Solano County
Water Agency

DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

Rio Vista Flood Control Feasibility Study

County of Solano
State of California

April, 2020

WOOD RODGERS
BUILDING RELATIONSHIPS ONE PROJECT AT A TIME

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TABLES

I. ACRONYMS AND ABBREVIATIONS

AEP – Annual Exceedance Probability
AC – Acre
APN – Assessor’s Parcel Number
BCR – Benefit to Cost Ratio
BFE – Base Flood Elevation
BWFS – Basin-Wide Feasibility Study
Cal-IPC – California Invasive Plant Council
Caltrans – California Department of Transportation
CDFW – California Department of Fish and Wildlife
CDIAC – California Debt and Investment Advisory Commission
CEQA – California Environmental Quality Act
CIP – Capital Improvement Program
CMU – Concrete-Masonry-Unit
CNDDB – California Natural Diversity Database
CPA – Conservation Planning Areas
CPT – Cone Penetration Tests
CRPR – California Rare Plant Rank
CVFED – Central Valley Floodplain Evaluation and Delineation Project
CVFPB – Central Valley Flood Protection Board
CVFPP – Central Valley Flood Protection Plan
CVHS – Central Valley Hydrology Study
CVP – Central Valley Project
DFM – Division of Flood Management
DPS – Distinct Population Segment
DWR – California Department of Water Resources
DWSE – Design Water Surface Elevation
EIP – Early Implementation Program
ESU – Evolutionary Significant Unit
FDRP – Flood Damage Reduction Projects
FEMA – Federal Emergency Management Agency
FIRM – Floodplain Insurance Rate Maps
FIS – Flood Insurance Study
FMA – Flood Mitigation Assistance
FPS – Feet Per Second
FRMP – Flood Risk Management Plan
FRP – Fish Restoration Program
FSFC – Flood Study Feasibility Study
FSRP – Flood System Repair Projects

FT – Feet or Foot
FY – Fiscal Year
GAR – Geotechnical Assessment Report
GEI – GEI Consultants
GGS – Giant Garter Snake
GIS – Geographic Information System
GO – General Obligation
GOR – Geotechnical Overview Report
HERP – Habitat Enhancement and Restoration Program
HMGP – Hazard Mitigation Grant Program
HSI – Habitat Suitability Index
IWC – Inland Wetlands Conservation Program
LAMP – Levee Analysis and Mapping Procedures
LiDAR – Light Detection and Ranging
LF – Lineal Feet
LS – Landside
MOU – Memorandum of Understanding
MTOL – Minimum Top-of-Levee
NAVD 88 – The North American Vertical Datum of 1988
NGVD 29 – The National Geodetic Vertical Datum of 1929
NEPA – National Environmental Policy Act of 1969
NFIP – National Flood Insurance Program
NMFS – National Marine Fisheries Service
NRCS – Natural Resource Conservation Service
NRHP – National Register of Historic Places
NULE – Non-Urban Levee Evaluations
O&M – Operation and Maintenance
OMRRR – Operation, Maintenance, Repair, Replacement, and Rehabilitation
PDM – Pre-Disaster Mitigation
PIR – Problem Identification Report
RACER – Remedial Alternatives and Cost Estimates Report
RD – Reclamation District
RFMP – Regional Flood Management Planning
RMA – Resource Management Associates
ROW – Right-of-Way
RWQCB – California Regional Water Quality Control Board
SAFCA – Sacramento Area Flood Control Agency
SCFRRP – Small Communities Flood Risk Reduction Program
SCWA – Solano County Water Agency
SFHA – Special Flood Hazard Area

SLR – Sea Level Rise
SM – silty sand
SP – poorly graded sand
SPFC – State Plan of Flood Control
SR – State Route
SRFCP – Sacramento River Flood Control Project
TCE – Temporary Construction Easement
ULDC – Urban Levee Design Criteria
ULE – Urban Levee Evaluations
UPRR – Union Pacific Railroad
USACE – US Army Corps of Engineers
WFPO – Watershed and Flood Prevention
WPIC – Western Pacific Interceptor
WS – Waterside
WSE – Water Surface Elevation
YFFPP – Yuba Feather Flood Protection Program

II. EXECUTIVE SUMMARY

The goal of the Rio Vista Flood Control Feasibility Study (Feasibility Study or FCFS) is to identify a preferred alternative to reduce the risk of flooding in Rio Vista that is compatible with local and state-level planning documents. This Feasibility Study was funded under the California Department of Water Resources (DWR) Small Communities Flood Risk Reduction Program (SCFRRP) and conducted with the guidance of the City of Rio Vista (City), the Solano County Water Agency (SCWA), DWR, the Sacramento Area Flood Control Agency (SAFCA), the California Department of Transportation (Caltrans) and the Solano County Transportation Authority.

A. Background and Existing Conditions

The City is located along the west bank of the Sacramento River in Solano County, California, and is situated directly downstream of the confluence of the Yolo Bypass and the Sacramento Deep Water Ship Channel, Steamboat Slough, and the Sacramento River. Current land use designations within the study area include residential, commercial, industrial, agricultural, and public lands. Critical infrastructure in the project area includes: City of Rio Vista City Hall, four sewer lift stations, two public water supply wells, and State Route (SR) 84. Therefore, elevated river stages in the Sacramento River could affect or disrupt the water supply to the City, disrupt the City's wastewater collection systems, and impact emergency response efforts.

The City is vulnerable to flooding from both the Sacramento River and the Yolo Bypass. The City receives modest flood protection from an existing concrete-masonry-unit (CMU) floodwall that extends from the dock located at the end of Montezuma Street to just north of Main Street. This floodwall was overtopped in 1986, and was subsequently raised by two courses of CMU block. Since the raising, the floodwall has not been overtopped by a flood event. However, downtown Rio Vista regularly experiences flooding from minor storm events and high tides.

Elevated water stages resulting from a 10-year flood event in the Sacramento River also overtop the west bank of the Sacramento River upstream of SR 12 and flow through the highway underpass, thereby effectively flanking the existing floodwall and flooding downtown Rio Vista. During these high-water events, businesses upstream of SR 12 are forced to close until floodwaters recede, since flooding along SR 84 makes the businesses inaccessible.

In 2015, a Pre-Feasibility Study was prepared to evaluate alternatives that would provide 200-year protection to the City. This effort identified several possible alternatives to provide this protection, as well as the internal drainage improvements that would be necessary once the riverfront improvements were constructed. This Feasibility Study advances the work done as part of the Pre-Feasibility Study in order to identify a preferred alternative.

B. Formulation of Alternatives

As stated above, the goal of this Feasibility Study is to identify a project that will reduce the risk of flooding to the City of Rio Vista, while ensuring compatibility with state-level planning documents. This goal is supported by the following objectives:

- Develop an array of structural and nonstructural alternatives to reduce the risk of flooding in Rio Vista;
- Refine the floodwall alternatives evaluated in the Pre-Feasibility Study by determining the load-bearing capacities of floodwall foundation soils;
- Fully identify impacts to the local storm conveyance infrastructure and the improvements/modifications needed to mitigate these impacts;
- Develop appropriate design and phasing for accommodating uncertainty and sea-level rise;
- Coordinate flood risk reduction measures with the City's waterfront plans and the Sacramento River Basin-Wide Feasibility Study (BWFS);
- Identify multi-benefit opportunities and constraints; and
- Evaluate trade-offs associated with extending flood protection features.

In order to accomplish this, the project area was divided into three distinct areas: south of SR 12, north of SR 12, and the Mellin Levee. An array of alternatives was formulated for each distinct area, with each alternative evaluated against specific criteria and then subsequently assigned a rating. The ratings identified for each element of the analysis consisted of "poor", "fair", "good", or "excellent" based on a subjective analysis of how well each alternative achieved the desired objective. Using these ratings and, with them, a factoring cost, a preferred project was identified.

C. Findings and Recommendations

1. Preferred Plan

Based on the results of this Feasibility Study, the preferred alternative south of SR 12 was identified as S-4. It was the highest rated alternative and had the lowest overall estimated costs. The City is also very interested in alternative S-3, but the estimated costs might make it difficult to implement.

North of SR 12, the preferred plan is fairly close, between N-3 and N-4. If a mechanism can be developed wherein DWR can use SCFRRP funds to insure properties, it could be worthwhile to further explore N-4 in the future.

The preferred plan for the Mellin Levee is M-1 as the costs for the two alternatives were similar, and M-1 was the higher rated of the two.

2. Estimated Costs

Estimated feasibility-level costs for the recommended alternatives for each sub-area are provided below:

- South of SR 12: $29.7 Million
- North of SR 12: $50.5 Million
- Mellin Levee: $3.3 Million
- Total: $83.5 Million.

D. Next Steps

With a preferred alternative identified, the next steps focus on the transition from planning to project development, financing, and implementation.

1. Phasing

A single phased project would be ideal, but the reality of limited funding makes phasing an option used to implement the necessary improvements over time.

The area south of SR 12 has the highest density of properties in the floodplain. It is, therefore, recommended that options S-3 or S-4 be advanced to provide the greatest level of flood protection in the first phase.

The second phase should consist of implementing options N-3 and M-1 concurrently since the flooding north of SR 12 would continue to remain if both of these projects were not implemented at the same time.

2. Financing

Funding is expected to come mainly from DWR grant programs since the City of Rio Vista does not have the resources available to fund infrastructure of this magnitude. The relatively small population impacted by the flooding also makes an assessment district unrealistic.

3. Other Recommendations

Some of the other recommended actions that were identified as part of this study effort are given below:

- Coordination with Other Projects in the Region – Coordinating project planning with other projects in the region, such as the little Egbert Tract Project, would help to create synergy between projects and could result in cost savings.
- City Building Code Amendments – Due to the high number of undeveloped parcels within the City, it is recommended that updates to the building code requiring elevation to at least one foot above the 200-year floodplain be considered, as this would help prevent and mitigate future flood issues.

Grant Program/Flooding Raising Program – Funding a grant program that would provide a fixed dollar amount to homes and businesses in order to allow individual landowners to choose how they would meet new building standards (demolish and rebuild, raise existing structure, etc.) would allow landowners the freedom to make their own informed choices. It is believed that this would promote building enhancement and help to revitalize the City.

III. INTRODUCTION

In October of 2017, the City of Rio Vista was awarded a Small Communities Flood Risk Reduction Program grant from the DWR to prepare the Rio Vista Flood Control Feasibility Study. The goal of the Feasibility Study is to identify a preferred alternative to reduce the risk of flooding in Rio Vista that is compatible with local and state-level planning documents. It should be noted that, while the goal of the SCFRRP is to provide 100-year protection to small communities (i.e.: communities that are defined as having a population of less than 10,000), this study considered alternatives that would ultimately provide a 200-year level of protection. This level of protection was selected because the City is an urbanizing area which is expected to exceed the 10,000-resident threshold within the next 10 years and will, therefore, be required to have 200-year protection under the DWR Urban Level of Protection (ULOP) guidelines.

The project area considered in the Feasibility Study extends along the west bank of the Sacramento River from Marina Creek to the Mellin Levee. The Mellin Levee is also included. An overview of the area that was evaluated in the Feasibility Study is shown on **Figure 1** (attached).

This report provides a feasibility-level assessment of the flood hazards and risks in the project area. Alternatives that could be implemented in order to address these risks are also described, as well as the approach and methodology used to evaluate the alternatives in an effort to identify a preferred alternative. Based on this, a preferred alternative is presented in this report with recommended next steps.

IV. BACKGROUND

A. Regional Setting

The City is located along the west bank of the Sacramento River in Solano County, California, situated directly downstream of the confluence of the Yolo Bypass and the Sacramento River Deep Water Ship Channel, Steamboat Slough, and the Sacramento River. There are two major roadways running through the City: California SR 84 is located on the west bank of the Sacramento River. California SR 12 crosses the Sacramento River, bisecting the study area and a portion of the City.

The United States (US) census estimated the population of Rio Vista as 8,641 as of July 1, 2016. The City is considered to be an urbanizing area since it is expected to grow beyond a population of 10,000 within 10 years.

B. Land Uses and Critical Infrastructure

Current land use designations within the study area include residential, commercial, industrial, agricultural, and public lands. The south end of the study area includes the Delta Marina Yacht Harbor; residences that extend north to Main Street; and a combination of commercial, residential, and public land uses extending to the Rio Vista Bridge/SR 12. Public land use and facilities are located south of the Rio Vista Bridge/SR 12 and include City parks, a boat launch ramp, and a fishing pier. North of Rio Vista Bridge/SR 12, land use is primarily industrial and includes manufacturing and service companies located along River Road and is intermixed with scattered residences and the Rio Vista RV Park on the waterside.

Critical infrastructure in the project area includes: City of Rio Vista City Hall, four sewer lift stations, two public water supply wells, and SR 84. Therefore, elevated river stages in the Sacramento River could affect or disrupt the water supply in the City, disrupt the City’s wastewater collection systems, and impact emergency response efforts. Additionally, regional transportation would be impacted with the inundation of SR 84 upstream of SR 12. State Route 84 is a primary transportation corridor that connects Ryer Island to points west including Rio Vista and the San Francisco Bay Area via the Ryer Island Ferry.

C. Environmental and Cultural Resources

1. Biological Resources

According to the Natural Resource Conservation Service (NRCS 2018), there are three soil types that intersect the study area boundary. Tujunga fine sand is found throughout most of the study area. This is an alluvial soil composed of fine sands and silts and it is typically free of gravels. Valdez silt loam, drained, 0- to 2-percent slopes, is found at the northeast end of the study area. Valdez soils are poorly-drained alluvial silt loam to fine sandy loam with low permeability. A very small amount of Diablo-Ayar clay, which is characterized as a clay with silty clay loam and low permeability and 2- to 9-percent slopes, is found adjacent to the Rio Vista Bridge/SR 12.

The Sacramento River is the primary aquatic feature within the study area that also includes two drainages: Industrial Creek and Marina Creek. Industrial Creek is located approximately 500 feet to the north of the Rio Vista Bridge on SR 12. The creek drains through a pipe directly to the Sacramento River. Marina Creek, located at the southern end of the study area, flows through the Delta Marina Yacht Harbor and into the Sacramento River. There are two other irrigation drainages, one directly north of Airport Road, and one approximately 0.18 mile south of the Mellin Levee. The northern portion of the study area, north of Airport Road, lies within the boundary of the legal Delta.

Along the Sacramento River there are areas of floating vegetation on the water surface including water primrose (*Ludwigia peploides*) and water hyacinth (*Eichhornia crassipes*). Most of the waterside slope is covered with rip rap and has little to no emergent vegetation. To the north of the Rio Vista Bridge/SR 12, where the bank slope is more gentle and shallow water is adjacent to the bank, patches of freshwater marsh dominated by tules (*Schoenoplectus* spp*.*) are present.

Along the river's edge, primarily between Main Street and the Rio Vista Bridge/SR 12, are remnant patches of Great Valley mixed riparian forest dominated by white alder (*Alnus rhombifolia*). Native tree species present here include Fremont cottonwood (*Populus fremontii*), valley oak (*Quercus lobata*), and Oregon ash (*Fraxinus latifolia*). Native species are intermixed with patches of non-native trees and shrubs including stands of giant reed (*Arrundo donax*), Himalayan blackberry (*Rubus armeniacus*) and isolated patches of mature eucalyptus trees dominated by blue gum (*Eucalyptus globulus*) located adjacent to the Rio Vista Bridge/SR 12 and west of the Mellin Levee. North of the bridge, the overstory is limited with fewer native trees and larger stands of giant reed. The understory of these areas is dominated by non-native herbaceous vegetation including non-native annual grasses, Bermuda grass (*Cynodon dactylon*), and annual yellow sweet clover (*Melilotus indicus*). There are occurrences of native herbaceous species including common rush (*Juncus effusus*), salt marsh baccharis (*Baccharis glutinosa*), and common horsetail (*Equisetum arvense*) interspersed or above the rip rap edge.

Residential landscaped areas within the study area include backyard lawns, ornamental plantings and small structures (e.g., retaining walls, planters, stairs, etc.) along the edge of the river. These areas are characterized by ornamental and native species. This is also true within the public recreation facilities, except for the Waterfront Promenade that is landscaped with native vegetation including native bunchgrasses and shrubs including California rose (*Rosa californica*).

Areas with ruderal species of vegetation are found adjacent to buildings, SR 84 and other roadways, and drainage ditches. Much of the native vegetation in these areas has been completely removed. Weedy species commonly encountered within the study area include Bermuda grass, bur-clover (*Medicago polymorpha*), wild radish (*Raphanus sativus*), wild oats (*Avena fatua*), yellow star-thistle (*Centaurea solstitialis*), and umbrella sedge (*Cyperus eragrostis*), among others.

2. Special-Status Species

Review of special-status species occurrences found in the California Natural Diversity Database (CNDDB) and other biological data resources shows 42 special-status plant species and 38 special-status wildlife species have been documented or have the potential to occur in the survey area. There are 19 special-status plant species with a moderate potential to occur in the vicinity. One species, Suisun Marsh aster (*Symphyotricum lentum*), has a high potential to occur, with multiple CNDDB occurrences within the study area. There are nine special-status wildlife species with a moderate potential to occur in the vicinity.

The survey area supports suitable habitat for a number of special-status fish and wildlife species. The following fish species are considered to have a high potential to occur: green sturgeon sDPS (*Acipenser medirostris*), Delta smelt (*Hypomesus transpacificus*), longfin smelt (*Spirinchus thaleichthys*), steelhead- Central Valley population (*Oncorhynchus mykiss irideus*), Sacramento River winter-run and Central Valley spring-run Chinook Salmon (*Oncorhynchus tshawytascha*), and Sacramento splittail (*Pogonichthys macrolepidotus*). Wildlife species with high potential and/or were observed during the field survey are Northern harrier (*Circus cyaneus*), American peregrine falcon (*Falco peregrinus anatum*), and Mexican free-tailed bat (*Tadarida brasiliensis*).

3. Cultural Resources

A total of 20 historic resources were identified during the record search and were found to be located within the 250-foot buffer of the study area. These resources include one vessel or vessel-like structure located under water in the Sacramento River. It was evaluated and determined to be eligible under the National Register of Historic Places. This resource is located just north of the Marina Creek confluence with the Sacramento River. The other 19 resources require additional investigation and evaluation for potential eligibility under the National Register of Historic Places prior to project work that could impact the resources.

D. Relationship to Other Local and Regional Plans

1. City’s Waterfront Specific Plan

In 2007, the City developed a Waterfront Specific Plan. This plan established the framework for the redevelopment of approximately 15 acres of land in downtown Rio Vista along the west bank of the Sacramento River from Main Street to SR 12. Some of the guiding principles of the plan included: connecting the City to the waterfront, incorporating mixed-use neighborhoods, providing walkable streets, and establishing an attractive public waterfront promenade and an open space area.

The plan acknowledged that, without adequate flood control, new development would be subject to flooding. Flood control improvements were noted as the critical first step in the plan. To that end, the City prepared a conceptual design for a Waterfront Floodwall and Public Access Project (Floodwall Project) extending from City Hall to SR 12. The Floodwall Project would provide flood protection to the waterfront district and would be a supporting element for a 20-foot-wide public promenade. Construction of the floodwall and promenade was completed in 2017.

2. Lower Sacramento Delta North Regional Flood Management Plan

The City was also included in the Regional Flood Management Planning (RFMP) area. The RFMP noted that the highest priority for the City is the construction of the Floodwall Project. The Floodwall Project would protect downtown Rio Vista from Front Street to City Hall. However, the original design needs to be updated in order to meet the state Urban Levee Design Criteria (ULDC) which would include consideration of Sea Level Rise (SLR). Another high priority in the RFMP was the SR 84 Closure Structure Project. This project proposed a levee or seawall along SR 84 from SR 12 to the Mellin Levee in order to protect the industrial area along the river and to prevent floodwater from flanking the floodwall and entering the downtown area. A closure structure would also be needed across SR 84 at the Mellin Levee to prevent floodwater from flowing through this gap and flooding the industrial area. The RFMP noted that alternatives to building a levee or floodwall at this location could be either to raise SR 84 or to construct a floodwall along the Sacramento River in this area.

3. 2015 Pre-Feasibility Study

In cooperation with SCWA and SAFCA, the City prepared a pre-feasibility study in January of 2015 to evaluate alternatives that would provide 200-year flood protection for the City. The pre-feasibility study evaluated four floodwall/levee alternatives located south of SR 12 and two alternatives located north of SR 12. Each of the alternatives included provisions to accommodate projected SLR through the year 2100. The pre-feasibility study also preliminarily identified the internal drainage improvements that would be necessary once the riverfront improvements were constructed.

The pre-feasibility study referenced limited geotechnical information in the area that indicated that the soils along the waterfront were subject to lateral spreading and liquefaction. These poor foundation conditions yielded a conventional spread-footing type foundation design infeasible. Instead, a foundation supported by 55-foot-deep H-piles on a 6-foot x 6-foot grid was proposed. Due to these conditions, the pre-feasibility study estimated that it could cost as much as $50 million or more to provide flood protection to the City. Therefore, the pre-feasibility study recommended that additional geotechnical analyses be conducted in order to better define pile friction and the end-bearing capacities of the foundation soils, the results of which could significantly reduce estimated costs.

This Feasibility Study advances the work done as part of the pre-feasibility study in order to identify a preferred alternative. The goal of this preferred alternative will be to reduce the flood risk to the City by performing additional geotechnical exploration and evaluation, identifying multi-benefit opportunities and constraints, and engaging local and regional stakeholders.

4. Basin-Wide Feasibility Study

The goals of the Sacramento River Basin-Wide Feasibility Study are to improve flood risk management, promote ecosystem functions, and promote multi-benefit projects. In order to achieve the first goal of improving flood risk management, DWR developed the objective to improve flood system resiliency and facilitate adaptation to future climate variability and land use changes by adapting system features to be able to convey larger flows, recover quickly from large floods, and perform effectively under variable flood events.

To that end, the BWFS evaluated a suite of alternatives aimed at modifying and expanding the Yolo Bypass in support of the BWFS goals. Modifying the Yolo Bypass has the potential to impact the City since it could potentially contribute to water surface elevation increases by 0.20 foot or more for the 200-year flood event in the vicinity of the City. For this reason, DWR has included the floodwall and levee improvements recommended in the 2015 Pre-Feasibility Study as a common feature to all five options under consideration in order to modify the Yolo Bypass in the BWFS. The BWFS also notes that DWR could potentially participate in flood protection improvements for the City of Rio Vista to address potential hydraulic impacts of Yolo Bypass capacity improvements.

E. Stakeholders

Stakeholders for the Feasibility Study include:

- The City of Rio Vista
- SCWA
- DWR
- US Army Corps of Engineers (USACE)
- Sacramento Area Flood Control Agency
- California Department of Transportation (Caltrans)
- Solano Transportation Authority

Each of these stakeholders was engaged in the preparation of the Feasibility Study. Specifically, the City, SCWA, and DWR were invited to participate in bi-weekly conference calls held throughout the duration of the project. Presentations were also provided to the Lower Sacramento / Delta North Regional Planning team and the Rio Vista community as part of the Feasibility Study process.

F. Flood Hazards, Challenges, and Risks

1. Sources of Flooding

The City is vulnerable to flooding from both the Sacramento River and the Yolo Bypass. The City receives modest flood protection from an existing concrete-masonry-unit (CMU) floodwall that extends from the dock located at the end of Montezuma Street to just north of Main Street. This floodwall was overtopped in 1986, and was subsequently raised by two courses of CMU block. Since the raising, the floodwall has not been overtopped by a flood event. However, downtown Rio Vista regularly experiences flooding from minor storm events and high tides. **Figure 2** (attached) shows photos of flooding along the riverfront near City Hall after a rain event in December of 2014. The flooding shown on Figure 2 happened during a river stage that occurs approximately every two to three years.

Elevated water stages resulting from a 10-year flood event in the Sacramento River also overtop the west bank of the Sacramento River upstream of SR 12 and flow through the highway underpass, thereby effectively flanking the existing floodwall and flooding downtown Rio Vista. During these high-water events, businesses upstream of SR 12 are forced to close until floodwaters recede, since flooding along SR 84 makes the businesses inaccessible.

2. Sea Level Rise (SLR)

The Sacramento River transitions from tidally-influenced to riverine-controlled during large flood events near Rio Vista. Therefore, the SLR has the potential to increase river stages and the risk of flooding over time. For purposes of this Feasibility Study, SLR projections are based on mid-century estimates consistent with that of the Central Valley Flood Protection Plan (CVFPP) 2017 Update.

The National Research Council (NRC) provides sea level rise projections for 2030, 2050 and 2100, relative to the year 2000. Interpolating between the NRC projections for 2050 and 2100, the mean sea level rise projection for the year 2062 was determined to be 1.27 feet. The Resource Management Associates (RMA) Bay-Delta model was then used to translate the projected sea level rise to the downstream boundaries of the Sacramento River hydraulic model for the various Central Valley Hydrology Study (CVHS) flood events.

3. Climate Change

Impacts associated with climate change were not explicitly evaluated as part of the Feasibility Study. In lieu of determining how future climate change could impact hydrology, runoff, and river stages, an adjustment factor of one foot was added to the estimated 200-year water surface elevation in order to account for the uncertainty associated with hydrologic and hydraulic modeling and climate change.

4. Existing and Future Floodplains

In order to assess the potential flood damage to properties under a 200-year flood event, floodplains were developed that resulted from water surface elevations representing a 200-year flood event in the Sacramento River. The existing and future 200-year design water surface elevations (DWSEs) in the Sacramento River were projected landward (west) and compared to available DWR Light Detection and Ranging (LiDAR) Topographic Mapping for the Feasibility Study area in order to estimate the extents of the respective 200-year floodplains.

Development of the DWSEs is described in detail in **Attachment B** (attached).

The existing and future 200-year design water surface elevations from the DWSE TM are presented below in **Table 1** and **Table 2**.

Table 1
Existing 200-Year Design Water Surface Elevations

	Sacramento River at the Delta Marina (feet)	Sacramento River at California SR 12 (feet)	Sacramento River at the Mellin Levee (feet)
Base 200-year WSE	12.05	12.55	12.85
Uncertainty Adjustment	1.00	1.00	1.00
Adjusted DWSE	13.05	13.55	13.85

Note: Elevations are in North American Vertical Datum of 1988 (NAVD 88).

Table 2
Future 200-Year Design Water Surface Elevations

	Sacramento River at the Delta Marina (feet)	Sacramento River at SR 12 (feet)	Sacramento River at the Mellin Levee (feet)
200-year WSE with SLR	12.77	13.22	13.49
Uncertainty Adjustment	1.00	1.00	1.00
Adjusted DWSE	13.77	14.22	14.49

Note: Elevations are in NAVD 88.

The existing and future floodplains were used to estimate the number of residential, commercial/industrial, and agricultural properties that could potentially be impacted by flooding. The existing and future floodplains were also used to identify potential impacts to critical facilities and infrastructure such as highways, municipal wells, water/wastewater treatment facilities, hospitals, police and fire stations, etc.

For purposes of this analysis, it is assumed that parcels identified within the floodplain are developed, or would be developed, in accordance with their current land use designations.

The existing and future 200-year floodplains are shown on **Figure 3** and **Figure 4**, respectively. The estimated number of residential, commercial and industrial, agricultural, and public parcels impacted by the existing and future floodplains are shown in **Table 3** below.

Table 3
Parcels and Acreage Affected by the 200-Year Floodplain

Land Use	Existing 200-Year Floodplain		Future 200-Year Floodplain	
	No. of Parcels	Acres	No. of Parcels	Acres
Residential	126	36	140	40
Commercial / Industrial	61	128	61	140
Agricultural	1	4	2	5
Public (Excludes Roads)	23	19	27	168
Total	211	187	230	354

In addition to the parcels and acreage impacted by the existing and future floodplains shown in the table above, a number of critical facilities are also impacted, as shown on Figures 2 and 3. Identified critical infrastructure and facilities within the existing and future floodplains include:

- City of Rio Vista City Hall
- Four sewer lift stations
- Two public water supply wells
- State Route 84

Therefore, elevated river stages in the Sacramento River could impact or disrupt the water supply in the City, disrupt the City's wastewater collection systems, and impact emergency response efforts. Additionally, regional transportation would be impacted with the inundation of SR 84 upstream of SR 12. SR 84 is a primary transportation corridor that connects Ryer Island to points west including Rio Vista and the San Francisco Bay Area via the Ryer Island Ferry.

An analysis of the existing floodplains and the future floodplains prepared for the Feasibility Study indicate that a significant number of properties within the City are at risk of being flooded during a 200-year flood event. This analysis also indicates that several municipal services as well as SR 84 would be impacted during a 200-year flood event. Impacts associated with SLR are expected to increase the number of properties impacted in the future.

5. Multi-Benefit Opportunities and Constraints

Based on the analysis conducted, an initial list of existing recreation features and potential multi-benefit opportunities were identified. Existing recreation features may represent potential constraints because retaining these features would be important to stakeholders. There may also be opportunities to improve and/or expand these facilities as part of the project.

Potential restoration opportunities include proposed projects associated with other regional planning efforts that are currently in the planning phase, and other more localized opportunities. Opportunities within the study area include habitat enhancement and/or restoration along the Sacramento River and Industrial Creek as well as at the south end of the Waterfront Promenade. Benefits associated with wetland creation could potentially include groundwater recharge and/or flood attenuation. Refer to **Attachment E** for additional information on multi-benefit opportunities in the Study Area.

6. Geotechnical Challenges

This section includes a brief description of geotechnical challenges associated with the design and construction of flood control improvement measures within the FCFS area. The geotechnical conditions described herein factor heavily into the design and construction costs associated with floodwall alternatives. Refer to **Attachment C** (attached) for more information on the geotechnical explorations, evaluations, and recommendations included in this Feasibility Study.

Construction Testing Services (CTS) performed exploratory borings between Rio Vista Bridge/SR 12 and Main Street along the right bank of the Sacramento River in 2008 and 2011 (CTS, 2011). In general, the near-surface soils encountered at these explorations included sandy silt, sandy lean clay, and clayey and silty sand fill to depths of about five feet below the ground surface. Underlying the near-surface soils were fat clay, organic silt, and peat that was characterized as highly compressible and soft to very soft.

As part of the FCFS, GEI Consultants (GEI) performed additional exploratory borings and cone penetration tests (CPTs) within the study area. Boring locations and CPT locations are shown in Figure 2 of **Attachment C,** and a longitudinal profile along the Sacramento River right bank with the estimated subsurface stratigraphy is provided as Figures 3 and 4 of Attachment C. The borings and

CPTs performed by GEI within the southern portion of the study area confirm the presence of a relatively thick layer of soft, fine-grained sediment. At boring GEI_B-1, the layer of soft sediment is about 43 feet thick. The layer of soft sediment appears to become thinner from south to north within the study area. At GEI_CPT-6, the layer appears to be on the order of four feet thick, and at GEI_B-3, no soft sediment was encountered. The near-surface soils encountered in the GEI explorations were primarily loose coarse-grained materials ranging from poorly graded sand (SP) to silty sand (SM). At boring GEI_B-3, the near-surface soils consisted of medium dense silty sand (SM) above medium dense to dense silt.

Based on the available subsurface data, the following geotechnical challenges (that are relative to static and flood loading of potential flood control improvement measures along the right bank of the Sacramento River) appear to be present:

- The layer of soft sediment generally encountered within 10 feet of the ground surface along most of the Sacramento River right bank study area appears to be highly compressible. The addition of surficial loads, including potential loads from a flood wall foundation and engineered fill as well as loads from other sources, will induce long-term consolidation settlement that could continue for many years after construction. The magnitude and rate of settlement would be a function of the magnitude of the applied load, the thickness and consolidation characteristics of the compressible soil, and other factors. Measures used to address the potential for consolidation settlement will need to be included in the design of the selected alternative. Depending on the alternative, potential mitigation measures could include an appropriately-designed deep foundation (e.g., driven piles) as well as pre-loading/staged construction, and/or overbuilding.
- The soft sediment has low shear strength. Flood wall foundation loads and other potential surficial loads will need to be designed/selected to meet an appropriate post-construction stability factor of safety. Depending on the alternative, mitigation measures could include a deep foundation to transfer loads to stronger materials or pre-loading/staged construction.

Borings and CPTs were also performed in the vicinity of the Mellin Levee, and a longitudinal profile showing the approximate levee crest, landside toe, foundation stratigraphy, and design water surface elevation was prepared (refer to **Attachment C**, Figures 2 and 9, respectively). Using the available data, a preliminary qualitative evaluation of the Mellin Levee was performed. Details of the evaluation are presented in Attachment C. Based on the evaluation, the following was concluded:

- The Mellin Levee appears to be deficient for freeboard along its entire length within the project study area.

- The downstream section of the levee that is located approximately between Stations 0+00 and 10+00 appears to be deficient with respect to underseepage.
- The upstream section of the levee that is located approximately between Stations 10+00 to 30+00 may meet ULDC requirements for underseepage across the entire blanket thickness. However, the subsurface data in this section are limited and there may be shallow “leaker” layers in the foundation (e.g., the shallow silty sand layer encountered at boring GEI_B-4, as shown in Figure 9 of Attachment C). For these reasons, it is judged to be prudent at this stage of the project to assume underseepage remediation will be required along this stretch of levee.

Soft foundation soils were encountered at GEI_B-4 and GEI_CPT-8. The high compressibility and low strength of the soft foundation soils are key geotechnical considerations in the design of measures to remediate the Mellin Levee deficiencies described above.

V. FEASIBILITY STUDY GOALS AND OBJECTIVES

The overarching goal of the Feasibility Study is to advance the work done as part of the 2015 Pre-Feasibility Study and identify a preferred alternative to reduce the flood risk to the City of Rio Vista. This goal is supported by the following objectives:

- Develop an array of structural and nonstructural alternatives to reduce the risk of flooding in Rio Vista;
- Refine the floodwall alternatives evaluated in the pre-feasibility study by determining the load-bearing capacities of floodwall foundation soils;
- Fully identify impacts to the local storm conveyance infrastructure and the improvements/modifications needed to mitigate these impacts;
- Develop appropriate design and phasing for accommodating uncertainty and sea-level rise;
- Coordinate flood risk reduction measures with the City’s waterfront plans and the BWFS;
- Identify multi-benefit opportunities and constraints; and
- Evaluate trade-offs associated with extending flood protection features.

VI. EVALUATION CRITERIA

Each alternative developed was evaluated against specific criteria and was subjectively assigned a rating. The ratings identified for each element of the analysis consisted of “poor”, “fair”, “good”, or “excellent” based on how well each alternative achieved the desired objective. A description of the criteria and the basis for the ratings applied to each are described below.

A. Flood Risk Reduction Benefits

This criterion applies to the extent to which an alternative would reduce flood risk to people and property within the 200-year floodplain. Specifically, the increase of estimated population, economic assets, and critical infrastructure facilities protected by each alternative were used as metrics to compare the flood risk reduction benefits between alternatives.

In order to provide a metric to evaluate and compare the flood risk reduction benefits associated with each of the alternatives considered in this analysis, each alternative was qualitatively assessed based on its ability to provide flood protection for events exceeding a 200-year event.

Alternatives that are expected to provide flood risk reduction against 200-year flood events were rated as “good”. Alternatives that are expected to provide flood risk reduction and are resilient against flood events equal to a 500-year flood event were rated “excellent”. These were the only two rating classifications for this objective since all alternatives are expected to provide at least a 200-year level of flood risk reduction.

B. Flood System Flexibility and Resiliency

Flood system flexibility is the ability of the flood management system to adapt to changing conditions (e.g.: hydrologic, social, climate change, regulatory, political, or ecological conditions, etc.). Resiliency is the ability of the flood management system to continue to function and recover quickly after damaging floods.

All of the alternatives considered herein were developed to provide 200-year flood protection. A 200-year flood is a flood that has a 1-in-200 (0.5%) chance of occurring in any given year.

In order to provide a metric to evaluate the resiliency of each alternative, each alternative was qualitatively assessed based on its ability to remain resilient for events exceeding a 200-year event. Alternatives that are expected to remain resilient against flood events equal to a 500-year flood event were rated “good”. Alternatives that would sustain significant damage for flood events greater than 200-year flood events were rated as “poor”. These were the only two rating classifications for this objective since all alternatives are expected to provide at least a 200-year level of flood risk reduction.

C. Floodplain Management/Wise Use of the Floodplain

The 2017 CVFPP Update describes Wise Use of Floodplains (Wise Use) as enjoying the benefits of floodplain lands and waters while still minimizing the loss of life and damage from flooding and, at the same time, preserving and restoring the natural resources of floodplains as much as possible. Wise Use, thus, is any activity or set of activities that is compatible with both the risks to the natural resources of floodplains and the risks to human resources (life and property). Therefore, the extents to which an alternative would not increase urbanization in undeveloped areas and in areas of deep or rapid flooding were used as metrics to evaluate each alternative's Floodplain Management performance.

Alternatives that are not expected to promote development in areas within the existing 200-year floodplain were rated as "good". Alternatives that would be expected to promote development within the existing 200-year floodplain were rated "poor". These were the only two rating classifications.

D. Ecosystem Enhancement

Evaluation of the Ecosystem Enhancement criteria consisted of assessing the ability of each alternative to promote or enhance ecosystem processes and riverine and floodplain habitat, as well as to reduce ecosystem stressors.

Promoting ecosystem processes relates to how well an alternative improves and enhances the natural dynamic, hydrologic, and geomorphic processes. The number of inundated habitat acres, natural banks preserved, and potential river meander acreage were all used as metrics to evaluate each alternative's performance for this evaluation criteria.

This criterion is also defined as how well an alternative improves the quality, size, and connectivity of riverine and aquatic habitat. The acreage of riparian habitat created, marsh/wetland habitat created, and shaded riverine aquatic habitat created were all used as metrics to evaluate each alternative's performance for this evaluation criteria.

Finally, the development and operation of flood management systems can negatively affect species that live near these facilities. The extent to which an alternative reduces stressors to species was used as a criteria in the evaluation of ecosystem enhancement. The length of revetment removed and the number of acres of invasive plant species removed were used as additional metrics for this evaluation criteria.

The degree to which an alternative is believed to promote ecosystem enhancement was used to qualitatively assess ecosystem enhancement benefits. Each of the alternatives was qualitatively assigned a rating of "excellent", "good", "fair", or "poor" depending on how well each is believed to promote ecosystem enhancement.

E. Multi-Benefit Potential / Compatibility with the City's Waterfront Specific Plan

A vibrant, engaging, and accessible waterfront is a core goal of the City's Waterfront Specific Plan. Public interaction and access to the water was used to qualitatively assess the compatibility of alternatives with the City's Waterfront Specific Plan. Specific metrics used to evaluate alternatives against this criterion include passive and active uses such as educational and interpretive activities associated with environmental habitat and ecology, connectivity to the Sacramento River for boating, and potential for new park facilities and water access.

Each of the alternatives is qualitatively assigned a rating of “excellent”, “good”, “fair”, or “poor” depending on how well each is compatible with the City’s Waterfront Specific Plan.

F. Improve Operation and Maintenance

Each of the alternatives considered in this Feasibility Study have different Operation and Maintenance (O&M) requirements. Therefore, the long-term cost of O&M was used to assess how well each alternative improved O&M.

The degree to which an alternative is believed to impact O&M requirements was used to qualitatively assess each alternative. Each of the alternatives was qualitatively assigned a rating of “excellent”, “good”, “fair”, or “poor” depending on how well each is believed to improve operations and maintenance activities. The criteria used to rate the O&M impact for each alternative is shown below in **Table 4**.

Table 4
O&M Rating Criteria

	Reduce Current O&M Cost/Activities	No Change to Current Cost/Activities	Slight/Moderate Increase to O&M Cost/Activities	Moderate/Significant Increase to Current O&M Cost/Activities
Rating Assigned	Excellent	Good	Fair	Poor

G. Institutional Support

It is important that any alternative selected to move forward be supported by local stakeholders including the City, SCWA, Caltrans, SAFCA, and DWR. Each of the alternatives was qualitatively assigned a rating of “excellent”, “good”, “fair”, or “poor” depending on how well each alternative is supported by the local community and stakeholders.

H. Overall Rating

After ratings were designated for each of the individual criteria, an overall rating was developed for the purpose of ranking the alternatives relative to each other. The overall ratings were developed by assigning numerical values to the “excellent”, “good”, “fair”, “poor”, and “unacceptable” individual criteria ratings and summarizing the values associated with each alternative.

“Excellent” ratings were assigned a value of four points; “good” ratings were assigned a value of three points; “fair” ratings were assigned a value of two points; and “poor” ratings were assigned a value of one point. An overall rating was then determined based on the total points associated with each alternative, as shown in **Table 5**.

Table 5
Overall Rating Criteria

	Total Points			
	28 – 23	**22 – 17**	**16 – 11**	**≤ 10**
Rating Assigned	Excellent	Good	Fair	Poor

I. Estimated Costs

An estimate of the probable construction cost was prepared for each alternative. Cost was not an explicit evaluation criterion; however, the estimated construction cost was used to compare alternatives with similar overall ratings. The approach used to develop cost estimates is discussed in more detail later in this document.

VII. BASIS FOR PRELIMINARY DESIGN

A. General

The guidance in the DWR ULDC was used to determine the required geometry and height of the alternatives evaluated in the Feasibility Study. The ULDC was also used to ensure that appropriate seepage and stability criteria were achieved with each alternative. As discussed later in this section, site-specific geotechnical explorations were conducted in order to provide the basis for settlement and foundation-bearing capacity. Each of the specific criteria used to develop the alternatives are described below.

B. Topographic Mapping

Topographic mapping was obtained from the DWR Central Valley Floodplain Evaluation and Delineation (CVFED) LiDAR data. This data was collected in the spring of 2008. The horizontal accuracy of the post-processed LiDAR data is 3.5 feet at the 95-percent confidence level. Vertical accuracy is 0.6 foot at the 95-percent confidence level. This accuracy is sufficient for developing 1-foot contour mapping.

The mapping is presented in the NAVD 88. This datum is also the basis for elevations reported within this report.

C. Design Water Surface Elevation

The approach to develop the DWSE was based on guidance provided in the DWR ULDC. The ULDC offers two options for determining the appropriate DWSE and the Minimum Top-of-Levee (MTOL). These are the Federal Emergency Management Agency (FEMA) deterministic approach and the USACE combined deterministic and probabilistic approaches. The FEMA approach was used as the basis for the DWSE and MTOL in the Feasibility Study. The FEMA approach was selected because it frequently results in higher and, therefore, more conservative water surface elevations.

The ULDC also recommends that the DWSE be adjusted to consider potential increases associated with climate change, updated hydrology, updated hydraulic modeling, and sea level rise. Adjustments for wind setup, wave runup, and freeboard also need to be considered and accounted for. These adjustments provide an additional factor of safety in the design and allow for additional system resiliency.

The development of the DWSE and the associated adjustment factors is described in the technical memorandum titled "*Rio Vista Flood Control Feasibility Study – Design Water Surface Elevation*", included in **Attachment A** (attached). Based on the information presented in Attachment A, the recommended DWSE and MTOL at various locations along the project area are shown in **Table 6** (below). A profile of the base 200-year WSE, adjusted DWSE and MTOL are shown graphically on Figure 3 (attached).

