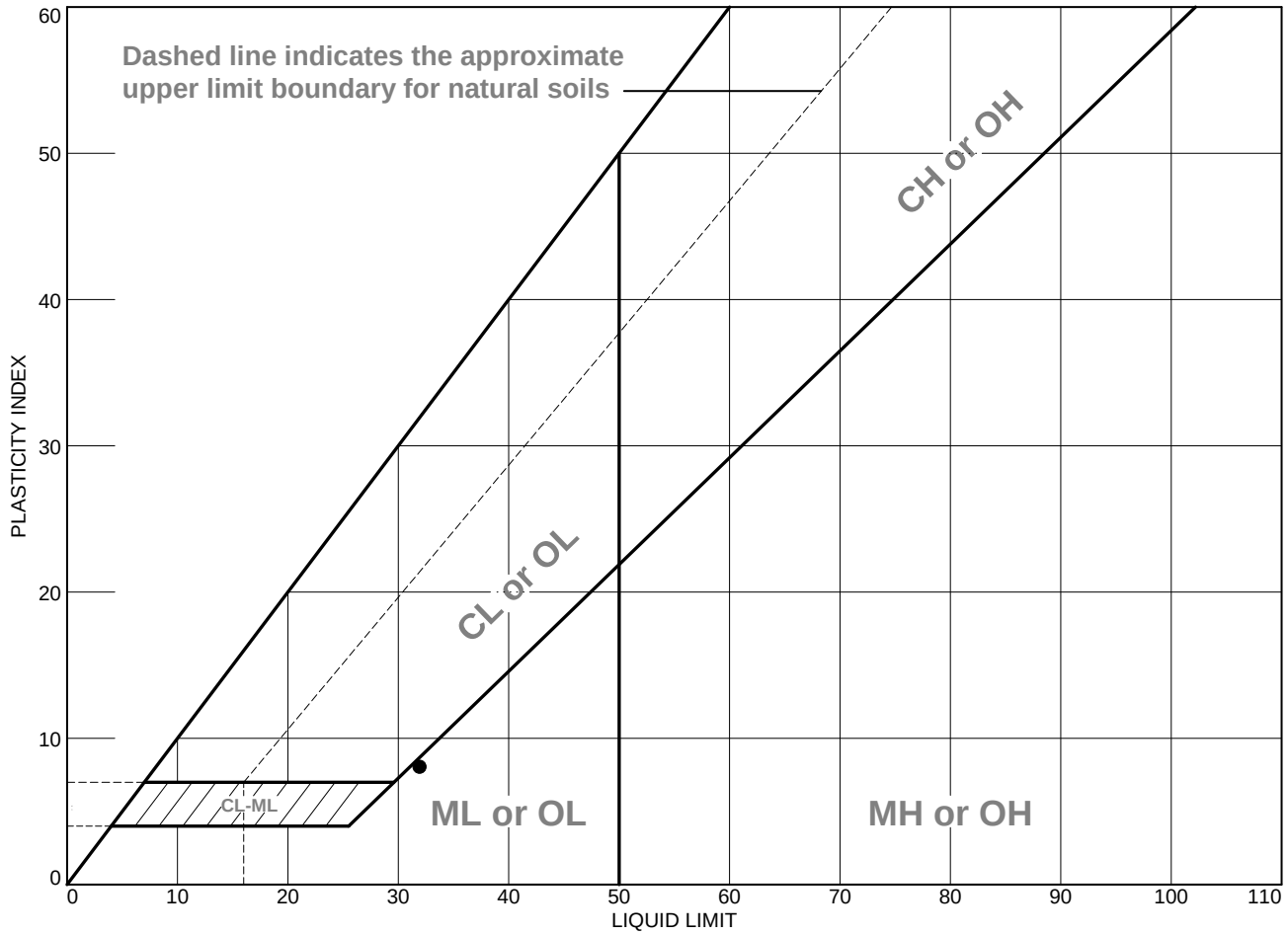
Remarks:

Blackburn Consulting

W. Sacramento, CA

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	SANDY SILT, dark olive brown	32	24	8		62.1	ML

Project No. 3755.X 003 **Client:** GEI Consultants, Inc.

Project: Small Communities - Courtland (1800758)

●**Source:** GEI_RD551_003C **Depth:** 6-8' **Sample No.:** S03,04 A/B

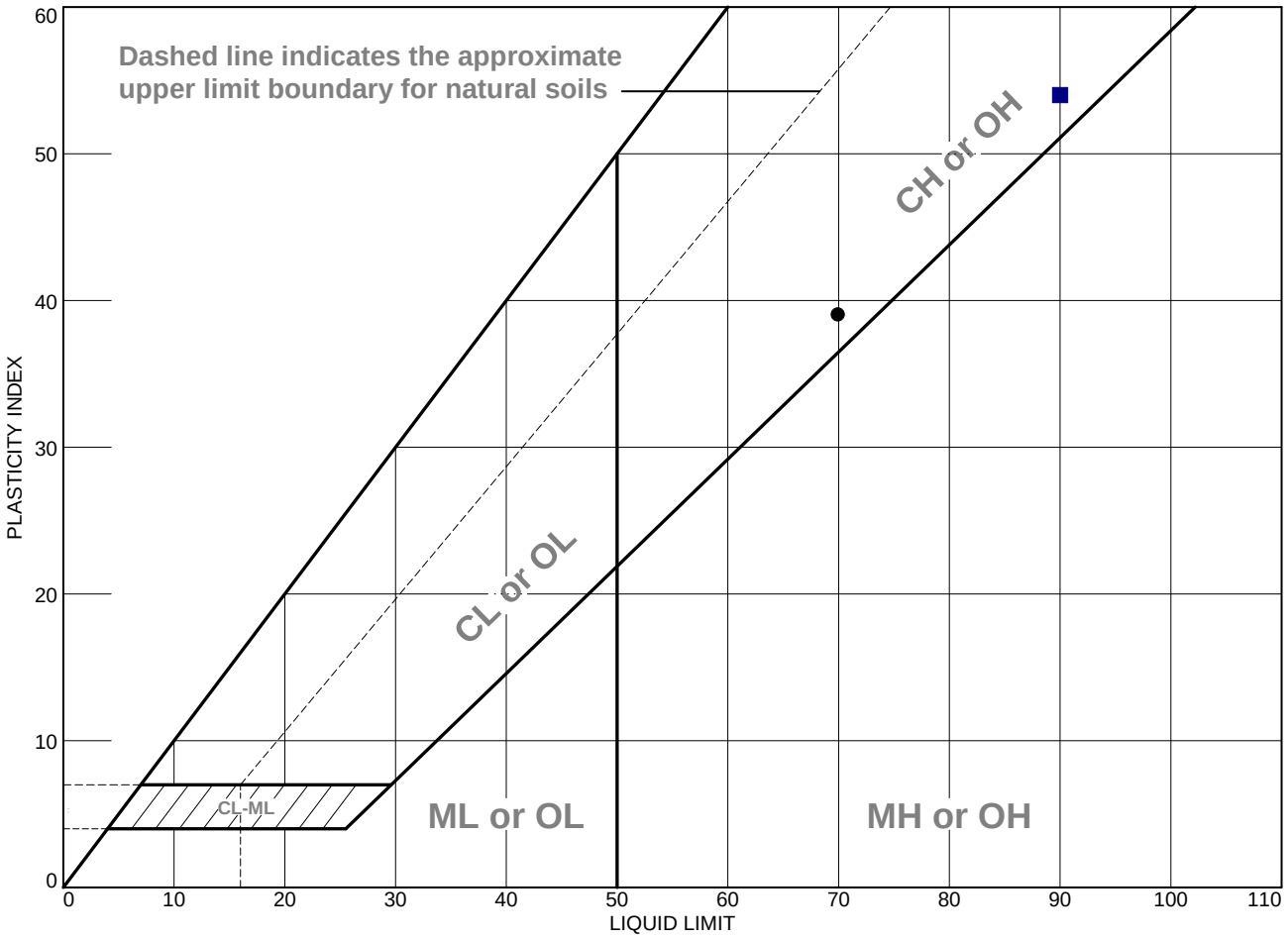
Remarks:

Blackburn Consulting

W. Sacramento, CA

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Fat CLAY, very dark grayish brown	70	31	39	98.8	92.6	CH
■	Fat CLAY, dark grayish brown	90	36	54		96.9	CH

Project No. 3755.X 003 **Client:** GEI Consultants, Inc.

Project: Small Communities - Courtland (1800758)

●**Source:** GEI_RD551_006C **Depth:** 10-12' **Sample No.:** S01,02 A/B

■**Source:** GEI_RD551_006C **Depth:** 23-25' **Sample No.:** S03,04 A/B

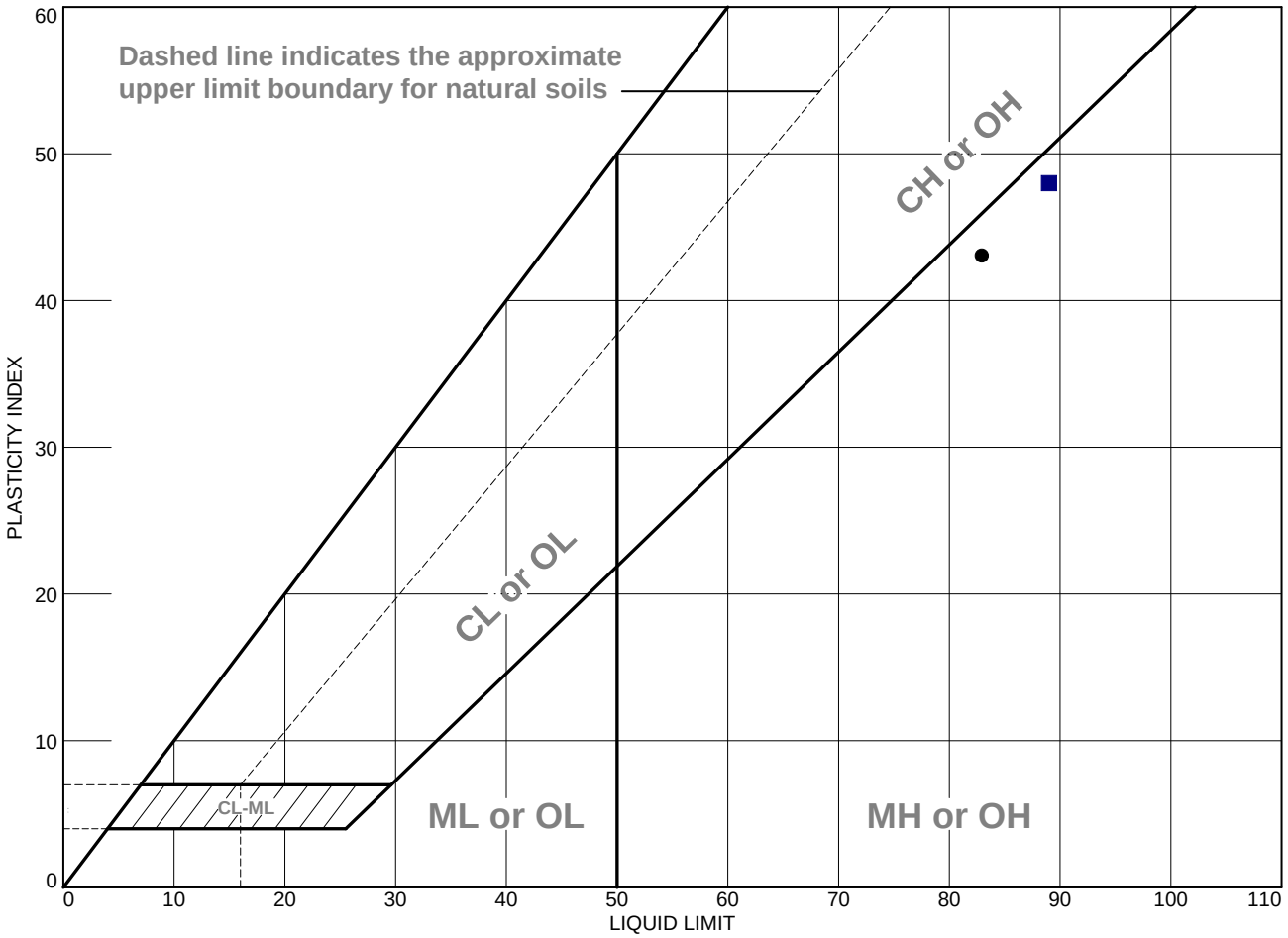
Remarks:

Blackburn Consulting

W. Sacramento, CA

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Elastic SILT, very dark brown	83	40	43		88.3	MH
■	Elastic SILT, very dark gray	89	41	48		96.4	

Project No. 3755.X 003 **Client:** GEI Consultants, Inc.