Table 6
Recommended DWSE and MTOL

	Sacramento River at the Delta Marina (feet)	Sacramento River at State Route 12 (feet)	Sacramento River at the Mellin Levee (feet)
Base 200-year WSE	12.05	12.55	12.85
200-year WSE with SLR (Year 2062)	12.77	13.22	13.49
Uncertainty Adjustment	1.00	1.00	1.00
Adjusted DWSE	13.77	14.22	14.49
Settlement	0.58	0.58	0.58
Wind / Wave / Freeboard Adjustment	3.19	3.19	3.19
Recommended MTOL	17.54	17.99	18.26

D. Geotechnical Considerations

Geotechnical evaluations were performed to support the development and evaluation of several alternatives. The evaluations were based on subsurface data collected previously by CTS (2008 and 2011) and additional data collected as part of the FCFS by GEI. The subsurface data were used to develop stratigraphic profiles within the study area along the right bank of the Sacramento River and the Mellin Levee, and geotechnical parameters for feasibility-level analyses were selected in accordance with available field and laboratory test data. The evaluations performed are described in **Attachment C**.

E. Impacts to Local Runoff Conveyance Facilities

A levee or floodwall along the Sacramento River has the potential to create a barrier to existing overland flow, as well as to present an impact to existing storm runoff conveyance facilities. This potential impact was evaluated in the technical memorandum titled "*Rio Vista Flood Control Feasibility Study – Local Storm Runoff Conveyance Facility Impact Analysis*", included in **Attachment D**. This evaluation concluded that a levee or floodwall along the Sacramento River has the potential to impact the drainage of approximately 19 watersheds. It should be noted that two additional watersheds were evaluated for potential runoff to the river, but were found to drain to low points within their respective sheds, which must fill up before overflowing and discharging to other areas. See Attachment D for more information on the watersheds analyzed.

Based on the results of this analysis, a series of storm drains and pump stations have been proposed in order to mitigate runoff impacts associated with a proposed flood barrier along the Sacramento River. The recommended facilities are shown graphically on **Figure 8** (attached).

The proposed runoff conveyance facilities were designed as a direct conduit system to the river that could maintain hydraulic-grade profiles above ground levels (under pressure) when the river is elevated without flooding low-lying areas (which would require backflow prevention devices and pumping). Wherever possible, the proposed storm drains were located within existing streets or unoccupied/paved spaces. Refer to the *Local Storm Runoff Conveyance TM* included in Attachment D for more information on the local storm runoff conveyance improvements recommended as part of the construction of a flood barrier along the Sacramento River.

VIII. PRELIMINARY ARRAY OF ALTERNATIVES

The Feasibility Study considered different suites of alternatives for three distinct areas within the Study Area due to the unique opportunities and challenges found in each area. These three areas encompass land south of SR 12 and north of SR 12 as well as the Mellin Levee. Each of the specific flood protection alternatives for these areas are described below.

A. South of State Route 12

1. Alternative S-1A: Traditional Floodwall with Cutoff Wall (SR 12 to Montezuma Dock)

This alternative consists of a traditional floodwall with a top elevation of 18 feet and with a sheet pile cutoff wall that extends down to elevation -55 feet from SR 12 south to the Montezuma Dock. Closure structures would be installed at the SR 12 undercrossing and at the entrance to the Montezuma Dock. South of the Montezuma Dock, approximately 37 existing structures in the floodplain would be raised to one foot above the future 200-year water surface elevation. This alternative includes the drainage infrastructure needed to mitigate the internal drainage issues created by a floodwall along the Sacramento River. A graphical depiction of this alternative is included as **Figure 5** (attached).

2. Alternative S-1B: Traditional Floodwall with Cutoff Wall (SR 12 to Marina Creek)

Alternative S-1B was developed in order to determine the incremental benefits and trade-offs of extending Alternative S-1A south of the Montezuma Dock. This alternative consists of a traditional floodwall with a top elevation of 18 feet and with a sheet pile cutoff wall that extends down to elevation -55 feet from SR 12 south to Marina Creek. Closure structures would be installed at the SR 12 undercrossing and at the entrance to the Montezuma Dock. South of the Montezuma Dock, existing structures waterward of Edgewater Drive would need to be acquired because adequate right-of-way does not exist between the waterfront homes and the Sacramento River. This alternative includes the drainage infrastructure needed to mitigate internal drainage issues created by a floodwall along the Sacramento River. A graphical depiction of this alternative is included as **Figure 6** (attached).

3. Alternative S-2: Traditional Levee with Cutoff Wall (SR 12 to Montezuma Dock)

This alternative consists of a traditional levee with a top elevation of 18 feet and with a sheet pile cutoff wall that extends down to elevation -55 feet from SR 12 south to the Montezuma Dock. Closure structures would be installed at the SR 12 undercrossing and at the entrance to the Montezuma Dock. South of the Montezuma Dock, approximately 37 existing structures in the floodplain would be raised to one foot above the future 200-year water surface elevation. This alternative includes the drainage infrastructure needed to mitigate the internal drainage issues created by a levee along the Sacramento River. A graphical depiction of this alternative is included as **Figure 7** (attached).

4. Alternative S-3: Activated Barrier Floodwall with Cutoff Wall (SR 12 to City Hall)

This alternative consists of an activated barrier floodwall with a top elevation of 18 feet and with a sheet pile cutoff wall that extends down to elevation -55 feet from SR 12 south to City Hall. Closure structures would be installed at the SR 12 undercrossing and at the entrance to the Montezuma Dock. The areas around the Montezuma Dock would have a traditional floodwall. South of the Montezuma Dock, approximately 37 existing structures in the floodplain would be raised to one foot above the future 200-year water surface elevation. This alternative includes the drainage infrastructure needed to mitigate the internal drainage issues created by a floodwall along the Sacramento River. A graphical depiction of this alternative is included as **Figure 8** (attached).

5. Alternative S-4: Structure Raising

This alternative considers raising approximately 135 existing structures within the future 200-year floodplain to one foot above the future 200-year floodplain. For future development, building restrictions would require that new structures be elevated above the 200-year floodplain. There are no structural improvements included in this alternative. A graphical depiction of this alternative is included as **Figure 9** (attached).

6. Alternative S-5: Insuring Properties within the 200-year Floodplain

This alternative would entail purchasing flood insurance for properties within the future 200-year floodplain as a measure to mitigate the financial risk associated with the floodplain. For future development, building restrictions would require that new structures be elevated above the 200-year floodplain. There are no structural improvements included in this alternative. A graphical depiction of this alternative is included as **Figure 10** (attached).

B. North of SR 12

1. Alternative N-1: Traditional Floodwall with Cutoff Wall (SR 12 to Mellin Levee)

This alternative consists of a traditional floodwall with a top elevation of 18 feet and with a sheet pile cutoff wall that extends down to elevation -55 feet waterward of SR 84, from SR 12 north to the Mellin Levee. Closure structures would be added at the entrances to the trailer park and Dutra Marine sites waterward of the proposed floodwall. Existing residential structures waterward of the floodwall would be acquired to allow for adequate right-of-way to be obtained for the floodwall. This alternative includes the drainage infrastructure needed to mitigate the internal drainage issues created by a floodwall along the Sacramento River. A graphical depiction of this alternative is included as **Figure 11** (attached).

2. Alternative N-2: Traditional Levee with Cutoff Wall (SR 12 to Mellin Levee)

This alternative consists of raising SR 84 and replacing SR 84 atop a traditional levee with a top elevation of 18 feet and with a sheet pile cutoff wall that extends down to elevation -55 feet from SR 12 north to the Mellin Levee. Ramps down to existing development landward and waterward of the levee would be constructed with the new levee. Existing residential structures waterward of the floodwall would be raised to one-foot above the future 200-year water surface elevation. This alternative includes drainage infrastructure needed to mitigate internal drainage issues created by a floodwall along the Sacramento River. A graphical depiction of this alternative is included as **Figure 12** (attached).

3. Alternative N-3: Structure Raising

This alternative considers raising structures within the future 200-year floodplain to one foot above the future 200-year floodplain. For future development, building restrictions would require new structures be elevated above the 200-year floodplain. There are no structural improvements included in this alternative. A graphical depiction of this alternative is included as **Figure 13** (attached).

4. Alternative N-4: Insuring Properties within the 200-year Floodplain

This alternative consists of purchasing flood insurance for properties within the future 200-year floodplain as a measure to mitigate the financial risk associated with the floodplain. For future development, building restrictions would require new structures be elevated above the 200-year floodplain. There are no structural improvements included in this alternative. A graphical depiction of this alternative is included as **Figure 14** (attached).

C. Mellin Levee

1. Alternative M-1: Levee Raising and Seepage Berm

This alternative consists of raising the existing Mellin Levee by approximately 8 feet to an elevation of 23.4 feet, and constructing a 70-foot-wide, 5-foot-thick seepage berm along the landside (south side) of the Mellin Levee. A graphical depiction of this alternative is included as **Figure 15** (attached).

2. Alternative M-2: Levee Raising and Cutoff Wall

This alternative consists of raising the existing Mellin Levee by approximately 8 feet to an elevation of 23.4 feet, and constructing a soil-bentonite cutoff wall that extends down to an elevation of -55 feet. A graphical depiction of this alternative is included as **Figure 16** (attached).

D. Considered but Rejected Alternatives

The alternatives below were considered, but were ultimately removed from further consideration in this Feasibility Study.

1. Acquiring Properties within the 200-year Floodplain

This alternative would consist of purchasing homes and businesses within the future 200-year floodplain. This alternative was determined to be cost-prohibitive and potentially very controversial with the community. For these reasons, it was determined to be infeasible and was screened out from further consideration.

2. Breaching the Sacramento River East Levee Across from Rio Vista

This alternative would consist of breaching and/or degrading a portion of the Sacramento River East Levee across from Rio Vista in order to limit water stages in the Sacramento River adjacent to Rio Vista. This alternative would shift flood risk from Rio Vista to the small communities across the river, and potentially could be very controversial with the affected communities. This option would flood Brannan Island, Twitchill Island, several communities and marinas, SR 12, county roads, a state recreation area, and impact a different county (Sacramento County). The California Drainage Law does not allow for the intentional flooding of others. For these reasons, it was determined to be infeasible and was screened out from further consideration.

3. Dredging the Sacramento River

This alternative would consist of dredging the Sacramento River in the vicinity of Rio Vista. The would be to increase the flood capacity by increasing the cross-sectional area of the Sacramento River using excavating and dredging methods instead of constructing levees and floodwalls. However, historical dredging has only occurred within a relatively small portion of the Sacramento River because of the need to accommodate large watercraft; this historical dredging was not conducted across the entire width of the river, as the width amount that would be needed in order to significantly increase conveyance capacity.

Furthermore, there would be significant environmental concerns associated with increasing a dredging program. Specifically, there would be significant water quality concerns, particularly with historic mercury in the sediments and endangered species impacts (including Delta Smelt, Longfin Smelt, and Green Sturgeon). Finally, dredging would be a continuous activity that would need to be performed in perpetuity in order to be effective. For these reasons, dredging the Sacramento River was determined to be ineffective in providing significant flood-risk reduction benefits and was, therefore, screened out from further consideration.

IX. BASIS FOR ESTIMATED COSTS

A. General

To estimate the project costs, unit prices were developed and material quantities were calculated for the project features associated with each alternative. Unit prices for typical floodwall and levee construction (such as site clearing, embankment fill, floodwalls, and storm drainage infrastructure) were determined based upon recent contractor bid summaries for applicable improvement projects in Northern California. Where recent bid tabulations were not available, cost-determination publications (such as RS Means' *Heavy Construction Cost Data*) were used to develop costs. Costs are presented in 2019 dollars.

Due to the uncertainty associated with site conditions, a 30-percent contingency has been included in the cost estimate for each line item. Planning, Engineering, and Design were included at 10 percent; Environmental Mitigation was included at 7 percent; and Construction Management was included at 5 percent. Cost estimates are contained in **Attachment F** (attached).

B. Land Acquisition

The residential areas within the project footprint are generally made up of single-family houses. For these areas, Solano County's geographic information systems (GIS) data was used to find the assessor's parcel number (APN) for affected parcels (for each alternative). This APN information was used to find the address of each parcel, which was then used to search sites such as Redfin.com and Zillow.com for approximate house values in the study area. Prices for each affected property were not available, but the collected value data was used to calculate and average house prices, which were then used as the costs for acquiring the parcels.

For the agricultural and industrial areas, Solano County GIS data was used to find the land use for the affected parcels. The acreage of the affected area was then determined for each alternative footprint. A unit cost for each land use type was then applied to the acreages to calculate an acquisition cost. The calculated values for the two methodologies described above were then combined to determine a total land acquisition cost for each alternative.

C. Structure Raising Costs

The estimated costs to raise existing structures were based on previous similar projects by SCWA. For purposes of this Feasibility Study, the estimated costs to raise structures are: $150,000 to raise a structure less than two feet; $175,000 to raise a structure between two and four feet; $200,000 to raise a structure between four and six feet; and $250,000 to raise a structure more than six feet. A 30-percent contingency was added to these costs.

D. Flood Insurance Costs

The annual premium in 2019 dollars was estimated using FEMA Rate Table 2B. The annual premiums assume that flood insurance premiums would be for primary residences using Pre-Firm rates. Properties in FEMA Flood zones A and AE were determined to have an annual premium of $1.12 per $100 of coverage. Properties in FEMA Flood zone X were determined to have an annual premium of $1.10 per $100 of coverage. The average structure value used in development of the flood insurance premium was $400,000. It should be noted that, as time goes on, factors such as sea level rise, variability of the National Flood Insurance Program (NFIP), and inflation can all have a marked effect on the assumptions on which these costs are based.

X. ALTERNATIVES ANALYSIS

A. South of SR 12

1. Alternative S-1A: Traditional Floodwall with Cutoff Wall (SR 12 to Montezuma Dock)

a. Flood Risk Reduction Benefits

This alternative will provide 200-year flood protection benefits for the areas south of SR 12, but will not provide benefits above the 200-year flood event. For that reason, Alternative S-1A was assigned a Flood Risk Reduction rating of “good”.

b. Flood System Flexibility and Resiliency

Alternative S-1A can incorporate the structural design necessary to remain resilient and to withstand damage from flood events exceeding a 200-year flood event. For that reason, Alternative S-1A was assigned a Flood System Flexibility and Resiliency Rating of “good”.

c. Floodplain Management/Wise Use of the Floodplain

Alternative S-1A would remove a significant portion of land within the 200-year floodplain. This action could promote development in these areas. For that reason, Alternative S-1A was assigned a Flood Management of “poor”.

d. Ecosystem Enhancement

Due to the nature of existing development along the waterfront, the proposed floodwall with Alternative S-1A is located very close to the bank of the Sacramento River. The location of the proposed floodwall and other improvements associated with this alternative limit the amount of inundated habitat acres and/or riparian habitat that can be created with this alternative. Additionally, the revetment that would be needed to protect the proposed floodwall from erosion could have a negative impact on species stressors. Therefore, Alternative S-1A was assigned a “poor” Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City’s Waterfront Specific Plan

The proposed floodwall along the waterfront would pose a negative impact to recreation and the scenic beauty of the waterfront. Furthermore, it is not compatible with the City’s Waterfront Specific Plan. Therefore, Alternative S-1A was assigned a “poor” Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

The floodwall included with Alternative S-1A would need to be patrolled and inspected during routine inspections. Mechanical equipment associated with the proposed closure structures at SR 12 and the Montezuma Dock would require routine inspection and installation testing. Additionally, the internal drainage infrastructure needed due to construction of the floodwall would have to be maintained. This is expected to increase O&M costs and activities significantly. For these reasons, Alternative S-1A was assigned an O&M rating of “poor”.

g. Institutional Support

The floodwall concept has not been a popular alternative with the City staff. Furthermore, the majority of the public’s comments received at the public workshops were opposed to a floodwall along the Sacramento River. For these reasons, Alternative S-1A was assigned a “poor” Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative S-1A had two “good” ratings and five “poor” ratings. These individual ratings earned this alternative a total of 11 points. Therefore, Alternative S-1A was assigned an overall rating of “Fair”.

i. Estimated Costs

Alternative S-1A would have an estimated cost of approximately $49.9 million. For more details regarding the estimated construction cost, see Attachment F.

2. Alternative S-1B: Traditional Floodwall with Cutoff Wall (SR 12 to Marina Creek)

a. Flood Risk Reduction Benefits

This alternative will provide 200-year flood protection benefits for the areas south of SR 12, but will not provide benefits above the 200-year flood event. For that reason, Alternative S-1B was assigned a Flood Risk Reduction rating of “good”.

b. Flood System Flexibility and Resiliency

Alternative S-1B can incorporate the structural design necessary in order to remain resilient and withstand damage from flood events exceeding a 200-year flood event. For that reason, Alternative S-1B was assigned a Flood System Flexibility and Resiliency Rating of “good”.

c. Floodplain Management/Wise Use of the Floodplain

Alternative S-1B would remove a significant portion of land within the 200-year floodplain. This could promote development in these areas. For that reason, Alternative S-1B was assigned a Flood Management rating of “poor”.

d. Ecosystem Enhancement

The possible ecosystem impacts of this alternative are similar to those associated with Alternative S-1A. Therefore, Alternative S-1B was similarly assigned a “poor” Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City’s Waterfront Specific Plan

The proposed floodwall along the waterfront would have a negative impact on recreation and the scenic beauty of the waterfront. Furthermore, it is not compatible with the City’s Waterfront Specific Plan. Therefore, Alternative S-1B was assigned a “poor” Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

The floodwall included with Alternative S-1B would need to be patrolled and undergo routine inspections. Mechanical equipment associated with the proposed closure structures at SR 12 and at the Montezuma Dock would necessitate routine inspections and installation testing. Additionally, the internal drainage infrastructure required due to construction of the floodwall would need to be maintained. These additional requirements are expected to increase O&M

costs and activities significantly. For these reasons, Alternative S-1B was assigned an O&M rating of “poor”.

g. Institutional Support

The floodwall concept has not been a popular alternative with the City staff. Furthermore, the majority of the public’s comments received at the public workshops were opposed to a floodwall along the Sacramento River. For these reasons, Alternative S-1B was assigned a “poor” Institutional Support rating.

h. Overall Rating

Alternative S-1B had two “good” ratings and five “poor” ratings. These individual ratings earned this alternative a total of 11 points. Therefore, Alternative S-1B was assigned an overall rating of “Fair”.

i. Estimated Costs

Alternative S-1B would have an estimated cost of approximately $91.8 million. For more details regarding the estimated construction cost, see Attachment F.

3. Alternative S-2: Traditional Levee with Cutoff Wall (SR 12 to Montezuma Dock)

a. Flood Risk Reduction Benefits

This alternative would provide 200-year flood protection benefits for the areas south of SR 12, but would not provide benefits above the 200-year flood event. For that reason, Alternative S-2 was assigned a Flood Risk Reduction rating of “good”.

b. Flood System Flexibility and Resiliency

Alternative S-2 can incorporate the structural design necessary in order to remain resilient and withstand damage from flood events exceeding a 200-year flood event. For that reason, Alternative S-2 was assigned a Flood System Flexibility and Resiliency Rating of “good”.

c. Floodplain Management/Wise Use of the Floodplain

Alternative S-2 would remove a significant portion of land within the 200-year floodplain. This could promote development in these areas. For that reason, Alternative S-2 was assigned a Flood Management rating of “poor”.

d. Ecosystem Enhancement

Due to the nature of existing development along the waterfront, the proposed levee with Alternative S-2 is located very close to the bank of the Sacramento River. The location of the proposed levee and other improvements associated with this alternative limit the amount of inundated habitat acres and/or riparian habitat that can be created with this alternative. Additionally, the revetment that would be needed to protect the proposed levee from erosion could have a negative impact on species stressors. Therefore, Alternative S-2 was assigned a “poor” Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City’s Waterfront Specific Plan

The proposed floodwall along the waterfront would have a negative impact to recreation and the scenic beauty of the waterfront. Furthermore, it is not compatible with the City’s Waterfront Specific Plan. Therefore, Alternative S-2 was assigned a “poor” Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

The proposed levee included with Alternative S-2 would need to be patrolled and undergo routine inspections. Mechanical equipment associated with the proposed closure structures would require routine inspections and installation testing. Additionally, the internal drainage infrastructure required due to construction of the floodwall would need to be maintained. This is expected to increase O&M costs and activities significantly. For these reasons, Alternative S-2 was assigned an O&M rating of “poor”.

g. Institutional Support

The floodwall concept has not been a popular alternative with the City staff. Furthermore, the majority of the public’s comments received at the public workshops were opposed to a floodwall along the Sacramento River. For these reasons, Alternative S-2 was assigned a “poor” Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative S-2 had two “good” ratings and five “fair” ratings. These individual ratings earned this alternative a total of 11 points. Therefore, Alternative S-2 was assigned an overall rating of “Fair”.

i. Estimated Costs

Alternative S-2 would have an estimated cost of approximately $51.4 million. For more details regarding the estimated construction cost, see Attachment F.

4. Alternative S-3: Activated Barrier Floodwall with Cutoff Wall (SR 12 to City Hall)

a. Flood Risk Reduction Benefits

This alternative would provide 200-year flood protection benefits for the areas south of SR 12, but would not provide benefits above the 200-year flood event.

For that reason, Alternative S-3 was assigned a Flood Risk Reduction rating of "good".

b. Flood System Flexibility and Resiliency

Alternative S-3 can incorporate the structural design that is necessary to remain resilient and withstand damage for flood events exceeding a 200-year flood event. For that reason, Alternative S-3 was assigned a Flood System Flexibility and Resiliency Rating of "good".

c. Floodplain Management/Wise Use of the Floodplain

Alternative S-3 would remove a significant portion of land within the 200-year floodplain. This could promote development in these areas. For that reason, Alternative S-3 was assigned a Flood Management rating of "poor".

d. Ecosystem Enhancement

The proposed activated barrier with Alternative S-3 would be located very close to the bank of the Sacramento River due to the location of existing development along the river. The location of the proposed activated barrier and other improvements associated with this alternative limit the amount of inundated habitat acres and/or riparian habitat that can be created with this alternative. Additionally, the revetment that would be needed to protect the proposed embankment from erosion could have a negative impact on species stressors. Therefore, Alternative S-3 was assigned a "poor" Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City's Waterfront Specific Plan

This alternative proposes a barrier that would be passively activated by high-water levels in the Sacramento River. During periods of low water, the barriers would remain inactive. This would preserve the scenic views of the Sacramento River and allow the promenade along the Sacramento River to be used for recreational purposes. Furthermore, this alternative is compatible with the City's Waterfront Specific Plan. For these reasons, Alternative S-3 was assigned an "excellent" Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

The proposed embankment and activated barrier included with Alternative S-3 would need to be patrolled and undergo routine inspections. Mechanical equipment associated with the proposed closure structures would require routine inspections and installation testing. Additionally, the internal drainage infrastructure that would be needed due to construction of the floodwall would have to be maintained. This is expected to increase O&M costs and activities significantly. For these reasons, Alternative S-3 was assigned an O&M rating of “poor”.

g. Institutional Support

The floodwall concept has not been a popular alternative with the City staff. Furthermore, the majority of the public’s comments received at the public workshops were opposed to a floodwall along the Sacramento River. However, some feedback received from the community was in favor of a “do-nothing” or “structure-raising” alternative as opposed to a structural alternative. For these reasons, Alternative S-3 was assigned a “good” Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative S-3 had three “good” ratings, three “poor” ratings, and one “excellent” rating. These individual ratings earned this alternative a total of 16 points. Therefore, Alternative S-3 was assigned an overall rating of “Fair”.

i. Estimated Costs

Alternative S-3 would have an estimated cost of approximately $64.8 million. For more details regarding the estimated construction cost, see Attachment F.

5. Alternative S-4: Structure Raising

a. Flood Risk Reduction Benefits

This alternative would provide 200-year flood protection benefits for the areas south of SR 12, but would not provide benefits above the 200-year flood event. For that reason, Alternative S-4 was assigned a Flood Risk Reduction rating of “good”.

b. Flood System Flexibility and Resiliency

The insured properties would remain vulnerable to damage from flood events exceeding a 200-year flood event. Additionally, roads and other infrastructure would be susceptible to damage from large flood events. For that reason, Alternative S-4 was assigned a Flood System Flexibility and Resiliency Rating of “poor”.

c. Floodplain Management/Wise Use of the Floodplain

Alternative S-4 would not physically remove floodplain, but instead would elevate structures above the floodplain. Therefore, this alternative is not expected to promote development within the 200-year floodplain. For that reason, Alternative S-4 was assigned a Flood Management rating of “good”.

d. Ecosystem Enhancement

Alternative S-4 proposes to elevate structures out of the floodplain, so it is expected to have a neutral ecosystem impact. Additionally, it could be possible to add a stand-alone ecosystem enhancement element along the west bank of the Sacramento River, if desired. However, these elements have not been included in this alternative description. For these reasons, Alternative S-4 was assigned a “fair” Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City’s Waterfront Specific Plan

Alternative S-4 would preserve the scenic views of the Sacramento River and allow the promenade along the riverside to be used for recreational purposes. Furthermore, this alternative is compatible with the City’s Waterfront Specific Plan. For these reasons, Alternative S-4 was assigned an “excellent” Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

Alternative S-4 would not increase the annual flood system O&M expenditure. Therefore, Alternative S-4 was assigned an O&M rating of “good”.

g. Institutional Support

Support from the City and the community have generally been split between an activated barrier, a “do-nothing” approach, or “structure raising”. For these reasons, Alternative S-4 was assigned a “good” Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative S-4 had four “good” ratings, one “fair” rating, one “poor” rating, and one “excellent” rating. These individual ratings earned this alternative a total of 19 points. Therefore, Alternative S-4 was assigned an overall rating of “Good”.

i. Estimated Costs

Alternative S-4 would have an estimated cost of approximately $29.7 million. For more details regarding the estimated construction costs see Attachment F.

6. Alternative S-5: Insuring Properties within the 200-year Floodplain

a. Flood Risk Reduction Benefits

This alternative proposes to mitigate the financial risks to properties that are prone to flooding by insuring the properties that are located within the 200-year floodplain. However, this alternative does not physically remove the risk of flooding. For that reason, Alternative S-5 was assigned a Flood Risk Reduction rating of “fair”.

b. Flood System Flexibility and Resiliency

The elevated structures would remain vulnerable to damage from flood events exceeding a 200-year flood event. Additionally, roads and other infrastructure would be susceptible to damage from large flood events. For that reason, Alternative S-5 was assigned a Flood System Flexibility and Resiliency Rating of “poor”.

c. Floodplain Management/Wise Use of the Floodplain

Alternative S-5 would not physically remove floodplain, but instead would insure properties in the floodplain. This insurance would only apply to existing structures; new structures would be required to elevate above the 200-year floodplain. Therefore, this alternative is not expected to promote development within the 200-year floodplain. For that reason, Alternative S-5 was assigned a Flood Management rating of “good”.

d. Ecosystem Enhancement

Alternative S-5 proposes to develop a funding program that would be used to provide flood insurance for existing structures within the 200-year floodplain; therefore, it is expected to have a neutral ecosystem impact. Additionally, it could be possible to add a stand-alone ecosystem enhancement element along the west bank of the Sacramento River, if desired. However, these elements have not been included in this alternative description. For these reasons, Alternative S-5 was assigned a “fair” Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City’s Waterfront Specific Plan

Alternative S-5 would preserve the scenic views of the Sacramento River and allow the promenade along the Sacramento River to be used for recreational purposes. Furthermore, this alternative is compatible with the City’s Waterfront Specific Plan. For these reasons, Alternative S-5 was assigned an “excellent” Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

Alternative S-5 would not increase the annual flood system O&M expenditure. Therefore, Alternative S-5 was assigned an O&M rating of “good”.

g. Institutional Support

The floodwall concept has not been a popular alternative with the City staff. Furthermore, the majority of the public’s comments received at the public workshops were opposed to a floodwall along the Sacramento River. However, some feedback received from the community was in favor of a “do-nothing” or "structure-raising" alternative as opposed to a structural alternative. For these reasons, Alternative S-5 was assigned a "good" Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative S-5 had three "good" ratings, two "fair" ratings, one "poor" rating, and one "excellent" rating. These individual ratings earned this alternative a total of 18 points. Therefore, Alternative S-5 was assigned an overall rating of "Good".

i. Estimated Costs

Alternative S-5 would have an estimated cost of approximately $883,000 for annual flood insurance premiums. This comes to approximately $38 million between now and 2062 (the design horizon used in this Study). For more details regarding the estimated construction cost, see Attachment F.

B. North of SR 12

1. Alternative N-1: Traditional Floodwall with Cutoff Wall (SR 12 to Mellin Levee)

a. Flood Risk Reduction Benefits

This alternative would provide 200-year flood protection benefits for the area north of SR 12, but would not provide benefits above the 200-year flood event. For that reason, Alternative N-1 was assigned a Flood Risk Reduction rating of "good".

b. Flood System Flexibility and Resiliency

Alternative N-1 can incorporate the structural design necessary to remain resilient and withstand damage for flood events exceeding a 200-year flood event. For that reason, Alternative N-1 was assigned a Flood System Flexibility and Resiliency Rating of "good".

c. Floodplain Management/Wise Use of the Floodplain

Alternative N-1 would remove a significant portion of land within the 200-year floodplain. This could promote development in these areas. For that reason, Alternative N-1 was assigned a Flood Management of "poor".

d. Ecosystem Enhancement

Due to the nature of existing development along the waterfront, the proposed floodwall with Alternative N-1 is located very close to the bank of the Sacramento River. The location of the proposed floodwall and other improvements associated with this alternative limit the amount of inundated habitat acres and/or riparian habitat that can be created with this alternative. Additionally, the revetment that would be needed to protect the proposed floodwall from erosion could have a negative impact on species stressors. Therefore, Alternative N-1 was assigned a “poor” Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City’s Waterfront Specific Plan

The City’s Waterfront Specific Plan does not extend north of SR 12, but the proposed floodwall along the waterfront in this area would pose a negative impact to recreation and the scenic beauty of the waterfront north of SR 12. Therefore, Alternative N-1 was assigned a “poor” Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

The floodwall included with Alternative N-1 would need to be patrolled and inspected during routine inspections. Additionally, the internal drainage infrastructure needed due to construction of the floodwall would need to be maintained. This is expected to increase O&M costs and activities significantly. For these reasons, Alternative N-1 was assigned an O&M rating of “poor”.

g. Institutional Support

The floodwall concept has not been a popular alternative with the City staff. Furthermore, the majority of the public comments received at the public workshops were opposed to a floodwall along the Sacramento River. For these reasons, Alternative N-1 was assigned a “poor” Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative N-1 had two “good” ratings and five “poor” ratings. These individual ratings earned this alternative a total of 11 points. Therefore, Alternative N-1 was assigned an overall rating of “Fair”.

i. Estimated Costs

Alternative N-1 would have an estimated cost of approximately $57.7 million. For more details regarding the estimated construction cost, see Attachment F.

2. Alternative N-2: Traditional Levee with Cutoff Wall (SR 12 to Mellin Levee)

a. Flood Risk Reduction Benefits

This alternative will provide 200-year flood protection benefits for the areas north of SR 12, but will not provide benefits above the 200-year flood event. For that reason, Alternative N-2 was assigned a Flood Risk Reduction rating of “good”.

b. Flood System Flexibility and Resiliency

Alternative N-2 can incorporate the structural design necessary in order to remain resilient and withstand damage for flood events exceeding a 200-year flood event. For that reason, Alternative N-2 was assigned a Flood System Flexibility and Resiliency Rating of “good”.

c. Floodplain Management/Wise Use of the Floodplain

Alternative N-2 would remove a significant portion of land within the 200-year floodplain. This could promote development in these areas. For that reason, Alternative N-2 was assigned a Flood Management rating of “poor”.

d. Ecosystem Enhancement

Due to the nature of existing development along the waterfront, the proposed levee with Alternative N-2 is located very close to the banks of the Sacramento River. The location of the proposed levee and other improvements associated with this alternative limit the amount of inundated habitat acres and/or riparian habitat that can be created with this alternative. Additionally, the revetment that would be needed to protect the proposed levee from erosion could have a negative impact on species stressors. Therefore, Alternative N-2 was assigned a “poor” Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City’s Waterfront Specific Plan

The City’s Waterfront Specific Plan does not extend north of SR 12, but the proposed levee along the waterfront in this area would pose a negative impact to recreation and the scenic beauty of the waterfront north of SR 12. Therefore, Alternative N-2 was assigned a “poor” Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

The proposed levee included with Alternative N-2 would need to be patrolled and inspected during routine inspections. Additionally, the internal drainage infrastructure needed because of the floodwall construction would need to be maintained. This is expected to increase O&M costs and activities significantly. For these reasons, Alternative S-2 was assigned an O&M rating of “poor”.

g. Institutional Support

The levee concept has not been a popular alternative with the City staff. Furthermore, the majority of the public comments received at the public workshops were opposed to a raised embankment along the Sacramento River. For these reasons, Alternative N-2 was assigned a “poor” Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative N-2 had two "good" ratings and five "fair" ratings. These individual ratings earned this alternative a total of 11 points. Therefore, Alternative N-2 was assigned an overall rating of "Fair".

i. Estimated Costs

Alternative N-2 would have an estimated cost of approximately $80.4 million. For more details regarding the estimated construction cost, see Attachment F.

3. Alternative N-3: Structure Raising

a. Flood Risk Reduction Benefits

This alternative will provide 200-year flood protection benefits for the areas north of SR 12, but will not provide benefits above the 200-year flood event. For that reason, Alternative N-3 was assigned a Flood Risk Reduction rating of "good".

b. Flood System Flexibility and Resiliency

The elevated structures would remain vulnerable to damage from flood events exceeding a 200-year flood event. Additionally, roads and other infrastructure would be susceptible to damage caused by large flood events. For that reason, Alternative N-3 was assigned a Flood System Flexibility and Resiliency Rating of "poor".

c. Floodplain Management/Wise Use of the Floodplain

Alternative N-3 would not physically remove floodplain, but it would elevate structures above the floodplain. Therefore, this alternative is not expected to promote development within the 200-year floodplain. For that reason, Alternative N-3 was assigned a Flood Management rating of "good".

d. Ecosystem Enhancement

Alternative N-3 proposes to elevate structures out of the floodplain; therefore, it is expected to have a neutral ecosystem impact. Additionally, it could be possible to add a stand-alone ecosystem enhancement element along the west bank of the Sacramento River, if desired. However, these elements have not been included in this alternative description. For these reasons, Alternative N-3 was assigned a "fair" Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City's Waterfront Specific Plan

The City's Waterfront Specific Plan does not extend north of SR 12, but Alternative N-3 would preserve the scenic views of the Sacramento River and would not negatively impact recreation in the area. For these reasons, Alternative N-3 was assigned an “excellent” Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

Alternative N-3 would not increase the annual flood system O&M expenditure. Therefore, Alternative N-3 was assigned an O&M rating of “good”.

g. Institutional Support

Support from the City and the community generally have been divided between an activated barrier, a “do-nothing” approach, or “structure raising”. For these reasons, Alternative N-3 was assigned a “good” Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative N-3 had four “good” ratings, one “fair” rating, one “poor” rating, and one “excellent” rating. These individual ratings earned this alternative a total of 19 points. Therefore, Alternative N-3 was assigned an overall rating of “Good”.

i. Estimated Costs

Alternative N-3 would have an estimated cost of approximately $50.5 million. For more details regarding the estimated construction cost, see Attachment F.

4. Alternative N-4: Insuring Properties within the 200-Year Floodplain

a. Flood Risk Reduction Benefits

This alternative proposes mitigating the financial risks to properties prone to flooding by insuring properties within the 200-year floodplain. However, this alternative does not physically remove the risk of flooding. For that reason, Alternative N-4 was assigned a Flood Risk Reduction rating of “fair”.

b. Flood System Flexibility and Resiliency

With Alternative N-4, the elevated structures would remain vulnerable to damage from flood events exceeding a 200-year flood event. Additionally, roads and other infrastructure would be susceptible to damage from large flood events. For that reason, Alternative N-4 was assigned a Flood System Flexibility and Resiliency Rating of “poor”.

c. Floodplain Management/Wise Use of the Floodplain

Alternative N-4 would not physically remove floodplain but, instead, would insure properties in the floodplain. This would only apply to existing structures; new structures would be required to elevate above the 200-yaer floodplain. Therefore, this alternative is not expected to promote development within the

200-year floodplain. For that reason, Alternative N-4 was assigned a Flood Management rating of “good”.

d. Ecosystem Enhancement

Alternative N-4 proposes to develop a funding program that would be used to provide flood insurance for existing structures within the 200-year floodplain, so it is expected to have a neutral ecosystem impact. Additionally, it could be possible to add a stand-alone ecosystem enhancement element along the west bank of the Sacramento River, if desired. However, these elements have not been included in this alternative description. For these reasons, Alternative N-4 was assigned a “fair” Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City’s Waterfront Specific Plan

The City’s Waterfront Specific Plan does not extend north of SR 12, but Alternative N-4 would preserve the scenic views of the Sacramento River and would not negatively impact recreation in the area. For these reasons, Alternative N-4 was assigned an “excellent” Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

Alternative N-4 would not increase the annual flood system O&M expenditure. Therefore, Alternative N-4 was assigned an O&M rating of “excellent”.

g. Institutional Support

The floodwall concept has not been a popular alternative with the City staff. Furthermore, the majority of the public comments received at the public workshops were opposed to a floodwall along the Sacramento River. However, some feedback received from the community was in favor of a “do-nothing” or “structure-raising” alternative as opposed to a structural alternative. For these reasons, Alternative N-4 was assigned a “good” Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative N-4 had three “good” ratings, two “fair” ratings, one “poor” rating, and one “excellent” rating. These individual ratings earned this alternative a total of 18 points. Therefore, Alternative N-4 was assigned an overall rating of “Good”.

i. Estimated Costs

Alternative N-4 would have an estimated cost of approximately $1,260,000 for annual flood insurance premiums. This annual cost would add up to approximately $54 million between now and 2062 (the design horizon used in this Study). For more details regarding the estimated construction cost, see Attachment F.

C. Mellin Levee

1. Alternative M-1: Levee Raising and Seepage Berm

a. Flood Risk Reduction Benefits

This alternative will improve the Mellin Levee so that it meets ULDC criteria (i.e.: 200-year flood protection), but this alternative does not propose improvements above the 200-year flood event. For that reason, Alternative M-1 was assigned a Flood Risk Reduction rating of “good”.

b. Flood System Flexibility and Resiliency

Alternative M-1 can incorporate the structural design necessary in order to remain resilient and withstand damage for flood events exceeding a 200-year flood event. For that reason, Alternative M-1 was assigned a Flood System Flexibility and Resiliency Rating of “good”.

c. Floodplain Management/Wise Use of the Floodplain

Alternative M-1 would remove a significant portion of land within the 200-year floodplain. This could promote development in these areas. For that reason, Alternative M-1 was assigned a Flood Management rating of “poor”.

d. Ecosystem Enhancement

The location of the proposed levee and other improvements associated with this alternative limit the amount of inundated habitat acres and/or riparian habitat that can be created with this alternative. Additionally, the revetment that would be needed to protect the proposed levee from erosion could have a negative impact on species stressors. Therefore, Alternative M-1 was assigned a “poor” Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City’s Waterfront Specific Plan

The City’s Waterfront Specific Plan does not extend north of SR 12, and the proposed levee raising in this segment is expected to have a neutral impact to scenic views and recreation. Therefore, Alternative M-1 was assigned a “good” Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

The levee included with Alternative M-1 would need to be patrolled and inspected during routine inspections. The Mellin Levee is already patrolled and inspected, but the inspections and O&M would need to be expanded slightly to include the new seepage berm. For these reasons, M-1 was assigned an O&M rating of “fair”.

g. Institutional Support

The proposed raising and berm are relatively noncontroversial since they maintain the existing flood control feature of the Mellin Levee. For this reason, Alternative M-1 was assigned a “good” Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative M-1 had four “good” ratings, two “poor” ratings, and one “fair” rating. These individual ratings earned this alternative a total of 16 points. Therefore, Alternative M-1 was assigned an overall rating of “Good”.

i. Estimated Costs

Alternative M-1 would have an estimated cost of approximately $3.3 million. For more details regarding the estimated construction cost, see Attachment F.

2. Alternative M-2: Levee Raising and Cutoff Wall

a. Flood Risk Reduction Benefits

Alternative M-2 will improve the Mellin Levee so that it meets ULDC criteria (i.e.: 200-year flood protection), but this alternative does not propose improvements above the 200-year flood event. For that reason, Alternative M-2 was assigned a Flood Risk Reduction rating of “good”.

b. Flood System Flexibility and Resiliency

Alternative M-2 can incorporate the structural design that is necessary in order to remain resilient and withstand damage for flood events exceeding a 200-year flood event. For that reason, Alternative M-2 was assigned a Flood System Flexibility and Resiliency Rating of “good”.

c. Floodplain Management / Wise Use of the Floodplain

Alternative M-2 would remove a significant portion of land within the 200-year floodplain. This could promote development in these areas. For that reason, Alternative M-2 was assigned a Flood Management rating of “poor”.

d. Ecosystem Enhancement

The location of the proposed levee and other improvements associated with this alternative limit the amount of inundated habitat acres and/or riparian habitat that can be created with this alternative. Additionally, the revetment that would be needed to protect the proposed levee from erosion could have a negative impact on species stressors. Therefore, Alternative M-2 was assigned a “poor” Ecosystem Enhancement rating.

e. Multi-Benefit Potential/Compatibility with the City's Waterfront Specific Plan

The City's Waterfront Specific Plan does not extend north of SR 12, and the proposed levee raising in this segment is expected to have a neutral impact to scenic views and recreation. Therefore, Alternative M-2 was assigned a "good" Multi-Benefit Potential rating.

f. Improve Operation and Maintenance

The levee included with Alternative M-2 would need to be patrolled and inspected during routine inspections. Since the Mellin Levee is already patrolled and inspected, this alternative is not expected to significantly change O&M costs and activities. For these reasons, M-2 was assigned an O&M rating of "good".

g. Institutional Support

The proposed raising and cutoff wall are relatively noncontroversial since they maintain the existing flood control feature of the Mellin Levee. For this reason, Alternative M-2 was assigned a "good" Institutional Support rating.

h. Overall Rating

Based on the information and individual ratings above, Alternative M-2 had five "good" ratings and two "poor" ratings. These individual ratings earned this alternative a total of 17 points. Therefore, Alternative M-2 was assigned an overall rating of "Good".

i. Estimated Costs

Alternative M-2 would have an estimated cost of approximately $2.9 million. For more details regarding the estimated construction cost, see Attachment F.

XI. RESULTS AND DISCUSSIONS

A. Results

A performance summary of the alternatives considered in this analysis is shown below in **Table 7**.

Table 7
Performance Summary

Alt.	Alternative Ratings for Individual Project Objectives							Overall Rating	Est. Cost
	Flood Risk Reduction	Flood System Flexibility & Resiliency	Floodplain Management	Ecosystem Enhancement	Multi-Benefit Potential / Compatibility with the City's Waterfront Specific Plan	O&M	Institutional Support		
S-1A	Good	Good	Poor	Poor	Poor	Poor	Poor	Fair (11/28)	$49.9 M
S-1B	Good	Good	Poor	Poor	Poor	Poor	Poor	Fair (11/28)	$91.8 M
S-2	Good	Good	Poor	Poor	Poor	Poor	Poor	Fair (11/28)	$51.4 M
S-3	Good	Good	Poor	Poor	Excellent	Poor	Good	Fair (16/28)	$64.8 M
S-4	Good	Poor	Good	Fair	Excellent	Good	Good	Good (19/28)	$29.7 M
S-5	Fair	Poor	Good	Fair	Excellent	Good	Good	Good (18/28)	$38 M
N-1	Good	Good	Poor	Poor	Poor	Poor	Poor	Fair (11/28)	$57.7 M
N-2	Good	Good	Poor	Poor	Poor	Poor	Poor	Fair (11/28)	$80.4 M
N-3	Good	Poor	Good	Fair	Excellent	Good	Good	Good (19/28)	$50.5 M
N-4	Fair	Poor	Good	Fair	Excellent	Good	Good	Good (19/28)	$54 M
M-1	Good	Good	Poor	Poor	Good	Fair	Good	Good (17/28)	$3.3 M
M-2	Good	Good	Poor	Poor	Good	Good	Good	Fair (16/28)	$2.9 M

XII. CONCLUSIONS AND RECOMMENDATIONS

A. Preferred Plan

Based on the results of this Feasibility Study, the preferred plan south of SR 12 is Alternative S-4. It is the highest rated alternative and has the lowest overall estimated costs. The City is also very interested in Alternative S-3, but the estimated costs might make it difficult to implement

North of SR 12, the choice of a preferred plan is a fairly close one between Alternatives N-3 and N-4. If a mechanism can be developed that would allow DWR to use SCFRRP funds to insure properties, it might be worthwhile to explore N-4 further in the future. The preferred plan for the Mellin Levee is Alternative M-1.

B. Project Implementation Plan

1. Phasing

A single phased project would be ideal, but the reality of limited funding makes phasing necessary improvements an option to implement over time.

The area south of SR 12 has the highest density of properties in the floodplain. It is, therefore, recommended that Alternatives S-3 or S-4 be advanced to provide the greatest level of flood protection in the first phase.

The second phase should consist of implementing Alternative N-3 and Alternative M-1 concurrently because the flooding north of SR 12 would continue to occur if both of these projects were not implemented at the same time.

2. Potential Funding Sources

Funding is expected to come primarily from DWR grant programs since the City of Rio Vista does not have the resources available to fund infrastructure of this magnitude. The relatively small population impacted by the flooding also makes an assessment district unrealistic.

C. Other Recommendations and Next Steps

1. Coordination with Other Projects in the Region

The Little Egbert Tract Project is located north of the Mellin Levee. The Little Egbert Tract Project may be required to improve the Mellin Levee as part of their required mitigation. It will be imperative that the City, SCWA, SAFCA, DWR, and others follow the Little Egbert Tract Project because this could significantly mitigate the flood improvement costs to the Mellin Levee.

2. City Building Code Amendments

There are many undeveloped parcels that are currently located in the 200-year floodplain in the Study Area. In order to minimize the risk of flooding to new structures, it is recommended that the City of Rio Vista consider updating their building codes to require new development be elevated at least one foot above the future 200-year floodplain. This would be an important step in helping to prevent and mitigate flood issues within the City, and would be consistent with the City's Waterfront Plan.

3. Grant Program – Flooding Raising Program

Rather than fully funding a structure-raising program, a comparable program could be set up to provide a fixed dollar amount for homes and/or business (i.e.: $100-150K). Individual landowners could then choose how they wanted to use these funds to demolish, raise, or rebuild to the new Building Standards (i.e.: 200-year flood plain). This option would also allow landowners to make their own informed choices, promote building enhancements, and help to revitalize the City.

FIGURES

ATTACHMENTS

A. 200-Year DWSE TM
B. Existing and Future Floodplains TM
C. Geotechnical Exploration and Evaluation TM
D. Local Runoff Conveyance Impacts TM
E. Multi-Benefit Assessment and Permitting Needs TM
F. Cost Estimates

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Feasibility Study Area

SOURCES:
California DWR - State-Federal Levees
ESRI - City/County Boundary
Microsoft Virtual Earth - Aerial Background

NORTH
0 1,375 2,750
FEET

WOOD RODGERS

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FIGURE 1

Solano County Water Agency
Rio Vista Flood Protection Pre-Feasibility Study
Flood Hazards

SOURCES:
Solano County - Ground Elevations
FEMA - Base Flood Elevations
California DWR - State-Federal Levees
ESRI - City/County Boundary
and Aerial Background

NOTES:
All Elevations Shown are NAVD88.
Pictures Taken on 12/22/14 when river was at 7.8' +/-

NORTH

0 400 800
FEET

WOOD RODGERS

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FIGURE 2

▭ 200-yr Existing Floodplain
▨ Existing SD Detention Basin
P Police Station
F Fire Station
CH City Hall
L Ex. Sewer Lift Station
⊕ Ex. Well

Land Within 200-yr Existing Floodplain

Land Use	# of Parcels	Total Acreage
Residential	126	36
Commercial/ Industrial/ Manufacturing	61	128
Agricultural	1	4
Public	23	19
TOTAL	**211**	**187**

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Existing 200-Yr Floodplain Depth

NOTE:
FLOODPLAIN EXTENTS WERE DEVELOPED BY PROJECTING THE EXISTING 200-YR WSE IN THE SACRAMENTO RIVER LANDWARD (WEST) OVER EXISTING LIDAR TOPOGRAPHY.

WOOD RODGERS

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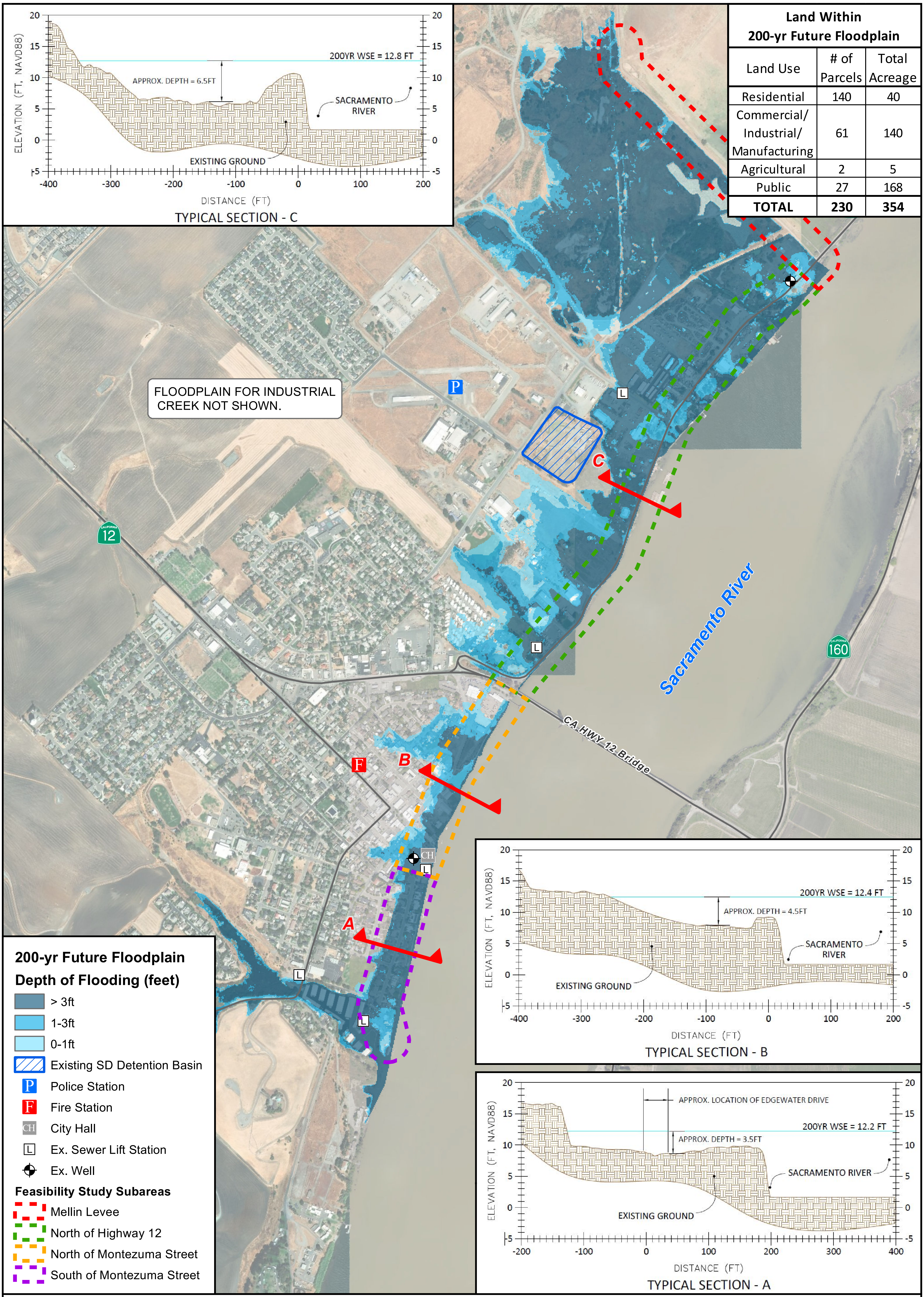
FIGURE 3



Land Use	# of Parcels	Total Acreage
Residential	140	40
Commercial/ Industrial/ Manufacturing	61	140
Agricultural	2	5
Public	27	168
TOTAL	**230**	**354**

Land Within 200-yr Future Floodplain

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Future 200-yr Floodplain Depth

NOTE:
FLOODPLAIN EXTENTS WERE DEVELOPED BY PROJECTING THE 200-YR FUTURE WSE IN THE SACRAMENTO RIVER LANDWARD (WEST) OVER EXISTING LIDAR TOPOGRAPHY.

NORTH
0 500 1,000
FEET

WOOD RODGERS

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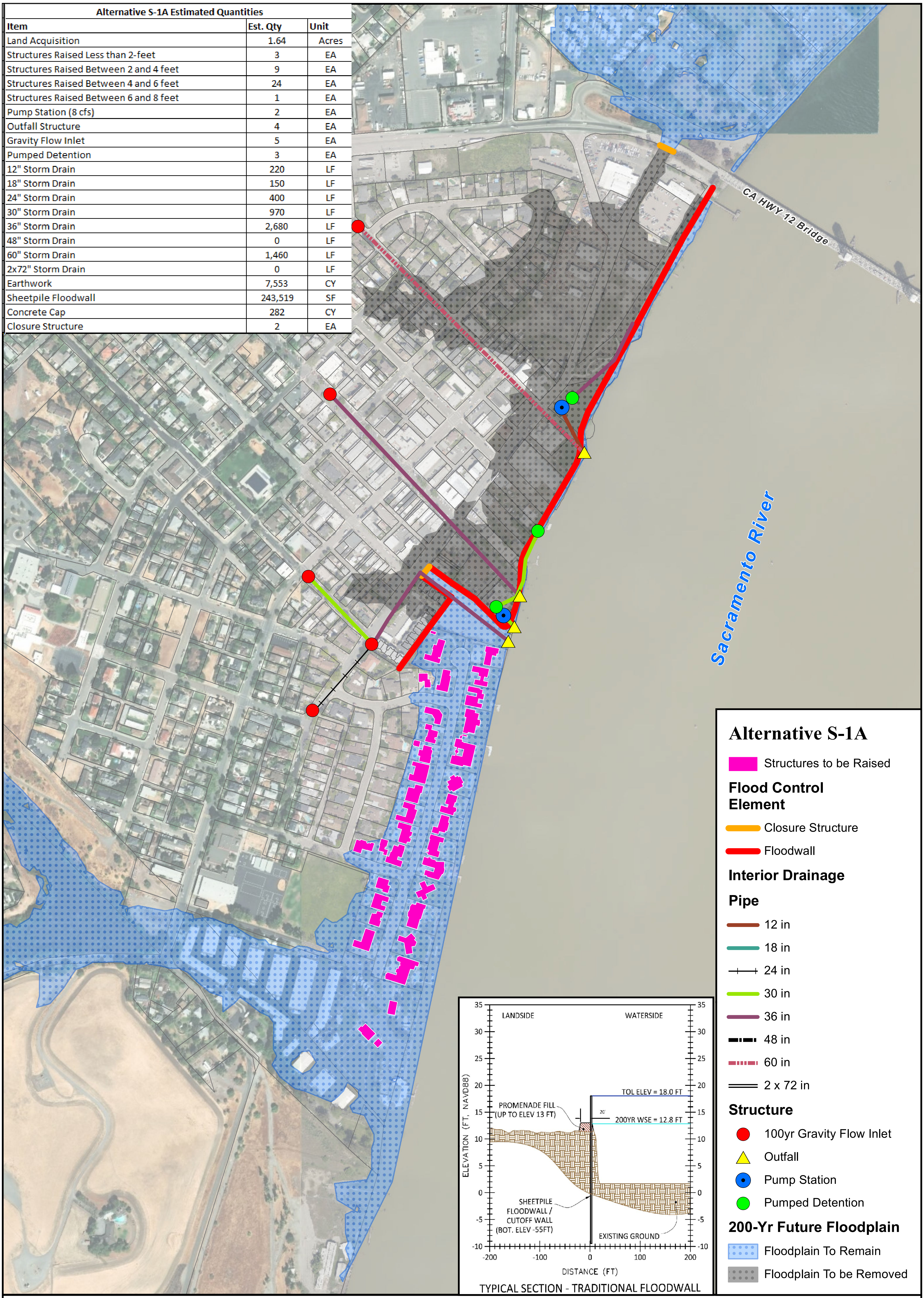
FIGURE 4

Alternative S-1A Estimated Quantities		
Item	Est. Qty	Unit
Land Acquisition	1.64	Acres
Structures Raised Less than 2-feet	3	EA
Structures Raised Between 2 and 4 feet	9	EA
Structures Raised Between 4 and 6 feet	24	EA
Structures Raised Between 6 and 8 feet	1	EA
Pump Station (8 cfs)	2	EA
Outfall Structure	4	EA
Gravity Flow Inlet	5	EA
Pumped Detention	3	EA
12" Storm Drain	220	LF
18" Storm Drain	150	LF
24" Storm Drain	400	LF
30" Storm Drain	970	LF
36" Storm Drain	2,680	LF
48" Storm Drain	0	LF
60" Storm Drain	1,460	LF
2x72" Storm Drain	0	LF
Earthwork	7,553	CY
Sheetpile Floodwall	243,519	SF
Concrete Cap	282	CY
Closure Structure	2	EA



Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative S-1A

NORTH
0 200 400
FEET

WOOD RODGERS

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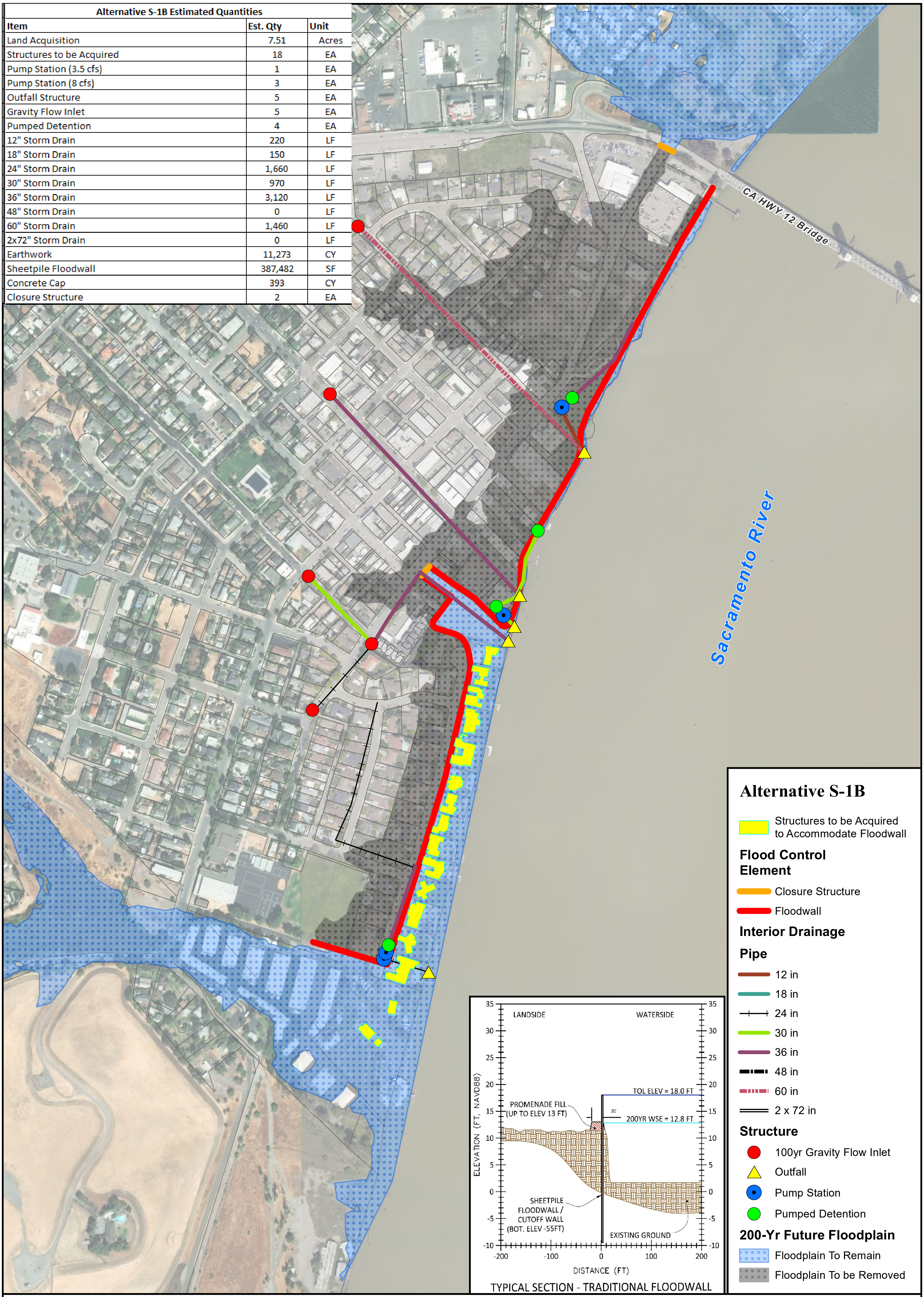
FIGURE 5

Alternative S-1B Estimated Quantities

Item	Est. Qty	Unit
Land Acquisition	7.51	Acres
Structures to be Acquired	18	EA
Pump Station (3.5 cfs)	1	EA
Pump Station (8 cfs)	3	EA
Outfall Structure	5	EA
Gravity Flow Inlet	5	EA
Pumped Detention	4	EA
12" Storm Drain	220	LF
18" Storm Drain	150	LF
24" Storm Drain	1,660	LF
30" Storm Drain	970	LF
36" Storm Drain	3,120	LF
48" Storm Drain	0	LF
60" Storm Drain	1,460	LF
2x72" Storm Drain	0	LF
Earthwork	11,273	CY
Sheetpile Floodwall	387,482	SF
Concrete Cap	393	CY
Closure Structure	2	EA



Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative S-1B

NORTH
0 200 400
FEET

WOOD RODGERS

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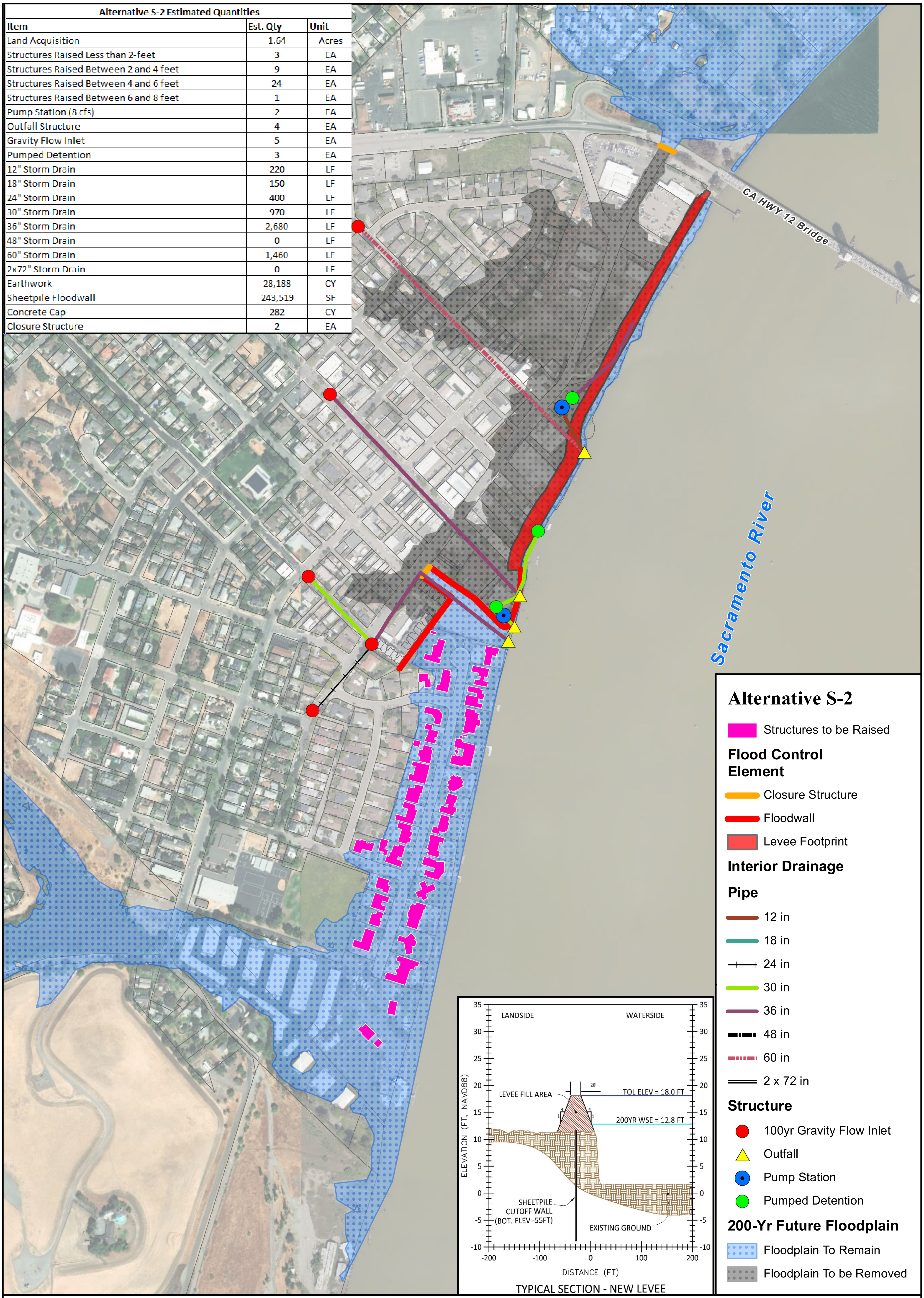
FIGURE 6

Alternative S-2 Estimated Quantities

Item	Est. Qty	Unit
Land Acquisition	1.64	Acres
Structures Raised Less than 2-feet	3	EA
Structures Raised Between 2 and 4 feet	9	EA
Structures Raised Between 4 and 6 feet	24	EA
Structures Raised Between 6 and 8 feet	1	EA
Pump Station (8 cfs)	2	EA
Outfall Structure	4	EA
Gravity Flow Inlet	5	EA
Pumped Detention	3	EA
12" Storm Drain	220	LF
18" Storm Drain	150	LF
24" Storm Drain	400	LF
30" Storm Drain	970	LF
36" Storm Drain	2,680	LF
48" Storm Drain	0	LF
60" Storm Drain	1,460	LF
2x72" Storm Drain	0	LF
Earthwork	28,188	CY
Sheetpile Floodwall	243,519	SF
Concrete Cap	282	CY
Closure Structure	2	EA



TYPICAL SECTION - NEW LEVEE

Alternative S-2

- 🟪 Structures to be Raised

Flood Control Element

- ▬ Closure Structure
- ▬ Floodwall
- 🟥 Levee Footprint

Interior Drainage

Pipe

- ▬ 12 in
- ▬ 18 in
- ┼ 24 in
- ▬ 30 in
- ▬ 36 in
- ▬ 48 in
- ▬ 60 in
- ═ 2 x 72 in

Structure

- ● 100yr Gravity Flow Inlet
- △ Outfall
- ● Pump Station
- ● Pumped Detention

200-Yr Future Floodplain

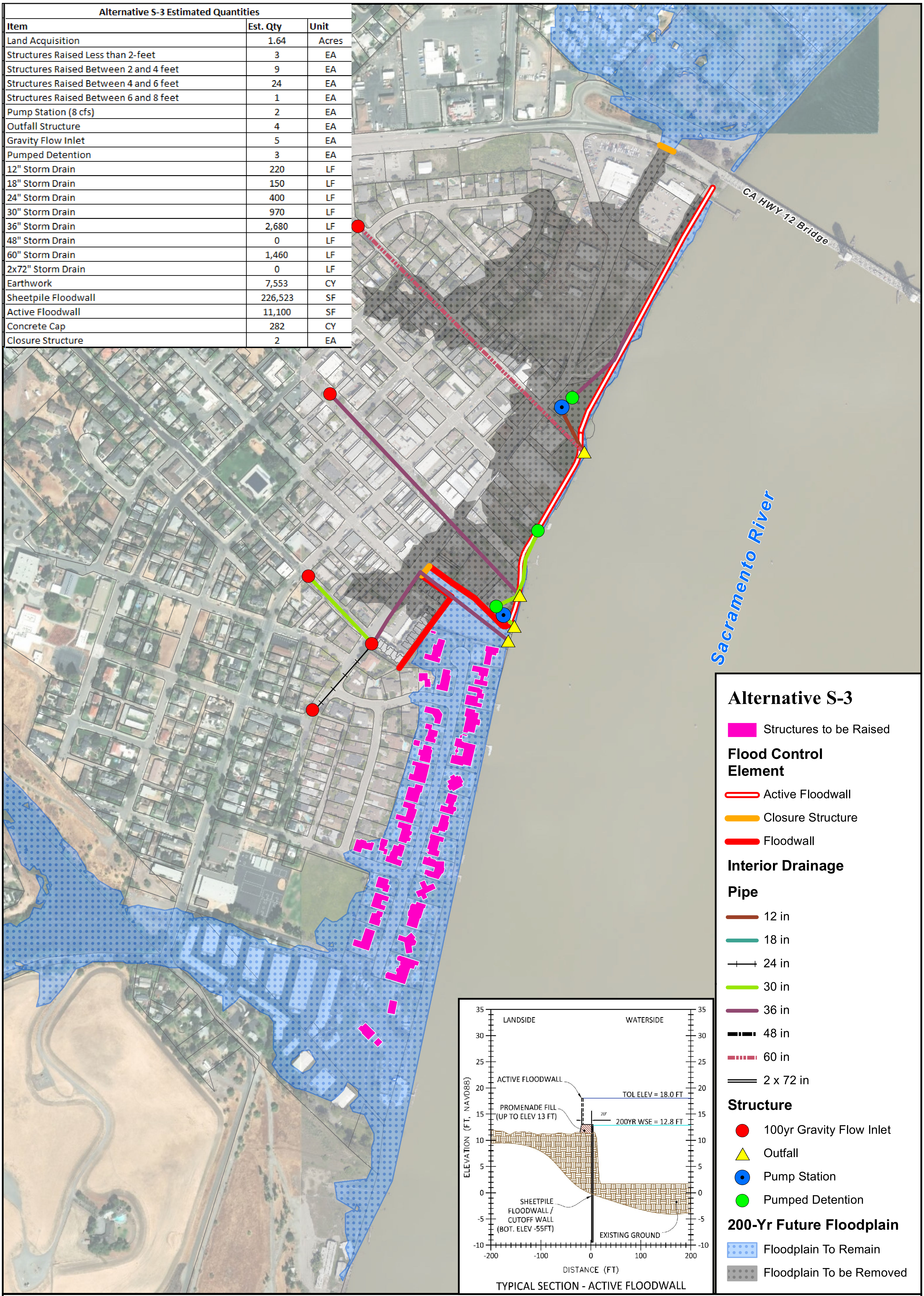
- ▨ Floodplain To Remain
- ▨ Floodplain To be Removed

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
South of HWY 12 Bridge
Alternative S-2

NORTH
0 200 400
FEET

WOOD RODGERS

Alternative S-3 Estimated Quantities		
Item	Est. Qty	Unit
Land Acquisition	1.64	Acres
Structures Raised Less than 2-feet	3	EA
Structures Raised Between 2 and 4 feet	9	EA
Structures Raised Between 4 and 6 feet	24	EA
Structures Raised Between 6 and 8 feet	1	EA
Pump Station (8 cfs)	2	EA
Outfall Structure	4	EA
Gravity Flow Inlet	5	EA
Pumped Detention	3	EA
12" Storm Drain	220	LF
18" Storm Drain	150	LF
24" Storm Drain	400	LF
30" Storm Drain	970	LF
36" Storm Drain	2,680	LF
48" Storm Drain	0	LF
60" Storm Drain	1,460	LF
2x72" Storm Drain	0	LF
Earthwork	7,553	CY
Sheetpile Floodwall	226,523	SF
Active Floodwall	11,100	SF
Concrete Cap	282	CY
Closure Structure	2	EA



Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative S-3

WOOD RODGERS

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FIGURE 8

Alternative S-4 Estimated Quantities		
Item	Est. Qty	Unit
Land Acquisition	0	Acres
Structures Raised Less than 2-feet	71	EA
Structures Raised Between 2 and 4 feet	29	EA
Structures Raised Between 4 and 6 feet	32	EA
Structures Raised Between 6 and 8 feet	3	EA

Alternative S-4

🟥	Building Structure Footprint
▨	200-Yr- Future Flooplain to Remain

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative S-4

WOOD RODGERS

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FIGURE 9

Alternative S-5 Estimated Quantities

Item	Est. Qty	Unit
Land Acquisition	0	Acres
Number of Structures inside FEMA 500-yr Floodplain	114	EA
Number of Structures Outside FEMA 500-yr Floodplain	20	EA
Number of Structures inside FEMA 100-yr Floodplain	20	EA

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative S-5

WOOD RODGERS

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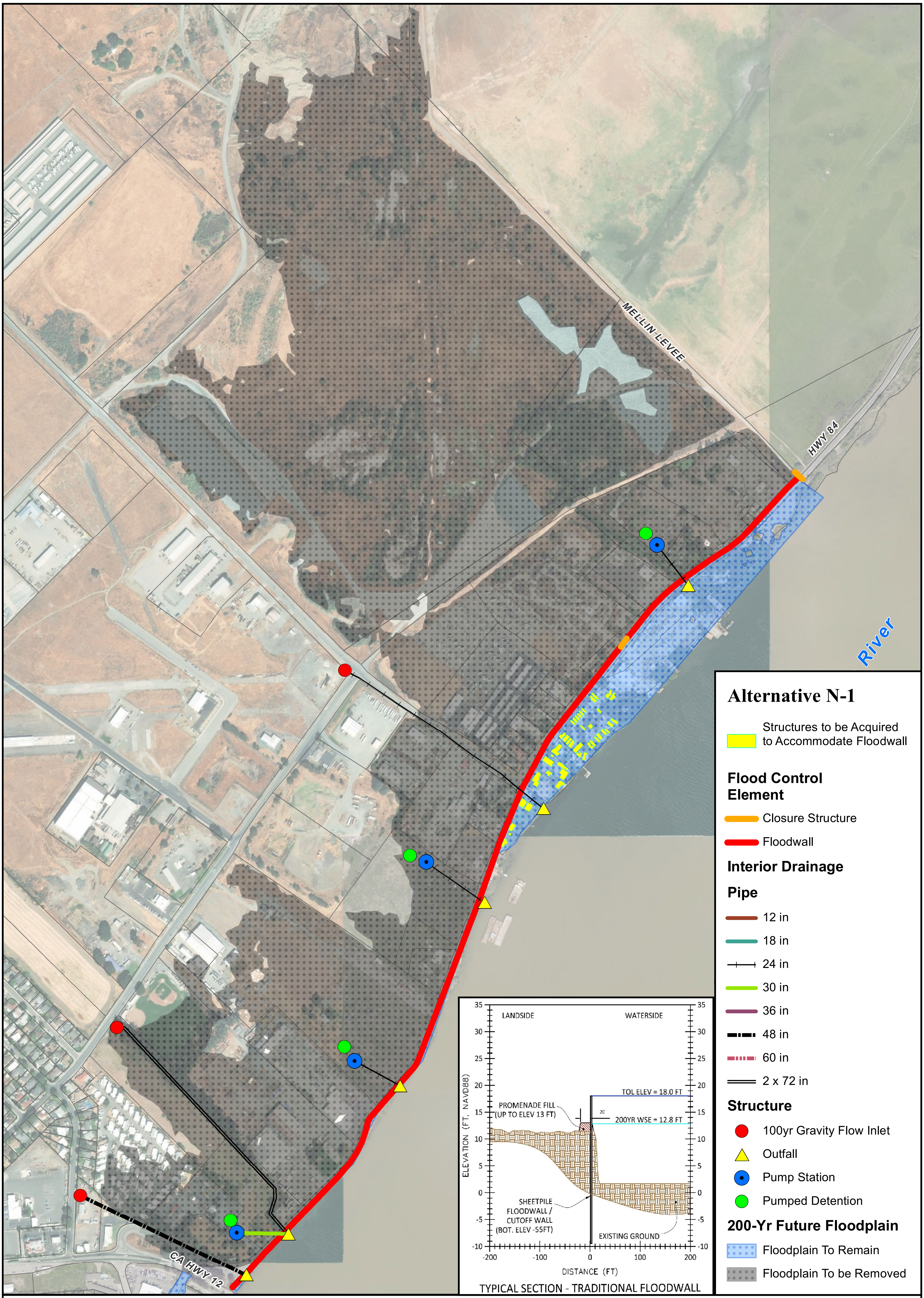
FIGURE 10



Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative N-1

NORTH
0 200 400
FEET

WOOD RODGERS

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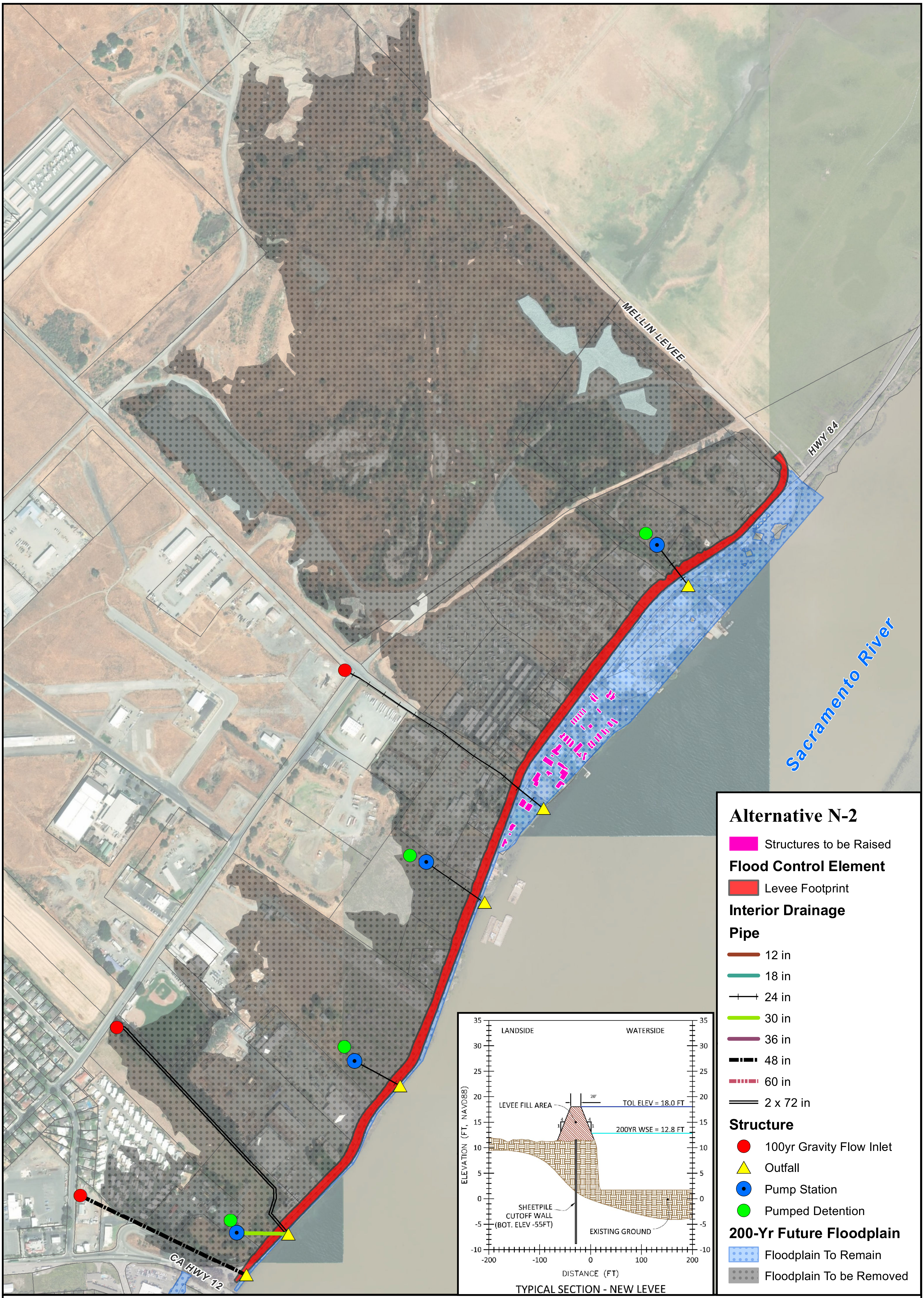
FIGURE 11



Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative N-2

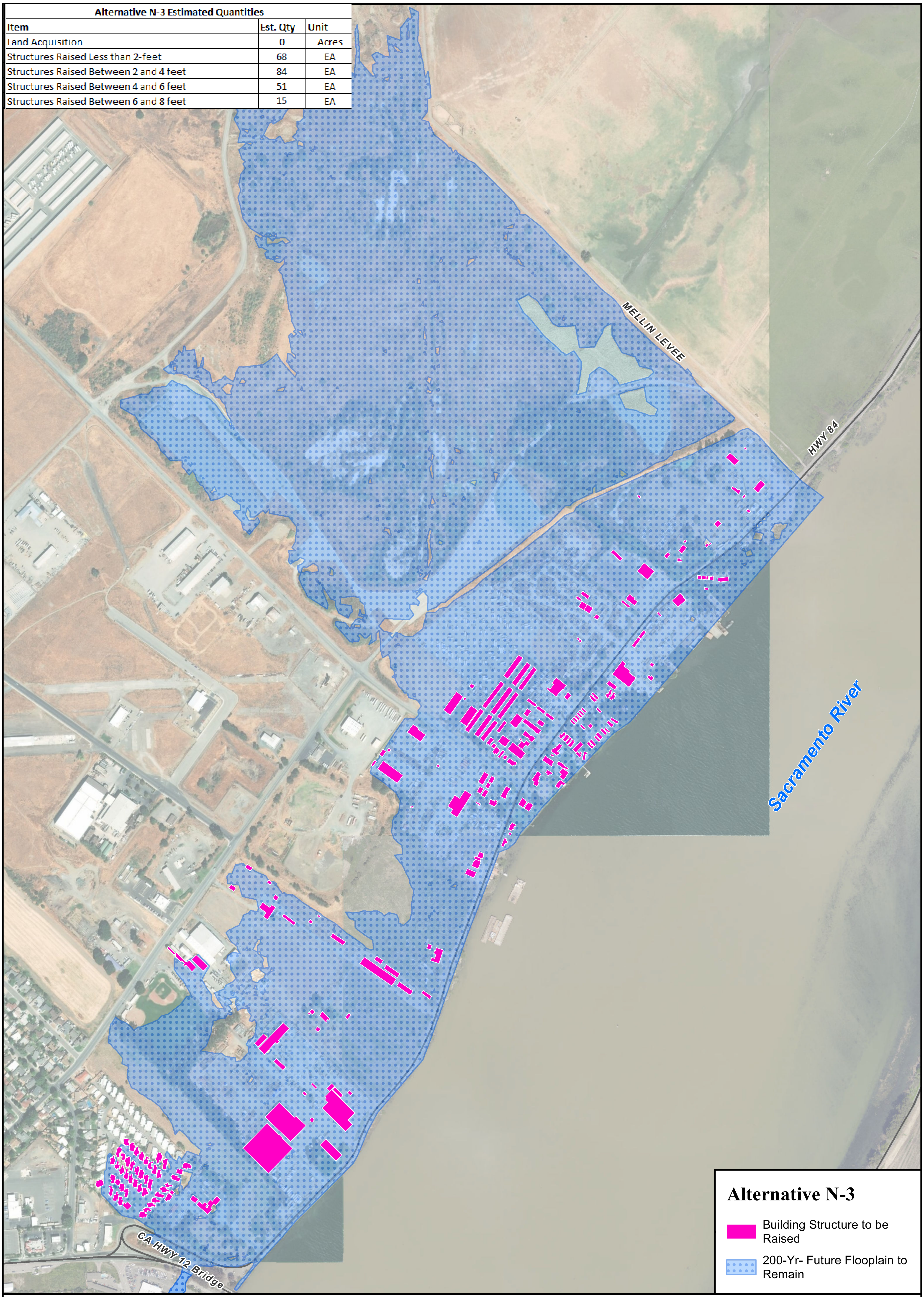
NORTH
0 200 400
Feet

WOOD RODGERS

FIGURE 12

Alternative N-3 Estimated Quantities

Item	Est. Qty	Unit
Land Acquisition	0	Acres
Structures Raised Less than 2-feet	68	EA
Structures Raised Between 2 and 4 feet	84	EA
Structures Raised Between 4 and 6 feet	51	EA
Structures Raised Between 6 and 8 feet	15	EA