Project: Small Communities - Courtland (1800758)

●**Source:** GEI_RD551_007C **Depth:** 5-7' **Sample No.:** S02,03 A/B

■**Source:** GEI_RD551_007C **Depth:** 19.5-20',21-22' **Sample No.:** S04,06 A/B

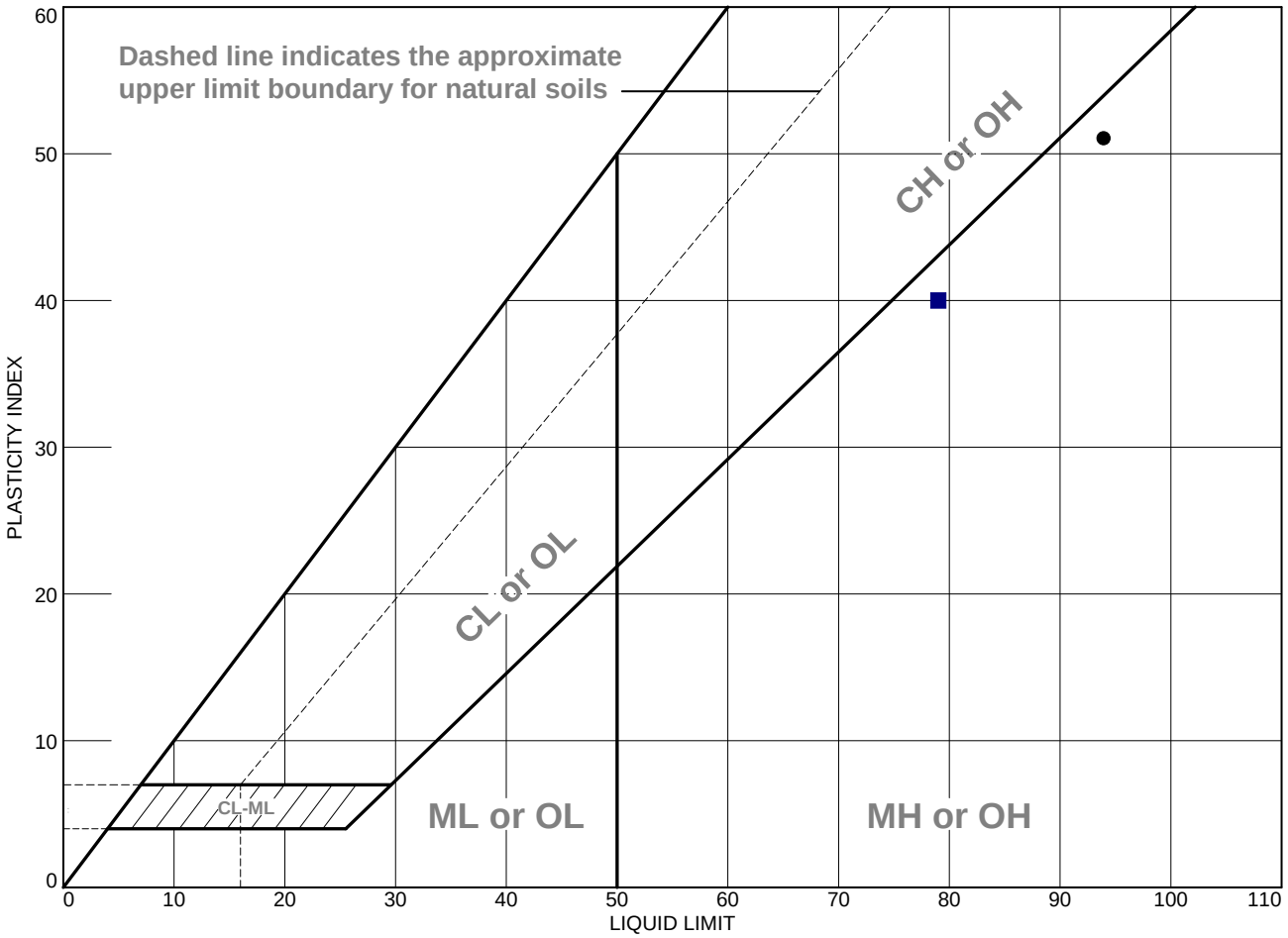
Remarks:

Blackburn Consulting

W. Sacramento, CA

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Elastic SILT, black	94	43	51		85.9	MH
■	Elastic SILT, very dark gray	79	39	40	99.8	98.8	MH

Project No. 3755.X 003 **Client:** GEI Consultants, Inc.

Project: Small Communities - Courtland (1800758)

●**Source:** GEI_RD551_008C **Depth:** 10-12' **Sample No.:** S01,02 A/B

■**Source:** GEI_RD551_008C **Depth:** 27-29' **Sample No.:** S04,05 A/B

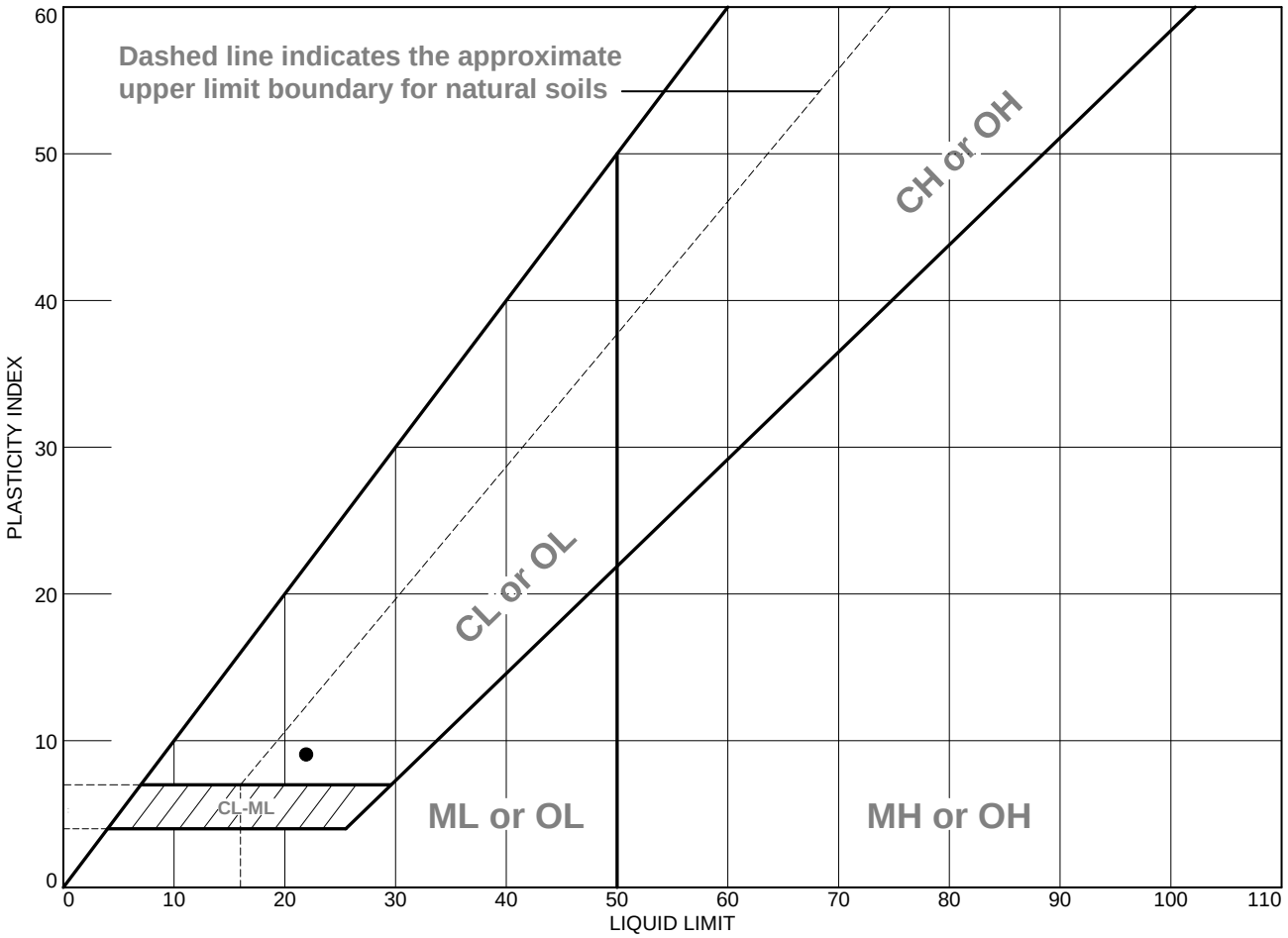
Remarks:

Blackburn Consulting

W. Sacramento, CA

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	CLAYEY SAND, very dark brown	22	13	9		46.3	SC

Project No. 3755.X 003 **Client:** GEI Consultants, Inc.

Project: Small Communities - Courtland (1800758)

●**Source:** GEI_RD551_009C_b **Depth:** 17-19' **Sample No.:** S03,04 A/B

Remarks:

Blackburn Consulting

W. Sacramento, CA

Figure

Appendix E

MBK ENGINEERS

Water Resources • Flood Control • Water Rights

GILBERT COSIO, JR., P.E.
MARC VAN CAMP, P.E.
WALTER BOUREZ, III, P.E.
RIC REINHARDT, P.E.
GARY KIENLEN, P.E.
DON TRIEU, P.E.
DARREN CORDOVA, P.E.
NATHAN HERSHEY, P.E., P.L.S.
LEE G. BERGFELD, P.E.
BEN TUSTISON, P.E.

ANGUS NORMAN MURRAY
1913-1985

CONSULTANTS:
JOSEPH I. BURNS, P.E.
DONALD E. KIENLEN, P.E.

December 22, 2017

Ms. Mary Jimenez
Acting Chief Engineer
Central Valley Flood Protection Board
3310 El Camino Ave., Ste. 170
Sacramento, CA 95821

Subject: **Central Valley Flood Protection Board September 18, 2017 Letter**
Reclamation District 551, Justification for Site Classifications
DWR Emergency Rehabilitation, 2017 Storm Damages

Dear Ms. Jimenez:

This letter is in response to your September 18, 2017 letter provided to Reclamation District No. 551 (District) regarding the classification and contingency planning for distress caused to our levee system as a result of high water in 2017. In your letter, these distress sites were classified as either critical, serious, or areas of concern by the Department of Water Resources (DWR), indicating the site's likelihood of causing a levee breach and priority in being repaired. This letter serves as the District's response to the Central Valley Flood Protection Board (CVFPB) and DWR site assessment.

In performing our assessment of the erosion sites within the District, we accounted for multiple variables that effect the likelihood of levee failure, the ability to flood fight successfully, and the consequences of levee failure. These included whether the erosion impinges on the theoretical minimum levee template, the failure mechanism, presence of riprap or vegetation, apparent levee slope stability, levee embankment materials, access and visibility of the site, height and length of the site, and critical infrastructure protected by the levee.

As documented in our June 30, 2017 PL 84-99 rehabilitation assistance request, 25 distress sites were identified as having experienced waterside erosion during the 2017 high water event. The following is a summary of our assessment.

- Not included in DWR list: 4 sites
- Warranting re-classification: 6 sites
- Critical: 1 site

- Serious: 7 sites
- Area of concern: 17 sites

In general, high velocity and duration flows down the Sacramento River have caused erosion above the existing riprap, caused the riprap to fail and then eroded the levee, or eroded the levee where no riprap existed. The levee and bank slopes are comprised of very loose and highly erodible sands. Our assessment classified sites as critical where erosion significantly encroached into the levee or occurred above the midpoint of the levee to the crest. Sites considered serious showed erosion near the levee toe up to the midpoint or caused rip rap to fail, but did not significantly encroach on the levee template. Areas of concern were typically localized erosion sites with limited progression into the levee. Length along the levee and width into the levee also was factored into the assessment. Serious and critical sites within RD 551 are of particular concern due to the levee material and high velocity of the Sacramento River. Because the materials are highly erodible, the erosion cannot be detected during a flood event and can progress very quickly from minor to significant. If addressed immediately the serious and critical sites could be repaired with smaller less intrusive riprap designs. If addressed as part of an emergency response, the size and cost of the repair will be substantial.

We do not agree that the current site characterization is appropriate given the anticipated levee performance and associated consequences. We appreciate your efforts in performing critical repairs and contingency planning, and look forward to continuing to meet with you on how best to address these distress sites. If you have any questions or require any further information please contact Michael Kynett or me at (916) 456-4400.

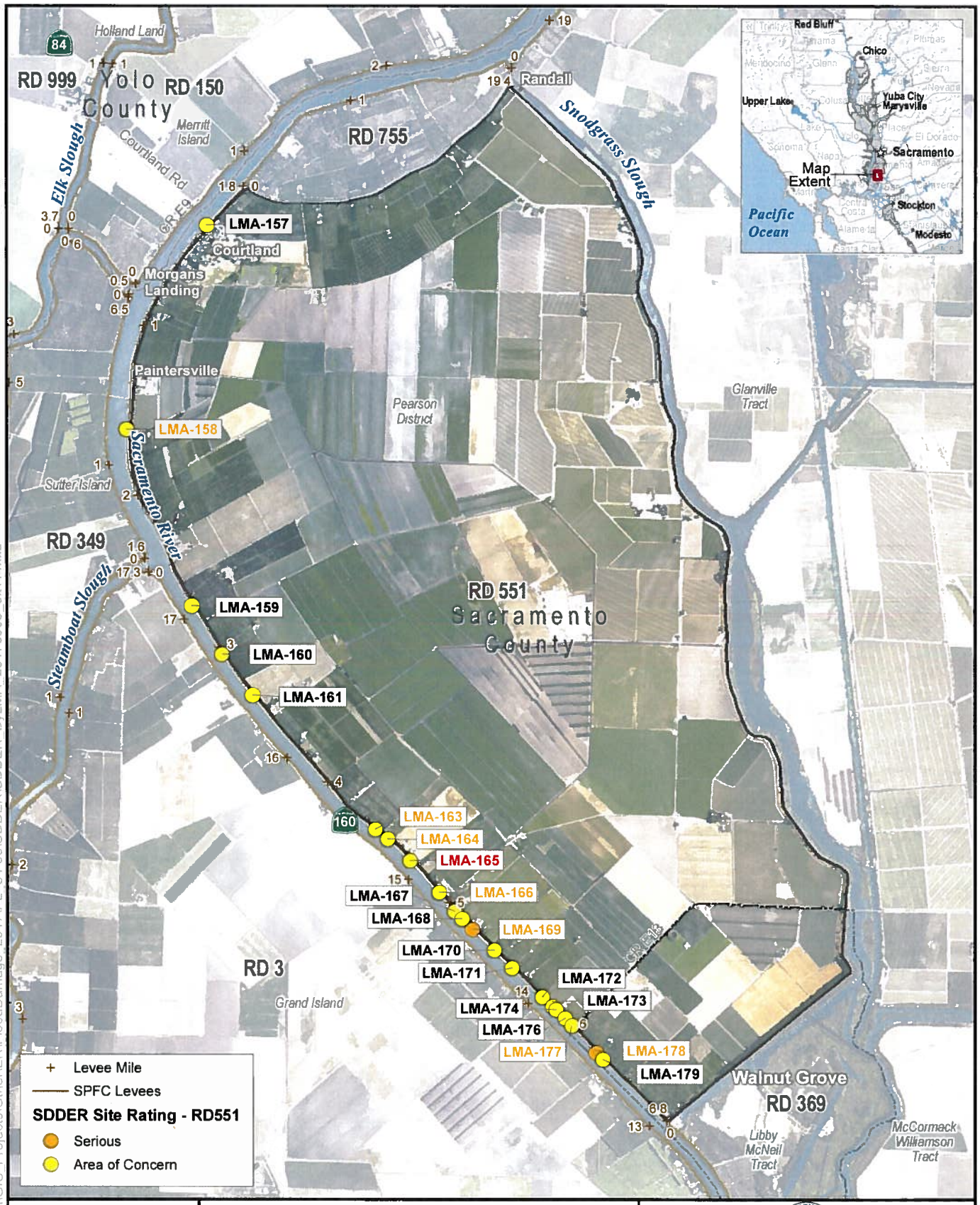
Sincerely,
MBK Engineers

Gilbert Cosio, P.E.
District Engineer

MK/mm/nl
3398.6 RD 551 Contingency Plan Response Letter

cc: Ms. Leslie Gallagher, Executive Director, Central Valley Flood Protection Board
Mr. Don Rasmussen, Chief, Flood Project Integrity and Inspection Branch
Mr. Sterling York, Senior Engineer, Flood Project Integrity and Inspection Branch
Mr. Topper Van Loben Sels, President, Reclamation District No. 551

RD 551 Pearson District												
	MBK Site	State Site	Begin Site			End Site			Length (ft)	State Assessment	MBK Assessment
			Station	Latitude	Longitude	Station	Latitude	Longitude			
Project Levee	1	157	15+43	N38° 19' 59.30"	W121° 34' 07.07"	17+09	N38° 19' 58.10"	W121° 34' 08.46"	166	A	A
	2	158	84+15	N38° 18' 57.32"	W121° 34' 36.71"	87+60	N38° 18' 53.92"	W121° 34' 36.97"	345	A	S
	3	159	142+31	N38° 18' 04.53"	W121° 34' 10.38"	143+80	N38° 18' 03.32"	W121° 34' 09.33"	149	A	A
	4	160	159+69	N38° 17' 50.13"	W121° 33' 58.43"	170+73	N38° 17' 41.30"	W121° 33' 50.25"	1,104	A	A
	5	161	175+36	N38° 17' 37.83"	W121° 33' 46.50"	176+30	N38° 17' 37.11"	W121° 33' 45.75"	94	A	A
	6		204+35	N38° 17' 16.31"	W121° 33' 22.45"	205+16	N38° 17' 15.72"	W121° 33' 21.77"	81		A
	7	163	231+12	N38° 16' 58.00"	W121° 32' 58.31"	235+26	N38° 16' 55.59"	W121° 32' 54.19"	414	A	S
	8	164	235+90	N38° 16' 55.18"	W121° 32' 53.57"	237+83	N38° 16' 53.95"	W121° 32' 51.72"	193	A	S
	9	165	245+47	N38° 16' 48.85"	W121° 32' 44.73"	247+26	N38° 16' 47.61"	W121° 32' 43.13"	179	A	C
	10	166	258+80	N38° 16' 39.32"	W121° 32' 33.27"	260+40	N38° 16' 38.12"	W121° 32' 31.96"	160	A	S
	11	167	266+16	N38° 16' 33.86"	W121° 32' 27.13"	267+71	N38° 16' 32.74"	W121° 32' 25.79"	155	A	A
	12	168	269+37	N38° 16' 31.59"	W121° 32' 24.34"	271+66	N38° 16' 29.99"	W121° 32' 22.25"	229	A	A
	13	169	273+82	N38° 16' 28.53"	W121° 32' 20.25"	278+08	N38° 16' 25.68"	W121° 32' 16.33"	426	S	S
	14	170	283+08	N38° 16' 22.32"	W121° 32' 11.75"	285+49	N38° 16' 20.68"	W121° 32' 09.54"	241	A	A
	15	171	290+80	N38° 16' 17.06"	W121° 32' 04.72"	291+85	N38° 16' 16.35"	W121° 32' 03.77"	105	A	A
	16	172	303+60	N38° 16' 08.49"	W121° 31' 52.90"	304+75	N38° 16' 07.73"	W121° 31' 51.81"	115	A	A
	17	173	307+90	N38° 16' 05.68"	W121° 31' 48.84"	308+49	N38° 16' 05.30"	W121° 31' 48.27"	59	A	A
	18	174	309+33	N38° 16' 04.76"	W121° 31' 47.47"	310+53	N38° 16' 03.99"	W121° 31' 46.32"	120	A	A
	19		311+08	N38° 16' 03.66"	W121° 31' 45.84"	312+06	N38° 16' 02.98"	W121° 31' 44.95"	98		A
	20	176	313+15	N38° 16' 02.23"	W121° 31' 43.99"	314+15	N38° 16' 01.54"	W121° 31' 43.11"	100	A	A
	21	177	316+24	N38° 16' 00.07"	W121° 31' 41.26"	320+12	N38° 15' 57.30"	W121° 31' 37.90"	388	A	S
	22	178	327+45	N38° 15' 51.97"	W121° 31' 31.70"	328+45	N38° 15' 51.24"	W121° 31' 30.79"	100	S	S
	23	179	330+19	N38° 15' 50.06"	W121° 31' 29.20"	330+99	N38° 15' 49.52"	W121° 31' 28.47"	80	A	A
	24		339+20	N38° 15' 43.99"	W121° 31' 20.93"	340+51	N38° 15' 43.11"	W121° 31' 19.73"	131		A
	25		344+58	N38° 15' 40.35"	W121° 31' 16.02"	345+51	N38° 15' 39.72"	W121° 31' 15.18"	93		A