Alternative N-3

🟪	Building Structure to be Raised
▨	200-Yr- Future Flooplain to Remain

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative N-3

WOOD RODGERS

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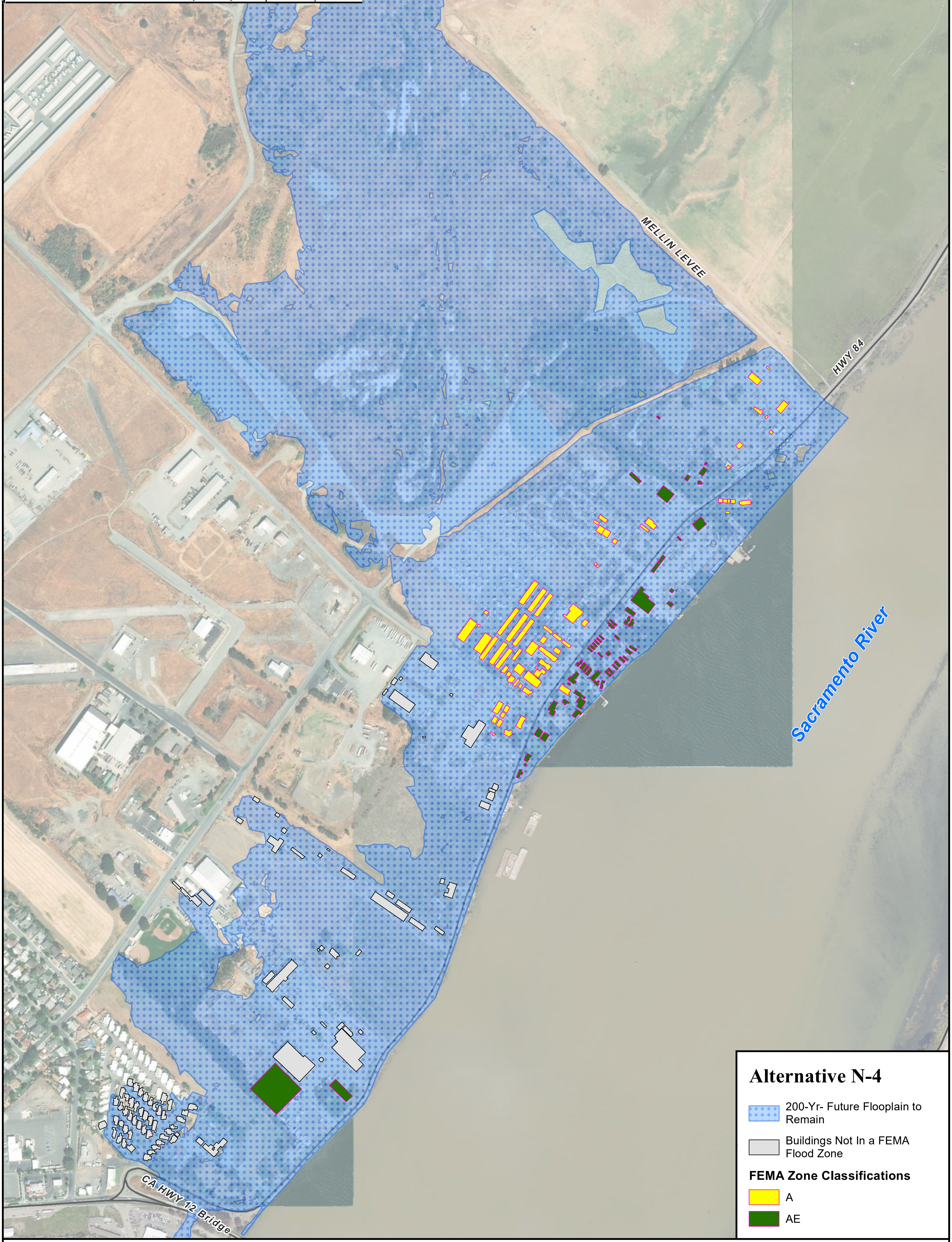
FIGURE 13

Alternative N-4 Estimated Quantities

Item	Est. Qty	Unit
Land Acquisition	0	Acres
Number of Structures inside FEMA 500-yr Flooplain	0	EA
Number of Structures Outside FEMA 500-yr Flooplain	95	EA
Number of Structures inside FEMA 100-yr Floodplain	123	EA



Alternative N-4

- ▨ 200-Yr- Future Flooplain to Remain
- ☐ Buildings Not In a FEMA Flood Zone

FEMA Zone Classifications

- 🟨 A
- 🟩 AE

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative N-4

NORTH
0 200 400
FEET

WOOD RODGERS

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FIGURE 14

Alternative M-1 Estimated Quantities

Item	Est. Qty	Unit
Land Acquisition	20.3	Acres
Levee Fill	98,900	CY
Seepage Berm Fill	57,500	CY

Alternative M-1

▨ Parcels to be Acquired

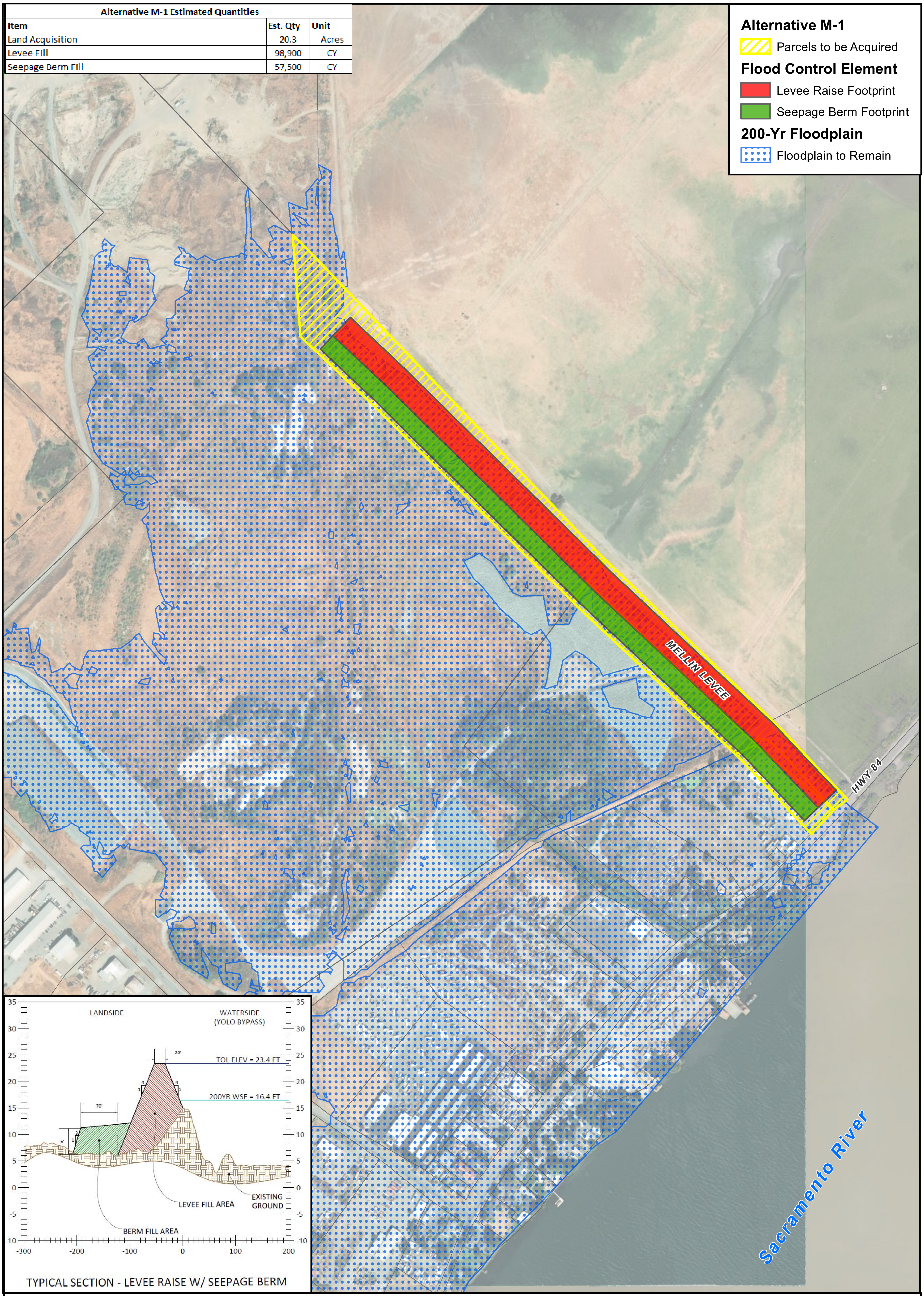
Flood Control Element

🟥 Levee Raise Footprint

🟩 Seepage Berm Footprint

200-Yr Floodplain

⁘ Floodplain to Remain



TYPICAL SECTION - LEVEE RAISE W/ SEEPAGE BERM

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative M-1

NORTH

0 200 400

FEET

WOOD RODGERS

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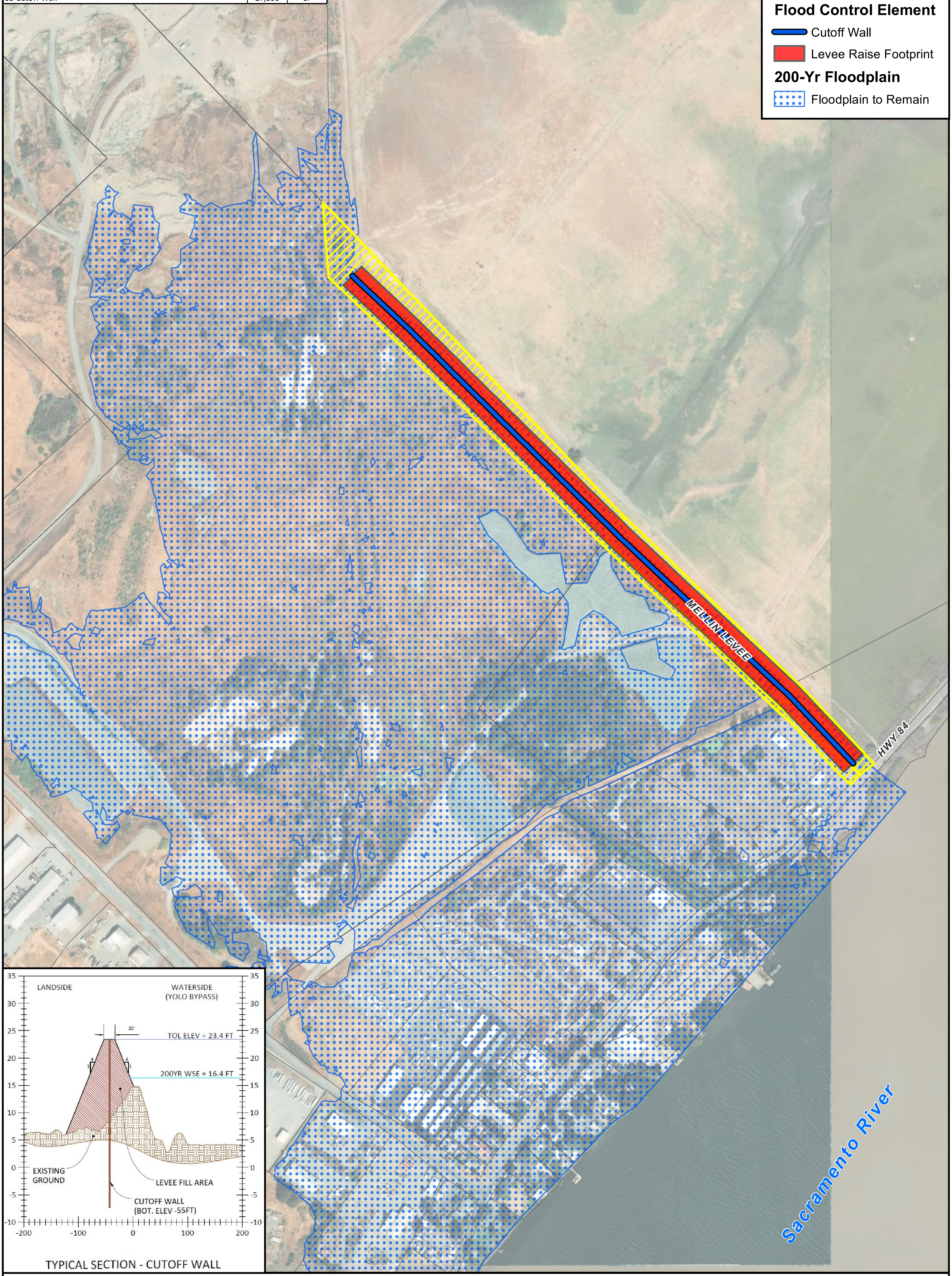
FIGURE 15

Alternative M-2 Estimated Quantities		
Item	**Est. Qty**	**Unit**
Land Acquisition	13.3	Acres
Levee Fille	98,900	CY
SB Cutoff Wall	27,000	SF



Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Alternative Layout Exhibit
Alternative M-2

WOOD RODGERS

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FIGURE 16

ATTACHMENTS

A. 200-Year DWSE TM
B. Existing and Future Floodplains TM
C. Geotechnical Exploration and Evaluation TM
D. Local Runoff Conveyance Impacts TM
E. Multi-Benefit Assessment and Permitting Needs TM
F. Cost Estimates

Attachments

A. 200-Year DWSE TM
B. Existing and Future Floodplains TM
C. Geotechnical Exploration and Evaluation TM
D. Local Runoff Conveyance Impacts TM
E. Multi-Benefit Assessment and Permitting Needs TM
F. Cost Estimates

Attachment A: 200-Year DWSE TM

TECHNICAL MEMORANDUM

PREPARED FOR: Mr. Jeff M. Barich, P.E., Solano County Water Agency

PREPARED BY: Mr. Jesse J. Patchett, P.E., CFM (Wood Rodgers, Inc.)
Mr. Don Trieu, P.E. (MBK Engineers)

REVIEWED BY: Mr. Michael C. Nowlan, P.E., CFM (Wood Rodgers, Inc.)

DATE: March 15, 2018

SUBJECT: Rio Vista Flood Control Feasibility Study – Design Water Surface Elevation

INTRODUCTION

The City of Rio Vista (City) and the Solano County Water Agency (SCWA) are in the process of developing the Rio Vista Flood Control Feasibility Study (Feasibility Study). The area to be included in the Feasibility Study extends along the west bank of the Sacramento River from Marina Creek to the Mellin Levee. The Mellin Levee is also included. An overview of the area that will be evaluated in the Feasibility Study is shown on **Figure 1** (attached).

The goal of the Feasibility Study is to identify a preferred alternative to reduce the risk of flooding in Rio Vista that is compatible with the City's Waterfront Specific Plan and the Basin-Wide Feasibility Study (BWFS). In support of this goal, a design water surface elevation (DWSE) first needs to be developed. The DWSE needs to be based on the 200-year water surface profile and needs to include appropriate adjustment factors for uncertainty and sea-level rise.

This Technical Memorandum (TM) describes the approach used to develop the 200-year water surface elevation. The approach used to develop the appropriate adjustments for uncertainty and sea-level rise are also discussed. Based on this information, this TM presents a recommended DWSE for use in the Feasibility Study.

BACKGROUND

The City prepared a pre-feasibility study in January of 2015 to evaluate alternatives that would provide 200-year flood protection for the City. The DWSE used in the pre-feasibility study was based on the U. S. Army Corps of Engineers (USACE) Comprehensive Study (Comp Study) hydrology, and utilized the 200-year boundary conditions from the USACE Common Features General Reevaluation Report.

Some of the hydrologic assumptions used in the Comp Study are approximately 15 years old. While using the Comp Study model in the pre-Feasibility Study was appropriate given the preliminary nature of that effort, some of the assumptions used in the Comp Study have become outdated due to recent activities by the California Department of Water Resources (DWR). Specifically, new hydrology for the Sacramento River Basin has been developed by DWR as part of the Central Valley Hydrology Study (CVHS). Therefore, the 200-year water surface elevation to be used in this

Feasibility Study should be based on the latest hydrologic assumptions and models available from DWR.

APPROACH

Design Water Surface Elevation

The approach to develop the DWSE was based on guidance provided in the DWR Urban Levee Design Criteria (ULDC) (Reference 1). The ULDC offers two options for determining the appropriate DWSE and the Minimum Top-of-Levee (MTOL). These are the Federal Emergency Management Agency (FEMA) deterministic approach and the USACE combined deterministic and probabilistic approaches. The FEMA approach was used as the basis for the DWSE and MTOL in the Feasibility Study. The FEMA approach was selected because it frequently results in higher, and therefore more conservative, water surface elevations.

Adjustment Factors

The ULDC recommends that the DWSE be adjusted to consider potential increases associated with climate change, updated hydrology, updated hydraulic modeling, and sea level rise. These adjustments provide an additional factor of safety in the design and allow for additional system resiliency.

The Sacramento River transitions from tidally-influenced to riverine-controlled during large flood events near Rio Vista. Therefore, the tidal boundary condition has the potential to affect the DWSE in this area. In support of the Central Valley Flood Protection Plan (CVFPP), DWR developed deterministic tidal hydrographs at the Golden Gate Bridge for ten CVHS flood events, then used the RMA Bay-Delta Model to translate these tidal hydrographs to the Sacramento River hydraulic model downstream boundary locations (Reference 2). The determination of the DWSE for the Feasibility Study used the tidal boundary conditions developed by DWR in support of the 2017 CVFPP Update. These tidal boundary conditions also included adjustments to account for sea level rise.

In order to develop appropriate adjustment factors, another project located in the Sacramento-San Joaquin Delta (Delta) was reviewed. A project known as the Smith Canal Gate Project (Reference 3), located in Stockton, California was identified as being a good candidate to review since its location is potentially impacted by sea level rise, and the project was at the 65-percent design phase as of June 2017.

RESULTS AND DISCUSSION

Design Water Surface Elevation

Hydraulic Model

The DWSE was computed using the MBK Engineers version (MBK Model) of Release 4 of the USACE Sacramento River Basin HEC-RAS model (USACE Model), which had been developed by USACE for use in support of the American River Common Features General Re-evaluation Report and the West Sacramento General Re-evaluation Report. A schematic of the model domain is provided on **Figure 2** (attached).

The USACE model was updated to improve calibration, stability, and execution efficiency. **Exhibit 1** (below) compares the computed maximum water surface elevations from calibration simulations of the January 1997 flood event.

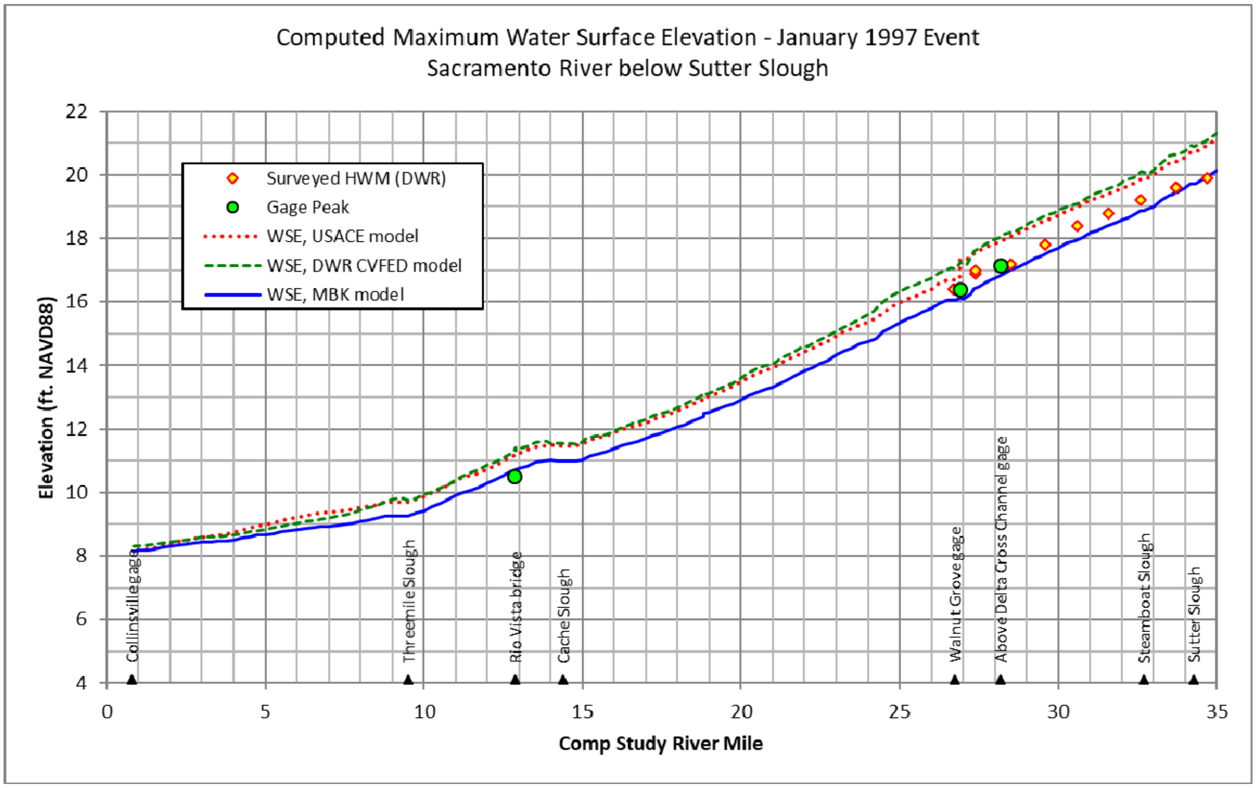


Exhibit 1 – Hydraulic Model Calibration Results, January 1997 Flood Event

A new hydraulic model of the Sacramento River Basin has also been recently developed by DWR as part of the Central Valley Floodplain Evaluation and Delineation project (CVFED model). The CVFED model calibration in the vicinity of Rio Vista was reviewed (also included in Exhibit 1) and it was concluded that further refinement of the CVFED model would be necessary for use in the

Rio Vista area. Refinement of the CVFED model was not part of the Feasibility Study scope. Therefore, the CVFED model was not used for this Feasibility Study.

The hydraulic model used for the Feasibility Study has been used for determination of design water surface elevations and hydraulic impact analyses for Sacramento Area Flood Control Agency (SAFCA) and West Sacramento Area Flood Control Agency (WSAFCA) levees, work that has been shared with and reviewed by USACE.

Due to Rio Vista's location in the Delta, appropriate downstream boundary conditions were used to establish the necessary tidal downstream boundary conditions for the model. The three downstream conditions are shown below:

1. Sacramento River at Collinsville
2. Georgianna Slough at the Mokelumne River
3. Threemile Slough at the San Joaquin River

These downstream boundary conditions, as well as all of the boundary conditions used in the model are shown on Figure 2 (attached).

The hydraulic model used for the Feasibility Study assumes that urban levees have a minimum height equal to the 200-year WSE plus three feet, non-urban State-Federal Project levees were assumed to satisfy the minimum design conditions of the Sacramento River Flood Control Project (1957 Profile), and all levees were assumed to act as weirs if overtopped without failing. This approach is consistent with the ULDC. The hydraulic model used for the Feasibility Study DWSE determination does not include any of the assumptions from the pre-feasibility study listed in the "Background" section above with the exception of the Folsom Joint Federal Project (completed) and Folsom Dam Raise Project (authorized).

Hydrology

The DWSE was computed using hydrology from the Central Valley Hydrology Study, which was commissioned by DWR and prepared by USACE. The CVHS defines a procedure in which a scaled flood event with a pattern based on a historical flood event is selected to represent the flood of a specific frequency at a specific location. Hydrologic data for the scaled flood events were developed as part of the CVHS. For determination of the DWSE at Rio Vista, two flood "centerings" were evaluated. The first was a flood that stressed the system at the latitude of the Fremont Weir. The second was a flood that stressed the Sacramento River at Sacramento. The DWSE was then determined using the maximum computed water surface elevation from the two flood centerings. The CVHS scaled flood events that represent the 200-year flood at these locations are summarized below in **Table 1**. Also included in Table 1 are the corresponding CVFPP downstream boundary CVHS flood events that were used in the analysis. CVFPP developed downstream boundaries for only ten CVHS flood events, and these represent the closest matches to the upstream flood events.

TABLE 1

Flood Centering	200-year CVHS Flood Event	CVFPP Downstream Boundary CVHS Flood Event
Latitude of Fremont Weir (CVHS analysis point SAC-79)	1997 100%	1997 115%
Sacramento River at Sacramento (CVHS analysis point SAC-60)	1986 90% with 140% on American River	1986 100%

Adjustment Factors

Uncertainty

Some projects incorporate a one-foot addition to the water surface profile in order to account for the uncertainty associated with hydrologic and hydraulic modeling and climate change. Other projects determine that the addition of several feet for freeboard also accommodates uncertainty. Ultimately, the recommended adjustment for uncertainty is based on the professional judgement of the design team, as well as on input from stakeholders.

For the Feasibility Study, one foot will be added in order to account for uncertainty. This was the same approach used in the Pre-Feasibility Study. The addition of one foot is also consistent with the uncertainty adjustment used in the Smith Canal Gate Project. For these reasons, the adjustment factor of one foot to account for uncertainty is considered appropriate.

Wind Set-up and Wave Run-up

The FEMA approach requires that the MTOL be at least three feet above 200-year water surface elevation or the height needed to accommodate wind set-up and wave run-up. The URS Corporation (URS, now AECOM) prepared a memorandum in support of a floodwall design for the City which estimated the wave run-up on the Rio Vista shoreline for a design wind speed of 100 mph and 50 mph (Reference 4). The URS study did not separate the values for wind set-up and wave runup and so only the resulting wave runup heights are presented in this report.

The URS memorandum stated that the 100-mph value was unrealistically high since this was the highest recorded value in 15 years of data. Furthermore, on the same day, the peak wind speed associated with this event was recorded by other sensors in the Delta as considerably lower.

Therefore, URS estimated the wave run-up for a 50-mph design wind speed, since it represents a more realistic high-wind scenario. The results from the URS memorandum are presented below in **Table 2**. For purposes of this Study, the 50-mph design speed wave run-up is used.

Table 2 – Estimated Peak Wave Heights at Rio Vista

	100-mph Design Speed			50-mph Design Speed		
Wind Incidence Direction (degrees)	180	145	110	180	145	110
Fetch (feet)	9,840	4,100	2,460	9,840	4,100	2,460
Wave Height (feet)	5.58	3.61	2.62	2.30	1.64	1.31
Average Wave Run-up Height (feet)	5.58	3.61	2.62	2.30	1.64	1.31
Max 10% Wave Run-up Height on a Vertical Seawall (feet)	6.89	4.60	2.95	2.95	1.97	1.31
Max 2% Wave Run-up Height on Riprap Slope (feet)	5.58	3.61	2.95	2.62	1.64	1.31

It is not clear whether wind setup was included in the wave height calculations in the URS memorandum. Therefore, wind setup calculations were performed for this TM. Wind setup was derived from the Zeider Zee equation from USACE EM 1110-2-1420:

$$S = \frac{U^2 F}{1400d}$$

Where S = wind setup (ft)
U = average wind speed (mph)
F = fetch distance (miles)
d = average water depth along the fetch line (ft)

For a 50mph wind, a fetch distance of approximately 1.86 miles, and an average depth of 14-feet, the estimated wind setup value is approximately 0.24-feet. Adding this value to the 10% wave run-up value of 2.95-feet in Table 2 yeilds a combined wind setup and wave run-up height of approximately 3.19-feet. Since this is larger than FEMA's required 3-feet of freeboard, 3.19-feet is used as the required freeboard.

It should also be noted that the URS memo provided 2% wave runup heights for riprap slopes. These values were slightly lower than the 10% wave run-up estimates. If a riprap levee slope is considered during later phases of the Feasibility Study, the required freeboard may be reduced to three feet.

Sea-Level Rise

A sea level rise adjustment was incorporated in the CVFPP downstream boundary conditions based on findings by the National Research Council (NRC) in *Sea-Level Rise for Coasts of California, Oregon, and Washington: Past, Present and Future* (2012). The NRC provides sea level rise projections for 2030, 2050, and 2100, relative to the year 2000. The CVFPP analysis had a target projection year of 2062. Interpolating between the NRC projections for 2050 and 2100, the mean sea level rise projection for the year 2062 was determined to be 1.27 feet. The RMA Bay-Delta model was then used to translate the projected sea level rise to the downstream boundaries of the Sacramento River hydraulic model for the various CVHS flood events.

Other Factors - Settlement

The long-term consolidation of soft, compressible materials below an embankment or floodwall reduces the design freeboard. Therefore, adjustments need to be made to accommodate settlement in order to ensure that design freeboard is maintained once settlement has occurred.

A report prepared in 2011 by Construction Testing Services, Inc. (CTS, Reference 7) in support of a sidewalk project along the Sacramento River immediately downstream of the Highway 12 Bridge indicated that settlement on the order of seven inches could be anticipated. The long-term settlement will be developed by GEI Consultants, Inc. (GEI) during later phases of the Feasibility Study. In the meantime, seven inches of settlement will be assumed based on information in the CTS report. Once updated settlement information is available from GEI, the MTOL will be adjusted as needed to accommodate anticipated settlement in order to ensure that the design freeboard is maintained above the DWSE after settlement occurs.

RECOMMENDATIONS AND CONCLUSION

Based on the information presented in this TM, the recommended DWSE and MTOL at various locations along the project area are shown in **Table 3** (below). A profile of the base 200-year WSE, adjusted DWSE and MTOL are shown graphically on **Figure 3** (attached).

TABLE 3 – Recommended DWSE and MTOL

	Sacramento River at the Delta Marina (feet)	Sacramento River at State Highway 12 (feet)	Sacramento River at the Mellin Levee (feet)
Base 200-year WSE	12.05	12.55	12.85
200-year WSE with SLR (Year 2062)	12.77	13.22	13.49
Uncertainty Adjustment	1.0	1.0	1.0
Adjusted DWSE	**13.77**	**14.22**	**14.49**
Settlement	0.58	0.58	0.58
Wind / Wave / Freeboard Adjustment	3.19*	3.19*	3.19*
Recommended MTOL	**17.54**	**17.99**	**18.26**

Note. Elevations are in NAVD 88.

* Freeboard value may be reduced to 3-feet if a levee is proposed instead of a levee

REFERENCES

1. California Department of Water Resources. (2012a). *Urban Levee Design Criteria*. DWR: Sacramento, CA.
2. California Department of Water Resources. 2017 CVFPP Update – Scenario Technical Analyses Summary Report, Public Draft. February 2017.
3. URS, Draft Final Rio Vista Waterfront Promenade – Engineering Assistance Memorandum, July 19, 2011
4. ICF International, Smith Canal Gate Project EIR, November 2015
5. Intergovernmental Panel on Climate Change, Emissions Scenarios, 2000
6. California Ocean Protection Council. (2017). *Resolution of the California Ocean Protection Council on Updating the State of California Sea-Level Rise Guidance Document – Adopted on April 26, 2017*.
7. Construction Testing Services, Inc., Report of Geotechnical Investigation: The City of Rio Vista Seawall Project, June 30, 2011.

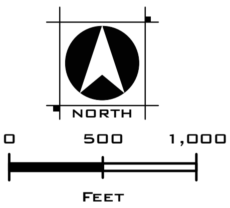
Enclosures:

Figures

- Figure 1 – Feasibility Study Project Area
- Figure 2 – Boundary Condition Locations
- Figure 3 – DWSE and MTOL Profiles

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Location Map

SOURCES:
California DWR - State-Federal Levees
ESRI - City/County Boundary
Microsoft Virtual Earth - Aerial Background



WOOD RODGERS

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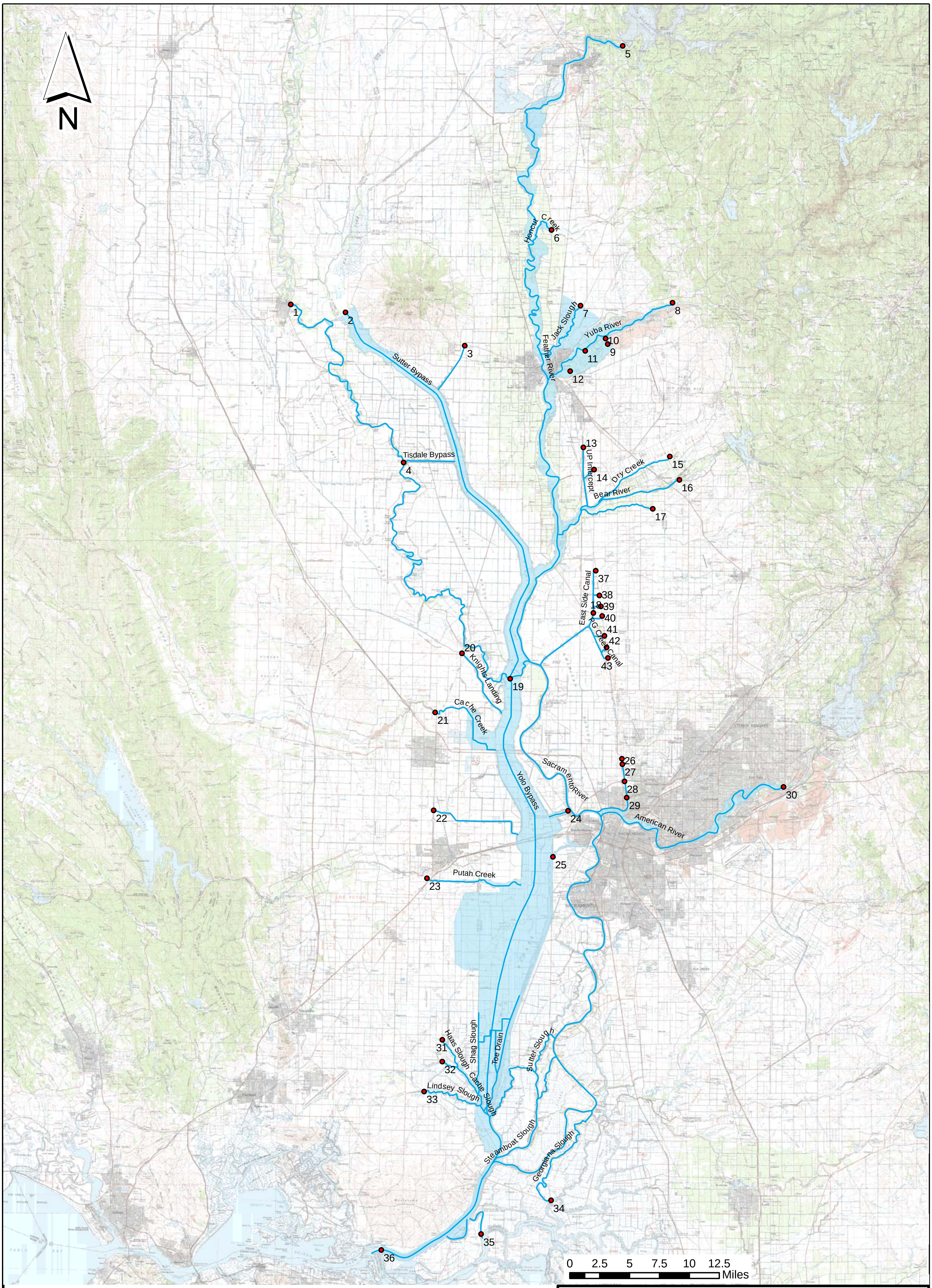
FIGURE 1



Legend

● Boundary Condition Locations

— Stream Centerlines

▨ Modeled Channel

American River Watershed Common Features GRR

Sacramento Basin HEC-RAS Model Development

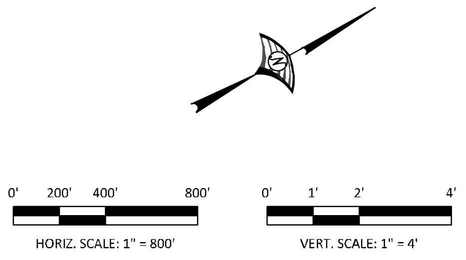
Boundary Condition Locations

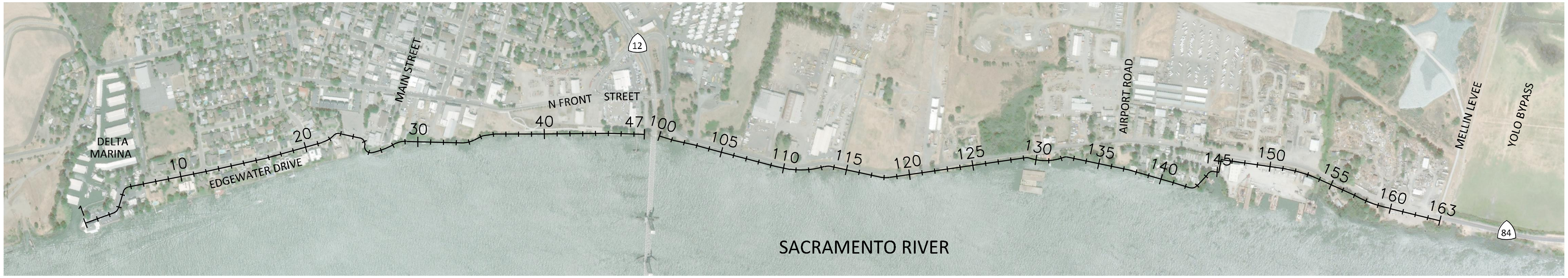
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

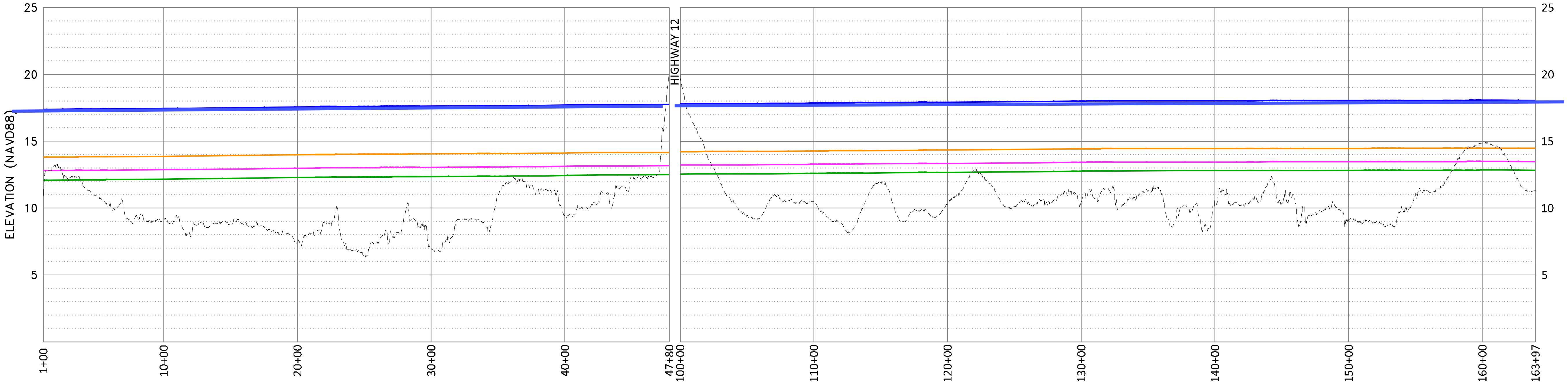
FIGURE 2

SOLANO COUNTY WATER AGENCY
RIO VISTA FLOOD PROTECTION FEASIBILITY STUDY
WATER SURFACE ELEVATION PROFILE

FEBRUARY, 2018







SOUTH OF HWY 12

NORTH OF HWY 12

NOTES:
1. WATER SURFACE ELEVATIONS WERE BASED ON INFORMATION PROVIDED BY MBK ENGINEERS DATED JANUARY 2018.

LEGEND

- 200-YR WSE +SLR +1' UNCERTAINTY +3' FB (MTOL)
- 200-YR WSE +SLR +1' UNCERTAINTY
- 200-YR WSE +SLR
- 200-YR WSE
- – – – – – – EXISTING GROUND

Recommended DWSE, Adjustment Factors, and MTOL

Scenario	Location Sacramento River at the Delta Marina (feet)	Sacramento River at State Highway 12 (feet)	Sacramento River at the Mellin Levee (feet)
Base 200-year WSE	12.05	12.55	12.85
200-year WSE with SLR (Year 2062)	12.77	13.22	13.49
Uncertainty Adjustment	1	1	1
Adjusted DWSE	**13.77**	**14.22**	**14.49**
Settlement	0.58	0.58	0.58
Wind / Wave / Freeboard Adjustment	3.19	3.19	3.19
Recommended MTOL	**17.54**	**17.99**	**18.26**

MBK ENGINEERS
CONSULTING ENGINEERS

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Sacramento, CA 95816 Fax 916.341.7767

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FIGURE 3

Attachment B: Existing and Future Floodplains TM

TECHNICAL MEMORANDUM

PREPARED FOR: Mr. Jeff M. Barich, P.E., Solano County Water Agency

PREPARED BY: Mr. Jesse J. Patchett, P.E., CFM, Wood Rodgers, Inc.
Mr. Chuck Hilliard, P.E., Wood Rodgers, Inc.

REVIEWED BY: Mr. Jonathan Kors, P.E., Wood Rodgers, Inc.

DATE: March 20, 2018

SUBJECT: Rio Vista Flood Control Feasibility Study – Determination of Existing and Future Floodplains

INTRODUCTION

The City of Rio Vista (City) and the Solano County Water Agency (SCWA) are in the process of developing the Rio Vista Flood Control Feasibility Study (Feasibility Study). The Feasibility Study is being prepared by way of a California Department of Water Resources (DWR) Small Communities Flood Risk Reduction Program grant. The area to be included in the Feasibility Study extends along the west bank of the Sacramento River at Rio Vista from Marina Creek to the Mellin Levee. Evaluation of the Mellin Levee is also included in the study. An overview of the Project area is shown on **Figure 1** (attached).

The goal of the Feasibility Study is to identify a preferred alternative that will reduce the risk of flooding in Rio Vista and that is compatible with the City's Waterfront Specific Plan and the DWR Sacramento River Basin-Wide Feasibility Study (BWFS). In order to assess the potential flood damage to properties under a 200-year flood event, floodplains resulting from water surface elevations representing a 200-year flood event in the Sacramento River were developed.

Since the Sacramento River transitions from being tidally-influenced to being riverine-controlled during large flood events near Rio Vista, a sea-level rise (SLR) has the potential to affect future water surface elevations in this area. Therefore, 200-year floodplains were developed for existing conditions and future conditions. For future conditions, inland climate change is not included in this analysis; sea level rise projections is based on mid-century estimate consistent with that of the Central Valley Flood Protection Plan 2017 Update.

The existing and future floodplains were used to estimate the number of residential, commercial/ industrial, and agricultural properties that could potentially be impacted by flooding. The existing and future floodplains were also used to identify potential impacts to critical facilities and infrastructure such as highways, municipal wells, water/wastewater treatment facilities, hospitals, police/fire stations, etc.

This Technical Memorandum (TM) describes the assumptions, approach, and results of the existing and future floodplains analyses.

BACKGROUND

The existing and future design water surface elevations in the Sacramento River are described in the March 15, 2018 TM titled *Rio Vista Flood Control Feasibility Study – Design Water Surface Elevation* (Reference 1, DWSE TM) prepared by Wood Rodgers, Inc. (Wood Rodgers) and MBK Engineers (MBK). The existing and future 200-year design water surface elevations from the DWSE TM are presented below in

Table 1 and **Table 2**.

TABLE 1 – Existing 200-year Design Water Surface Elevations

	Sacramento River at the Delta Marina (feet)	Sacramento River at California State Route 12 (SR 12) (feet)	Sacramento River at the Mellin Levee (feet)
Base 200-year WSE	12.05	12.55	12.85
Uncertainty Adjustment	1.00	1.00	1.00
Adjusted DWSE	**13.05**	**13.55**	**13.85**

Note: Elevations are in North American Vertical Datum of 1988 (NAVD 88).