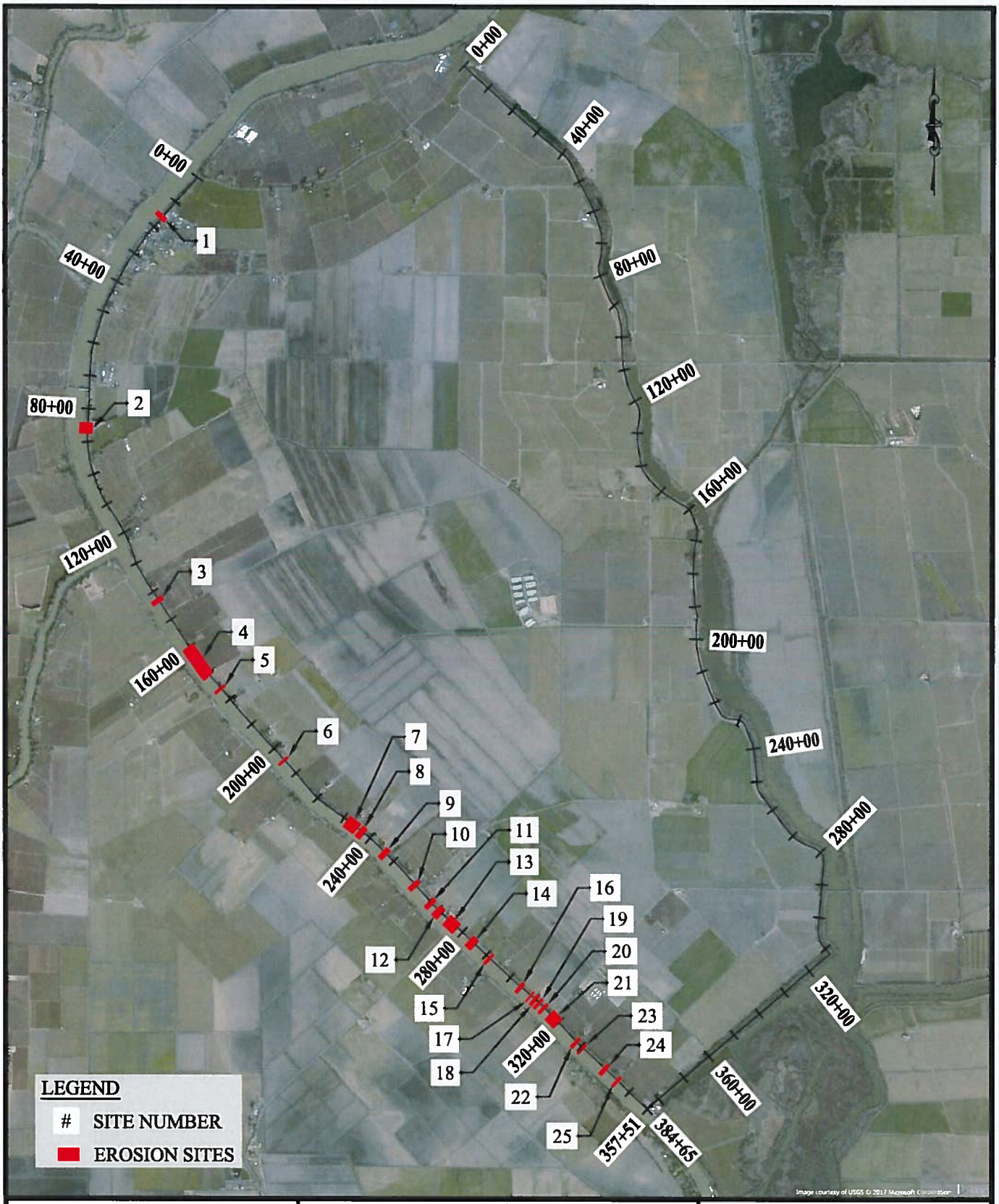


X:\CVFPO\Data\GIS_Projects\Other\ER\FloodDamage_2017\PL_84-99\SDDER\SDDER_ByLMA_20170908_8x11.mxd

Flood Planning Office

2017 Storm Damages
DWR Emergency Rehabilitation (SDDER)

Prepared By: M Jacobson	Figure: 1
Job No.:	Date: September 8, 2017



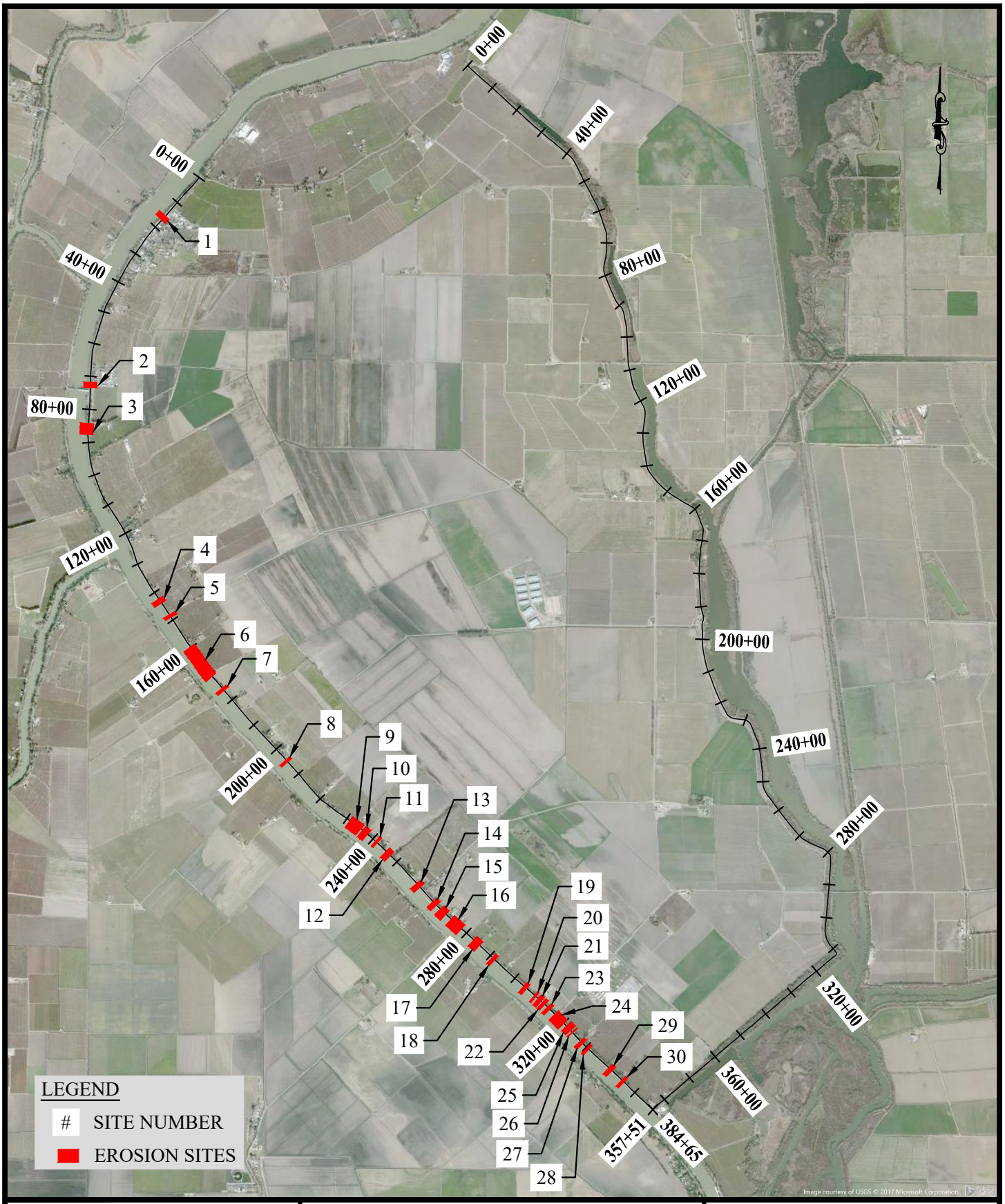
MBK ENGINEERS
455 University Avenue, Suite 100
Sacramento, California 95825
Phone: (916) 456-4400 • Fax: (916) 456-0253

RECLAMATION DISTRICT NO. 551
PEARSON DISTRICT

EROSION SITES

SCALE:	1" = 4000'
JOB NUMBER:	3998.6
DRAWN BY:	AR
DATE:	06/22/2017
SHEET:	1 OF 1

R:\3998.00 RD 0551 – Pearson District\2017-06 Erosion Sites\ACAD\RD 551 – Pearson District – Erosion Sites.dwg 6/22/2017 2:42 PM reece



MBK ENGINEERS
455 University Avenue, Suite 100
Sacramento, California 95825
Phone: (916) 456-4400 • Fax: (916) 456-0253

RECLAMATION DISTRICT NO. 551
PEARSON DISTRICT

EROSION SITES

SCALE:	1" = 4000'
JOB NUMBER:	3998.6
DRAWN BY:	MN
DATE:	07/08/2019
SHEET:	1 OF 1

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Appendix F

Preliminary Evaluation of Levees Protecting the Community of Courtland

Segment	NULE Alignment ID	Reach	NULE Station	Levee Geometry: Crest Elev (ft)	LS Toe Elev (ft)	LS Levee Height (ft)	Crest Width (ft)	Base Width (ft)	Ditch Location	Bottom of Ditch Elev.	Berm Width (ft) (if present)	Average LS Slope (wh:1V)	Average WS Slope (wh:1V)	WSE (ft)	Available Freeboard (ft)	Index Indicators: Net Head above toe (ft)	Net Head above ditch (ft)	Creep Ratio C_r=W/h_e	Critical Blanket at Toe (ft)	Critical Blanket at Ditch (ft)	Exploration	Exploration Stationing	Blanket Thinkness-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	Past Performance (Green "X" = FSRP site): Boils	Seepage	LS Slip/ Slough/ Subsidence	WS Erosion/ Slip/Slough	Reach	Preliminary Evaluation Notes
1040	TMSS-L	1040-A	1000+00	High Ground										16.21		16.2			28.4	NA											95.0				TMSS-L	1000+00	Rob						Reach Characteristics: - Predominantly historical overbank deposits with some crevasse splay deposits on the landside; waterside is underlain by Holocene marsh deposits - Avg 12 feet of head above landside toe - No history of past performance - 2 explorations along reach indicate a blanket ranging from 12 to 35 feet Levee Geometry: - Average Height: 24 feet - Average LS Slope: 5.3H:1V - Average WS Slope: 3.1H:1V - Average Crest Width: 16 feet Conclusions: - Underseepage: Identified as vulnerable due to the high head condition with a blanket that does not meet criteria - Through Seepage: Identified as vulnerable due to an erodible embankment material and head that exceeds criteria - Slope Stability: Not identified as vulnerable due to flat landside slopes - Erosion: Identified as vulnerable due to waterside slopes steeper than 3H:1V at isolated locations throughout
1040	TMSS-L	1040-A	1005+00	26.5	10.8	15.7	14.84	155				5.5	3.4	16.21	10.3	5.4		28.5	6.8	NA											145.0				TMSS-L	1005+00	Rob, W1937						
1040	TMSS-L	1040-A	1010+00	27.9	6.6	21.3	15.23	190				5.1	3.1	16.21	11.7	9.6		19.8	15.3	NA	RD369-003C	1010+00	35.0	35.0		Meets			SM, ML	Erodible	170.0	confining	3.4	DNM	TMSS-L	1010+00	Rob, W1937						
1040	TMSS-L	1040-A	1015+00	26.7	5.9	20.8	13.28	194				5.9	2.7	16.21	10.5	10.3		18.8	16.6	NA											170.0				TMSS-L	1015+00	Rcs, W1937						
1040	TMSS-L	1040-A	1020+00	25.3	4.3	21.0	17.97	203				6.2	3.0	16.21	9.1	11.9		17.1	19.7	NA											195.0				TMSS-L	1020+00	Rcs, W1937						
1040	TMSS-L	1040-A	1025+00	27.0	3.6	23.4	20.70	218				5.3	3.1	16.21	10.8	12.7		17.2	21.3	NA	RD369-004C	1025+00	12.0	12.0		DNM-Grad			SM, ML	Erodible	195.0	confining	3.4	DNM	TMSS-L	1025+00	Rcs, W1937						
1040	TMSS-L	1040-A	1030+00	26.5	3.3	23.2	21.48	190				4.8	2.4	16.21	10.3	12.9		14.7	21.8	NA											170.0				TMSS-L	1030+00	Rob, Rcs, W1937						
1040	TMSS-L	1040-A	1035+00	29.0	2.4	26.6	14.84	218				4.5	3.6	16.21	12.8	13.8		15.8	23.7	NA											195.0				TMSS-L	1035+00	Rob, Hs						
1040	TMSS-L	1040-A	1040+00	29.5	1.6	27.9	10.94	241				5.1	3.8	16.21	13.3	14.6		16.5	25.3	NA											220.0				TMSS-L	1040+00	Rob, Hs						
1040	TMSS-L	1040-A	1045+00	29.0	1.4	27.6	15.23	229				5.3	2.8	16.21	12.8	14.8		15.5	25.5	NA											220.0				TMSS-L	1045+00	Rob, Hs						
1040	TMSS-L	1040-A	1050+00	29.5	3.7	25.8	16.02	234				5.5	3.4	16.21	13.3	12.5		18.7	21.1	NA											220.0				TMSS-L	1050+00	Rob, Hs						
1040	TMSS-L	1040-B	1055+00	29.0	1.6	27.4	14.84	248				5.6	3.6	16.21	12.8	14.6		16.9	25.3	NA											245.0				TMSS-L	1055+00	Rob, Hs		x				Reach Characteristics: - Predominantly historical overbank deposits with some crevasse splay deposits on the landside; waterside is underlain by Holocene marsh deposits - History of seepage along the reach - Avg 14 feet of head above landside toe - No explorations performed in this reach Levee Geometry: - Average Height: 26 feet - Average LS Slope: 5.1H:1V - Average WS Slope: 3.9H:1V - Average Crest Width: 16 feet
1040	TMSS-L	1040-B	1060+00	28.4	2.0	26.5	19.92	246				5.1	3.8	16.21	12.2	14.2		17.3	24.5	NA											245.0				TMSS-L	1060+00	Rob, Hs, W1937, Qb		x				
1040	TMSS-L	1040-B	1065+00	27.7	3.0	24.7	13.67	218				5.1	3.3	16.20	11.5	13.2		16.5	22.3	NA											195.0				TMSS-L	1065+00	Qb		x				
1040	TMSS-L	1040-B	1070+00	29.3	3.0	26.3	17.19	224				4.7	4.7	16.19	13.1	13.2		17.0	22.3	NA											220.0				TMSS-L	1070+00	Qb		x				
1041	SDSS-R	1041-A	1235+00	27.0	8.6	18.4	21.09	198				6.4	3.2	16.19	10.8	7.6		26.0	11.3	NA											195.0				SDSS-R	1235+00	Qb		x				
1041	SDSS-R	1041-A	1240+00	29.2	15.0	14.2	19.53	149				5.1	4.1	16.19	13.0	1.2		125.6	-1.6	NA											145.0				SDSS-R	1240+00	Qb		x				
1041	SDSS-R	1041-A	1245+00	30.6	10.3	20.3	23.05	178				4.4	3.3	16.18	14.4	5.9		30.1	7.8	NA											170.0				SDSS-R	1245+00	Qb		x				
1041	SDSS-R	1041-A	1250+00	26.4	18.8	7.6	37.50	143				11.8	2.0	16.18	10.2	-2.6		-54.1	-9.3	NA	pier-tra-10	1250+00	30+	30.0		Meets		CL		Erodible	120.0	confining	3.4	Meets	SDSS-R	1250+00	Qb		x				
1041	SDSS-R	1041-A	1255+00	27.2	9.6	17.6	25.78	172				5.5	2.8	16.18	11.1	6.6		26.1	9.1	NA											170.0				SDSS-R	1255+00	Qb		x				
1041	SDSS-R	1041-A	1260+00	27.9	11.7	16.2	37.11	180				6.0	2.8	16.17	11.7	4.5		40.4	4.9	NA											170.0				SDSS-R	1260+00	Qb		x				
1041	SDSS-R	1041-A	1265+00	29.4	4.9	24.5	25.78	219				4.6	3.3	16.16	13.2	11.3		19.4	18.6	NA											195.0				SDSS-R	1265+00	Qb		x				
1041	SDSS-R	1041-A	1270+00	28.5	4.2	24.3	23.44	236				5.3	3.4	16.16	12.4	11.9		19.7	19.9	NA											220.0				SDSS-R	1270+00	Qb		x				
1041	SDSS-R	1041-A	1275+00	27.5	4.7	22.7	28.52	232				5.7	3.2	16.16	11.3	11.4		20.3	18.8	NA											220.0				SDSS-R	1275+00	Qb		x				
1041	SDSS-R	1041-A	1280+00	26.6	2.2	24.3	30.08	226				4.8	4.3	16.16	10.4	13.9		16.2	23.8	NA											220.0				SDSS-R	1280+00	Qb		x				
1041	SDSS-R	1041-A	1285+00	26.1	0.9	25.1	20.70	198				4.1	4.0	16.16	9.9	15.2		13.0	26.5	NA	RDS51-006C	1285+00	29.0	29.0		Meets		CH (96.9%)	SM, ML,CH (92.6%)	Erodible	195.0	confining	3.4	DNM	SDSS-R	1285+00	Qb		x				Reach Characteristics: - Predominantly Holocene alluvium of supratidal floodplain on the landside and waterside - History of seepage along the reach - History of LS slough along the Sta. 1305+00 to 1380+00 - Avg 12.5 feet of head above landside toe - Five borings along reach indicate a blanket thickness of greater than 29 feet Levee Geometry: - Average Height: 23 feet - Average LS Slope: 5.0H:1V - Average WS Slope: 3.2H:1V - Average Crest Width: 27.5 feet Conclusions: - Underseepage: Not identified as vulnerable due to the thick blanket condition shown in the explorations, except where ditches are present along the landside toe in isolated locations. - Through Seepage: Identified as vulnerable due to an erodible embankment material (especially in the downstream portion of the reach) and head that exceeds criteria - Slope Stability: Not identified as vulnerable due to flat landside slopes - Erosion: Not identified as vulnerable due to waterside slopes flatter than 3H:1V along a majority of the levee and wide levee sections (>20-foot crest width) at locations that are steeper than 3H:1V. - Freeboard: More than 3 feet freeboard present along the reach
1041	SDSS-R	1041-A	1290+00	25.9	0.4	25.5	30.47	216				4.9	2.3	16.16	9.7	15.8		13.7	27.5	NA											195.0				SDSS-R	1290+00	Qb		x				
1041	SDSS-R	1041-A	1295+00	26.6	0.5	26.1	26.56	222				4.3	3.6	16.15	10.5	15.6		14.2	27.3	NA											220.0				SDSS-R	1295+00	Qb		x				
1041	SDSS-R	1041-A	1300+00	25.9	-3.9	29.8	21.48	206				4.2	1.8	16.15	9.7	20.1		10.3	36.2	NA											195.0				SDSS-R	1300+00	Qb		x				
1041	SDSS-R	1041-A	1305+00	26.1	0.5	25.6	30.86	193	At Toe	-7		3.9	3.6	16.15	9.9	15.6	23.1	12.4	27.2	42.3											170.0				SDSS-R	1305+00	Qb		x	x			
1041	SDSS-R	1041-A	1310+00	26.9	3.6	23.3	25.78	231				5.4	2.8	16.15	10.7	12.6		18.3	21.2	NA											220.0				SDSS-R	1310+00	Qb		x	x			
1041	SDSS-R	1041-A	1315+00	25.8	0.4	25.4	25.78	211				4.9	3.5	16.15	9.7	15.8		13.4	27.5	NA											195.0				SDSS-R	1315+00	Qb		x	x			
1041	SDSS-R	1041-A	1320+00	26.3	-1.1	27.4	40.63	238				4.8	1.4	16.15	10.2	17.2		13.8	30.4	NA											220.0				SDSS-R	1320+00	Qb		x	x			
1041	SDSS-R	1041-A	1325+00	26.5	-0.9	27.4	29.69	222	At Toe	-8		4.7	1.9	16.15	10.3	17.1	23.7	13.0	30.1	43.3	RDS51-008C	1325+00	32.0	32.0	25.4	Meets	DNM-Grad	MH (98.8%)	MH (85.9%), CL, ML	Erodible	220.0	confining	3.4	DNM	SDSS-R	1325+00	Qb, Qpm		x	x			
1041	SDSS-R	1041-A	1330+00	27.0	-0.9	27.9	24.61	234				4.4	4.3	16.14	10.9	17.1		13.7	30.1	NA											220.0				SDSS-R	1330+00	Qb, Qpm		x	x			
1041	SDSS-R	1041-A	1335+00	27.0	0.9	26.1	35.94	223				3.8	4.0	16.12	10.9	15.2		14.6	26.4	NA											220.0				SDSS-R	1335+00	Qpm		x	x			
1041	SDSS-R	1041-A	1340+00	27.4	1.2	26.2	28.13	204				3.9	3.1	16.13	11.3	14.9		13.6	25.9	NA											195.0				SDSS-R	1340+00	Qpm		x	x			
1041	SDSS-R	1041-A	1345+00	27.0	1.4	25.5	24.22	214				4.1	3.4	16.14	10.8	14.7		14.5	25.4	NA	RDS51-007C pier-tra-11	1347+50 1345+00	31 ≥29.8	31.0		Meets		MH (96.4%)	MH (88.3%), CL, SM	Erodible	195.0	confining	3.4	DNM	SDSS-R	1345+00	Qpm		x	x			
1041	SDSS-R	1041-A	1350+00	24.1	5.0	19.1	30.08	142				2.7	3.3	16.14	7.9	11.1		12.8	18.3	NA											120.0				SDSS-R	1350+00	Qpm		x	x			
1041	SDSS-R	1041-A	1355+00	23.6	3.2	20.5	43.75	200				5.4	2.3	16.14	7.5	13.0		15.4	22.0	NA											195.0				SDSS-R	1355+00	Qpm		x	x			
1041	SDSS-R	1041-A	1360+00	24.6	5.4	19.2	22.27	192				5.2	3.2	16.14	8.5	10.7		17.8	17.5	NA											170.0				SDSS-R	1360+00	Qb, Qpm		x	x			
1041	SDSS-R	1041-A	1365+00	26.1	1.3	24.8	28.13	196				4.4	3.3	16.14	10.0	14.8		13.3	25.6	NA											195.0				SDSS-R	1365+00	Qb		x	x			
1041	SDSS-R	1041-A	1370+00	27.1	0.5	26.6	25.78	202				3.8	3.5	16.14	11.0	15.6		13.0	27.2	NA											195.0				SDSS-R	1370+00	Qb		x	x			
1041	SDSS-R	1041-A	1375+00	26.6	2.8	23.9	17.58	216				5.6	3.3	16.14	10.5	13.4		16.1	22.8	NA											195.0				SDSS-R	1375+00	Qb		x	x			
1041	SDSS-R	1041-A	1380+00	25.8	5.4	20.4	25.00	181				4.5	3.6	16.14	9.7	10.7		16.9	17.5	NA											170.0				SDSS-R	1380+00	Qb, Ql			x			