TABLE 2 – Future 200-year Design Water Surface Elevations

	Sacramento River at the Delta Marina (feet)	Sacramento River at SR 12 (feet)	Sacramento River at the Mellin Levee (feet)
200-year WSE with SLR	12.77	13.22	13.49
Uncertainty Adjustment	1.00	1.00	1.00
Adjusted DWSE	**13.77**	**14.22**	**14.49**

Note: Elevations are in NAVD 88.

APPROACH

The existing and future DWSEs in the Sacramento River were projected landward (west) and compared to available DWR Light Detection and Ranging (LiDAR) Topographic Mapping for the Feasibility Study area in order to estimate the extents of the respective 200-year floodplains. Based on this analysis, the number of parcels and critical facilities within the existing and future floodplains were determined using the Solano County Assessor's parcel and land use data as well as information provided by the City and SCWA.

ASSUMPTIONS

For purposes of this TM, it is assumed that parcels identified within the floodplain are developed, or would be developed in accordance with their current land use designations.

RESULTS

The existing and future 200-year floodplains are shown on **Figure 2** and **Figure 3**, respectively. The estimated number of residential, commercial/industrial, agricultural, and public parcels impacted by the existing and future floodplains are shown in **Table 3** below.

Table 3: Parcels and Acreage Affected by the 200-Year Floodplain

Land Use	Existing 200-Year Floodplain		Future 200-Year Floodplain	
	No. of Parcels	Acres	No. of Parcels	Acres
Residential	126	36	140	40
Commercial / Industrial	61	128	61	140
Agricultural	1	4	2	5
Public (Excludes Roads)	23	19	27	168
Total	**211**	**187**	**230**	**354**

In addition to the parcels and acreage impacted by the existing and future floodplains shown in the table above, a number of critical facilities are also impacted as shown on Figures 2 and 3. Identified critical infrastructure and facilities within the existing and future floodplains include:

- City of Rio Vista City Hall
- Four sewer lift stations
- Two public water supply wells
- State Route 84

Therefore, elevated river stages in the Sacramento River could impact or disrupt the water supply in the City, disrupt the City's wastewater collection systems, and impact emergency response efforts. Additionally, regional transportation would be impacted with the inundation of SR 84 upstream of SR 12. SR 84 is a primary transportation corridor that connects Ryer Island to points west including Rio Vista and the San Francisco Bay Area via the Ryer Island Ferry.

CONCLUSION

The existing and future floodplains prepared for the Feasibility Study indicate that a significant number of properties within the City are at risk of being flooded during a 200-year flood event. This analysis also indicates that several municipal services as well as SR 84 would be impacted during a 200-year flood event. Impacts associated with SLR are expected to increase the number of properties impacted in the future.

NEXT STEPS

Alternatives to reduce the risk of flooding to people and properties within the City will be developed and evaluated as part of the Feasibility Study. The information included in this TM will be used to assess the effectiveness of the alternatives.

REFERENCES

1. Wood Rodgers, Inc. & MBK Engineers, *Rio Vista Flood Control Feasibility Study – Design Water Surface Elevation,* March 15, 2018.

Enclosures:

Figures
- Figure 1 – Feasibility Study Project Area
- Figure 2 – Existing 200-year Floodplain
- Figure 3 – Future 200-year Floodplain

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
Location Map

SOURCES:
California DWR - State-Federal Levees
ESRI - City/County Boundary
Microsoft Virtual Earth - Aerial Background

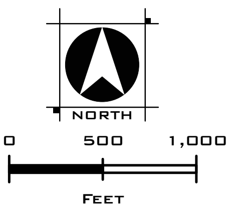

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FIGURE 1

Land Within 200-yr Existing Floodplain

Land Use	# of Parcels	Total Acreage
Residential	126	36
Commercial/ Industrial/ Manufacturing	61	128
Agricultural	1	4
Public	23	19
TOTAL	**211**	**187**

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
200-Yr Existing Floodplain Exhibit

NOTE:
FLOODPLAIN EXTENTS WERE DEVELOPED BY PROJECTING THE EXISTING 200-YR WSE IN THE SACRAMENTO RIVER LANDWARD (WEST) OVER EXISTING LIDAR TOPOGRAPHY.

NORTH
0 500 1,000
FEET

WOOD RODGERS

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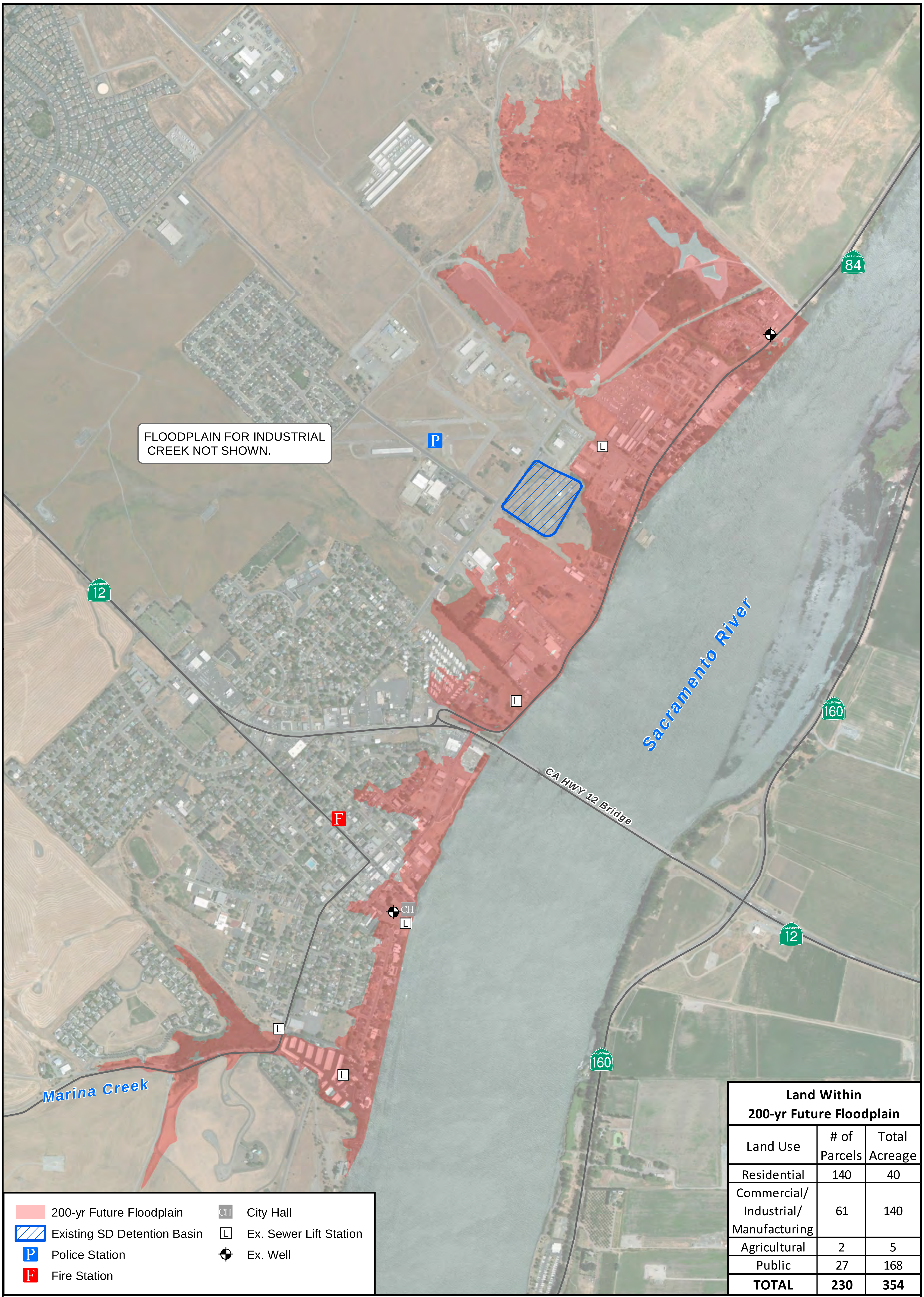
FIGURE 2



Land Within 200-yr Future Floodplain		
Land Use	# of Parcels	Total Acreage
Residential	140	40
Commercial/ Industrial/ Manufacturing	61	140
Agricultural	2	5
Public	27	168
TOTAL	**230**	**354**

Solano County Water Agency
Rio Vista Flood Protection Feasibility Study
200-Yr Future Floodplain Exhibit

NOTE:
FLOODPLAIN EXTENTS WERE DEVELOPED BY PROJECTING THE 200-YR FUTURE WSE IN THE SACRAMENTO RIVER LANDWARD (WEST) OVER EXISTING LIDAR TOPOGRAPHY.

J:\Jobs\8246-Solano County Water Agency\8246008 Rio Vista Feasibility Study\GIS\Tasks\FIG_03_Future_200-yr_Floodplain.mxd 2/22/2018 10:23:25 AM chilliard

FIGURE 3

Attachment C: Geotechnical Exploration and Evaluation TM

Memo

To: Jesse Patchett, PE

From: Josh Zupan, PE, PhD

Reviewed By: Graham Bradner, CEG and Mark Freitas, PE, GE

Date: December 13, 2019

Re: Geotechnical Evaluations to Support Development of Selected Rio Vista Flood Control Feasibility Study Alternatives

---

Background and Purpose

Wood Rodgers has been contracted by the Solano County Water Agency (SCWA) to perform a Flood Control Feasibility Study (FCFS) for the city of Rio Vista, CA (City). GEI Consultants (GEI) is providing geotechnical services to Wood Rodgers for the study under the Agreement between Wood Rodgers and GEI dated November 3, 2017.

Rio Vista is located along the west bank of the Sacramento River in Solano County, California, just downstream of the confluence of the Yolo Bypass and the Sacramento Deep Water Ship Channel, Steamboat Slough, and Sacramento River. This location makes the City vulnerable to external flooding from the Sacramento River and the Yolo Bypass. Internal drainage deficiencies also cause flooding in localized areas of the City. Some flood protection along the Sacramento River is provided by an existing cement-mortar unit (CMU) flood wall that extends from the dock at the end of Montezuma Street to just north of Main Street, but Rio Vista remains susceptible to flooding from minor flood events and high tides (Wood Rodgers, 2015). The project study area is shown in Figure 1.

The Mellin Levee is located along the right bank of the Yolo Bypass immediately upstream of the confluence with the Sacramento River, and it provides some protection to the City from flooding within the Yolo Bypass (Figure 1). The levee extends several miles upstream, but the portion of the Mellin Levee included in the FCFS is limited to that which directly protects the City as determined by hydraulic modeling and analyses.

The FCFS includes an evaluation of improvement alternatives to reduce the risk of flooding in the City. To support the development and evaluation of alternatives, GEI has performed the following analyses/evaluations at the request of Wood Rodgers:

1. Evaluate the required embedment depth for a sheetpile flood wall alternative and provide general design considerations;
2. Evaluate the required pile embedment depths and pile lateral displacements for a pile-supported concrete flood wall alternative; and
3. Provide a preliminary (qualitative) evaluation of the Mellin Levee.

The purpose of this memorandum is to summarize the results/conclusions of the requested analyses/evaluations.

Geotechnical Data

Previous subsurface/geotechnical explorations within the FCFS study area included the following:

1. Sixteen borings performed by the State of California, Division of Highways in the vicinity of the west approach to the SR-12 Sacramento River Bridge in 1958;
2. Four borings performed by Construction Testing Services, Inc. (CTS) to support the Rio Vista Waterfront Promenade Project in 2008 (CTS, 2008); and
3. Four additional borings performed by CTS in 2011 to support the design of potential flood wall improvements along the Sacramento River right bank between the Rio Vista City Hall and SR-12 (CTS, 2011).

Historical boring logs are included in the FCFS Geotechnical Exploration Work Plan (GEI, 2018).

To supplement the existing geotechnical data, GEI performed the following subsurface explorations in March and April 2018:

1. Hollow-stem auger/mud-rotary borings at three locations along the Sacramento River right bank;
2. Cone penetration tests (CPTs) at six locations along the Sacramento River right bank;
3. Hollow-stem auger/mud-rotary borings at one location at the toe of the Mellin Levee; and
4. CPTs at two locations along the toe of the Mellin Levee.

Drilling, sampling, and field testing procedures for the GEI explorations are described in the FCFS Geotechnical Exploration Work Plan (GEI, 2018). The Work Plan also includes a description of soil classification/description procedures and laboratory testing.

The explorations performed by GEI are summarized in Table 1 and the locations are shown in Figure 2. Boring logs are provided in Appendix A, CPT data are provided in Appendix B, and laboratory test data are provided in Appendix C.

In summary, the analyses/evaluations described herein are based on the following:

1. The geotechnical explorations (i.e., borings and cone penetration tests) shown in Figure 2;
2. The subsurface profile along the Sacramento River right bank shown in Figures 3 and 4;
3. The geotechnical data summarized in Figures 5 through 8; and
4. The subsurface profile along the Mellin Levee shown in Figure 9.

Sheetpile Flood Wall Alternative

Evaluation Scope

One of the alternatives evaluated by Wood Rodgers to protect Rio Vista from flooding by the Sacramento River is a cantilever sheet pile flood wall. Draft sheet pile wall calculations were performed by Wood Rodgers and the geotechnical parameters applied in the analyses were reviewed by GEI. The preliminary sheet pile wall geometry provided by Wood Rodgers is shown in Figure 10 and the calculations are included in Appendix D. The conclusions from GEI's review were provided to Wood Rodgers by email and included the following:

1. The active pressures selected by Wood Rodgers appear to be on the conservative side for the predominantly coarse-grained materials and silty materials of Unit Nos. 1, 4, and 5 (refer to Figures 3 through 8). The selected pressures could be refined for each unit using available subsurface data. However, performing a relatively-simple analysis with some conservatism at this stage of the project was judged to be reasonable.

2. Within Reach 1 and extending into Reach 2 to about Station 43+50, the available subsurface data indicate that a relatively-thick layer of soft clay (Unit No. 2) may be present. Although the active pressures selected by Wood Rodgers are on the conservative side for the predominantly coarse-grained layers, Unit No. 2 is a weaker material and analyses assuming undrained response of the soft clay had not been performed. GEI recommended that analyses incorporating an undrained response of Unit No. 2 be performed to confirm that the embedment depths estimated by Wood Rodgers are sufficient for this section of the project.

Wood Rodgers subsequently requested that GEI perform the calculations described in bullet No. 2.

The following subsections of this memorandum summarize feasibility-level sheet pile wall design considerations and the approach to estimate the minimum depth of embedment for the sheet pile flood wall alternative within Reach 1 and up to about Station 43+50 (within Reach 2).

Sheet Pile Flood Wall (I-wall) General Design Considerations

The sheet pile flood wall alternative was developed by Wood Rodgers and the geometry is shown in Figure 10. This type of wall is referred to as an I-wall by the United States Army Corps of Engineers (USACE).

The design of I-walls has been a topic of much study by the USACE over the past 13 years, following a number of failures in the flood protection system in New Orleans, LA during Hurricane Katrina in August 2005. Failure mechanisms of I-walls were investigated by the Interagency Performance Evaluation Taskforce (IPET, 2007), and several case histories are presented by Duncan et al., (2008). Four failures and breaches during Hurricane Katrina occurred before the water level reached the top of the wall and were not caused by overtopping erosion. One of the key findings in the evaluation of case histories described by Duncan et al. (2008) was the development of a gap behind the I-wall as the water level rose and caused the wall to deflect.

In April 2011, the USACE issued interim guidance for the design of I-walls (EC 1110-2-6066). While the interim guidance expired in March 2013, updates to this document have not yet been made available. Thus, the interim guidance provided in EC 1110-2-6066 represents the most-recent and likely the most-relevant design guidance available for the proposed sheet pile wall alternative for the project.

Several design considerations taken from EC 1110-2-6066 that are pertinent to the Rio Vista Flood Control Feasibility Study include:

1. Based on the results of the IPET study and associated lessons learned, I-walls should be used only in instances where other flood barrier types are impractical.

2. Large lateral deflections of I-walls may occur on flat ground with soft soil conditions. For I-walls constructed on existing levees or in soft soils, the height of the I-wall as measured on the protected side should be limited to 6 feet. Field load tests at a soft soil site were completed by the USACE New Orleans District (MVN) after the preparation of the draft EC 1110-2-6066 document. At this site, the wall deflected more than anticipated, and based on the field test results, MVN reduced the maximum height of the I-wall to 4 feet.

3. The USACE considers normally-consolidated to slightly-overconsolidated soft clays, silts, or peat having an SPT resistance less than 4 blows per foot or shear strength less than 500 psf to be troublesome foundation conditions when these materials are located within 10 feet of the original ground surface. If these conditions exist, feasibility-level design for flood protection should be completed using T-based flood walls, L-walls, or levees. I-walls can be substituted for other wall types or levees during subsequent design phases if they meet the design criteria presented in EC 1110-2-6066.

4. All I-walls should be designed in accordance with the strength, stability, and deflection criteria/requirements described in Chapter 6 of EC 1110-2-6066.

5. I-walls should not overtop or fail during the authorized design flood. In addition, I-walls should have sufficient reliability, resilience, and redundancy to survive a specified depth and duration of overtopping and/or interior flooding without catastrophic failure during events that exceed the design flood. Damage caused should be repairable prior to the next major storm. Scour protection from overtopping of structures should be built into selected areas that are intended to overtop first.

6. I-walls serving as flood control barriers are critical structures and cannot be designed or evaluated based on limited site information.

7. I-walls should be designed to be stable with a gap between the wall and the levee on the water side of the wall, with hydrostatic pressure acting through the depth of the gap.

8. Interlocks of hot-rolled sheet piles were found by the IPET to have lower permeability and higher strength than cold-formed sheet piles. Cold-formed sheet piling should not be used in I-walls that serve as a flood barrier.

9. Precast prestressed concrete sheet piles can undergo settlement due to dead weight. Consolidation settlement of the soft clay layer would be expected due to an applied load increment.

10. Vinyl sheet piles are not permitted for I-walls acting as flood protection barriers.

11. Loss of protection due to lowering the top of the flood barrier relative to the design water levels (e.g., due to local settlement) should be accounted for in the design of the system.

Required Embedment Depth

The required embedment depth for a cantilever sheet pile wall was estimated by evaluating rotational stability assuming rigid body rotation of the sheet pile wall and using classical earth pressure theory. Embedment depth calculations are based on an idealized section, judged to be the critical section, within Reach 1 and up to about Station 43+50 (within Reach 2). The idealized section is shown in Figure 11. The section assumes the soft clay unit extends from the ground surface to a significant depth such that the wall will be entirely embedded in soft clay.

Preliminary calculations to estimate the required depth of embedment were performed in general accordance with the chart-based procedure described by US Steel (1984) for a cantilever sheet pile wall in cohesive soil with granular backfill. The applied chart from US Steel (1984) is shown in Figure 12. To apply this solution the design flood load was idealized as a granular backfill with a unit weight equal to the unit weight of water. The preliminary calculations indicate a required embedment depth of 16 feet. A summary of the preliminary calculations is provided in Table 2.

As described in Chapter 6 of EC 1110-2-6066, the embedment depth should also be estimated/checked assuming a gap forms behind the I-wall (i.e., on the flood side). The required assumptions for the gap analysis described in EC 1110-2-6066 are somewhat unclear, but the USACE has recently developed a software program to perform the analysis (Corps_I-Wall Version 2.0; USACE ERDC, December 2018). This program is not yet available to the public, but it should be used when made publicly available to confirm the design embedment depth at later stages of design.

In lieu of performing a gap analysis at this time and given the recent and ongoing changes in USACE design guidance for I-walls since Hurricane Katrina, it is recommended that an additional contingency factor of 1.5 be applied to the preliminary calculated embedment depth using the classical US Steel approach. Therefore, the recommended depth of embedment within Reach 1 and up to about Station 43+50 can be taken as 24 feet for the purpose of estimating costs at the feasibility level.

It is noted that EC 1110-2-6066 requires the calculated embedment depth to be compared to empirically-based minimum depths. In this case, the recommended embedment depth of 24 feet exceeds the empirically-based minimum depth of two times the exposed height of the wall (18 feet).

Another consideration for the required depth of embedment is that the foundation soils have sufficient resistance against the applied vertical loads transferred by the sheet piles. Based on the drawing provided by Wood Rodgers (Figure 10), the applied vertical loads include the self-weight of the sheet piles and the weight of the concrete cap. The resistance from the foundation soils is transferred through skin friction along the sides of the sheet piles. A preliminary calculation was performed for NZ 19 Hot-Rolled Steel Sheet Piles embedded 24 feet into the soft clay encountered at shallow depths in Reach 1 and up to about Station 43+50. The calculated factor of safety for vertical loading was greater than 3.

Conclusions and Recommendations

The following conclusions and recommendations are offered:

1. The sheet pile flood wall is referred to as an I-wall by the USACE. In response to a number of failures in New Orleans, LA during Hurricane Katrina in August 2005, the USACE has studied I-walls in detail over the past 13 plus years. Interim design guidance was published by the USACE in 2011 (EC 1110-2-6066). While the interim guidance expired in March 2013, updates to the guidance have not yet been made available by the USACE.

2. The USACE is expected to serve in a review capacity as the Rio Vista Flood Control Feasibility Study project advances. Therefore, the interim I-wall design guidance provided by the USACE should serve to guide the development of this alternative at the feasibility level. Several pertinent considerations are noted for this alternative:

    a. The USACE considers normally-consolidated to slightly-overconsolidated soft clays, silts, or peat having an SPT resistance less than 4 blows per foot or shear strength less than 500 psf to be troublesome foundation conditions when these materials are located within 10 feet of the original ground surface. Based on the available geotechnical data, such conditions may exist for the majority of the project alignment (Station 1+00 to about Station 153+00).

    b. The interim guidance requires I-walls constructed in soft soils to be limited to 6 feet, as measured on the protected side. It is unclear if the USACE defines this limitation relative to the design water surface elevation or to the top of the wall including required freeboard. Based on the interim guidance and assuming the wall height is measured to the design water surface elevation, engineered fill placement to raise the grade in the vicinity of the wall may be required in areas where the existing ground surface elevation is below elevation (El.) 9 feet (NAVD88) on the land side.

    c. Placing engineered fill will induce long-term consolidation settlement in the soft clay layer. The induced settlement will be a function of the engineering properties of the soft clay, the layer thickness, and the thickness of the fill materials (i.e., the applied load). Available consolidation test data indicate the soft clay encountered at GEI Boring B-1 is highly compressible. For example, placing a 2-foot thick layer of engineered fill at the ground surface at boring B-1 could cause consolidation settlement at that location on the order of 1.5 feet (see Table 3).

    d. If fill placement is required, long-term consolidation settlements will need to be estimated so that the top of the sheet pile wall elevation can be set to provide the required freeboard and so that the ground surface in the vicinity of the sheet pile wall remains within the USACE wall height maximum throughout the life of the project. Stability analyses would also need to be performed to confirm that fill placement will not cause instability in the areas with shallow soft clays.

    e. Additional geotechnical data (e.g., borings, CPTs, and laboratory tests) will need to be collected in the next phase of the project to improve the understanding of subsurface conditions and to meet the USACE's requirements for ordinary site information.

    f. EC 1110-2-6066 indicates that I-walls should be able to survive a specified depth and duration of overtopping and/or interior flooding without catastrophic failure during events that exceed the design flood. There is some uncertainty in the design criteria with this guidance. At the feasibility level, it may be worth considering including cost allowances for landside scour protection in selected areas which may be designed to overtop first.

3. Based on the available subsurface data and assuming a design water surface elevation of 15 feet, the minimum depth of embedment for a cantilever sheet pile wall between Stations 1+00 and about 43+50 can be taken as 24 feet below the waterside ground surface (dredge line) for this feasibility-level evaluation.
    a. This depth will need to be confirmed with additional analyses, including the gap analysis described in EC 1110-2-6066, during later stages of design.
4. As described previously, the soft clay unit is a highly compressible material. Surface load increments due to fill placement from earthwork activities or structural loads from the foundations of adjacent structures could induce consolidation within the soft clay and cause settlement. If the sheet pile wall is not designed to penetrate completely through the soft clay layer, settlement of the sheet pile wall should be expected and accounted for in the design. For the feasibility-level cost estimate, it is suggested to include an additional 5 feet of sheet pile per lineal foot of wall to account for potential long-term settlements. Additional engineered fill placement may also be required over time to maintain the wall height within the USACE-recommended maximum height.
5. Structural design of the sheet piles has not been performed by GEI. It is recommended that structural design calculations be performed in general accordance with EC 1110-2-6066.

Pile-Supported Concrete Flood Wall Alternative

Evaluation Scope

Wood Rodgers is also evaluating a pile-supported concrete flood wall alternative to protect Rio Vista from flooding by the Sacramento River. As part of this evaluation, Wood Rodgers provided to GEI preliminary wall design geometry (Figure 13) and service axial and shear loads (Figure 14) and requested that GEI calculate the required pile embedment depth and estimate the lateral displacement at the top of the pile. The following subsections of this memorandum summarize the results of the requested feasibility-level analyses.

Pile Embedment Depth

Calculations were performed to estimate the required embedment depth of the pile-supported concrete flood wall within Reach 1 using an idealized soil profile consistent with the subsurface conditions encountered at Station 7+49 for the maximum axial load provided by Wood Rodgers (Figure 14). Soil parameters were selected based on the data summarized in Figure 5. In accordance with the preliminary design geometry provided by Wood Rodgers, the wall was assumed to be supported by 1-foot by 1-foot precast, prestressed driven concrete piles.

Of key importance to the pile evaluations is the presence of the soft clay layer (Unit No. 2 in Figures 3 and 5). The soft clay is weak and highly compressible. Consolidation of this layer could cause drag forces to develop along the length of the piles. Based on the preliminary drawing provided by Wood Rodgers (Figure 13), it does not appear that significant new loading will be applied to the compressible soft clay layer with this alternative. However, a minor load increment may be applied due to excavation and backfill activities associated with construction of the pile cap and final grading. Given the early stages of design, we have included potential drag loads in the pile axial capacity calculations.

For the selected Reach 1 subsurface profile, calculations indicate that a pile toe elevation of -68 feet (approximately 5 feet of penetration into Unit No. 5) will provide sufficient capacity to support the axial loads provided by Wood Rodgers (Figure 14). This corresponds to a pile length of 73 feet below the grade beam.

Not including drag loads, the factor of safety (FS) is about 5.2 for an applied axial load of 32.5 kips. If drag loads develop due to consolidation of the soft clay layer, the FS is about 1.8 for an axial load of 32.5 kips. Based on the pile spacing indicated on Figure 13, the axial capacity of a pile group could be less than the sum of the collective single pile capacities. Quantitative evaluation of group effects is recommended during later stages of design.

Pile Lateral Displacements

Lateral displacements at the top of pile were estimated using the computer software program LPile (Ensoft, 2013) with published soil resistance versus deflection relationships (i.e., p-y curves). Calculations were performed with LPile assuming fixed-head conditions for a single pile. The displacement at the top of the pile was calculated to be about 0.7 inches with an applied shear force of 18.95 kips and axial load of 6.46 kips.

Calculations assuming free-head conditions led to pile head displacements that exceeded the maximum threshold in the software program LPile.

Considering group effects, the displacement at the top of the group is expected to be higher than that of a single pile. Using published simplified relationships, the fixed-head lateral displacement incorporating group effects could be about 1 inch for the applied loads with the provided pile geometry and spacing.

Conclusions and Recommendations

Based on the available geotechnical data and the preliminary wall design information provided by Wood Rodgers, the following conclusions and recommendations are offered:

1. It appears necessary to extend the piles through the soft clay and medium stiff clay and five feet into the underlying SM/ML material (Unit 5) to about El. -68 feet in Reach 1. This analysis is based on evaluation at Station 7+49.

2. It is recommended to assume that this pile embedment depth would be required up to about Station 41+50, where GEI_CPT-3 shows distinctly different foundation conditions. If the pile-supported flood wall alternative were to be considered upstream of Station 41+50, the required pile embedment depths could be shallower, but additional analyses would need to be performed to confirm and select an appropriate embedment depth.

3. The pile tip depth should be refined during later stages of design and may become shallower heading upstream if the SM/ML (Unit 5) also shallows. Additional deep explorations to at least El. -68 ft between GEI_CPT-2 and GEI_CPT-3 will be required as part of this evaluation.

Preliminary Evaluation of the Mellin Levee

Evaluation Scope

A longitudinal profile along the Mellin Levee alignment is shown on Figure 9. The profile shows the approximate levee crest, landside toe, and design water surface elevation along the length of the levee. Subsurface stratigraphy based on two borings and two cone penetration tests (CPTs) performed along the landside toe or landward area for this study is also shown. Investigations were not performed through the levee crest since it is a federal "project" levee, which requires permitting through the U.S. Army Corps of Engineers (USACE), which could not be obtained within the project feasibility study schedule. Further investigations should be performed to characterize the embankment and foundation as the project progresses beyond the feasibility stage.

Information shown on the profile were utilized to evaluate the Mellin Levee primarily for freeboard and underseepage. Insufficient data is available to evaluate the levee for through seepage or embankment stability. However, it should also be noted that through seepage and stability would only need to be considered separately at this time if underseepage and freeboard appear to be satisfactory under existing conditions and thereby not requiring remediation. Based on our initial evaluations the extent of the Mellin Levee within the project appears to require underseepage remediation which are likely to also address through seepage or landside stability concerns depending on the ultimate remediation.

The following subsections of this memorandum include the results of the qualitative Mellin Levee evaluations. General design considerations for conceptual remediation/improvement alternatives are also provided.

Evaluation of Freeboard

1. California Department of Water Resources (DWR) Urban Levee Design Criteria (ULDC) regulations call for a minimum of three feet of freeboard above the 200-year design water surface elevation (DWSE).

2. As shown on Figure 9, the DWSE is 16.4 feet along the length of the Mellin Levee. Based on the available topographic data, the DWSE is above the levee crest along a portion of the levee and within three feet of the levee crest along most of the remainder of the levee. Therefore, the existing Mellin Levee is deficient with respect to freeboard requirements.

Qualitative Seepage Evaluation

1. DWR ULDC requirements for underseepage include a maximum allowable gradient of 0.5 across the blanket layer measured at the landside levee toe. For preliminary evaluations with limited data, underseepage has been evaluated by comparing the head differential above the landside toe with the blanket thickness (i.e. head differential of 8 feet divided by a blanket thickness of 16 feet would result in an average exit gradient of 0.5). It should be noted that this approach ignores head losses created by subsurface seepage flow from the waterside to the landside, typically on the order of a few feet. However, given the relatively sparse available data for the Mellin Levee, the more simplistic evaluation is recommended as

described below. More refined geotechnical analyses should be performed as additional subsurface data is collected and as part of detailed design of levee remediations.

a. The downstream portion of the Mellin Levee between about Station 0+00 and 10+00 appears to have a silt (ML) blanket with a thickness of approximately 8 to 12 feet underlain by a more pervious layer composed of sand with silt and silty sand (SP-SM, SM). The head difference between the DWSE and the landside levee toe over this section of the levee is up to about 8 feet. Based on the available data, this portion of the Mellin Levee would appear to have an approximate exit gradient of 0.7 to 1.0 and would therefore be deficient with respect to underseepage.

b. The upstream portion of the Mellin Levee between about Station 10+00 and 30+00 appears to be underlain by a blanket of soft, compressible clayey soils. Based on the available subsurface data, the thickness of the soft soil appears to vary from about 22 to 30 feet, but with a relatively thin sandy layer near the ground surface that could convey shallow underseepage. The head difference between the DWSE and the landside levee toe over this section of the levee is up to about 9 feet resulting in an approximate exit gradient between 0.3 and 0.4 across the entire blanket thickness. However, exit gradients calculated across the very thin blanket layer overlying the shallow sand stringer are likely to significantly exceed maximum underseepage gradient criteria. This section of the levee will need to be evaluated further after additional subsurface data are collected. At this stage of the project, it is judged to be prudent to assume that underseepage remediations will be required.

Conclusions

1. The Mellin Levee appears to be deficient for freeboard along its entire length within the project study area.

2. The downstream section of the levee between about Stations 0+00 and 10+00 appears to be deficient with respect to underseepage.

3. The upstream section of the levee between about Stations 10+00 to 30+00 may meet ULDC requirements for underseepage across the entire blanket thickness. However, the subsurface data in this section are limited and there may be shallow “leaker” layers in the foundation (e.g., the shallow silty sand layer encountered at boring GEI_B-4). For these reasons, it is judged to be prudent at this stage of the project to assume underseepage remediation will be required along this stretch of levee.

4. Additional subsurface investigations should be performed during the next phase of the project to better characterize the embankment and foundation conditions of the Mellin Levee.

Remediation Design Considerations

1. Soft compressible clayey foundation soils were encountered at GEI_B-4 and GEI_CPT-8. If engineered fill is placed to increase freeboard where compressible soils are present, settlement will occur. The magnitude and rate of settlement will be a function of the amount of fill placed, the thickness and consolidation characteristics of the compressible soil, and other factors. Long-term consolidation settlements could continue for many years after construction. There are several

potential alternatives for accommodating settlement, such as overbuilding the levee such that freeboard requirements are satisfied after long-term consolidation settlements are complete.

2. The soft soils also have low undrained shear strength. During the design phase, stability analyses will be required to check/confirm that the placement of engineered fill to raise the levee will not cause a stability failure during construction. If this is found to be a concern, staged construction may be required.

3. As described above, the available subsurface data is relatively limited at this stage. One objective of the design-phase geotechnical investigation will be to identify with better confidence the portion of the levee that is not underlain by soft soils. Based on the available data, this portion appears to include the downstream end of the levee up to a point between GEI_CPT-7 and GEI_B-4 (refer to Figure 9 for subsurface profile).

4. Remediation due to underseepage appears to be required for the downstream portion of the Mellin Levee and may be required for the upstream portion of the levee. The following remediation alternatives could be considered at the feasibility level:

   <u>Alternative 1 - Conventional Soil-Bentonite Cutoff Wall through the crest of the levee</u>

   i. Based on the available data, a cutoff wall to a depth of about 40 feet (cutoff wall tip EL. = -25 feet) below a working platform at approximately EL. 15 feet should be assumed along the length of the levee.

   ii. Design-phase geotechnical investigations and analyses will provide an opportunity to refine the required depth of the cutoff wall.

   iii. Construction of a cutoff wall will also improve landside stability by reducing pore water pressures during flood events.

   <u>Alternative 2 – Landside Seepage Berm</u>

   i. A seepage berm could be considered to mitigate the underseepage deficiency along the length of the levee.

   ii. A typical approach for estimating seepage berm widths during the DWR Non-Urban Levee Evaluation (NULE) Program was to assume that a berm width of four times the levee height would be sufficient. For the Mellin Levee, this would equal roughly 60 feet (after accounting for the required crest raise). For the purpose of estimating earthwork quantities, the following conservative seepage berm geometry is recommended:

      Total width = 100 feet (inclusive of stability berm described below)
      Average thickness = 4 feet
      Length = 3,000 feet

   iii. Through seepage or stability concerns could also be mitigated by including a drained stability berm in combination with the above described seepage berm. For estimating purposes, the dimensions of the drained stability berm are recommended as:

Top of berm = 16.4 feet (based on DWSE)
Top width = 15 feet
Landside slope = 2H:1V
Length = 3,000 feet

iv. To accommodate short- and long-term settlements associated with fill placement for the seepage berm, it is recommended that a contingency factor of 10% be applied to the estimated earthwork quantities.

v. In addition, the landside topography appears to be irregular over much of the length of the levee and there appears to be a couple of sizeable landside gravel/cobble berms that were constructed along the southeast half of the levee between 2006 and 2008.Additional grading could be required to prepare the footprint of the seepage berm for fill placement.

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Limitations

In the performance of its professional services, GEI, its employees, and its agents comply with the standards of care and skill ordinarily exercised by members of our profession practicing in the same or similar localities. The preliminary analyses/evaluations described herein were based on relatively limited subsurface data. Subsurface conditions at other locations within the study area may differ and additional subsurface investigations will be needed during the next phase of the project to better characterize subsurface conditions within the study area.

No warranty, either express or implied, is made or intended in connection with the work performed by us, or by the proposal for consulting or other services, or by the furnishing of oral or written reports or findings. In the event conclusions or recommendations based on these data are made by others, such conclusions and recommendations are not our responsibility unless we have been given an opportunity to review and concur with such conclusions or recommendations in writing.

Figures

Tables

Appendices

Figures

Solano County Water Agency
Rio Vista Flood Protection Pre-Feasibility Study
Location Map

SOURCES:
California DWR - State-Federal Levees
ESRI - City/County Boundary
Microsoft Virtual Earth - Aerial Background

NORTH

0 500 1,000
FEET

WOOD RODGERS

J:\Jobs\8246-Solano County Water Agency\8246.007 Rio Vista Pre-Feasibility Study\GIS\Tasks\Floodwall\FIG_01_LocationMap_20150130_V1.mxd 01/30/2015 02:29:33 PM jpriest

FIGURE 1

17Oct2018 Z:\Projects\1704795_RioVista\SitePlan_Oct2018.mxd KM/RS

Rio Vista Flood Control Feasibility Study
Rio Vista, California

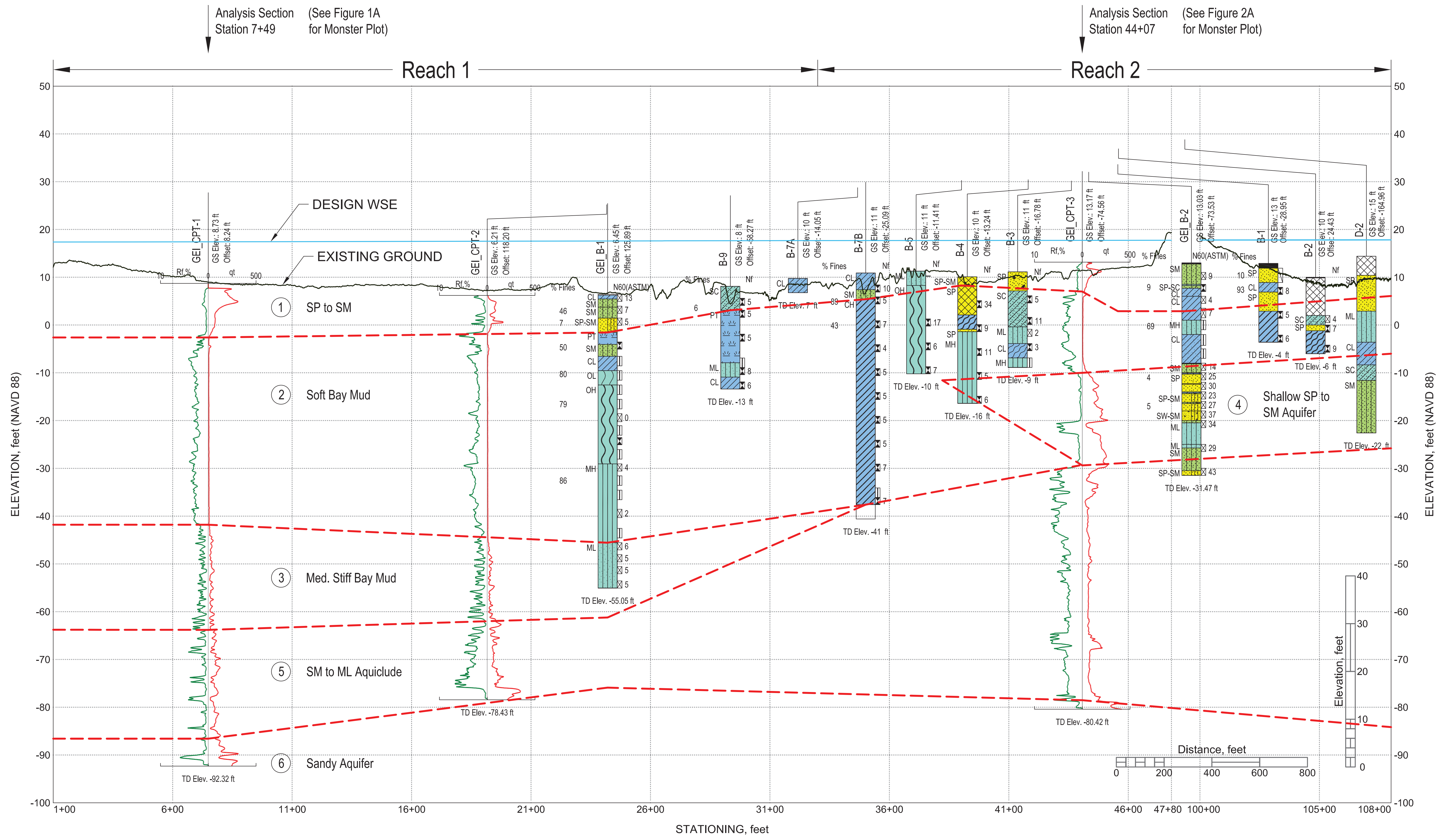
Solano County Water Agency

GEI Consultants

SITE PLAN

OCTOBER 2018

FIGURE 2



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Notes:

1. Projected Existing Ground Surface is along developed project alignment, and does not necessarily represent the top of interpreted stratigraphy.

Rio Vista Flood Control Feasibility Study
Rio Vista, CA

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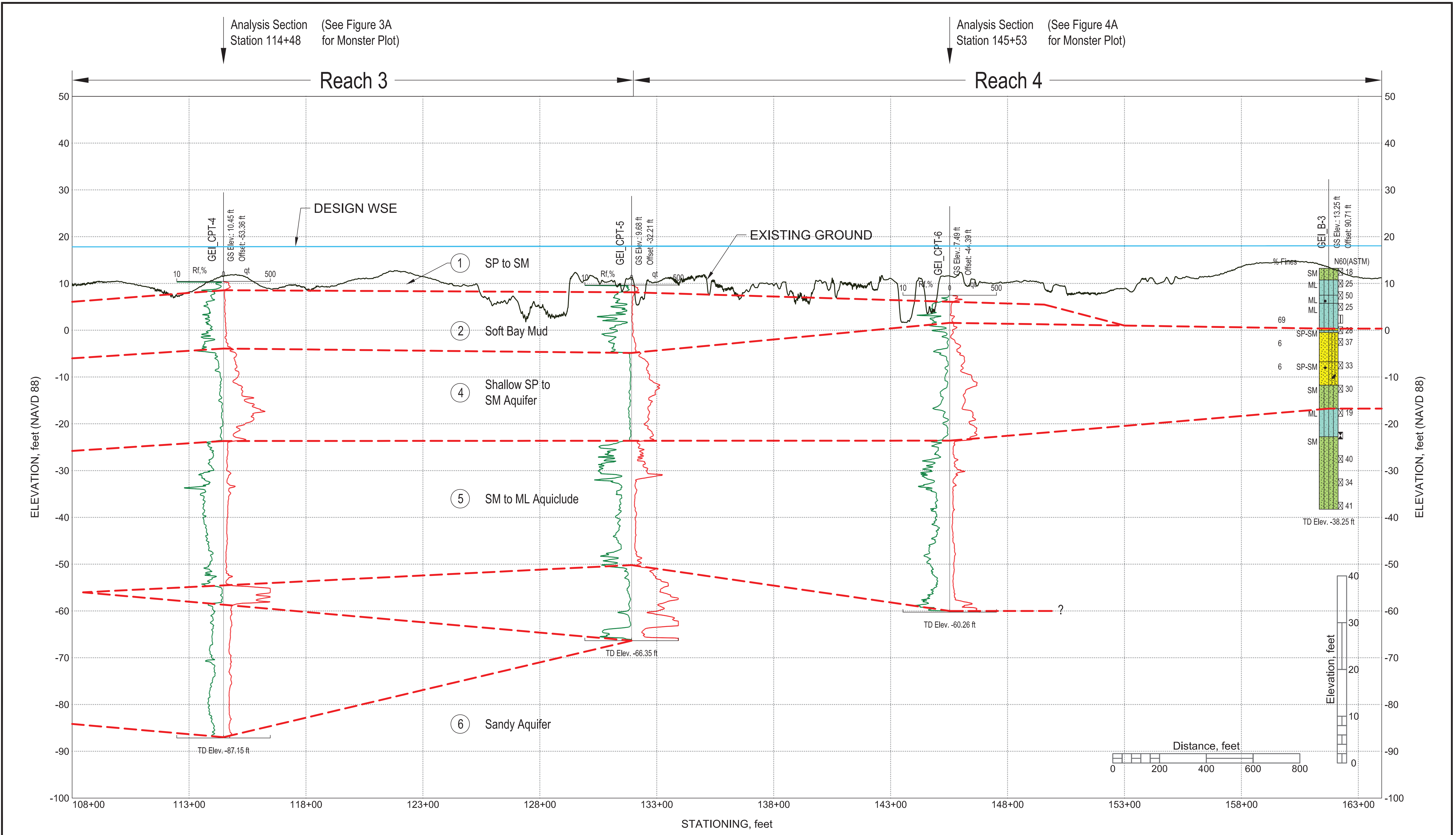
LONGITUDINAL PROFILE
SACRAMENTO RIVER RIGHT BANK

October 2018

Figure 3



Notes:

1. Projected Existing Ground Surface is along developed project alignment, and does not necessarily represent the top of interpreted stratigraphy.

Rio Vista Flood Control Feasibility Study
Rio Vista, CA

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LONGITUDINAL PROFILE
SACRAMENTO RIVER RIGHT BANK

Solano County Water Agency

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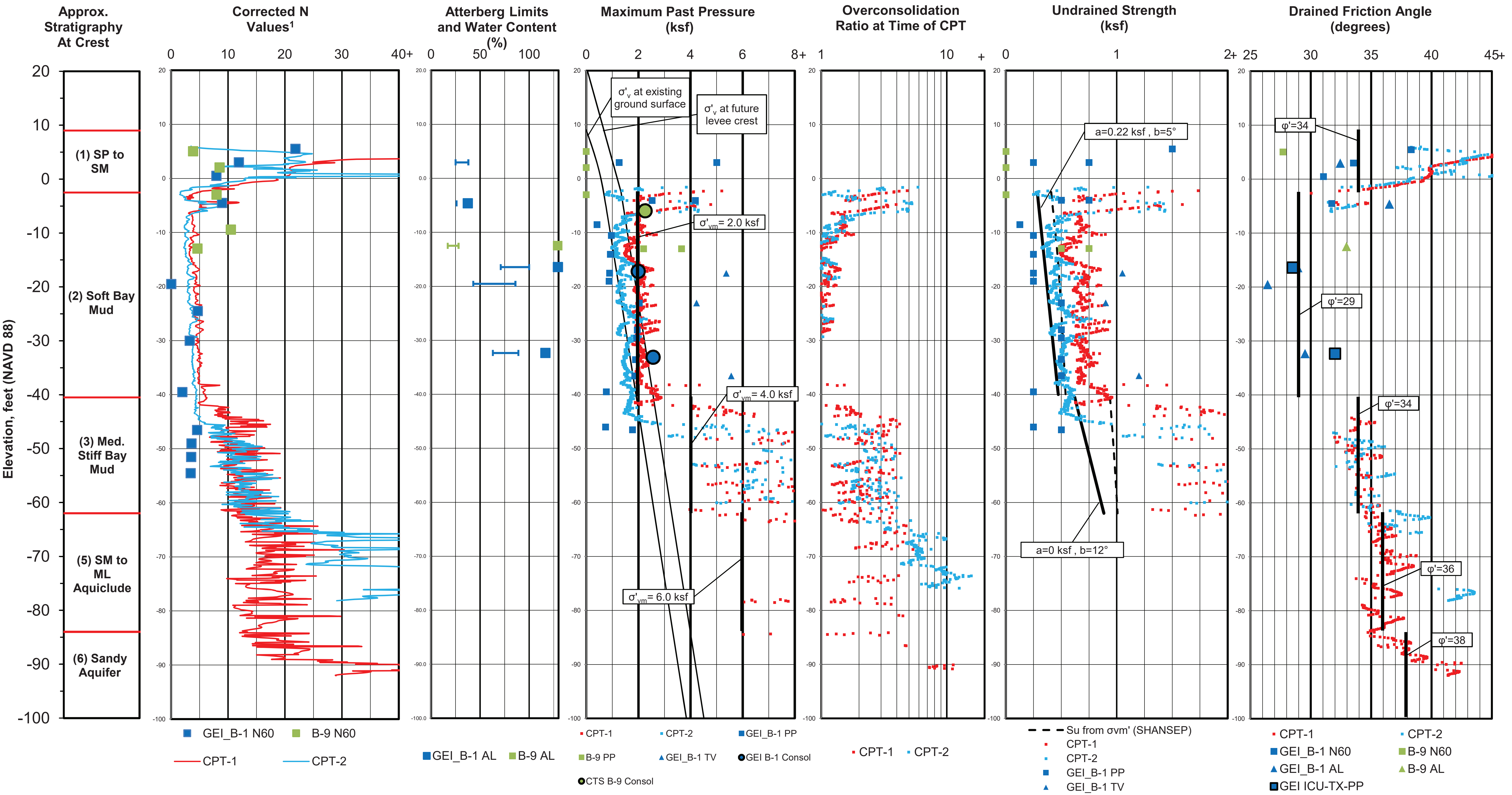
October 2018

Figure 4

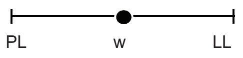
DRAWING: J:\Wood Rodgers\Projects\1704795 Rio Vista Feasibility Study\Task 3 - Problem ID_Data Gathering\3.1 - Geotech Expl_Eval\Analysis\Profiles\Rio Vista Profiles_20181015.dwg



Strength Parameters Used for Analysis:

	Layer	1	2	3	4	5	6
Drained Parameters	c' (psf)	0	220	230	NA	0	0
	ϕ' (deg)	34	29	34	NA	36	38
Undrained Parameters	a (psf)	NA	220	0	NA	NA	NA
	ϕ (deg)	NA	5	12	NA	NA	NA

Legend for Atterberg Limits



Atterberg Limits from Soil Sample

● As Received Water Content

Notes:

1. For clay-like soils, use N_{60}. For sand-like soils, use $N_{1,60}$.
2. LL=Liquid Limit, w=As Received Water Content, PL=Plastic Limit.

Rio Vista Feasibility Study
Solano County, California

City of Rio Vista

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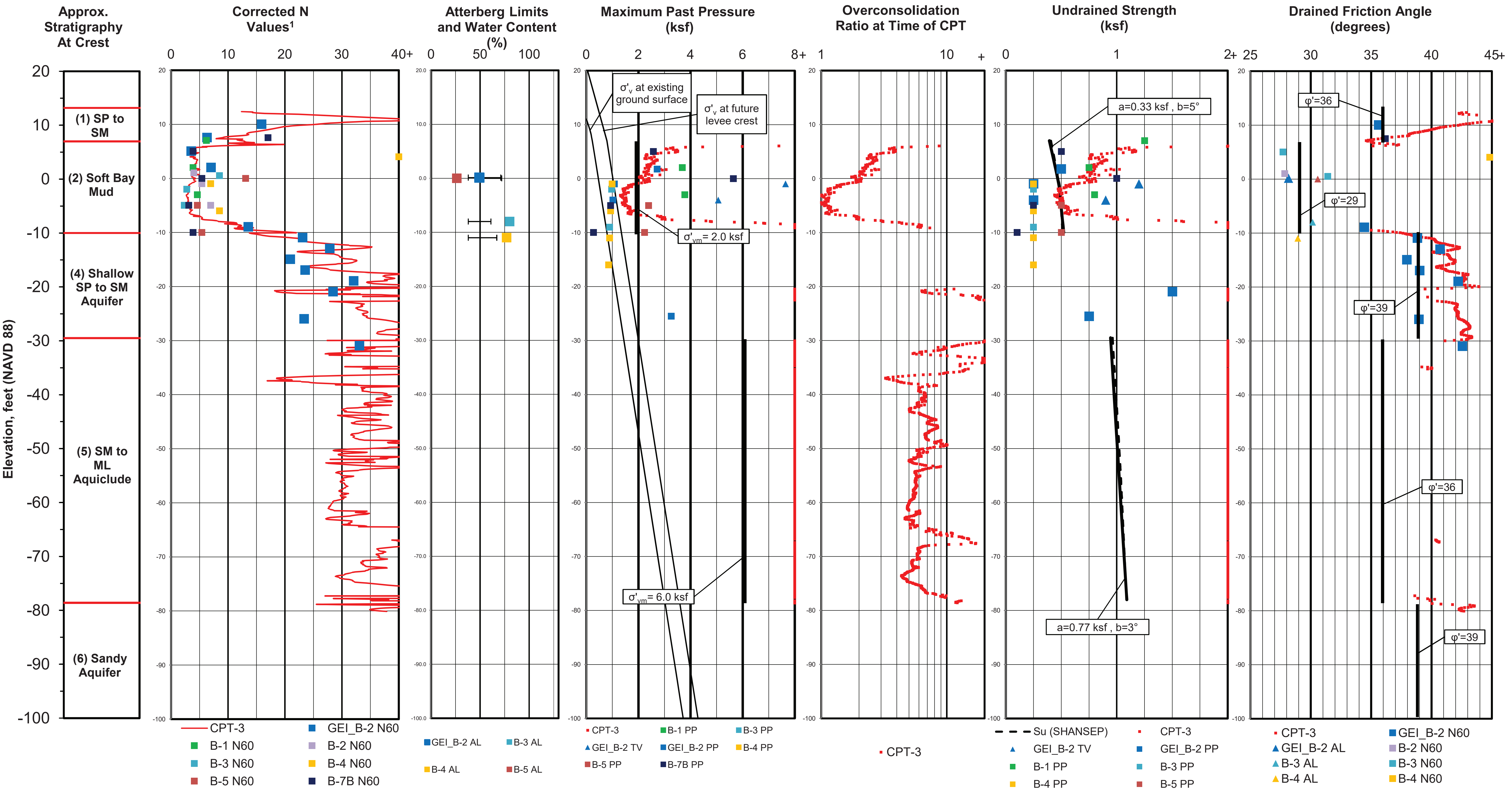
SOIL PROPERTIES VS. ELEVATION
STA. 7+49 (REACH 1)

October 2018

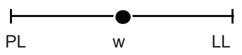
Figure 5



Strength Parameters Used for Analysis:

	Layer	1	2	3	4	5	6
Drained Parameters	c' (psf)	0	220	NA	0	0	0
	ϕ' (deg)	36	29	NA	39	36	39
Undrained Parameters	a (psf)	NA	330	NA	NA	770	NA
	ϕ (deg)	NA	5	NA	NA	3	NA

Legend for Atterberg Limits



Atterberg Limits from Soil Sample

● As Received Water Content

Notes:

1. For clay-like soils, use N_{60}. For sand-like soils, use $N_{1,60}$.
2. LL=Liquid Limit, w=As Received Water Content, PL=Plastic Limit.

Rio Vista Feasibility Study
Solano County, California

City of Rio Vista

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SOIL PROPERTIES VS. ELEVATION
STA. 44+07 (REACH 2)

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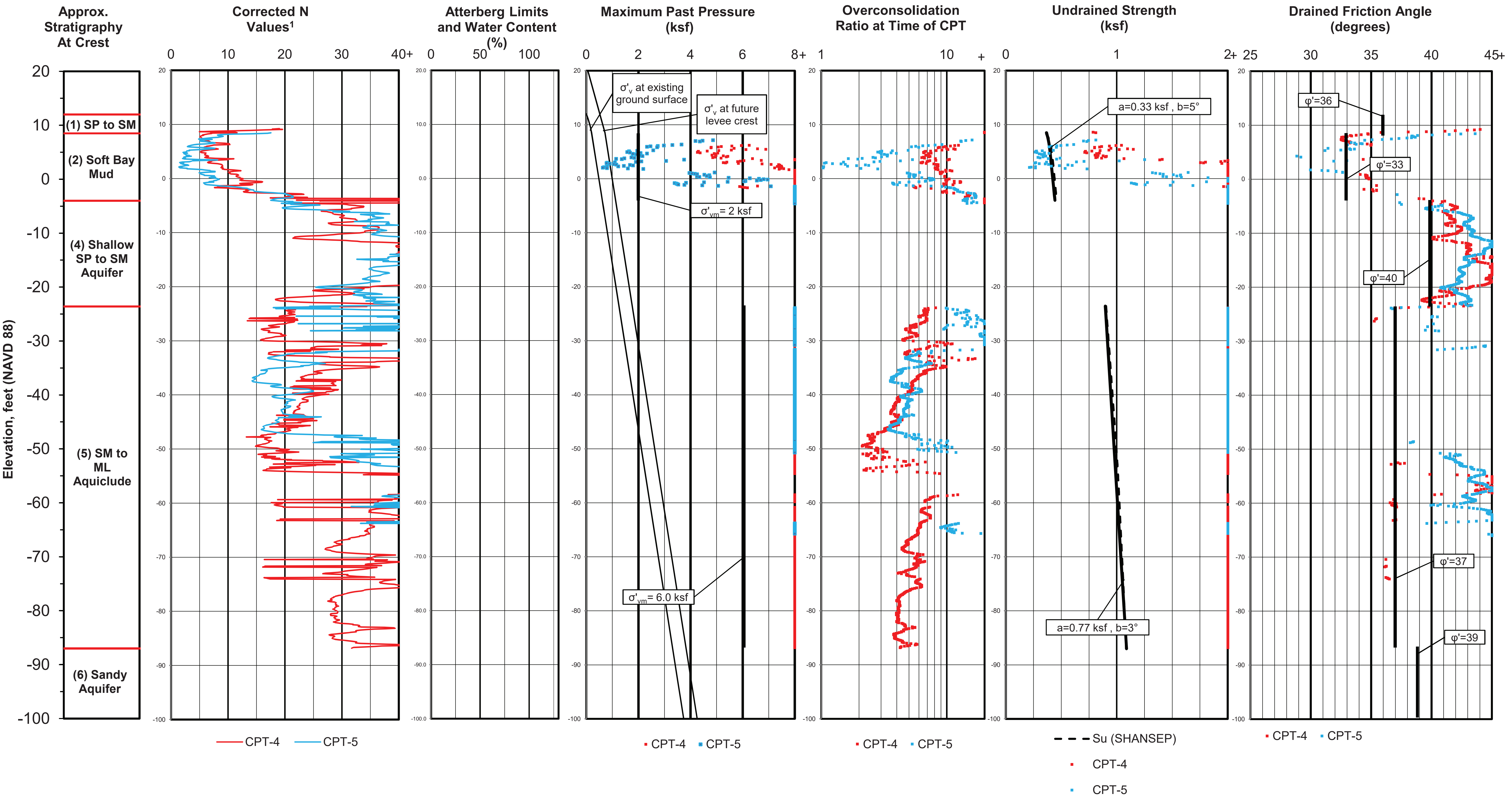
Figure 6



Strength Parameters Used for Analysis:

	Layer	1	2	3	4	5	6
Drained Parameters	c' (psf)	0	100	NA	0	0	0
	ϕ' (deg)	36	33	NA	40	37	39
Undrained Parameters	a (psf)	NA	330	NA	NA	770	NA
	ϕ (deg)	NA	5	NA	NA	3	NA

Legend for Atterberg Limits

PL —●— LL (w) Atterberg Limits from Soil Sample

● As Received Water Content

Notes:

1. For clay-like soils, use N_{60}. For sand-like soils, use $N_{1,60}$.
2. LL=Liquid Limit, w=As Received Water Content, PL=Plastic Limit.

Rio Vista Feasibility Study
Solano County, California

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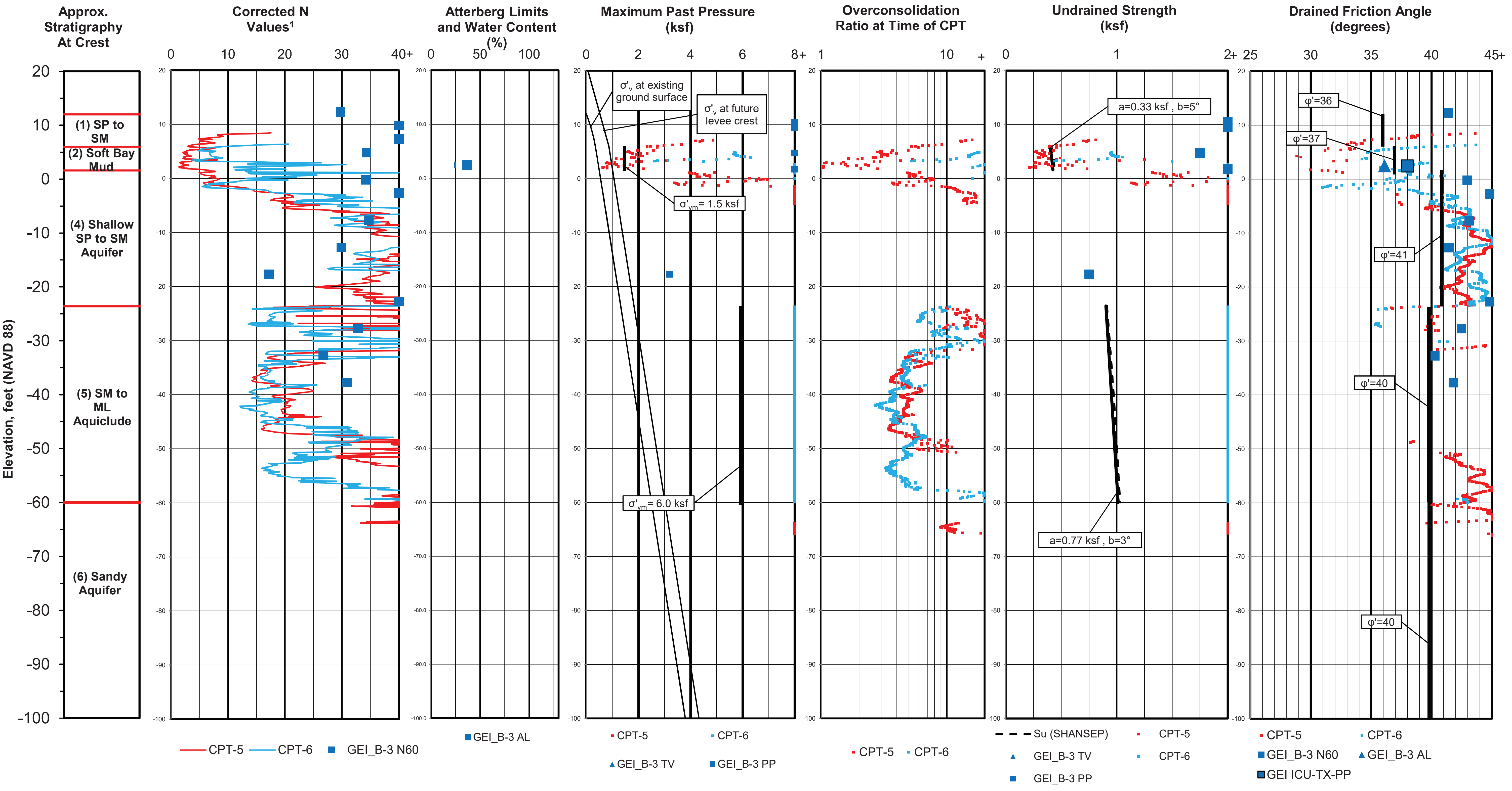
SOIL PROPERTIES VS. ELEVATION
STA. 114+48 (REACH 3)

Project 1704795

October 2018

Figure 7



Strength Parameters Used for Analysis:

	Layer	1	2	3	4	5	6
Drained Parameters	c' (psf)	0	220	NA	0	0	0
	ϕ' (deg)	36	37	NA	41	40	40
Undrained Parameters	a (psf)	NA	330	NA	NA	770	NA
	ϕ (deg)	NA	5	NA	NA	3	NA

Legend for Atterberg Limits

PL w LL — Atterberg Limits from Soil Sample

● As Received Water Content

Notes:

1. For clay-like soils, use N_{60}. For sand-like soils, use $N_{1,60}$.
2. LL=Liquid Limit, w=As Received Water Content, PL=Plastic Limit.

Rio Vista Feasibility Study
Solano County, California

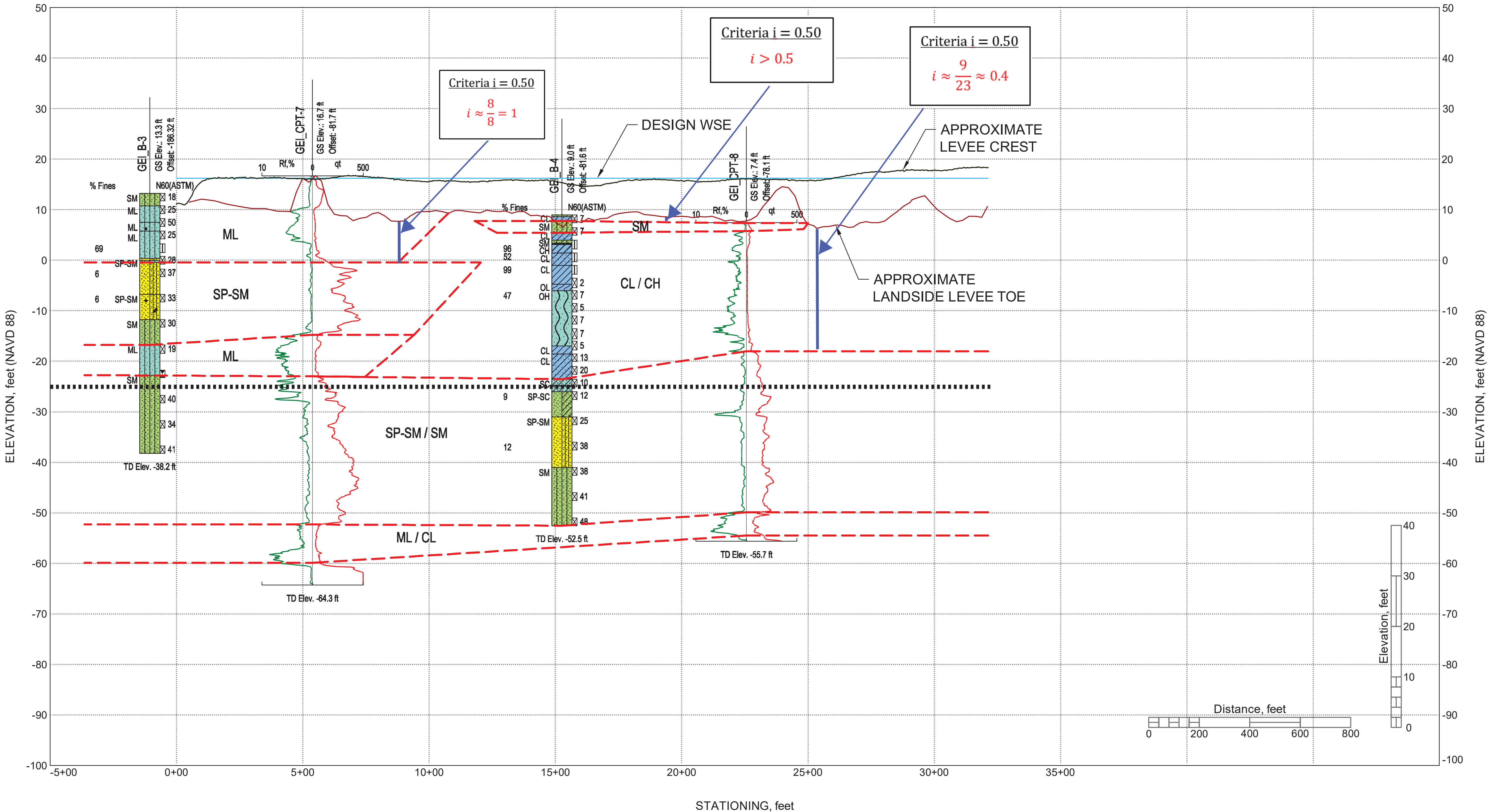
City of Rio Vista

Project 1704795

SOIL PROPERTIES VS. ELEVATION
STA. 145+53 (REACH 4)

October 2018

Figure 8



······ Preliminary cutoff wall depth

Rio Vista Flood Control Feasibility Study
Rio Vista, CA

Solano County Water Agency

GEI Consultants

Project 1704795

LONGITUDINAL PROFILE
MELLIN LEVEE

July 2019

Figure 9

DRAWING: J:\Wood Rodgers\Projects\1704795 Rio Vista Feasibility Study\Task 3 - Problem ID_Data Gathering\3.1 - Geotech Expl_Eval\Analysis\Profiles\Rio Vista Profiles_20190402.dwg

Figure 10. Sheet Pile Wall Geometry Provided by Wood Rodgers

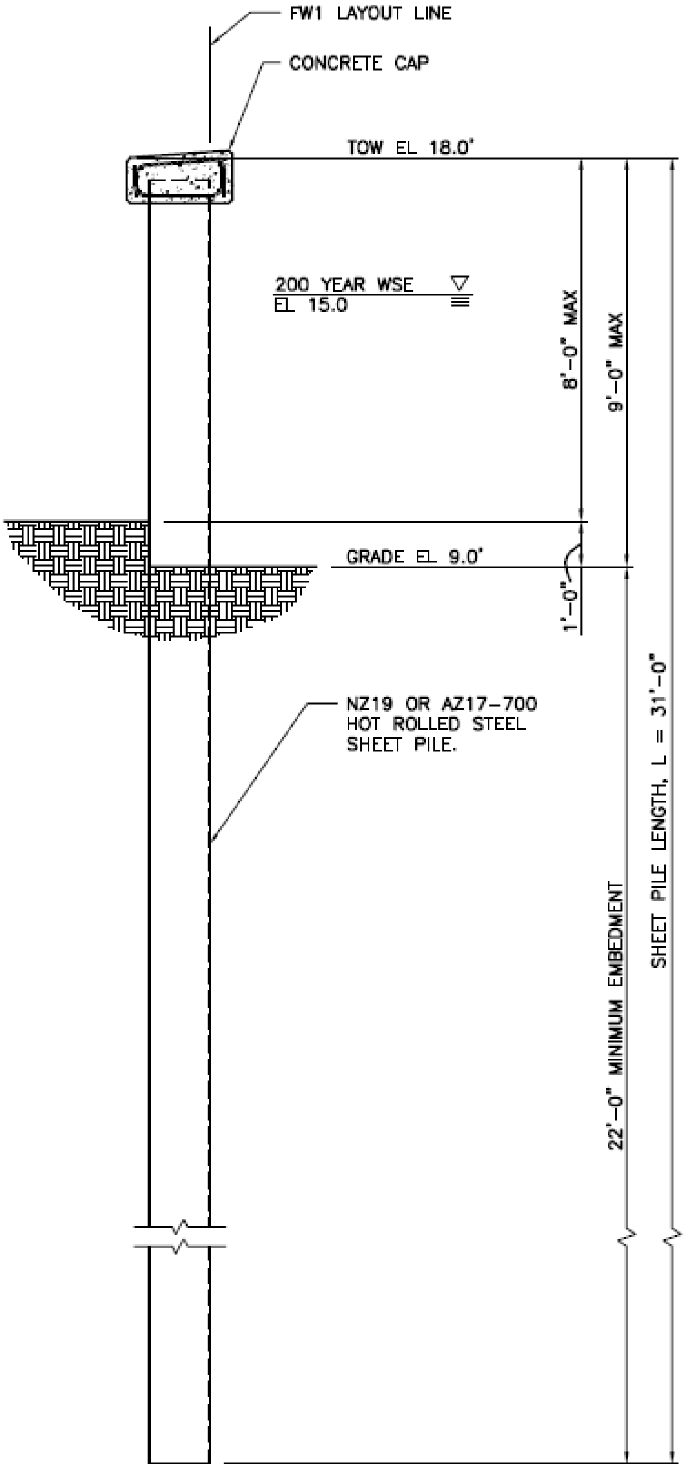


Figure 11. Idealized Analysis Section Between Stations 1+00 and 43+50

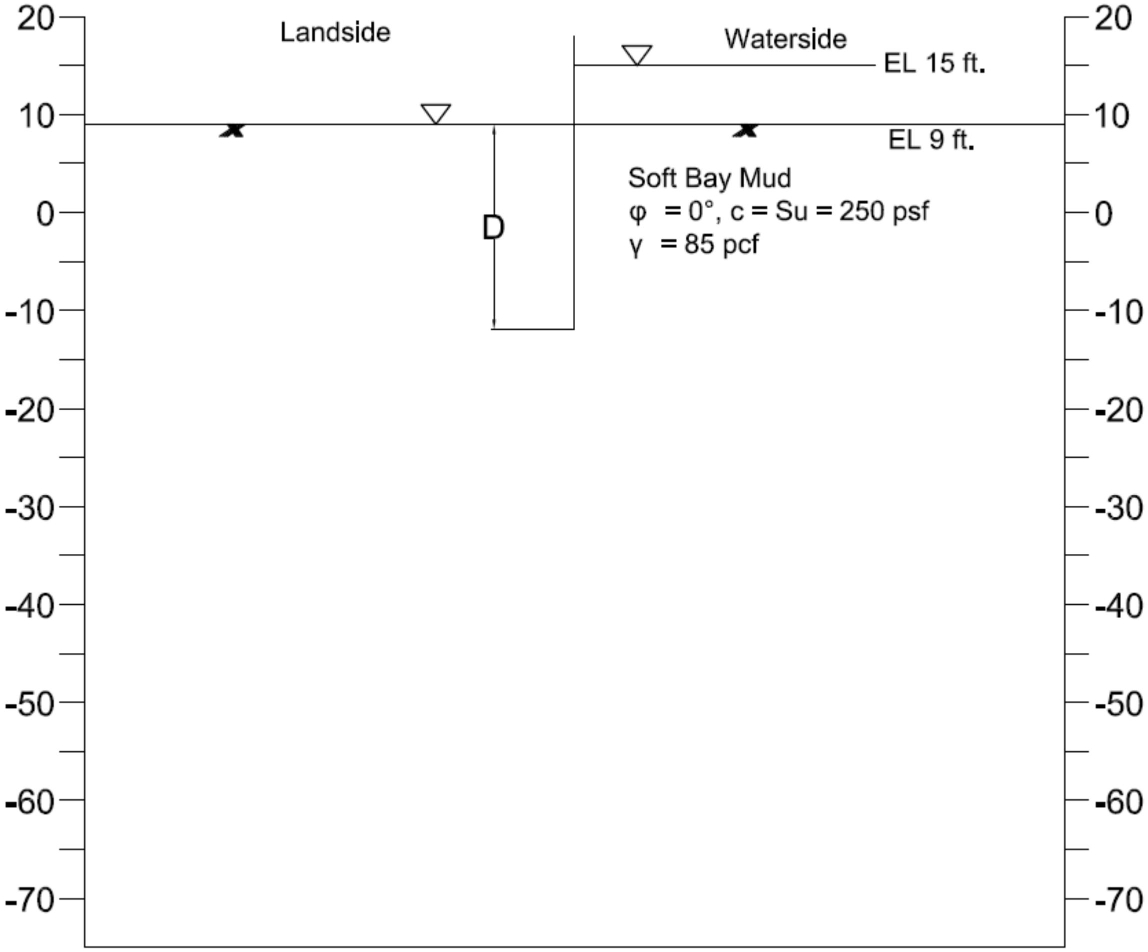
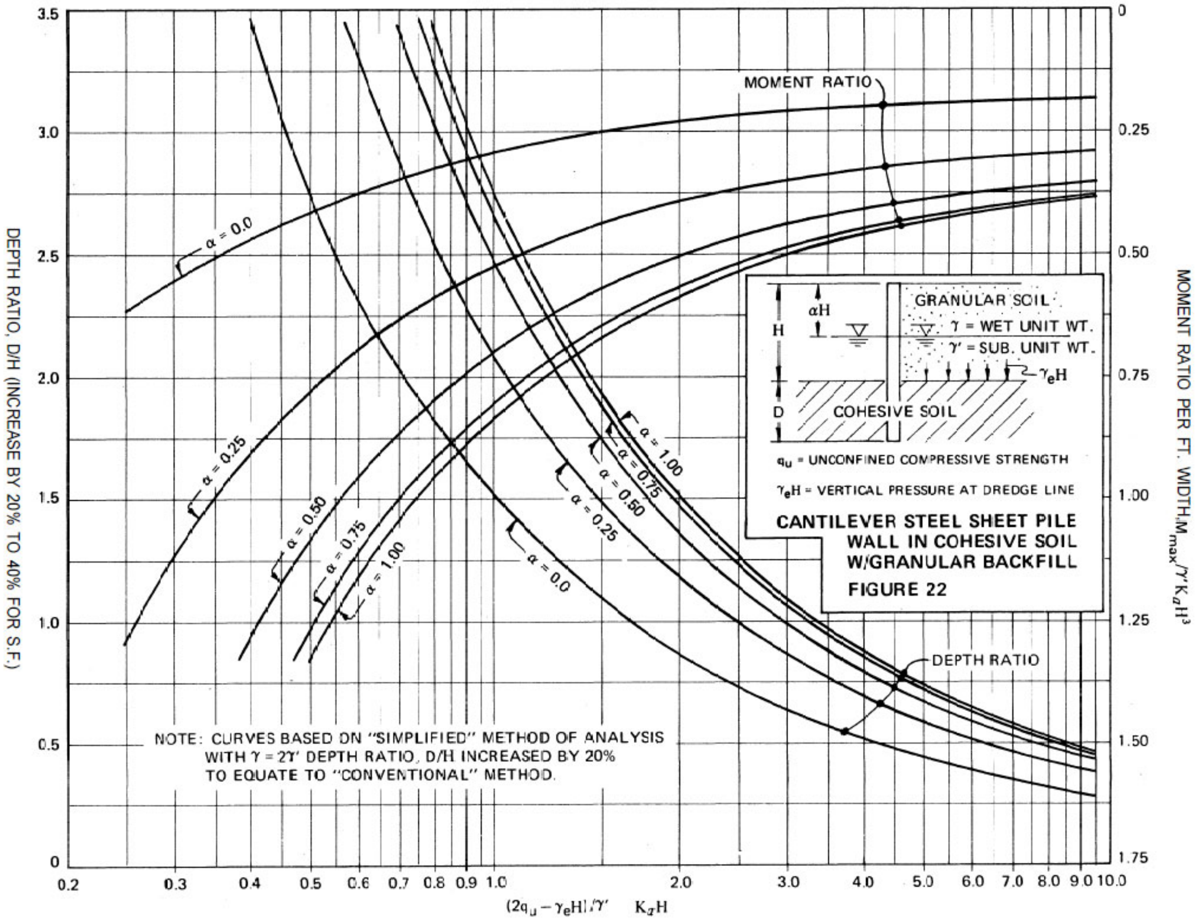


Figure 12. Chart-Based Procedure from US Steel (1984) for a Cantilever Sheet Pile Wall in Cohesive Soil with Granular Backfill



NOTE: CURVES BASED ON "SIMPLIFIED" METHOD OF ANALYSIS WITH $\gamma = 2\gamma'$ DEPTH RATIO, D/H INCREASED BY 20% TO EQUATE TO "CONVENTIONAL" METHOD.

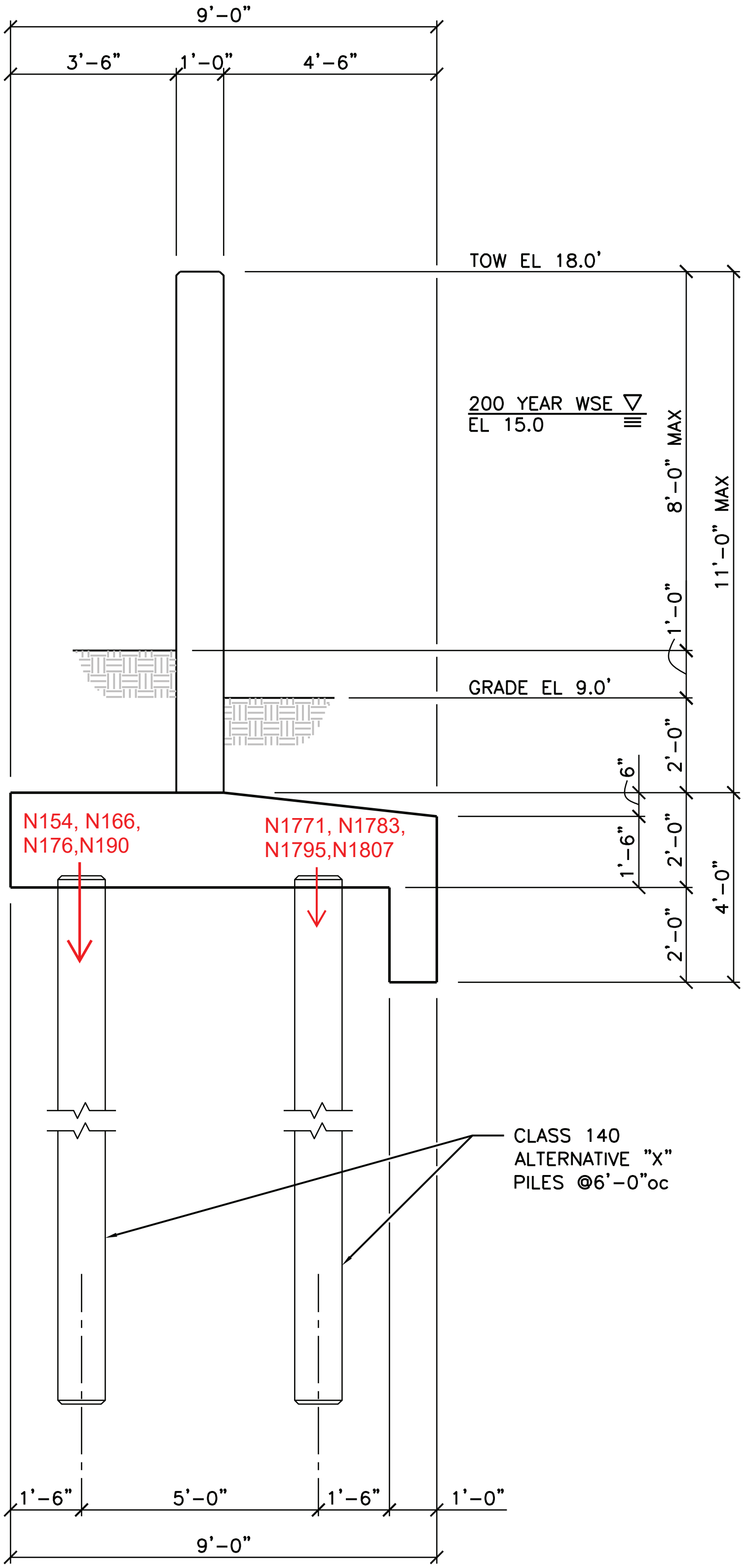


Figure 13. Pile-Supported Flood Wall Geometry from Wood Rodgers (12/2018)

WOOD RODGERS, INC.
Anthony Johnson
J:\Jobs\...\Calculations\Feasibility Study\Concrete Flood Wall on Piles\Concrete Floodwall.vap
Thursday, December 13, 2018 11:33 AM

Pile Axial Load (compression) Pile Shear Load (at top of pile)

Node Reactions Service Loads

Node	Result Case	FX K	FY K	FZ K
N154	D+.6H+F	0.06	28.93	**13.78**
N154	D+H+F	0.00	**32.53**	13.81
N166	D+.6H+F	0.01	28.49	13.90
N166	D+H+F	0.00	32.03	13.91
N178	D+.6H+F	-0.01	28.49	13.90
N178	D+H+F	0.00	32.03	13.91
N190	D+.6H+F	-0.06	28.93	**13.78**
N190	D+H+F	0.00	**32.53**	13.81
N1771	D+.6H+F	**0.33**	6.93	18.77
N1771	D+H+F	0.31	10.07	18.73
N1783	D+.6H+F	0.14	**6.46**	**18.95**
N1783	D+H+F	0.12	9.49	18.94
N1795	D+.6H+F	-0.14	**6.46**	**18.95**
N1795	D+H+F	-0.12	9.49	18.94
N1807	D+.6H+F	**-0.33**	6.93	18.77
N1807	D+H+F	-0.31	10.07	18.73

Factored Load Combinations

Name	Code	Effective Equation	Design	Deflection
.6D+.6W	ASCE 7-10 ASD	0.6D	Allowable	Other
D+.6H+F	ASCE 7-10 ASD	D + 0.6H + F	Allowable	Other
D+H+F	ASCE 7-10 ASD	D + H + F	Allowable	Other

Figure 14. Pile-Supported Flood Wall Service Loads from Wood Rodgers (12/2018)

Tables

Table 1. Summary of FCFS Subsurface Explorations

Rio Vista Feasibility Study

Solano County, California

Exploration ID	Ground Surface Elevation (ft, NAVD 88)	Latitude	Longitude	Exploration Depth[1] (ft)	Description	Date Started	Date Completed
GEI_B-1	6.5	-121.690148	38.154392	61.5	Truck mounted rig using 4.0" solid-stem flight auger method from 0' to 5', and mud rotary method with 3.5" side discharge bit used from 5' to 61.5'.	4/10/2018	4/10/2018
CPT-1	8.7	-121.692100	38.150278	101.0	Cone penetration test to exploration depth using 30-ton C15 truck rig.	3/28/2018	3/28/2018
CPT-2	6.2	-121.690176	38.154398	84.6	Cone penetration test to exploration depth using 30-ton C15 truck rig.	3/28/2018	3/28/2018
CPT-3	13.2	-121.687591	38.159262	93.6	Seismic cone penetration test with seismic taken at 5-foot intervals to exploration depth using 30-ton C15 truck rig.	3/28/2018	3/28/2018
GEI_B-2	13.0	-121.687568	38.159289	44.5	Truck mounted rig using 4.0" solid-stem flight auger method from 0' to 15', and mud rotary method with 3.5" side discharge bit used from 15' to 44.5'.	4/11/2018	4/11/2018
CPT-4	10.5	-121.683446	38.163453	97.6	Cone penetration test to exploration depth using 30-ton C15 truck rig.	3/29/2018	3/29/2018
CPT-5	9.7	-121.680724	38.167604	76.0	Cone penetration test to exploration depth using 30-ton C15 truck rig.	3/29/2018	3/29/2018
CPT-6	7.5	-121.678502	38.170741	67.7	Cone penetration test to exploration depth using 30-ton C15 truck rig.	3/29/2018	3/29/2018
GEI_B-3	13.2	-121.674413	38.173415	51.5	Truck mounted rig using 4.0" solid-stem flight auger method from 0' to 10', and mud rotary method with 3.5" side discharge bit used from 10' to 51.5'.	4/11/2018	4/11/2018
CPT-7	16.7	-121.675663	38.174886	81.0	Cone penetration test to exploration depth using 30-ton C15 truck rig.	3/29/2018	3/29/2018
GEI_B-4	9.0	-121.678162	38.176761	61.5	Track mounted rig using 4.0" solid-stem flight auger method from 0' to 5', and mud rotary method with 3.5" side discharge bit used from 5' to 61.5'.	4/12/2018	4/12/2018
CPT-8	7.4	-121.679952	38.178178	63.0	Cone penetration test to exploration depth using 20-ton GPT2 track rig.	3/30/2018	3/30/2018

Notes:

1. All explorations tremie backfilled with cement grout

Table 2. Summary of Sheet Pile Wall Embedment Depth Calculations (Refer to Figures 11 and 12 for Parameter Definitions).