Preliminary Evaluation of Levees Protecting the Community of Courtland

Segment	NULE Alignment ID	Reach	NULE Station	Levee Geometry										WSE (ft)	Available Freeboard (ft)	Index Indicators					Exploration	Exploration Stationing	Blanket Thinkness-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	Past Performance (Green "X" = FSRP site)				Reach	Preliminary Evaluation Notes
				Crest Elev (ft)	LS Toe Elev (ft)	LS Levee Height (ft)	Crest Width (ft)	Base Width (ft)	Ditch Location	Bottom of Ditch Elev.	Berm Width (ft) (if present)	Average LS Slope (wH:1V)	Average WS Slope (wH:1V)			Net Head above toe (ft)	Net Head above ditch (ft)	Creep Ratio C_r=W/h_e	Critical Blanket at Toe (ft)	Critical Blanket at Ditch (ft)																					Boils	Seepage	LS Slip/ Slough/ Subsidence	WS Erosion/ Slip/Slough		
1041	SDSS-R	1041-B	1385+00	26.0	5.8	20.2	48.05	229				5.8	3.0	16.10	9.9	10.3		22.2	16.6	NA												220.0					SDSS-R	1385+00	QJ						Reach Characteristics: - Predominantly Holocene alluvium basin deposits on the landside and waterside - No history of past performance - Avg 5 feet of head above landside toe - Two explorations along reach indicate the presence of 6.5-foot-thick blanket in one and no blanket in the other Levee Geometry: -Average Height: 17.5 feet -Average LS Slope: 5.7H:1V -Average WS Slope: 3.0H:1V -Average Crest Width: 22.5 feet Conclusions: -Underseepage: Identified as vulnerable due to the presence of a thin blanket at the landside levee toe -Through Seepage: Identified as vulnerable due to erodible embankment material and a head above the landside toe that exceeds criteria -Slope Stability: Not identified as vulnerable due to flat landside slopes -Erosion: Identified as vulnerable due to waterside slopes steeper than 3H:1V at isolated locations throughout the reach -Freeboard: More than 3 feet freeboard present along the reach
1041	SDSS-R	1041-B	1390+00	26.8	7.9	18.9	30.47	206				5.8	3.4	16.10	10.7	8.2		25.1	12.4	NA												195.0					SDSS-R	1390+00	QJ						
1041	SDSS-R	1041-B	1395+00	25.9	11.3	14.6	21.48	190				8.6	3.0	16.10	9.8	4.8		39.7	5.6	NA												170.0					SDSS-R	1395+00	QJ						
1041	SDSS-R	1041-B	1400+00	27.4	11.2	16.2	25.00	170				5.7	3.3	16.10	11.3	4.9		34.7	5.8	NA												170.0					SDSS-R	1400+00	QJ						
1041	SDSS-R	1041-B	1405+00	28.1	12.6	15.5	30.47	175				5.9	3.4	16.10	12.0	3.5		50.4	2.9	NA												170.0					SDSS-R	1405+00	QJ						
1041	SDSS-R	1041-B	1410+00	28.4	10.3	18.1	36.72	188				5.3	3.0	16.10	12.3	5.8		32.3	7.7	NA	pier-tra-12	1410+00	6.5	6.5		DNM-Grad		ML		Erodible	170.0	confining	3.4	DNM		SDSS-R	1410+00	QJ						
1041	SDSS-R	1041-B	1415+00	28.4	10.0	18.4	24.61	192				5.4	3.6	16.10	12.3	6.1		31.5	8.2	NA												170.0					SDSS-R	1415+00	QJ						
1041	SDSS-R	1041-B	1420+00	29.4	10.0	19.4	17.19	222				6.7	1.8	16.10	13.3	6.1		36.4	8.2	NA												220.0					SDSS-R	1420+00	QJ						
1041	SDSS-R	1041-B	1425+00	29.0	9.1	20.0	22.27	204				5.8	3.3	16.10	12.9	7.0		29.1	10.0	NA												195.0					SDSS-R	1425+00	QJ						
1041	SDSS-R	1041-B	1430+00	28.9	11.2	17.8	19.53	184				5.7	3.6	16.10	12.8	4.9		37.4	5.8	NA												170.0					SDSS-R	1430+00	QJ						
1041	SDSS-R	1041-B	1435+00	28.4	14.6	13.8	28.91	144				5.7	2.7	16.10	12.3	1.5		96.2	-1.0	NA												120.0					SDSS-R	1435+00	QJ						
1041	SDSS-R	1041-B	1440+00	28.6	11.4	17.1	10.55	150				5.4	2.7	16.10	12.5	4.7		32.2	5.3	NA												145.0					SDSS-R	1440+00	QJ, Qb						
1041	SDSS-R	1041-B	1445+00	28.7	11.6	17.2	11.72	109	At Toe	4		2.8	2.8	16.10	12.6	4.5	12.6	24.0	5.0	21.2	RDS51-009C-B	1445+00	0.0	0.0	0.0	Meets	Meets	SC (46.3%)	SM (32%)	Erodible	95.0	confining	3.4	DNM		SDSS-R	1445+00	QJ, Qb						
1041	SDSS-R	1041-B	1450+00	29.1	14.2	14.9	20.31	193				7.7	3.9	16.10	13.0	1.9		102.0	-0.2	NA												170.0					SDSS-R	1450+00	QJ, Qb						
1041	SDSS-R	1041-B	1455+00	28.5	9.6	18.9	17.58	173				5.4	2.8	16.10	12.4	6.5		26.6	9.0	NA												170.0					SDSS-R	1455+00	QJ, Qb						
1041	SDSS-R	1041-B	1460+00	28.3	8.2	20.1	16.41	190				5.4	3.2	16.10	12.2	7.9		23.9	11.9	NA												170.0					SDSS-R	1460+00	QJ, Qb						
1041	SDSS-R	1041-B	1465+00	28.4	15.0	13.4	19.14	145	At Toe	8		6.7	2.7	16.10	12.3	1.1	8.1	132.2	-1.8	12.2												145.0					SDSS-R	1465+00	QJ, Qb						
1041	SDSS-R	1041-B	1470+00	28.4	10.4	18.0	34.77	171				4.3	3.3	16.10	12.3	5.7		29.9	7.4	NA												170.0					SDSS-R	1470+00	Qb						
1041	SDSS-R	1041-B	1475+00	29.1	10.7	18.4	12.11	143				5.1	1.6	16.10	13.0	5.4		26.3	6.9	NA												120.0					SDSS-R	1475+00	Qb						
1041	SDSS-R	1041-B	1480+00	27.8	11.3	16.5	5.47	157				6.5	2.7	16.10	11.7	4.8		32.8	5.6	NA												145.0					SDSS-R	1480+00	QJ						
1041	SDSS-R	1041-B	1485+00	29.5	12.1	17.4	17.58	161				5.7	2.6	16.10	13.4	4.0		40.4	4.0	NA												145.0					SDSS-R	1485+00	QJ						
1041	SDSS-R	1041-B	1490+00	30.1	13.9	16.2	25.78	151				4.8	2.9	16.10	14.0	2.2		70.3	0.3	NA												145.0					SDSS-R	1490+00	QJ						
1041	SDSS-R	1041-C	1495+00	29.1	11.4	17.7	27.73	166	At Toe	7		4.7	3.2	16.10	13.0	4.7	9.1	35.8	5.3	14.2												145.0					SDSS-R	1495+00	Rcs, W1937						Reach Characteristics: - Predominantly historical crevasse splay deposits on the landside; waterside underlain by Holocene crevasse splay deposits and historical overbank deposits - No history of past performance - Avg 5.5 feet of head above landside toe - One exploration along reach indicates the presence of a leaker condition (no blanket) Levee Geometry: -Average Height: 18 feet -Average LS Slope: 4.5H:1V -Average WS Slope: 2.9H:1V -Average Crest Width: 23 feet Conclusions: -Underseepage: Not identified as vulnerable due to relatively low head and a creep ratio criteria that meets criteria -Through Seepage: Not identified as vulnerable due to head above the landside toe that meets criteria
1041	SDSS-R	1041-C	1500+00	29.4	10.3	19.1	29.30	194	At Toe	6		5.3	3.3	16.10	13.3	5.8	10.1	33.2	7.7	16.2	RDS51-010C	1500+00	0.0	0.0	0.0	Meets	Meets	SM (40%, 21.6%	ML (68.5%), SM	Erodible	170.0	draining	6.9	Meets		SDSS-R	1500+00	Rcs, W1937						
1041	SDSS-R	1041-C	1505+00	27.9	9.3	18.6	22.27	176				5.1	3.2	16.10	11.8	6.8		26.1	9.5	NA												170.0					SDSS-R	1505+00	Rcs, W1937						
1041	SDSS-R	1041-C	1510+00	28.8	8.2	20.6	21.09	169	At Toe	4		4.7	2.5	16.10	12.7	7.9	12.1	21.3	11.9	20.2												145.0					SDSS-R	1510+00	Rcs, W1937						
1041	SDSS-R	1041-C	1515+00	29.9	9.7	20.2	14.06	165	At Toe	5		4.8	2.7	16.10	13.8	6.4	11.1	25.9	8.7	18.2												145.0					SDSS-R	1515+00	Rcs, W1937						
1041	SDSS-R	1041-C	1520+00	30.1	10.8	19.3	19.14	160	At Toe	6		4.7	2.6	16.10	14.0	5.3	10.6	30.1	6.6	17.2												145.0					SDSS-R	1520+00	Rcs, W1937						
1041	SDSS-R	1041-C	1525+00	28.6	11.2	17.4	26.17	159	At Toe	7		4.4	3.3	16.10	12.5	4.9	9.6	32.4	5.8	15.2												145.0					SDSS-R	1525+00	Rcs, Bp/Hob						
1041	SDSS-R	1041-C	1530+00	28.0	12.5	15.5	21.48	136	At Toe	7		4.2	3.2	16.10	11.9	3.6	9.1	37.8	3.2	14.2												120.0					SDSS-R	1530+00	Rcs, Hob, BP/Hob						
1041	SDSS-R	1041-C	1535+00	27.6	12.2	15.4	23.05	132	At Toe	9		4.1	3.0	16.10	11.5	3.9	7.1	34.3	3.7	10.2												120.0					SDSS-R	1535+00	Rcs, Hob, BP/Hob						
1041	SDSS-R	1041-C	1540+00	29.8	13.4	16.3	24.61	99				3.0	1.8	16.10	13.7	2.7		36.9	1.4	NA												95.0					SDSS-R	1540+00	Rob, BP/Hob						
131	SACR-L	131-A	3010+00	27.1	15.4	11.7	55.08	141				4.0	2.2	22.5	4.5	7.2		19.8	10.3	NA	pc-pca-2-1	3010+00	2.0	2.0		DNM-Grad		ML	ML, ML-CL	Erodible	120.0	draining	6.3	DNM		SACR-L	3010+00	Rob				x		Reach Characteristics: - Predominantly historical overbank deposits on the landside; waterside underlain by Holocene overbank deposits. - History of boils, seepage, and WS erosion is typical along segment -Three explorations at approximate Sta. 2985+00, 3005+00, and 3010+00 show a blanket thickness ranging from 0 to 2 ft. - Avg 9 feet of head above landside toe Levee Geometry: -Average Height: 14.5 feet -Average LS Slope: 2.8H:1V -Average WS Slope: 2.1H:1V -Average Crest Width: 32.5 feet Conclusions: -Underseepage: Identified as vulnerable due the presence a thin blanket condition that does not meet criteria in one exploration and leaker conditions shown in two of the explorations with low creep ratios as well as seepage past performance throughout the reach -Through Seepage: Identified as vulnerable due to an erodible embankment material and head above the landside toe that exceeds criteria -Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along a majority of the reach and the one location that is steeper corresponds to an overbuilt section (i.e. wide crest width) -Erosion: Identified as vulnerable due to waterside slopes steeper than 3H:1V at locations throughout the reach and erosion past performance documented at multiple locations with the reach -Freeboard: More than 3 feet freeboard present along the reach
131	SACR-L	131-A	3005+00	28.3	15.7	12.6	25.00	75				2.5	1.5	22.5	5.7	6.9		11.0	9.7	NA	2F-91-40	3005+00	0.0	0.0		DNM-Leaker		SM/ML	SAND	Erodible	95.0	draining	5.8	DNM		SACR-L	3005+00	Rob	X	X		x	
131	SACR-L	131-A	3000+00	27.4	13.6	13.8	29.30	95				2.3	2.4	22.5	4.9	8.9		10.7	13.8	NA												95.0					SACR-L	3000+00	Rob	X	X			
131	SACR-L	131-A	2995+00	28.3	11.6	16.7	36.72	116				3.0	1.8	22.4	5.9	10.8		10.7	17.7	NA												95.0					SACR-L	2995+00	Rob, Hch	X	X			
131	SACR-L	131-A	2990+00	28.1	13.9	14.1	21.09	88				2.1	2.6	22.4	5.7	8.4		10.4	12.8	NA												95.0					SACR-L	2990+00	Rob	X	X		x	
131	SACR-L	131-A	2985+00	27.9	15.0	12.9	20.70	83				3.3	1.5	22.3	5.6	7.3		11.4	10.6	NA	pier-tra-1	2985+00	0.0	0.0		DNM-Leaker		SM		Erodible	95.0	draining	5.8	DNM		SACR-L	2985+00	Rob	X	X		x	
131	SACR-L	131-A	2980+00	27.2	15.5	11.7	60.94	110				2.5	1.7	22.3	4.9	6.8		16.3	9.5	NA												95.0					SACR-L	2980+00	Rob	X	X			
131	SACR-L	131-A	2975+00	28.5	16.5	12.0	38.28	189			50	1.2	3.5	22.3	6.2	5.8		41.3	7.6	NA												170.0					SACR-L	2975+00	Rob	X	X			
131	SACR-L	131-A	2970+00	27.8	7.5	20.3	21.09	137				3.6	2.1	22.3	5.5	14.8		9.3	25.5	NA												120.0					SACR-L	2970+00	Rob	X	X			
131	SACR-L	131-A	2965+00	28.8	8.9	19.8	16.41	118				3.2	2.0	22.2	6.5	13.3		8.9	22.6	NA												95.0					SACR-L	2965+00	Rob	X	X		x	
131	SACR-L	131-B	2960+00	29.8	12.2	17.6	20.31	94				2.2	2.0	22.2	7.6	9.9		9.5	15.9	NA												95.0					SACR-L	2960+00	Rob				x		Reach Characteristics: - Predominantly historical overbank deposits on the landside; waterside underlain by Holocene overbank deposits and historical crevasse splay deposits. - History of WS erosion is typical along segment - LS slough documented at approximately Sta. 2940+00 - Avg 9 feet of head above landside toe Levee Geometry: -Average Height: 16.5 feet -Average LS Slope: 3.1H:1V -Average WS Slope: 2.4H:1V -Average Crest Width: 27 feet Conclusions: -Underseepage: Identified as potentially vulnerable due an average head of 9 feet above the landside toe, a low
131	SACR-L	131-B	2955+00	28.5	14.2	14.3	23.44	95				2.1	2.4	22.1	6.4	7.9		12.0	11.8	NA												95.0					SACR-L	2955+00	Rob				x	
131	SACR-L	131-B	2950+00	29.4	12.2	17.1	24.61	141				3.0	3.2	22.1	7.3	9.8		14.4	15.7	NA												120.0					SACR-L	2950+00	Rob				x	
131	SACR-L	131-B	2945+00	28.5	11.3	17.2	28.13	130				2.3	3.2	22.0	6.5	10.7		12.2	17.4	NA												120.0					SACR-L	2945+00	Rob				x	
131	SACR-L	131-B	2940+00	29.5	12.8	16.7	21.88	107				2.8	2.3	21.9	7.6	9.1		11.7	14.3	NA												95.0					SACR-L	2940+00	Rob			x	x	
131	SACR-L	131-B	2935+00	29.0	12.4	16.7	36.72	105				2.0	2.1	21.9	7.2	9.5		11.0	15.0	NA												95.0					SACR-L	2935+00	Rob				x	
131	SACR-L	131-B	2930+00	26.5										21.8	4.6	21.8														95.0					SACR-L	2930+00	Rob				x	
131	SACR-L	131-B	2925+00	28.3	12.2	16.1	27.73	95				2.1	2.0	21.8	6.5	9.6		9.9	15.2	NA												95.0					SACR-L	2925+00	Rob				x	
131	SACR-L	131-B	2920+00	28.3	13.2	15.1	33.59	105				3.1	1.6	21.8	6.5	8.7		12.2	13.3	NA												95.0					SACR-L	2920+00	Rob				x	
131	SACR-L	131-B	2915+00	29.8	14.1	15.7	26.56	198				8.1	2.8	21.8	8.0	7.7		25.7	11.4	NA												195.0					SACR-L	2915+00	Rob, Rch				x	

Preliminary Evaluation of Levees Protecting the Community of Courtland

Segment	NULE Alignment ID	Reach	NULE Station	Levee Geometry										WSE (ft)	Available Freeboard (ft)	Index Indicators					Exploration	Exploration Stationing	Blanket Thinkness-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	Past Performance (Green "X" = FSRP site)				Reach	Preliminary Evaluation Notes
				Crest Elev (ft)	LS Toe Elev (ft)	LS Levee Height (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)			Net Head above toe (ft)	Net Head above ditch (ft)	Creep Ratio C_r=WL/h_w	Critical Blanket at Toe (ft)	Critical Blanket at Ditch (ft)																				Boils	Seepage	LS Slip/ Slough/ Subsidence	WS Erosion/ Slip/Slough		
126	SACR-L	126-A	2910+00	34.2	12.2	22.0	31.64	138				2.5	2.3	21.8	12.4	9.5		14.5	15.1	NA												120.0				SACR-L	2910+00	Rob		x		x		Reach Characteristics: - Predominantly historical overbank deposits on the landside; waterside underlain by historical overbank deposits and crevasse splay deposits. - History of seepage and WS erosion is typical along segment - 4 explorations ranging from approximate Sta. 2765+00 to 2900+00 show a blanket thickness ranging from 13 to 28 ft - Avg 8 feet of head above landside toe Levee Geometry: -Average Height: 18 feet -Average LS Slope: 2.6H:1V -Average WS Slope: 2.4H:1V -Average Crest Width: 36 feet Conclusions: -Underseepage: Not identified as vulnerable due to the thick blanket condition shown in the explorations. -Through Seepage: Identified as vulnerable due to head above the landside toe that exceeds criteria for an erodible embankment -Slope Stability: Not identified as vulnerable due to landside slopes greater than 2H:1V along the reach and no documented landside stability past performance -Erosion: Identified as vulnerable due to waterside slopes steeper than 3H:1V throughout the reach as well as erosion past performance documented throughout the reach -Freeboard: More than 3 feet freeboard present along the reach
126	SACR-L	126-A	2905+00	31.7	11.6	20.1	37.11	124				2.2	2.1	21.7	10.0	10.1		12.2	16.3	NA												120.0				SACR-L	2905+00	Rob		x		x		
126	SACR-L	126-A	2900+00	31.2	11.7	19.5	32.03	118				2.1	2.3	21.7	9.5	10.0		11.8	15.9	NA	RDS51-001C	2900+00	28.0	28.0		Meets		CL (64.7%)		Erodible	95.0	confining	3.4	DNM	SACR-L	2900+00	Rob		x		x		
126	SACR-L	126-A	2895+00	31.0		31.0								21.6	9.4																	95.0				SACR-L	2895+00	Rob		x		x		
126	SACR-L	126-A	2890+00	31.0	13.3	17.7	57.42	138				2.8	1.2	21.6	9.4	8.3		16.7	12.6	NA												120.0				SACR-L	2890+00	Rob		x		x		
126	SACR-L	126-A	2885+00	31.2	13.9	17.3	29.30	132				2.3	2.7	21.5	9.7	7.6		17.5	11.2	NA												120.0				SACR-L	2885+00	Rob		x		x		
126	SACR-L	126-A	2880+00	31.2	13.2	18.0	30.47	135				2.7	3.0	21.5	9.7	8.3		16.2	12.7	NA												120.0				SACR-L	2880+00	Rob		x		x		
126	SACR-L	126-A	2875+00	31.4	12.5	18.9	40.23	138				1.9	2.8	21.5	9.9	9.0		15.4	13.9	NA												120.0				SACR-L	2875+00	Rob		x		x		
126	SACR-L	126-A	2870+00	31.5	12.2	19.3	45.70	109				2.0	1.9	21.4	10.1	9.2		11.9	14.4	NA												95.0				SACR-L	2870+00	Rob, Rcs		x		x		
126	SACR-L	126-A	2865+00	32.4	15.3	17.1	35.16	117				2.3	2.5	21.4	11.0	6.1		19.1	8.2	NA												95.0				SACR-L	2865+00	Rcs		x		x		
126	SACR-L	126-A	2860+00	32.5	12.6	19.9	33.20	137				2.5	2.7	21.3	11.2	8.7		15.8	13.4	NA												120.0				SACR-L	2860+00	Rob		x		x		
126	SACR-L	126-A	2855+00	31.1	13.7	17.4	33.59	121				2.6	2.4	21.3	9.8	7.6		16.0	11.2	NA												120.0				SACR-L	2855+00	Rob		x		x		
126	SACR-L	126-A	2850+00	31.8	13.3	18.5	34.77	122				2.4	2.3	21.2	10.6	7.9		15.4	11.9	NA												120.0				SACR-L	2850+00	Rob		x		x		
126	SACR-L	126-A	2845+00	31.3	17.9	13.4	28.13	197				9.8	2.8	21.2	10.1	3.3		59.7		NA												195.0				SACR-L	2845+00	Rob		x		x		
126	SACR-L	126-A	2840+00	31.2	13.7	17.5	38.28	140	At Toe	10		2.0	2.6	21.2	10.0	7.5	11.2	18.7	11.0	18.4												120.0				SACR-L	2840+00	Rob		x		x		
126	SACR-L	126-A	2835+00	31.2	14.5	16.7	21.88	133	At Toe	10		2.8	3.3	21.2	10.0	6.7	11.2	19.9	9.4	18.4												120.0				SACR-L	2835+00	Rob		x		x		
126	SACR-L	126-A	2830+00	31.1	13.7	17.4	37.89	85				2.7		21.1	10.0	7.4		11.4	10.9	NA												95.0				SACR-L	2830+00	Rob		x		x		
126	SACR-L	126-A	2825+00	32.0	12.2	19.8	29.30	132				3.0	2.2	21.1	10.9	8.8		15.0	13.6	NA												120.0				SACR-L	2825+00	Rob		x		x		
126	SACR-L	126-A	2820+00	31.7	14.6	17.1	34.38	183				6.4	2.3	21.0	10.7	6.4		28.7	8.7	NA	pier-tra-2	2820+00	20.4	20.4		Meets		ML		Erodible	170.0	confining	3.4	DNM	SACR-L	2820+00	Rob		x		x		
126	SACR-L	126-A	2815+00	29.8	12.5	17.3	46.88	117				1.9	2.2	20.9	8.9	8.4		13.9	12.8	NA												95.0				SACR-L	2815+00	Rob		x		x		
126	SACR-L	126-A	2810+00	29.7	12.4	17.3	34.77	117				2.4	2.4	20.9	8.8	8.5		13.8	13.0	NA												95.0				SACR-L	2810+00	Rob		x		x		
126	SACR-L	126-A	2805+00	29.8	12.2	17.6	27.73	111				2.3	2.4	20.8	9.0	8.5		13.0	13.1	NA												95.0				SACR-L	2805+00	Rob		x		x		
126	SACR-L	126-A	2800+00	29.9	12.2	17.7	28.13	131				2.6	3.2	20.7	9.2	8.5		15.4	13.0	NA												120.0				SACR-L	2800+00	Rob		x		x		
126	SACR-L	126-A	2795+00	29.1	14.2	14.9	28.91	118				1.1	3.6	20.7	8.4	6.5		18.1	9.1	NA												95.0				SACR-L	2795+00	Rob		x		x		
126	SACR-L	126-A	2790+00	29.1	13.2	15.9	44.92	123				2.8	2.1	20.7	8.4	7.6		16.3	11.2	NA												120.0				SACR-L	2790+00	Rob, Rcs		x		x		
126	SACR-L	126-A	2785+00	29.3	12.5	16.8	30.86	95				2.0	1.8	20.7	8.6	8.2		11.6	12.4	NA	pier-tra-3	2785+00	13.4	13.4		Meets		ML		Erodible	95.0	confining	3.4	DNM	SACR-L	2785+00	Rob		x		x		
126	SACR-L	126-A	2780+00	29.2	12.5	16.7	33.20	111				2.0	2.3	20.7	8.5	8.2		13.6	12.3	NA												95.0				SACR-L	2780+00	Rob		x		x		
126	SACR-L	126-A	2775+00	31.1	12.8	18.3	71.09	139				1.6	2.0	20.6	10.5	7.8		17.8	11.6	NA												120.0				SACR-L	2775+00	Rob		x		x		
126	SACR-L	126-A	2770+00	30.5	12.5	18.0	37.11	120				1.9	2.7	20.6	9.9	8.1		14.9	12.1	NA												95.0				SACR-L	2770+00	Rob		x		x		
126	SACR-L	126-A	2765+00	29.6	11.4	18.1	34.38	108				2.1	2.0	20.5	9.1	9.1		11.9	14.2	NA	RDS51-002C	2765+00	23.0	23.0		Meets		SM (36.8%)		Erodible	95.0	confining	3.4	DNM	SACR-L	2765+00	Rob		x		x		
126	SACR-L	126-B	2760+00	28.7	12.0	16.7	35.16	109				2.2	2.2	20.5	8.2	8.5		12.8	13.1	NA												95.0				SACR-L	2760+00	Rob		x		x		Reach Characteristics: - Predominantly historical overbank deposits on the landside; waterside underlain by historical overbank deposits and crevasse splay deposits. - History of seepage and WS erosion is typical along segment - 9 explorations ranging from approximate Sta. 2560+00 to 2735+00 show a blanket thickness ranging from 0 to 23 ft - Avg 8 feet of head above landside toe Levee Geometry: -Average Height: 17 feet -Average LS Slope: 2.5H:1V -Average WS Slope: 2.0H:1V -Average Crest Width: 35 feet Conclusions: -Underseepage: Identified as vulnerable due to the presence of a thin blanket condition at multiple locations and a leaker condition shown in the explorations with a low creep ratio as well as seepage past performance throughout the reach -Through Seepage: Identified as vulnerable due to head above the landside toe that exceeds criteria for an erodible embankment -Slope Stability: Not identified as vulnerable due to landside slopes steeper than 3H:1V throughout the reach as well as erosion past performance documented throughout the reach -Freeboard: More than 3 feet freeboard present along the reach