Parameter	Value	Comment
γ (pcf)	62.4	Idealize water as granular soil with unit weight of water and Ka = 1
γ' (pcf)	62.4	
K_a	1	
H	6	
γ_e*H	374.4	
q_u (psf)	500	
α	1	
$(2q_u\text{-}y_eH)/(y'*K_aH)$	1.67	
D/H	1.83	From Figure 3
D (feet)_Unfactored	11	
Embedment Length Factor	1.4	US Steel suggests increasing the embedment by 20 – 40% to incorporate a factor of safety. 40% was used here.
Embedment Depth, D (feet)	16	
$M_{max}/(y'*Ka*H^3)$	0.65	
M_{max} (kips/ft)	8.8	From Figure 3

Table 3. Summary of Parameters and Assumptions for Ballpark Settlement Analysis at Boring B-1

Parameter	Value	Comment
Engineered Fill Layer Thickness (ft)	2	
Engineered Fill Unit Weight (pcf)	120	
Total Surcharge Load (psf)	240	
Overburden Layer Thickness (ft)	8	
Overburden Layer Unit Weight (pcf)	120	
Groundwater Depth (ft)	3	
Soft Clay Layer Thickness (ft)	44	
Soft Clay Unit Weight (pcf)	85	
Cc	1.6	Approximate average values from consolidation tests performed on samples from boring B-1
e0	3.25	
Initial Vertical Effective Stress (psf)	1145	Mid-depth of Soft Clay Layer
Final Vertical Effective Stress (psf)	1385	Mid-depth of Soft Clay Layer
Settlement (ft)	1.4	

Appendix A – Boring Logs from FCFS Geotechnical Exploration

DATE STARTED 4/10/18	**DATE COMPLETED** 4/10/18	**GROUND ELEVATION** 6.5 ft	**ELEVATION DATUM** NAVD 88
TOTAL DEPTH OF BORING 61.5 ft			
DRILLING CONTRACTOR Taber Drilling		**DRILLER'S NAME** Chad Jones	**HELPER'S NAME** Trevor Hall, Noe Ortiz
TOTAL DEPTH OF FILL 8 ft			
DRILLING METHOD Solid-Stem Auger 0-5 ft bgs, Mud Rotary 5-61.5 ft bgs		**DRILL RIG MAKE AND MODEL** CME 75 Truck Mounted	**CONSULTANT COMPANY** GEI Consultants, Inc.
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 4-inch bullet bit, 3.5-inch side discharge bit		**DRILLING ROD TYPE AND DIAMETER** AWJ	**FIELD LOGGER** R. Keizer
☒ **VERTICAL** ☐ **INCLINED**		**CASING TYPE, DIAMETER, INSTALLATION DEPTH** 5-inch steel, 3.5-feet	**FIELD LOG REVIEWER** E. Singleton
SAMPLER TYPE(S) SPT (1.375"), Std. Cal (2.5"), Shelby (2.87")		**HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP** Automatic Hammer, 140 lbs / 30 inch drop	**HAMMER EFFICIENCY** 70%
BOREHOLE BACKFILL OR COMPLETION Cement Grout		**GROUNDWATER READING:** **DURING DRILLING** 3.5 ft	**AFTER DRILLING (DATE-TIME)**

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	LABORATORY DATA Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	REMARKS
	0		Grass (2-inches).												
5			LEAN CLAY with Sand (CL); stiff; brown; moist; 75% low plasticity, low toughness fines; 25% fine to medium sand; trace gravel; trace roots present throughout sample.		S01	72	2 4 7 [11]	13	1.5P						Sand catcher used on all SPT samples S01A_000_002S 1-inch of Silty Sand (SM) recovered in shoe, not bagged
	2		SILTY SAND (SM); very dark greenish gray; moist; 80% fine to medium sand; 20% no plasticity fines.												
	3		SILTY SAND (SM); loose; very dark greenish gray; moist; 49% fine sand; 46% fines; 5% fine, subangular gravel, max. 0.5 in.; profile interbedded with Lean Clay (CL), Silty Sand (SM), and Silt (ML), with ML lenses ranging from 1 to 2-inches thick.		S02	83	0 3 3 [6]	7	0.25P 0.75P		38	13	46		S02A_003_004S 2-inches of Silty Sand (SM) recovered in S02 at 2.5 ft, not bagged
0	5		Poorly Graded SAND with Silt (SP-SM); loose; very dark greenish gray; wet; 93% fine to medium, subangular sand; 7% no plasticity fines; trace transparent shell-like particles; trace wood fragments present. At 5.2 ft.: 0.5-inch Lean Clay (CL) nodule.		S03	100	2 1 3 [4]	5					7	PA	S03A_005_007S CL nodule not bagged Switch to mud rotary drilling after S03
FILL	8		PEAT (PT); dark greenish gray; 25% no plasticity fines; 5% fine sand; 70% organics.												Soil cuttings indicated likely Silty Sand (SM) until 8 ft
-5	10		SILTY SAND (SM); medium stiff; dark greenish gray; wet; 50% fine sand; 50% fines; trace organics; trace roots present.		S04	100	2 1 4 [5]		0.5P 0.75P	37	26	NP	50	UW PA	S04C_010_012C S04B_010_012C S04A_010_012C S04C bagged
	13		LEAN CLAY (CL); very soft; very dark greenish gray; wet; 90% low plasticity, high dry strength, slow dilatancy, low toughness fines; 10% fine to coarse sand, predominantly fine; trace organic fibers present.		S05	38			<0.25P						S05A_013_015T Advanced fixed piston Gregory Undisturbed Sampler with 3-inch Shelby tube; sample slid down in tube after sampler extraction
-10	16		ORGANIC SILT (OL); very soft to soft; very dark greenish gray; 80% low plasticity fines; fine to coarse sand; 16% organics; sulfuric odor.		S06	71			<0.25P 0.25P 0.5P 0.25P <0.25P				80	OC	S06A_016_018T Advanced fixed piston Gregory Undisturbed Sampler with 3-inch Shelby tube
	19		ORGANIC ELASTIC SILT (OH); soft; very dark greenish gray; wet; 79% low to medium toughness		S07	75									S07A_019_021T Advanced fixed
	20														

Final Report Version 8/23/2018

RIO VISTA GINT.GPJ

Borehole Location: Near boat ramp off Montezuma St **County:** Solano
Coordinates: Northing: 1,818,198.62 **Easting:** 6,650,771.16
Latitude: 38.15439 **Longitude:** -121.69015
Levee Station or Milepost: 24+21 **Levee Mile:**
Levee Segment
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: Sacramento River West Bank

LOG OF BORING
GEI_B-1

Sheet 1 of 3

Rio Vista Feasibility Study, Solano County, California

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	LABORATORY DATA Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	REMARKS
	20		fines; 39% organics; sulfuric odor. ORGANIC ELASTIC SILT (OH); as above.		S07	75			0.25P						piston Gregory Undisturbed Sampler with 3-inch Shelby tube
-15	21														
	22														
	23				S08	88			0.25P 0.35T	98 129	100	29	79	CU OC CN	S08A_022_024T Advanced fixed piston Gregory Undisturbed Sampler with 3-inch Shelby tube
	24														
	25				S09	100	0 0 0 [0]	0	0.25P		86	43			S09A_025_027S Sample overdriven 2-inches
-20	26														
	27														
	28		As above except medium stiff.		S10	88			0.5P 0.3T						S10A_028_030T Advanced fixed piston Gregory Undisturbed Sampler with 3-inch Shelby tube
	29														
	30		As above except soft.		S11	0	0 2 2 [4]								S11A_030_032C No Recovery 3-inch sample of slough bagged
-25	31														
	32														
	33		As above except soft to medium stiff; dark greenish gray; low toughness fines.		S12	71			0.5P						S12A_033_035T Advanced fixed piston Gregory Undisturbed Sampler with 3-inch Shelby tube
	34														
	35														
-30	36		ELASTIC SILT (MH); soft to medium stiff; dark greenish gray; moist; 86% low toughness fines; 14% fine sand; trace organics; clayey particles present.		S13	100	0 2 1 [3]	4	0.5P						S13A_036_037S
	37														
	38														
	39				S14	83			0.5P	109 117	89	26	86	CU CN	S14A_038_040T Advanced fixed piston Gregory Undisturbed Sampler with 3-inch Shelby tube
	40														
-35	41				S15	75			0.5P 0.4T						S15A_041_043T Advanced fixed piston Gregory Undisturbed Sampler with 3-inch Shelby tube
	42														
	43														
	44														
	45														

Final Report Version 8/23/2018

Borehole Location: Near boat ramp off Montezuma St **County:** Solano
Coordinates: Northing: 1,818,198.62 **Easting:** 6,650,771.16
Latitude: 38.15439 **Longitude:** -121.69015
Levee Station or Milepost: 24+21 **Levee Mile:**
Levee Segment
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: Sacramento River West Bank

LOG OF BORING

GEI_B-1

Sheet 2 of 3

Rio Vista Feasibility Study, Solano County, California

Elevation, feet: -40, -45, -50, -55, -60

Depth, feet: 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70

Depth, feet	CLASSIFICATION OF MATERIALS (Description)	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	REMARKS
45	ELASTIC SILT (MH); as above.	S16	100	0 0 2 [2]	2	0.25P						S16A_045_047S Sample overdriven 3-inches
49		S17	71									S17A_049_051T Advanced fixed piston Gregory Undisturbed Sampler with 3-inch Shelby tube; appeared tube recovery is slough, 80% fine to medium sand, 20% no plasticity fines
52	SANDY SILT (ML); soft to medium stiff; dark greenish gray; wet; 65% no to low plasticity fines; 35% fine sand.	S18	94	2 2 3 [5]	6	0.25P 0.5P						S18A_052_054S
55	As above except interbedded with 1 to 2-inch thick Silt (ML) and Sandy Silt (ML) lenses.	S19	78	2 1 3 [4]	5							S19A_055_056S
57	As above except interbedded with 0.5 to 1.5-inch thick Silt (ML) and Silty Sand (SM) lenses.	S20	100	2 2 2 [4]	5							S20A_057_059S
60	As above except interbedded with 1 to 2-inch thick Silt (ML) and Silty Sand (SM) lenses.	S21	100	2 2 2 [4]	5							S21A_060_062S

Borehole terminated at 61.5 feet. Backfilled with Cement Grout.

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GEI Consultants

Borehole Location: Near boat ramp off Montezuma St **County:** Solano
Coordinates: **Northing:** 1,818,198.62 **Easting:** 6,650,771.16
Latitude: 38.15439 **Longitude:** -121.69015
Levee Station or Milepost: 24+21 **Levee Mile:**
Levee Segment
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: Sacramento River West Bank

LOG OF BORING
GEI_B-1
Sheet 3 of 3

Rio Vista Feasibility Study, Solano County, California

RIO VISTA GINT.GPJ

DATE STARTED 4/11/18	**DATE COMPLETED** 4/11/18	**GROUND ELEVATION** 13.0 ft	**ELEVATION DATUM** NAVD 88
TOTAL DEPTH OF BORING 44.5 ft			
DRILLING CONTRACTOR Taber Drilling		**DRILLER'S NAME** Chad Jones	**HELPER'S NAME** Trevor Hall, David Beunazarov
TOTAL DEPTH OF FILL 7 ft			
DRILLING METHOD Solid-Stem Auger 0-15 ft bgs, Mud Rotary 15-44.5 ft bgs		**DRILL RIG MAKE AND MODEL** CME 75 Truck Mounted	**CONSULTANT COMPANY** GEI Consultants, Inc.
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 4-inch bullet bit, 3.5-inch side discharge bit		**DRILLING ROD TYPE AND DIAMETER** AWJ	**FIELD LOGGER** R. Keizer
☒ **VERTICAL** ☐ **INCLINED**		**CASING TYPE, DIAMETER, INSTALLATION DEPTH** 5-inch steel, 3.5-feet	**FIELD LOG REVIEWER** E. Singleton
SAMPLER TYPE(S) SPT (1.375"), Std. Cal (2.5"), Shelby (2.87")		**HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP** Automatic Hammer, 140 lbs / 30 inch drop	**HAMMER EFFICIENCY** 70%
BOREHOLE BACKFILL OR COMPLETION Cement Grout		**GROUNDWATER READING:** **DURING DRILLING** 14 ft	**AFTER DRILLING (DATE-TIME)**

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N60(ASTM)	PP or TV, tsf	LABORATORY DATA					REMARKS
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	
	0		Asphalt (3-inches).												Sand catcher used on all SPT samples
	1		SILTY SAND (SM); loose; olive; moist; 55% fine sand; 45% no plasticity fines.												
10	2 3 4		At 2.3 ft.: As above except 80% sand; 20% fines.		S01	83	4 4 4 [8]	9							S01B_002_004S S01A_002_004S
	5		3-inch thick Silt (ML) lens. Poorly Graded SAND with Clay (SP-SC); dark yellowish brown mottled with orange and black; moist; 91% fine to medium sand; 9% low plasticity fines.		S02	67	4 4 3 [7]			12			9	UW PA	S02B_005_006C S02A_005_006C S02B bagged including ML lens 2-inch Sandy Lean Clay (CL) recovered in shoe, not bagged
FILL	6		SANDY LEAN CLAY (CL); dark yellowish brown mottled with orange and black; moist; 65% low plasticity fines; 35% fine sand.												
5	7 8		LEAN CLAY (CL); soft; dark yellowish brown mottled with orange and black; moist; 90% low plasticity, low toughness fines; 10% fine sand.		S03	83	2 1 2 [3]	4							S03A_007_009S
	9 10 11		As above except medium stiff; very dark greenish gray; also silty particles; trace organic roots present.		S04	100	0 3 3 [6]	7	0.5P 0.75P 1.0P 0.75P						S04A_010_012S Sample overdriven 6-inches
0 ▽	12 13 14		SANDY ELASTIC SILT (MH); soft; very dark greenish gray; moist; 69% low to medium toughness fines; 31% fine sand.		S05	94			0.25P 0.4T	49	71	33	69	CU	S05A_012_014T Pushed 3-inch Shelby tube at 100 psi from 0 to 16-inches, 150 psi from 16 to 24-inches
	15 16 17		SANDY LEAN CLAY (CL); soft; very dark greenish gray; moist; 55-65% low plasticity, low toughness fines; 30-40% fine to coarse sand; 5% organic roots and fibers.		S06	100			0.25P 0.3T						S06A_015_017T Pushed 3-inch Shelby tube at 100 psi; overpushed 3.5-inches Switch to mud rotary drilling after S06
-5	18 19 20		As above except wet; 55% fines; 40% fine to medium sand; 5% organics; slight sulfuric odor.		S07	83									S07A_018_020T Advanced fixed piston Gregory Undisturbed Sampler with 3-inch

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RIO VISTA GINT.GPJ

GEI Consultants

Borehole Location: 250 North Front Street at rear of lot **County:** Solano
Coordinates: **Northing:** 1,819,984.56 **Easting:** 6,651,506.91
Latitude: 38.15929 **Longitude:** -121.68757
Levee Station or Milepost: 44+19 **Levee Mile:**
Levee Segment
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: Sacramento River West Bank

LOG OF BORING
GEI_B-2

Sheet 1 of 3

Rio Vista Feasibility Study, Solano County, California

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	LABORATORY DATA Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	REMARKS
	20		SANDY LEAN CLAY (CL); as above.												Shelby tube
	21		SILTY SAND (SM); medium dense; very dark greenish gray; 75% predominantly fine with trace coarse sand; 25% no to low plasticity fines. 0.5-inch thick Gravelly Lean Clay (CL) lens.	X	S08	83	3 5 7 [12]	14							S08A_021_023S Gravelly CL lens not bagged
	22														
-10	23		Poorly Graded SAND (SP); medium dense; very dark greenish gray; 93% fine to coarse sand; 4% no plasticity fines; 3% fine gravel. 2-inch thick Sandy Lean Clay (CL) lens.	X	S09	94	4 9 12 [21]	25					4	PA	S09A_023_025S Sandy CL lens not bagged
	24														
	25		1-inch thick Gravelly Lean Clay (CL) lens.	X	S10	67	6 11 15 [26]	30							S10A_025_027S Gravelly CL lens not bagged
	26														
	27		2-inch thick Lean Clay (CL) lens. 2-inch thick Silty Gravel (GM) lens; max. 0.5 in. Poorly Graded SAND with Silt (SP-SM); medium dense; very dark greenish gray; 93% fine to medium sand; 5% no plasticity fines; 2% fine gravel.	X	S11	89	6 9 11 [20]	23							S11A_027_029S Lenses not bagged
-15	28														
	29		3-inch thick Clayey Gravel (GC) lens; max. 0.5 in.	X	S12	83	7 10 13 [23]	27					5	PA	S12A_029_031S GC lens not bagged
	30														
	31		Well-Graded SAND with Silt (SW-SM); dense; very dark greenish gray; 90% fine to coarse sand; 10% no plasticity fines.	X	S13	78	9 15 17 [32]	37							S13A_031_033S
	32														
-20	33		SILTY SAND with Gravel (SM); very dark greenish gray; 60% fine sand; 25% fine to coarse gravel, max. 1.0 in.; 15% no plasticity fines. SILT with Sand (ML); stiff; dark greenish gray; moist; 80% no to low plasticity fines; 20% fine sand.	X	S14	89	12 14 15 [29]	34	1.5P						S14B_033_035S S14A_033_035S
	34														
	35														
	36														
	37														
-25	38		SANDY SILT (ML); medium stiff; dark greenish gray; moist; 60% no to low plasticity fines; 40% fine sand. SILTY SAND (SM); very dark greenish gray; 65% fine sand; 35% no plasticity fines.	X	S15	89	5 10 15 [25]	29	0.75P						S15B_038_040S S15A_038_040S
	39														
	40														
	41														
	42														
-30	43		As above except dense; 75% sand; 25% fines. Poorly Graded SAND with Silt (SP-SM); dense; very dark greenish gray; 90% predominantly coarse to medium sand; 10% no plasticity fines.	X	S16	67	10 16 21 [37]	43							S16B_043_045S S16A_043_045S
	44														
	45														

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GEI Consultants

Borehole Location: 250 North Front Street at rear of lot **County:** Solano
Coordinates: Northing: 1,819,984.56 **Easting:** 6,651,506.91
Latitude: 38.15929 **Longitude:** -121.68757
Levee Station or Milepost: 44+19 **Levee Mile:**
Levee Segment
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: Sacramento River West Bank

LOG OF BORING

GEI_B-2

Sheet 2 of 3

Rio Vista Feasibility Study, Solano County, California

RIO VISTA GINT.GPJ

										LABORATORY DATA					
Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	REMARKS
	45														
	46		Borehole terminated at 44.5 feet. Backfilled with Cement Grout.												
	47														
-35	48														
	49														
	50														
	51														
	52														
-40	53														
	54														
	55														
	56														
	57														
-45	58														
	59														
	60														
	61														
	62														
-50	63														
	64														
	65														
	66														
	67														
-55	68														
	69														
	70														

Final Report Version 8/23/2018

GEI Consultants

Borehole Location: 250 North Front Street at rear of lot **County:** Solano

Coordinates: **Northing:** 1,819,984.56 **Easting:** 6,651,506.91

Latitude: 38.15929 **Longitude:** -121.68757

Levee Station or Milepost: 44+19 **Levee Mile:**

Levee Segment

Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II

Channel / River Name / Feature: Sacramento River West Bank

LOG OF BORING

GEI_B-2

Sheet 3 of 3

Rio Vista Feasibility Study, Solano County, California

DATE STARTED 4/11/18	**DATE COMPLETED** 4/11/18	**GROUND ELEVATION** 13.3 ft	**ELEVATION DATUM** NAVD 88	**TOTAL DEPTH OF BORING** 51.5 ft	
DRILLING CONTRACTOR Taber Drilling		**DRILLER'S NAME** Chad Jones	**HELPER'S NAME** Trevor Hall, David Beunazarov	**TOTAL DEPTH OF FILL** 5.8 ft	
DRILLING METHOD Solid-Stem Auger 0-10 ft bgs, Mud Rotary 10-51.5 ft bgs		**DRILL RIG MAKE AND MODEL** CME 75 Truck Mounted		**CONSULTANT COMPANY** GEI Consultants, Inc.	
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 4-inch bullet bit, 3.5-inch side discharge bit		**DRILLING ROD TYPE AND DIAMETER** AWJ		**FIELD LOGGER** R. Keizer	
☒ **VERTICAL**	☐ **INCLINED**	**CASING TYPE, DIAMETER, INSTALLATION DEPTH** 5-inch steel, 3.5-feet		**FIELD LOG REVIEWER** E. Singleton	
SAMPLER TYPE(S) SPT (1.375"), Std. Cal (2.5"), Shelby (2.87")		**HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP** Automatic Hammer, 140 lbs / 30 inch drop		**HAMMER EFFICIENCY** 70%	
BOREHOLE BACKFILL OR COMPLETION Cement Grout		**GROUNDWATER READING:**	**DURING DRILLING** 9 ft	**AFTER DRILLING (DATE-TIME)**	

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	LABORATORY DATA Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	REMARKS
	0 1 2		SILTY SAND (SM); medium dense; brown; dry; 65% fine sand; 35% no plasticity fines; trace fine gravel.	☒	S01	61	6 7 8 [15]	18							S01A_000_002S
10	3 4		SANDY SILT (ML); very stiff to hard; brown mottled with black; dry; 55% no to low plasticity fines; 45% fine sand; clay nodules present; [FILL].	☒	S02	83	9 10 11 [21]	25	>4.5P 3.0P						S02A_003_004S
	5			☒	S03	100	13 17 26 [43]	50							S03B_005_007S S03A_005_007S Sample overdriven 1-inch
FILL	6 7		SANDY SILT with Gravel (ML); dense; very dark grayish brown; moist; 50% no plasticity fines; 30% fine to coarse sand; 20% fine to coarse gravel.												
5	8 9 ▽		SANDY SILT (ML); stiff; yellowish brown; moist; 69% fines; 31% fine sand.	☒	S04	100	7 9 12 [21]	25	1.75P						S04A_008_009S
	10 11 12		As above except hard.	▮	S05	100			>4.5P 0.75T	37	25	1	69	CU	S05A_010_012T Pushed 3-inch Shelby tube at 200 psi from 0 to 15-inches, 500 psi from 15 to 21-inches Switch to mud rotary drilling after S05
0	13 14		Poorly Graded SAND with Silt (SP-SM); medium dense; dark brown; 92% fine to medium sand; 6% no to low plasticity fines; 2% fine gravel. 5-inch thick interbedded Silty Sand (SM) and Silt (ML) lens.	☒	S06	89	10 11 13 [24]	28							S06A_013_014S Lens not bagged; ML at 12.5 ft not bagged
	15 16 17		As above except dense.	☒	S07	67	11 13 19 [32]	37					6	PA	S07A_015_017S
-5	18 19 20														

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GEI Consultants

Borehole Location: River Road near river bank **County:** Solano
Coordinates: Northing: 1,825,142.37 **Easting:** 6,655,271.06
Latitude: 38.17341 **Longitude:** -121.67441
Levee Station or Milepost: 161+74 **Levee Mile:**
Levee Segment
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: Sacramento River West Bank

LOG OF BORING

GEI_B-3

Sheet 1 of 3

Rio Vista Feasibility Study, Solano County, California

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	LABORATORY DATA Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	REMARKS
	20		Poorly Graded SAND with Silt and Gravel (SP-SM); dense; very dark greenish gray; 76% fine to coarse sand; 18% fine gravel; 6% no plasticity fines.	⧖	S08	50	2 11 17 [28]	33					6	PA	S08B_020_022S S08A_020_022S S08B is 9-inches of slough, bagged
	21														
	22														
	23														
-10															
	24														
	25		SILTY SAND (SM); medium dense; very dark greenish gray; 80% fine to medium sand; 20% no plasticity fines.	⧖	S09	94	12 13 13 [26]	30							S09A_025_027S 2-inches of fine Poorly Graded Sand (SP) with Silt (ML) nodules recovered in shoe, not bagged
	26														
	27														
	28														
-15															
	29														
	30		SANDY SILT (ML); medium stiff; olive mottled with orange; wet; 70% low plasticity fines; 30% fine sand; clayey particles present.	⧖	S10	100	5 6 10 [16]	19	0.75P						S10A_030_032S Sample overdriven 2-inches
	31														
	32														
	33														
-20															
	34														
	35		As above except very dark greenish gray.	⧗	S11	100	11 19 45 [64]								S11C_035_037C S11B_035_037C S11A_035_037C S11C bagged
	36		SILTY SAND (SM); very dark greenish gray; 70% fine sand; 30% no plasticity fines; trace gravel.												
	37														
	38														
-25															
	39														
	40		As above except dense; 75% sand; 25% fines.	⧖	S12	100	12 16 18 [34]	40							S12A_040_042S
	41														
	42														
	43														
-30															
	44														
	45														

Final Report Version 8/23/2018

Borehole Location: River Road near river bank **County:** Solano
Coordinates: Northing: 1,825,142.37 **Easting:** 6,655,271.06
Latitude: 38.17341 **Longitude:** -121.67441
Levee Station or Milepost: 161+74 **Levee Mile:**
Levee Segment
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: Sacramento River West Bank

LOG OF BORING
GEI_B-3
Sheet 2 of 3

Rio Vista Feasibility Study, Solano County, California

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	LABORATORY DATA: Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	REMARKS
	45		SILTY SAND (SM); as above except 80% sand; 20% fines. At 45.8 ft.: 0.5-inch Lean Clay (CL) nodule.	☒	S13	100	8 14 15 [29]	34							S13A_045_047S CL nodule not bagged
	46														
	47														
-35	48														
	49														
	50		As above except 85% sand; 15% fines.	☒	S14	100	15 17 18 [35]	41							S14A_050_052S
	51														
	52		Borehole terminated at 51.5 feet. Backfilled with Cement Grout.												
-40	53														
	54														
	55														
	56														
	57														
-45	58														
	59														
	60														
	61														
	62														
-50	63														
	64														
	65														
	66														
	67														
-55	68														
	69														
	70														

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GEI Consultants

Borehole Location: River Road near river bank **County:** Solano
Coordinates: Northing: 1,825,142.37 **Easting:** 6,655,271.06
Latitude: 38.17341 **Longitude:** -121.67441
Levee Station or Milepost: 161+74 **Levee Mile:**
Levee Segment
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: Sacramento River West Bank

LOG OF BORING
GEI_B-3
Sheet 3 of 3

Rio Vista Feasibility Study, Solano County, California

DATE STARTED 4/12/18 **DATE COMPLETED** 4/12/18
GROUND ELEVATION 9.0 ft **ELEVATION DATUM** NAVD 88
TOTAL DEPTH OF BORING 61.5 ft
DRILLING CONTRACTOR Taber Drilling
DRILLER'S NAME Chad Jones **HELPER'S NAME** Trevor Hall
TOTAL DEPTH OF FILL
DRILLING METHOD Solid-Stem Auger 0-5 ft bgs, Mud Rotary 5-61.5 ft bgs
DRILL RIG MAKE AND MODEL CME 55 Track Mounted
CONSULTANT COMPANY GEI Consultants, Inc.
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 4-inch bullet bit, 3.5-inch side discharge bit
DRILLING ROD TYPE AND DIAMETER AWJ
FIELD LOGGER R. Keizer
☒ **VERTICAL** ☐ **INCLINED**
CASING TYPE, DIAMETER, INSTALLATION DEPTH 5-inch steel, 3.5-feet
FIELD LOG REVIEWER E. Singleton
SAMPLER TYPE(S) SPT (1.375"), Std. Cal (2.5"), Shelby (2.87")
HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP Automatic Hammer, 140 lbs / 30 inch drop
HAMMER EFFICIENCY 99%
BOREHOLE BACKFILL OR COMPLETION Cement Grout
GROUNDWATER READING: **DURING DRILLING** 2.5 ft **AFTER DRILLING (DATE-TIME)**

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	LABORATORY DATA					REMARKS
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	
	0		<u>SILTY SAND</u> (SM); dark olive brown; moist; 55% fine sand; 45% low plasticity fines; trace roots present.	☒	S01	89	2 2 2 [4]	7	0.75P						Sand catcher used on all SPT samples S01B_000_002S S01A_000_002S 2-inches Silty Sand (SM) with 85% fine sand recovered in shoe, not bagged
	1		<u>SANDY LEAN CLAY</u> (CL); medium stiff; dark olive brown; moist; 65% low plasticity fines; 35% fine sand; also silty particles; trace roots present.												
	2		<u>SILTY SAND</u> (SM); dark olive brown; wet; 85% fine to medium sand; 15% no plasticity fines.												
	3			☒	S02	100	1 2 2 [4]	7	1.25P						S02B_003_004S S02A_003_004S
5	4		<u>LEAN CLAY with Sand</u> (CL); stiff; dark grayish brown mottled with orange; moist; 80% low to medium plasticity, low to medium toughness fines; 20% fine to coarse sand; trace fine gravel.												
	5		<u>SILTY SAND</u> (SM); dark grayish brown; wet; 70% fine to coarse sand; 30% no plasticity fines. 2-inch thick Clayey Sand (SC) lens.	▌	S03	100			1.0P 2.5P 0.7T		57	28	96		S03A_005_007T Pushed 3-inch Shelby tube at 250 psi; sand in top of tube likely slough Switch to mud rotary drilling after S03
	6		<u>FAT CLAY</u> (CH); stiff to very stiff; dark grayish brown; moist; 96% fines; 4% fine to coarse sand.												
	7														
	8		<u>SANDY LEAN CLAY</u> (CL); very soft; olive brown; wet; 52% rapid dilatancy, low toughness fines; 48% fine sand.	▌	S04	95			0.5P 0.25P <0.25P 0.12T		32	12	52		S04A_008_010T Pushed 3-inch Shelby tube at 150 psi
0	9														
	10		<u>LEAN CLAY</u> (CL); very soft; dark greenish gray; wet; 99% fines; 1% fine sand; trace wood fragments.	▌	S05	0			<0.25P		48	22	99		S05A_010_012T Pushed 3-inch Shelby tube at 150 psi; no recovery; pushed CAL sampler without liners to recover S05
	11														
	12														
	13		As above except trace organics present.	☒	S06	100	0 0 1 [1]	2							S06B_013_015S S06A_013_015S Sample overdriven 5-inches
-5	14		<u>ORGANIC LEAN CLAY</u> (OL); very dark greenish gray; wet; 60% low plasticity fines; 10% fine to coarse sand; 30% organics.												
	15		<u>ORGANIC ELASTIC SILT with Sand</u> (OH); medium stiff; black; wet; 47% fines; 19% fine sand; 34% organics; slight sulfuric odor.	☒	S07	100	1 2 2 [4]	7	0.5P		119	45	47	OC	S07A_015_017S Sample overdriven 2-inches
	16														
	17														
	18			☒	S08	100	1 2 1 [3]	5	0.5P 0.75P 0.5P						S08A_018_020S Sample overdriven 2-inches
-10	19														
	20														

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GEI Consultants

Borehole Location: <u>Mellin Levee toe</u> **County:** <u>Solano</u>
Coordinates: Northing: <u>1,826,357.14</u> **Easting:** <u>6,654,189.11</u>
Latitude: <u>38.17676</u> **Longitude:** <u>-121.67816</u>
Levee Station or Milepost: <u>15+26</u> **Levee Mile:**
Levee Segment
Survey Method: <u>GIS/LiDAR</u> **Coord. System:** <u>CA State Plane Zone II</u>
Channel / River Name / Feature: <u>Yolo Bypass</u>

LOG OF BORING
GEI_B-4

Sheet 1 of 3

Rio Vista Feasibility Study, Solano County, California

RIO VISTA GINT.GPJ

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	LABORATORY DATA					REMARKS
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	
	20		ORGANIC ELASTIC SILT with Sand (OH); as above except increasing fines; decreasing organics.		S09	100	1 2 2 [4]	7	0.75P 0.75P 0.5P						S09A_020_022S Sample overdriven 1-inch
	21														
	22														
	23				S10	100	2 2 2 [4]	7	1.0P 1.0P 0.75P 0.5P						S10A_023_025S Sample overdriven 6-inches; rig hammer begins sluggish behavior during first and second 6-inch intervals
-15	24														
	25				S11	100	1 1 2 [3]	5	0.75P 0.5P 0.5P 0.75P 1.0P						S11B_025_027S S11A_025_027S Sample overdriven 3-inches
	26		LEAN CLAY (CL); medium stiff; very dark greenish gray; wet; 85% low to medium plasticity, medium toughness fines; 10% fine to medium sand; 5% organics.												
	27														
	28		SANDY LEAN CLAY (CL); stiff; very dark greenish gray; moist; 70% medium plasticity, medium toughness fines; 30% fine to coarse sand.		S12	100	3 4 4 [8]	13	1.5P						S12A_028_029S
-20	29														
	30		As above except 35% sand; 65% fines; trace fine gravel.		S13	100	3 6 6 [12]	20	1.5P						S13A_030_032S
	31														
	32														
	33		CLAYEY SAND (SC); loose; very dark greenish gray; 70-85% fine sand; 15-30 low plasticity fines; trace fine gravel.		S14	100	3 3 3 [6]	10							S14A_033_034S CL lens not bagged
-25	34		2-inch thick Sandy Lean Clay (CL) lens.												
	35		Poorly Graded SAND with Clay (SP-SC); medium dense; very dark greenish gray; 87% fine to coarse sand; 9% low plasticity fines; 4% fine gravel.		S15	94	3 3 4 [7]	12					9	PA	S15A_035_037S
	36														
	37														
	38														
-30	39														
	40		Poorly Graded SAND with Silt (SP-SM); medium dense; very dark greenish gray; 90-95% fine sand; 5-10 no to low plasticity fines.		S16	89	7 7 8 [15]	25							S16A_040_042S
	41														
	42														
	43														
-35	44														
	45														

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RIO VISTA GINT.GPJ

GEI Consultants

Borehole Location: Mellin Levee toe **County:** Solano
Coordinates: Northing: 1,826,357.14 **Easting:** 6,654,189.11
Latitude: 38.17676 **Longitude:** -121.67816
Levee Station or Milepost: 15+26 **Levee Mile:**
Levee Segment
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: Yolo Bypass

LOG OF BORING

GEI_B-4

Sheet 2 of 3

Rio Vista Feasibility Study, Solano County, California

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N_{60}(ASTM)	PP or TV, tsf	LABORATORY DATA Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	REMARKS
	45	▨	Poorly Graded SAND with Silt (SP-SM); as above except dense; 88% fine to medium sand; 12% fines.	☒	S17	100	7 11 12 [23]	38					12	PA	S17A_045_047S
	46														
	47														
	48														
-40	49														
	50	▨	SILTY SAND (SM); dense; very dark greenish gray; 70-85% fine to medium sand; 15-30 no to low plasticity fines.	☒	S18	94	7 11 12 [23]	38							S18A_050_052S
	51														
	52														
	53														
-45	54														
	55			☒	S19	100	9 12 13 [25]	41							S19A_055_057S
	56														
	57														
	58														
-50	59														
	60		As above except olive brown; no plasticity fines.	☒	S20	100	12 14 15 [29]	48							S20A_060_062S
	61														
	62		Borehole terminated at 61.5 feet. Backfilled with Cement Grout.												
	63														
-55	64														
	65														
	66														
	67														
	68														
-60	69														
	70														

Final Report Version 8/23/2018

RIO VISTA GINT.GPJ

GEI Consultants

Borehole Location: Mellin Levee toe **County:** Solano
Coordinates: Northing: 1,826,357.14 **Easting:** 6,654,189.11
Latitude: 38.17676 **Longitude:** -121.67816
Levee Station or Milepost: 15+26 **Levee Mile:**
Levee Segment
Survey Method: GIS/LiDAR **Coord. System:** CA State Plane Zone II
Channel / River Name / Feature: Yolo Bypass

LOG OF BORING
GEI_B-4
Sheet 3 of 3

Rio Vista Feasibility Study, Solano County, California

Appendix B – CPT Data from 2018 FCFS Geotechnical Exploration

PRESENTATION OF SITE INVESTIGATION RESULTS

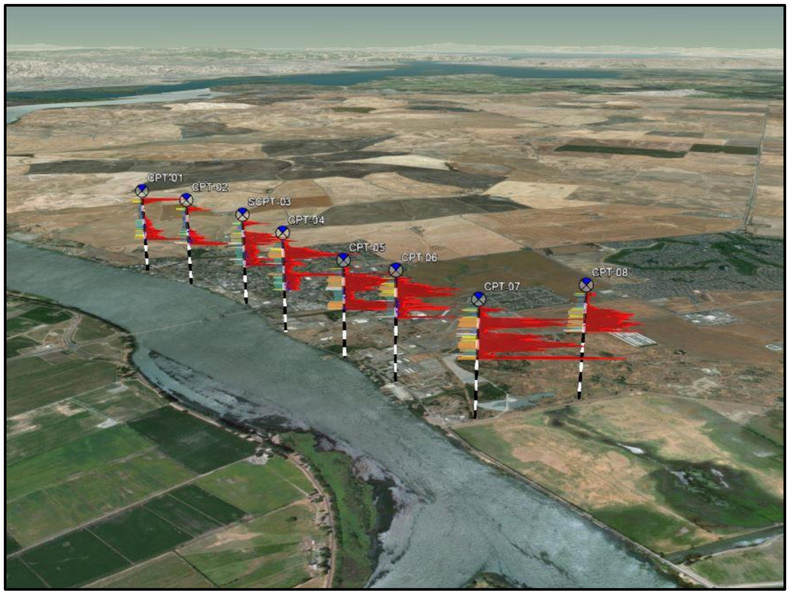
Rio Vista Feasibility Study

Prepared for:

GEI Consultants Inc.

CPT Inc. Job No: 18-56035

Project Start Date: 28-Mar-2018
Project End Date: 30-Mar-2018
Report Date: 04-Apr-2018



Prepared by:

California Push Technologies Inc.
820 Aladdin Avenue
San Leandro, CA 94577

Tel: (510) 357-3677

Email: cpt@cptinc.com
www.cptinc.com

Introduction

The enclosed report presents the results of the site investigation program conducted by CPT Inc. for GEI Consultants Inc. at Rio Vista, CA. The program consisted of seven cone penetration tests (CPT) and one seismic cone penetration test (SCPT).

Project Information

Project	
Client	GEI Consultants Inc.
Project	Rio Vista Feasibility Study
CPT Inc. project number	18-56035

An overview map displaying the CPT test locations is presented below.

Rig Description	Deployment System	Test Type
CPT truck rig (C15)	30 ton rig cylinder	CPT, SCPT
CPT track rig (GPT2)	20 ton rig cylinder	CPT

Coordinates		
Test Type	Collection Method	EPSG Reference
CPT, SCPT	Consumer grade GPS	32610

Cone Penetration Test (CPT)	
Depth reference	Depths are referenced to the existing ground surface at the time of each test.
Tip and sleeve data offset	0.1 meter This has been accounted for in the CPT data files.
Additional plots	Advanced plots with Ic, Su(Nkt), Phi and N1(60)Ic, cone penetration test plots with expanded range, seismic cone penetration plot and soil behavior type (SBT) scatter plots are provided in the data release package.

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)
446:T1500F15U500	446	15	225	1500	15	500
Cone 446 was used for all CPT soundings.						

CPT Calculated Parameters	
Additional information	The Normalized Soil Behavior Type Chart based on Q_{tn} (SBT Qtn) (Robertson, 2009) was used to classify the soil for this project. A detailed set of calculated CPT parameters have been generated and are provided in Excel format files in the release folder. The CPT parameter calculations are based on values of corrected tip resistance (q_t) sleeve friction (f_s), and pore pressure (u_2). Soils were classified as either drained or undrained based on the Q_{tn} Normalized Soil Behavior Type Chart (Robertson, 2009). Calculations for both drained and undrained parameters were included for materials that classified as silt mixtures – clayey silt to silty clay (zone 4).

Limitations

This report has been prepared for the exclusive use of GEI Consultants Inc. (Client) for the project titled "Rio Vista Feasibility Study". The report's contents may not be relied upon by any other party without the express written permission of CPT Inc. CPT Inc. 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 CPT Inc. 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.

The cone penetration tests (CPTu) are conducted using an integrated electronic piezocone penetrometer and data acquisition system manufactured by Adara Systems Ltd. of Richmond, British Columbia, Canada.

CPT Inc.'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.

The penetrometers are manufactured with various tip, friction and pore pressure capacities in both 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 44 mm diameter over a length of 32 mm with tapered leading and trailing edges) located at a distance of 585 mm 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 60 degree apex angle.

All 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 6 mm 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. Our calibration criteria also meet or exceed those of the current ASTM D5778 standard. An illustration of the piezocone penetrometer is presented in Figure CPTu.