126	SACR-L	126-B	2755+00	28.4	15.3	13.2	28.13	80				2.3	1.7	20.5	8.0	5.2		15.5	6.4	NA												95.0				SACR-L	2755+00	Rob		x		x		
126	SACR-L	126-B	2750+00	28.7	11.4	17.2	32.03	102				2.0	1.7	20.4	8.3	9.0		11.4	13.9	NA												95.0				SACR-L	2750+00	Rob		x		x		
126	SACR-L	126-B	2745+00	28.8	11.3	17.5	34.77	98				2.0	1.6	20.4	8.4	9.1		10.8	14.1	NA												95.0				SACR-L	2745+00	Rob		x		x		
126	SACR-L	126-B	2740+00	28.9	11.2	17.7	33.59	108				2.1	2.1	20.3	8.6	9.2		11.8	14.3	NA												95.0				SACR-L	2740+00	Rob		x		x		
126	SACR-L	126-B	2735+00	28.7	10.5	18.2	30.47	109				2.2	2.1	20.3	8.4	9.8		11.1	15.6	NA	pier-tra-5	2735+00	14.0	14.0		DNM-Grad		ML		Erodible	95.0	confining	3.4	DNM	SACR-L	2735+00	Rob		x		x		
126	SACR-L	126-B	2730+00	28.7	11.6	17.1	46.09	163				4.5	2.3	20.3	8.4	8.7		18.7	13.4	NA												145.0				SACR-L	2730+00	Rob		x		x		
126	SACR-L	126-B	2725+00	28.7	10.5	18.1	30.47	110				2.4	2.0	20.2	8.4	9.7		11.3	15.4	NA												95.0				SACR-L	2725+00	Rob		x		x		
126	SACR-L	126-B	2720+00	28.7	10.7	18.1	47.27	129				2.4	2.1	20.2	8.5	9.6		13.4	15.1	NA												120.0				SACR-L	2720+00	Rob		x		x		
126	SACR-L	126-B	2715+00	28.7	11.6	17.1	33.59	122				3.0	2.2	20.2	8.4	8.6		14.2	13.2	NA												120.0				SACR-L	2715+00	Rob		x		x		
126	SACR-L	126-B	2710+00	28.6	11.4	17.1	36.33	119				2.3	2.1	20.2	8.4	8.7		13.6	13.5	NA												95.0				SACR-L	2710+00	Rob		x		x		
126	SACR-L	126-B	2705+00	28.2	11.6	16.7	30.08	106				2.3	2.3	20.1	8.1	8.6		12.4	13.1	NA												95.0				SACR-L	2705+00	Rob		x		x		
126	SACR-L	126-B	2700+00	28.4	10.7	17.8	34.77	105				1.7	1.8	20.1	8.3	9.4		11.1	14.9	NA												95.0				SACR-L	2700+00	Rob		x		x		
126	SACR-L	126-B	2695+00	28.3	11.3	17.0	37.89	102				2.1	1.7	20.0	8.2	8.7		11.7	13.5	NA												95.0				SACR-L	2695+00	Rob		x		x		
126	SACR-L	126-B	2690+00	29.0	11.6	17.4	34.77	97				1.5	2.1	20.0	9.0	8.4		11.6	12.8	NA	pier-tra-6	2690+00	0.0	0.0		DNM-Leaker		SAND		Erodible	95.0	draining	5.8	DNM	SACR-L	2690+00	Rob		x		x		
126	SACR-L	126-B	2685+00	28.6	11.1	17.5	32.42	103				2.1	1.9	19.9	8.6	8.9		11.6	13.8	NA												95.0				SACR-L	2685+00	Rob		x		x		
126	SACR-L	126-B	2680+00	28.7	10.7	18.0	36.72	134				3.5	1.9	19.9	8.8	9.2		14.5	14.5	NA												120.0				SACR-L	2680+00	Rob		x		x		
126	SACR-L	126-B	2675+00	28.6	10.0	18.6	36.33	109				2.1	1.8	19.9	8.7	9.9		11.0	15.8	NA												95.0				SACR-L	2675+00	Rob		x		x		
126	SACR-L	126-B	2670+00	28.8	10.5	18.2	46.88	115				2.0	1.8	19.9	8.9	9.3		12.3	14.7	NA												95.0				SACR-L	2670+00	Rob		x		x		
126	SACR-L	126-B	2665+00	28.9	10.0	18.9	31.64	107				2.0	2.0	19.8	9.1	9.8		10.9	15.7	NA												95.0				SACR-L	2665+00	Rcs, single thread channel		x		x		
126	SACR-L	126-B	2660+00	28.7	11.6	17.1	29.30	113				2.9	2.0	19.8	8.9	8.2		13.7	12.5	NA												95.0				SACR-L	2660+00	Rob		x		x		
126	SACR-L	126-B	2655+00	28.6	11.4	17.2	53.52	143				3.3	2.0	19.8	8.8	8.4		17.1	12.7	NA												120.0				SACR-L	2655+00	Rob		x		x		
126	SACR-L	126-B	2650+00	27.8	12.0	15.8	59.38	150				3.5	2.2	19.8	8.0	7.8		19.3	11.6	NA												145.0				SACR-L	2650+00	Rob		x		x		
126	SACR-L	126-B	2645+00	28.3	9.6	18.7	26.95	125				2.6	2.6	19.7	8.6	10.1		12.4	16.2	NA	pier-tra-7	2645+00	8.7	8.7		DNM-Grad		ML			120.0	confining			SACR-L	2645+00	Rob		x		x		
126	SACR-L	126-B	2640+00	27.7	10.3	17.5	36.33	120				2.6	2.2	19.7	8.0	9.4		12.8	14.8	NA												120.0				SACR-L	2640+00	Rob		x		x		
126	SACR-L	126-B	2635+00	27.7	10.3	17.4	33.20	109				2.2	2.2	19.7	8.0	9.4		11.6	14.8	NA												95.0				SACR-L	2635+00	Rob		x		x		
126	SACR-L	126-B	2630+00	27.7	11.1	16.7	41.41	115				2.4	2.0	19.6	8.1	8.6		13.4	13.2	NA												95.0				SACR-L	2630+00	Rob		x		x		
126	SACR-L	126-B	2625+00	27.7	10.4	17.3	30.86	104				2.2	2.0	19.6	8.1	9.2		11.2	14.4	NA												95.0				SACR-L	2625+00	Rob		x		x		
126	SACR-L	126-B	2620+00	27.7	10.7	17.0	30.47	104				2.2	2.1	19.6	8.1	8.9		11.7	13.8	NA	2F-91-30/30A	2620+00	13.6	13.6		DNM-Grad		ML	SAND	Erodible	95.0	confining	3.4	DNM	SACR-L	2620+00	Rob		x		x		
126	SACR-L	126-B	2615+00	28.1	10.4	17.7	37.89	111				2.1	2.1	19.5	8.5	9.1		12.1	14.3	NA	pier-tra-8	2615+00	16.5	16.5		Meets		ML		Erodible	95.0	confining	3.4	DNM	SACR-L	2615+00	Rob		x		x		
126	SACR-L	126-B	2610+00	27.2	10.8	16.4	33.20	110				2.6	2.1	19.5	7.7	8.7		12.6	13.4	NA												95.0				SACR-L	2610+00	Rob		x		x		
126	SACR-L	126-B	2605+00	27.6	10.4	17.2	38.28	102	At Toe	9		2.1	1.6	19.5	8.1	9.1	10.5	11.2	14.1	16.9	2F-64-9	2605+00	12.4	12.4	11.0	DNM-Grad	DNM-Grad	ML		Erodible	95.0	confining	3.4	DNM	SACR-L	2605+00	Rob		x		x		
126	SACR-L	126-B	2600+00	27.7	10.7	17.0	40.23	110	At Toe	9		2.3	1.8	19.4	8.2	8.8	10.4	12.6	13.5	16.8												95.0				SACR-L	2600+00	Rob		x		x		
126	SACR-L	126-B	2595+00	28.0	10.3	17.8	32.03	105				2.2	1.9	19.4	8.6	9.1		11.5	14.2	NA	RDS51-003C	2595+00	19.0	19.0		Meets		ML (62.1%)		Erodible	95.0	confining	3.4	DNM	SACR-L	2595+00	Rob		x		x		
126	SACR-L	126-B	2590+00	28.2	10.9	17.3	33.59	100				2.0	1.9	19.3	8.8	8.4		11.9	12.8	NA												95.0				SACR-L	2590+00	Rob		x		x		
126	SACR-L	126-B	2585+00	27.8	12.1	15.7	25.00	99				2.6	2.1	19.3	8.5	7.2		13.8	10.4	NA												95.0				SACR-L	2585+00	Rob		x		x		
126	SACR-L	126-B	2580+00	27.6	10.4	17.2	33.59	120				3.0	2.0	19.3	8.3	8.9		13.5	13.7	NA												95.0				SACR-L	2580+00	Rob		x		x		
126	SACR-L	126-B	2575+00	27.8	12.4	15.4	28.52	111				3.3	2.0	19.2	8.6	6.9		16.2	9.7	NA												95.0				SACR-L	2575+00	Rob		x		x		
126	SACR-L	126-B	2570+00	27.9	14.2	13.7	29.30	108				4.0	1.9	19.2	8.7	5.0		21.6	6.0	NA												95.0				SACR-L	2570+00	Rob, Single thread channel		x		x		Reach Characteristics: - Predominantly historical overbank deposits on the landside; waterside underlain by historical overbank deposits and crevasse splay deposits. - History of seepage and WS erosion is typical along segment - 4 explorations ranging from approximate Sta. 2735+00 to 2900+00 show a blanket thickness ranging from 13 to 28 ft - Avg 8 feet of head above landside toe Levee Geometry: -Average Height: 17 feet -Average LS Slope: 2.5H:1V -Average WS Slope: 2.0H:1V -Average Crest Width: 36 feet Conclusions: -Underseepage: Identified as vulnerable due to the presence of a thin blanket condition at multiple locations and a leaker condition shown in the explorations with a low creep ratio as well as seepage past performance throughout the reach -Through Seepage: Identified as vulnerable due to head above the landside toe that exceeds criteria for an erodible embankment -Slope Stability: Not identified as vulnerable due to landside slopes steeper than 3H:1V throughout the reach as well as erosion past performance documented throughout the reach -Freeboard: More than 3 feet freeboard present along the reach
126	SACR-L	126-B	2565+00	27.9	11.3	16.6	32.42	101				2.5	1.7	19.2	8.7	7.9		12.9	11.7	NA	DCR-DH-011	2565+00	NA	NA		NA		NA	NA	NA	95.0	confining			SACR-L	2565+00	Rob		x		x		
126	SACR-L	126-B	2560+00	27.7	10.3	17.4	23.44	111				2.8	2.2	19.1	8.5	8.9		12.5	13.8	NA	pier-tra-9	2560+00	21.5	21.5		Meets		ML		Erodible	95.0	confining	3.4	DNM	SACR-L	2560+00	Rob		x		x		