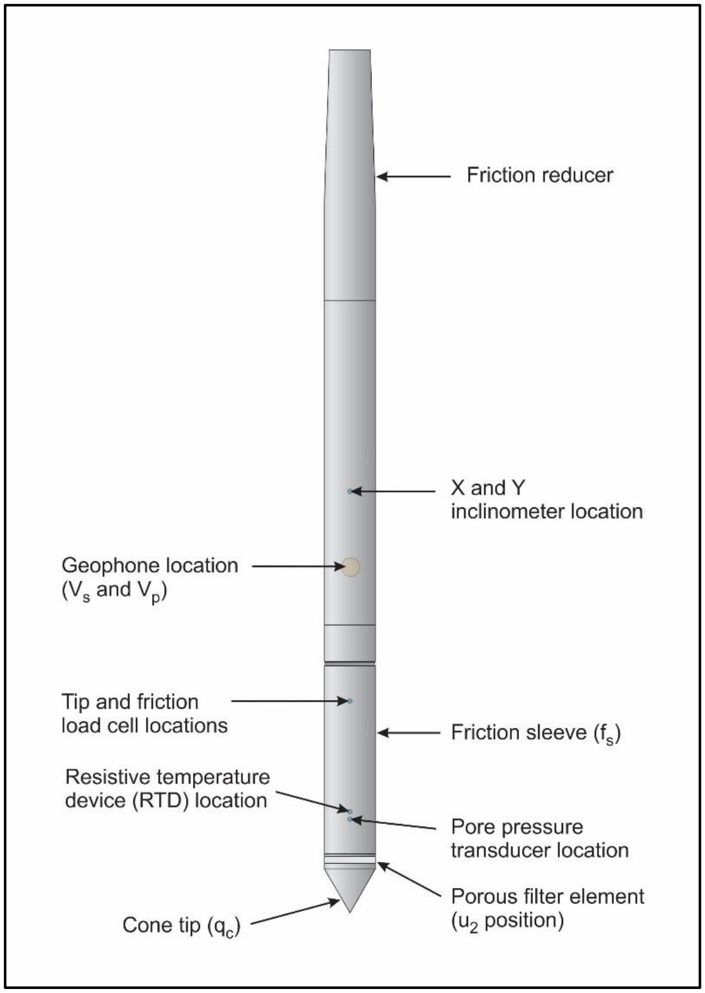


Figure CPTu. Piezocone Penetrometer (15 cm^2)

The data acquisition systems consist of a Windows based computer and a signal conditioner and power supply interface box with a 16 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 intervals are either 2.5 cm or 5.0 cm depending on project requirements; 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 CPT Inc.'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 either glycerin or 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 2 cm/s, within acceptable tolerances. Typically one meter length rods with an outer diameter of 1.5 inches are added to advance the cone to the sounding termination depth. After cone retraction final baselines are recorded.

Additional information pertaining to CPT Inc.'s cone penetration testing procedures:

- Each filter is saturated in silicone oil or glycerin 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 the piezocone data and associated calculated parameters for this report are 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 (1990) and Robertson (2009). It should be noted that it is not always possible to accurately identify a soil type based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behavior type.

The recorded tip resistance (q_c) is the total force acting on the piezocone tip divided by its base area. The tip resistance is corrected for pore pressure effects and termed corrected tip resistance (q_t) according to the following expression presented in Robertson et al, 1986:

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

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the piezocone (0.8 for CPT Inc. probes)

The sleeve friction (f_s) is the frictional force on the sleeve divided by its surface area. As all CPT Inc. 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).

Shear wave velocity testing is performed in conjunction with the piezocone penetration test (SCPTu) in order to collect interval velocities. For some projects seismic compression wave (Vp) velocity is also determined.

CPT Inc.'s piezocone penetrometers are manufactured with a horizontally active geophone (28 Hertz) that is rigidly mounted in the body of the cone penetrometer, 0.2 meters behind the cone tip.

Shear waves are typically generated by using an impact hammer horizontally striking a beam that is held in place by a normal load. In some instances an auger source or an imbedded impulsive source maybe used for both shear waves and compression waves. The hammer and beam act as a contact trigger that initiates the recording of the seismic wave traces. For impulsive devices an accelerometer trigger may be used. The traces are recorded using an up-hole integrated digital oscilloscope which is part of the SCPTu data acquisition system. An illustration of the shear wave testing configuration is presented in Figure SCPTu-1.

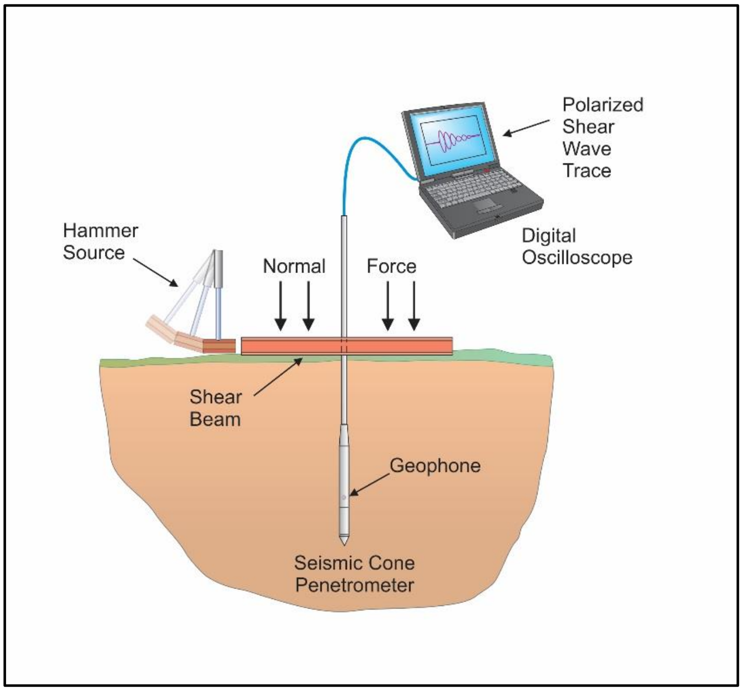


Figure SCPTu-1. Illustration of the SCPTu system

All testing is performed in accordance to CPT Inc.'s SCPTu operating procedures.

Prior to the start of a SCPTu sounding, the procedures described in the Cone Penetration Test section are followed. In addition, the active axis of the geophone is aligned parallel to the beam (or source) and the horizontal offset between the cone and the source is measured and recorded.

Prior to recording seismic waves at each test depth, cone penetration is stopped and the rods are decoupled from the rig to avoid transmission of rig energy down the rods. Multiple wave traces are recorded for quality control purposes. After reviewing wave traces for consistency the cone is pushed to the next test depth (typically one meter intervals or as requested by the client). Figure SCPTu-2 presents an illustration of a SCPTu test.

For additional information on seismic cone penetration testing refer to Robertson et.al. (1986).

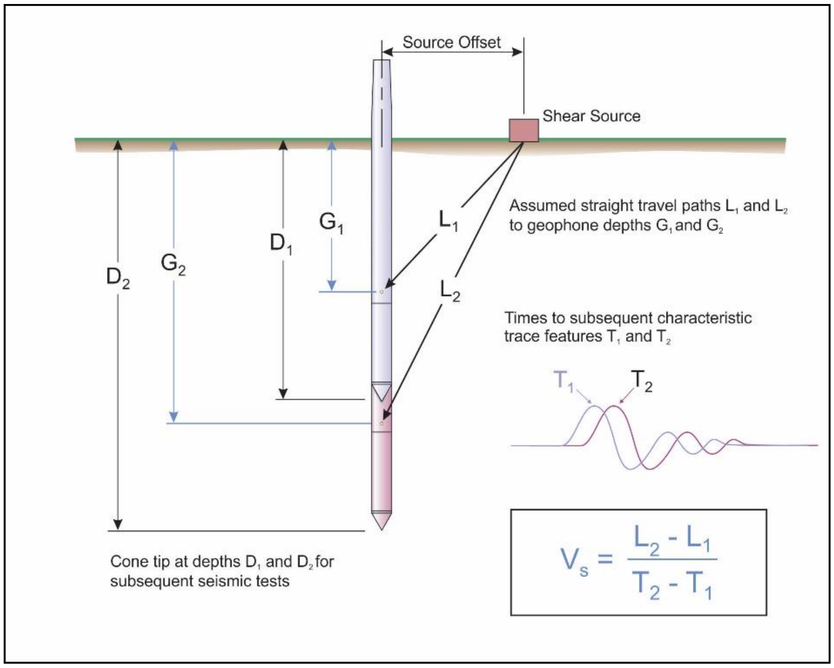


Figure SCPTu-2. Illustration of a seismic cone penetration test

Calculation of the interval velocities is performed by visually picking a common feature (e.g. the first characteristic peak, trough, or crossover) on all of the recorded wave sets and taking the difference in ray path divided by the time difference between subsequent features. Ray path is defined as the straight line distance from the seismic source to the geophone, accounting for beam offset, source depth and geophone offset from the cone tip.

The average shear wave velocity to a depth of 100 feet (30 meters) ($\bar{v}_s$) has been calculated and provided for all applicable soundings using the following equation presented in ASCE, 2010.

$$\bar{v}_s = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{v_{si}}}$$

where: $\bar{v}_s$ = average shear wave velocity ft/s (m/s)
d_i = the thickness of any layer between 0 and 100 ft (30 m)
v_{si} = the shear wave velocity in ft/s (m/s)
$\sum_{i=1}^{n} d_i$ = 100 ft (30 m)

Average shear wave velocity, $\bar{v}_s$ is also referenced to V_{s100} or V_{s30}.

The layer travel times refers to the travel times propagating in the vertical direction, not the measured travel times from an offset source.

Tabular results and SCPTu plots are presented in the relevant appendix.

The cone penetration test is halted at specific depths to carry out pore pressure dissipation (PPD) tests, shown in Figure PPD-1. For each dissipation test the cone and rods are decoupled from the rig and the data acquisition system measures and records the variation of the pore pressure (u) with time (t).

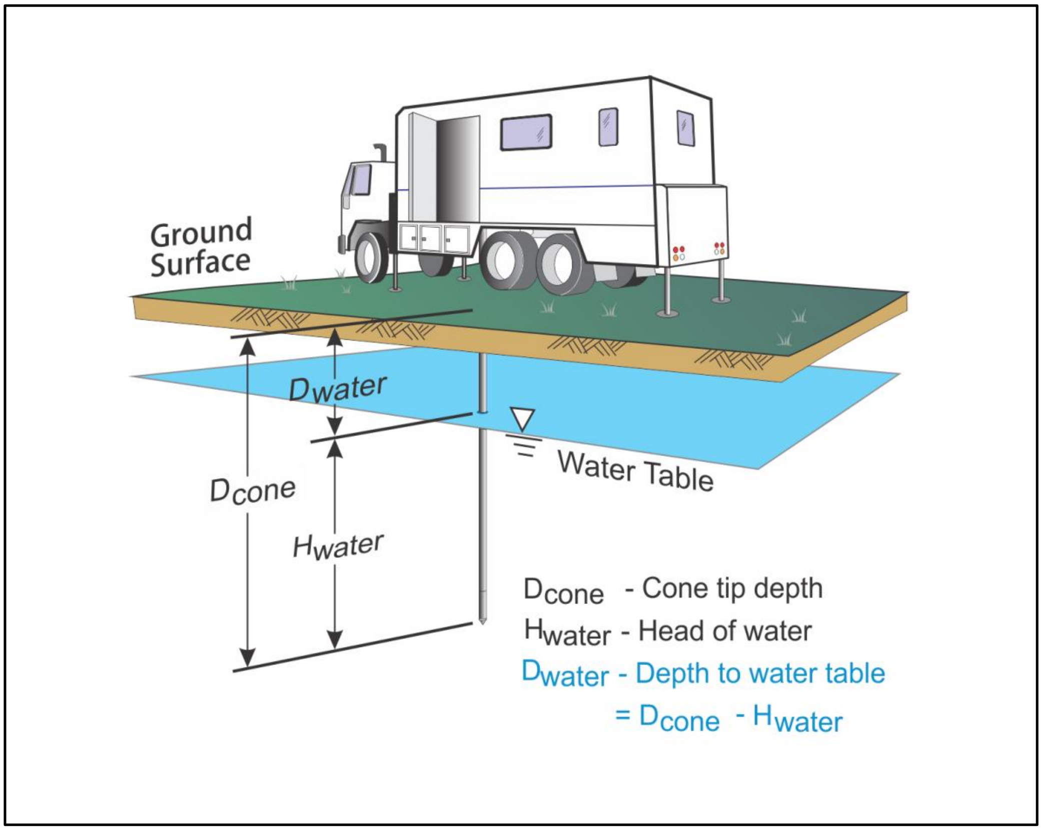


Figure PPD-1. Pore pressure dissipation test setup

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

The typical shapes of dissipation curves shown in Figure PPD-2 are very useful in assessing soil type, drainage, in situ pore pressure and soil properties. A flat curve that stabilizes quickly is typical of a freely draining sand. Undrained soils such as clays will typically show positive excess pore pressure and have long dissipation times. Dilative soils will often exhibit dynamic pore pressures below equilibrium that then rise over time. Overconsolidated fine-grained soils will often exhibit an initial dilatory response where there is an initial rise in pore pressure before reaching a peak and dissipating.

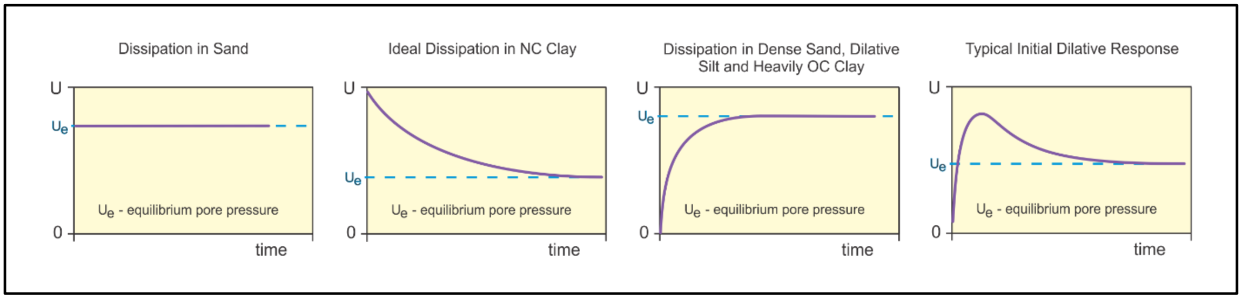


Figure PPD-2. Pore pressure dissipation curve examples

In order to interpret the equilibrium pore pressure (u_{eq}) and the apparent phreatic surface, the pore pressure should be monitored until such time as there is no variation in pore pressure with time as shown for each curve of 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.

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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.

Teh, C.I., and Houlsby, G.T., 1991, “An analytical study of the cone penetration test in clay”, Geotechnique, 41(1): 17-34.

The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Cone Penetration Test Plots with Expanded Range
- Advanced Cone Penetration Test Plots
- Soil Behavior Type (SBT) Scatter Plots
- Seismic Cone Penetration Test Plots
- Seismic Cone Penetration Test Tabular Results
- Seismic Cone Penetration Test Time Domain Traces
- Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

Cone Penetration Test Summary and Standard Cone Penetration Test Plots

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

Job No: 18-56035
Client: GEI Consultants Inc.
Project: Rio Vista Feasibility Study
Start Date: 28-Mar-2018
End Date: 30-Mar-2018

CONE PENETRATION TEST SUMMARY

Sounding ID	File Name	Date	Cone	Assumed Phreatic Surface[1] (ft)	Final Depth (ft)	Northing[2] (m)	Easting (m)	Refer to Notation Number
CPT-01	18-56035_CP01	28-Mar-2018	446:T1500F15U500	6.5	101.049	4223295	614599	
CPT-02	18-56035_CP02	28-Mar-2018	446:T1500F15U500	2.9	84.645	4223757	614760	
SCPT-03	18-56035_SP03	28-Mar-2018	446:T1500F15U500	6.7	93.585	4224299	614979	
CPT-04	18-56035_CP04	29-Mar-2018	446:T1500F15U500	7.0	97.604	4224766	615335	
CPT-05	18-56035_CP05	29-Mar-2018	446:T1500F15U500	5.9	76.033	4225232	615571	
CPT-06	18-56035_CP06	29-Mar-2018	446:T1500F15U500	4.3	67.749	4225584	615760	
CPT-07	18-56035_CP07	29-Mar-2018	446:T1500F15U500	12.6	81.036	4226047	616002	
CPT-08	18-56035_CP08	30-Mar-2018	446:T1500F15U500	3.4	63.073	4226404	615623	

1. The assumed phreatic surface was based on pore pressure dissipation tests, unless otherwise noted. Hydrostatic conditions were assumed for the calculated parameters.
2. Coordinates were acquired using consumer grade GPS equipment in datum: WGS 1984 / UTM Zone 10 North.

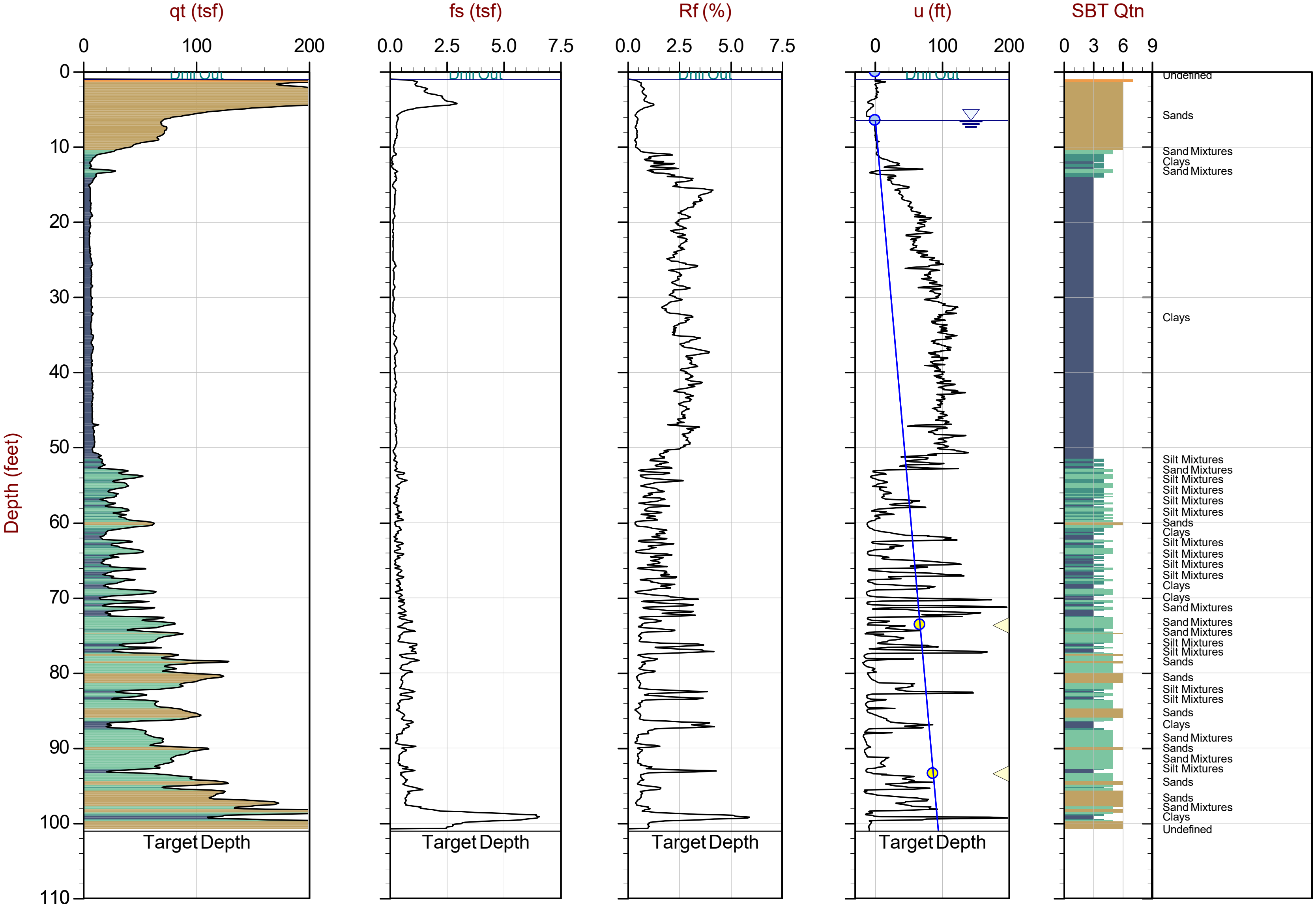
Sheet 1 of 1

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 09:11
Site: Rio Vista Feasibility Study

Sounding: CPT-01
Cone: 446:T1500F15U500



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

File: 18-56035_CP01.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4223295m E: 614599m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

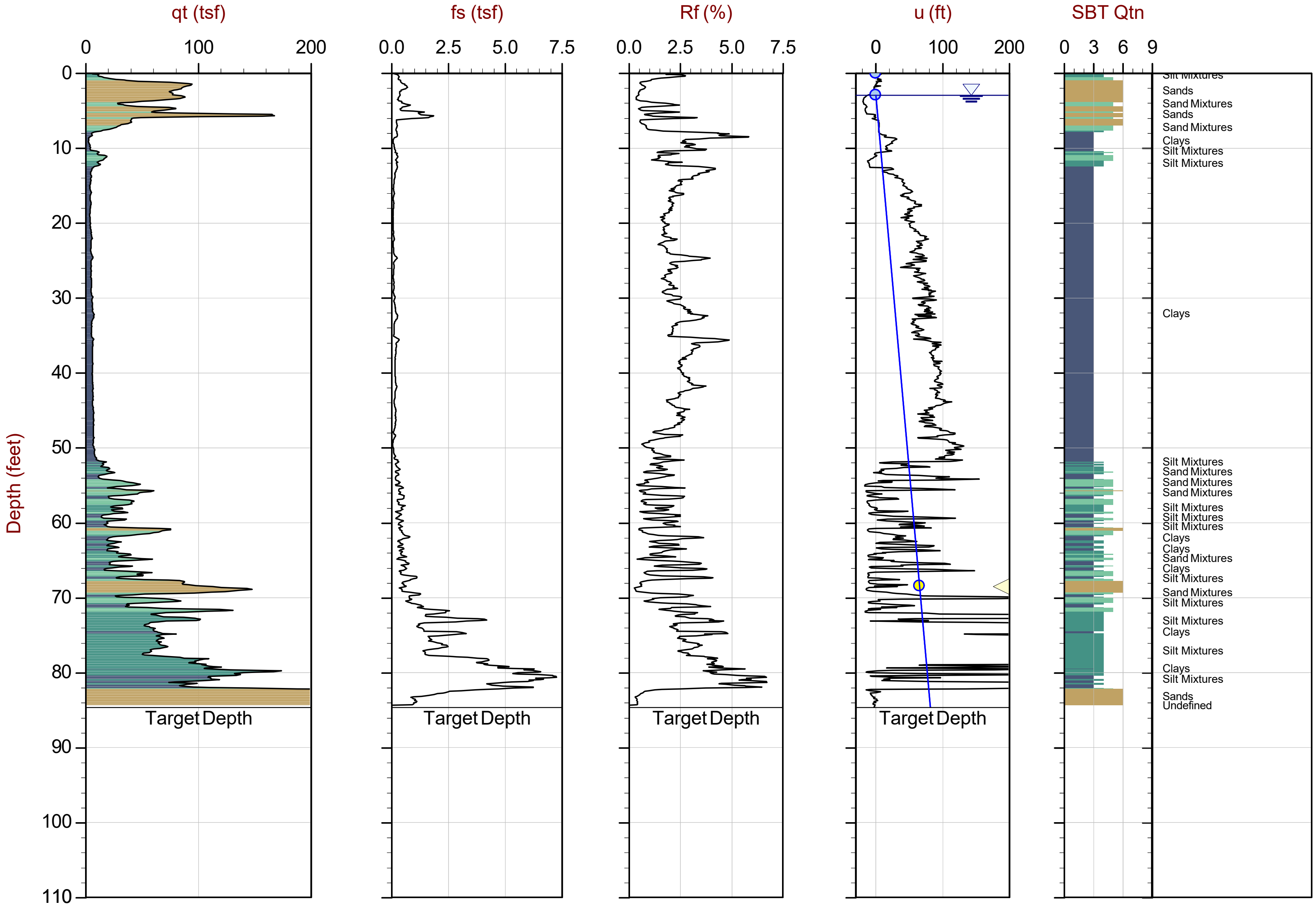
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 11:19
Site: Rio Vista Feasibility Study

Sounding: CPT-02
Cone: 446:T1500F15U500



Max Depth: 25.800 m / 84.64 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP02.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4223757m E: 614760m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

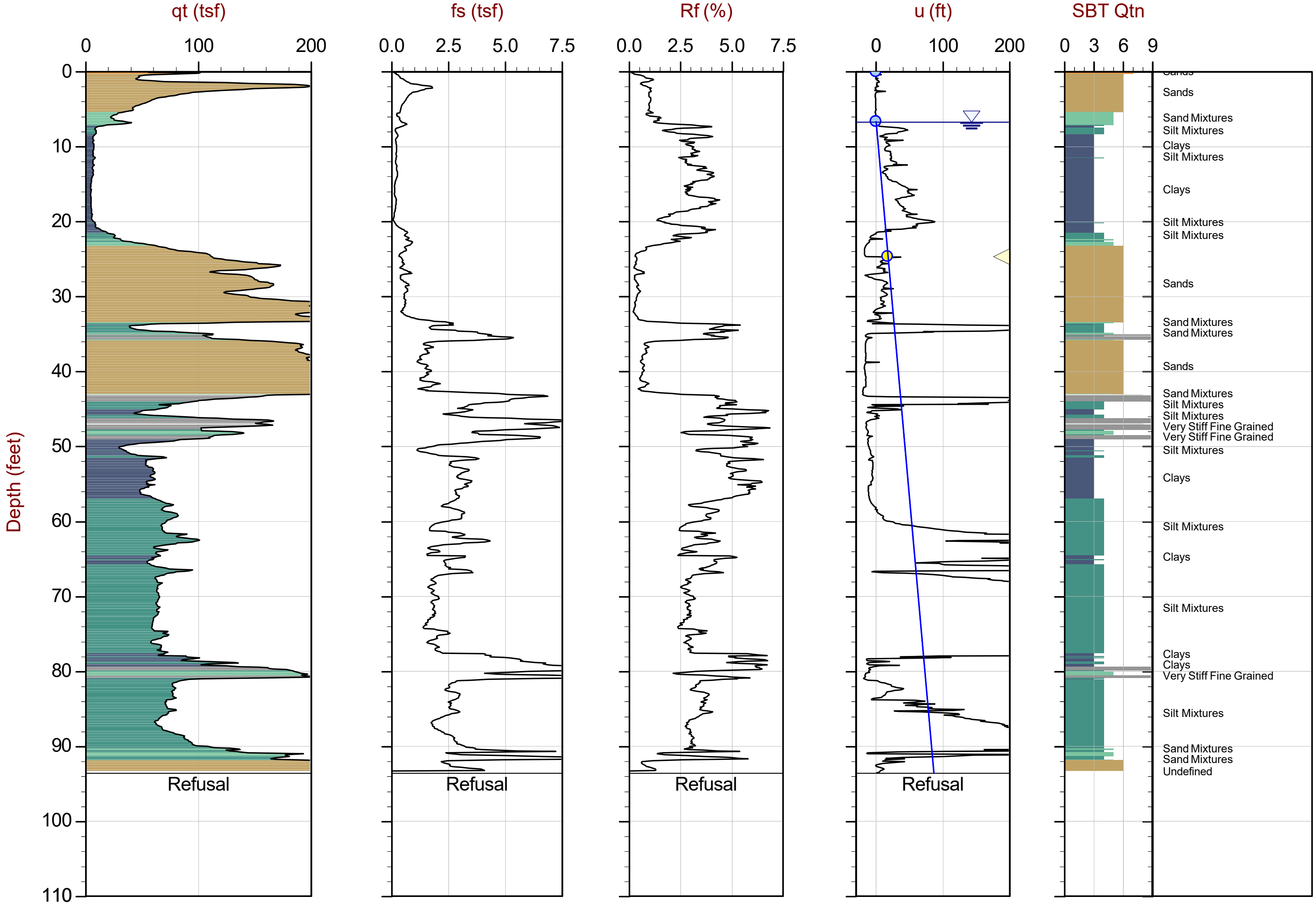
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 13:17
Site: Rio Vista Feasibility Study

Sounding: SCPT-03
Cone: 446:T1500F15U500



Max Depth: 28.525 m / 93.58 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_SP03.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4224299m E: 614979m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

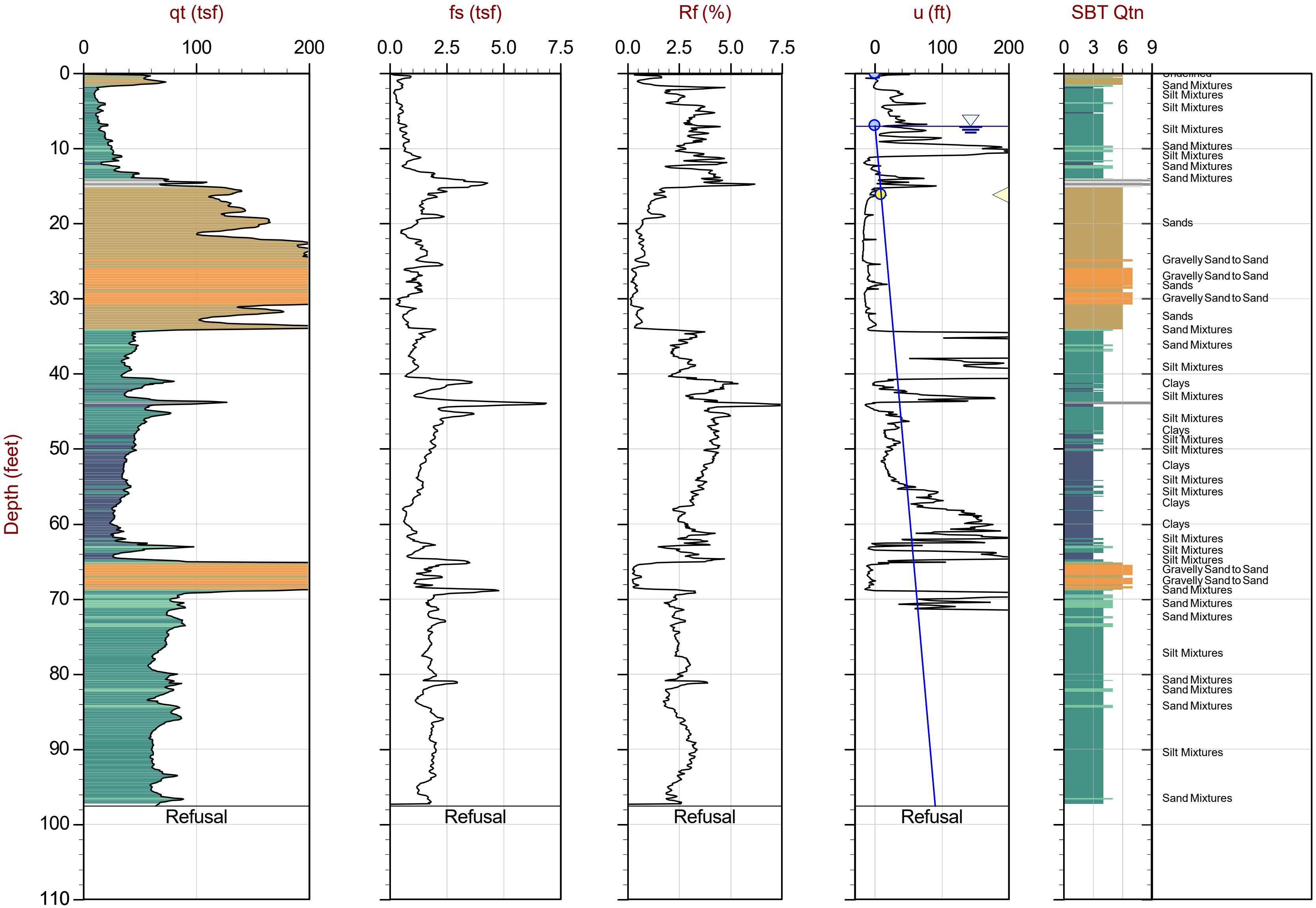
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 08:32
Site: Rio Vista Feasibility Study

Sounding: CPT-04
Cone: 446:T1500F15U500



Max Depth: 29.750 m / 97.60 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP04.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4224766m E: 615335m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

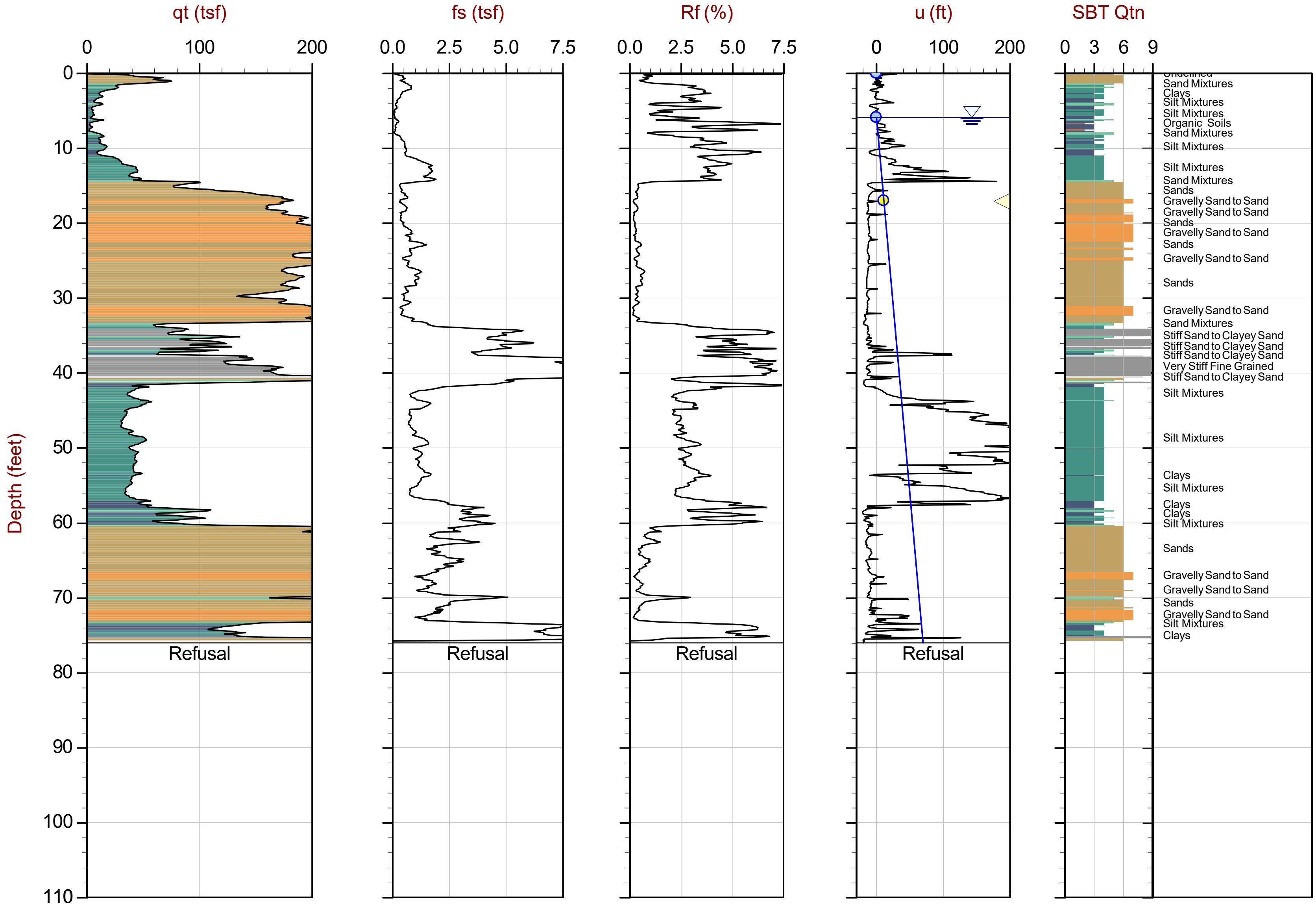
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 10:33
Site: Rio Vista Feasibility Study

Sounding: CPT-05
Cone: 446:T1500F15U500



Max Depth: 23.175 m / 76.03 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP05.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225232m E: 615571m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

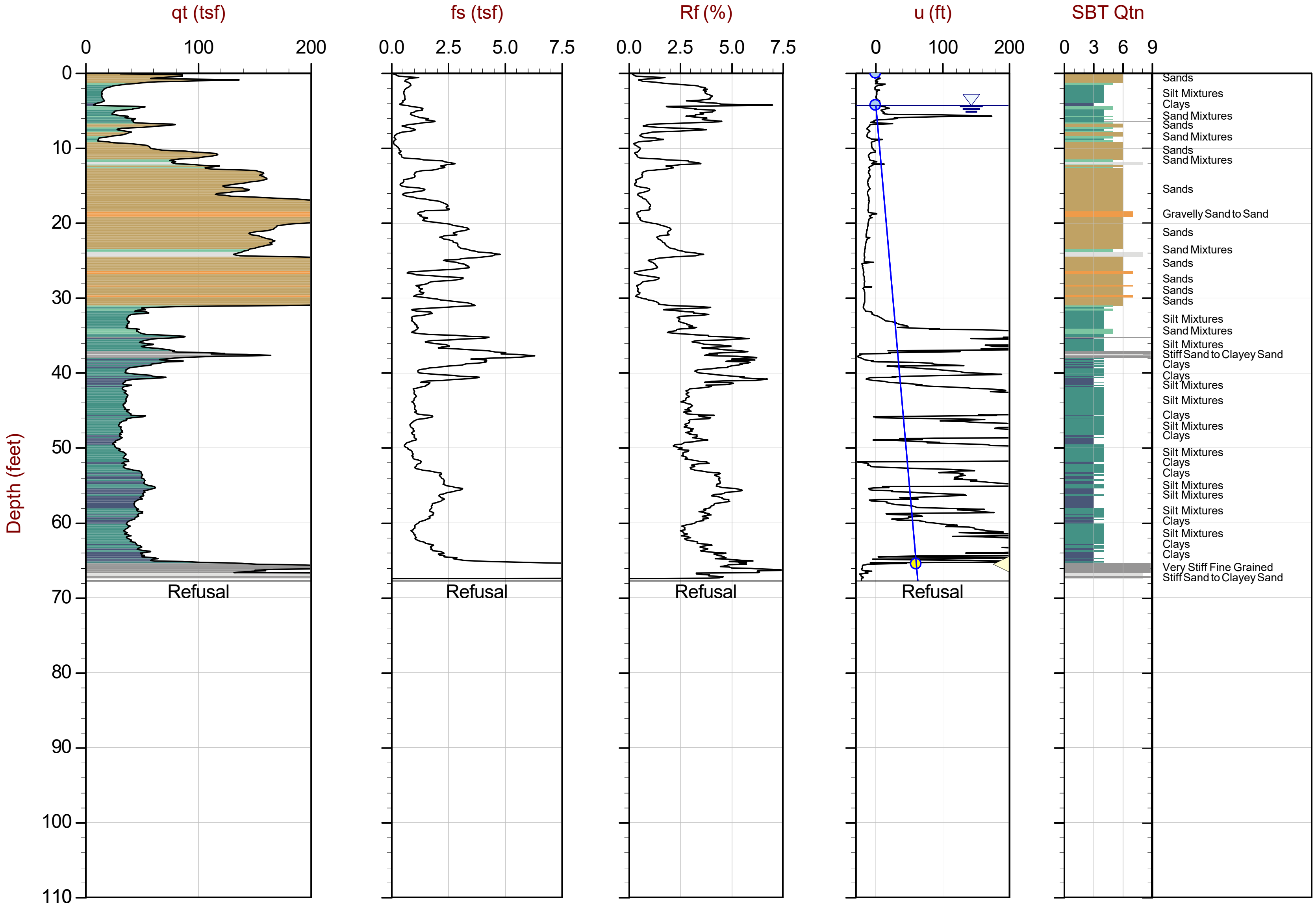
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 12:57
Site: Rio Vista Feasibility Study

Sounding: CPT-06
Cone: 446:T1500F15U500



Max Depth: 20.650 m / 67.75 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP06.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225584m E: 615760m
Sheet No: 1 of 1

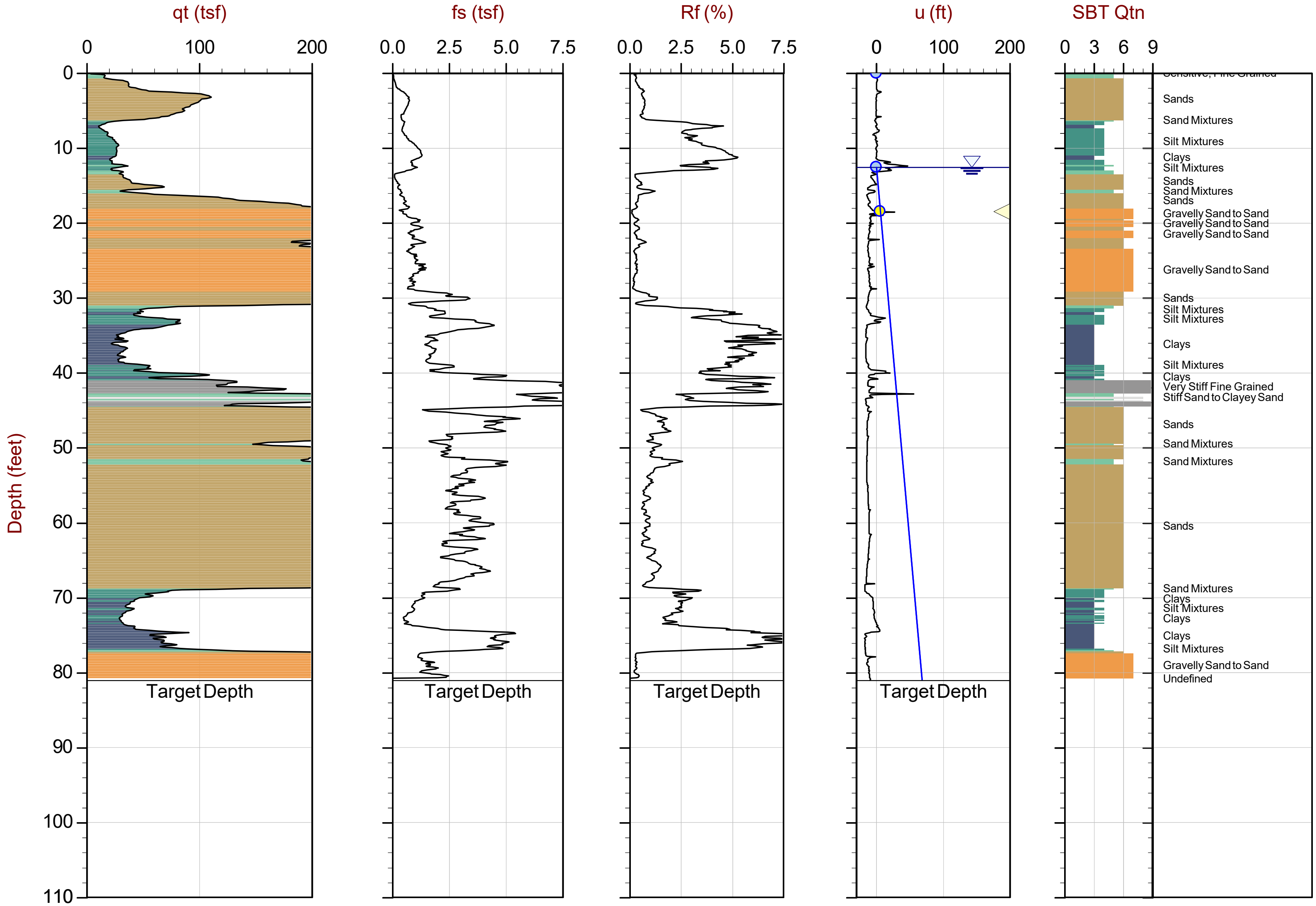
● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

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

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 14:45
Site: Rio Vista Feasibility Study

Sounding: CPT-07
Cone: 446:T1500F15U500



Max Depth: 24.700 m / 81.04 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP07.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4226047m E: 616002m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

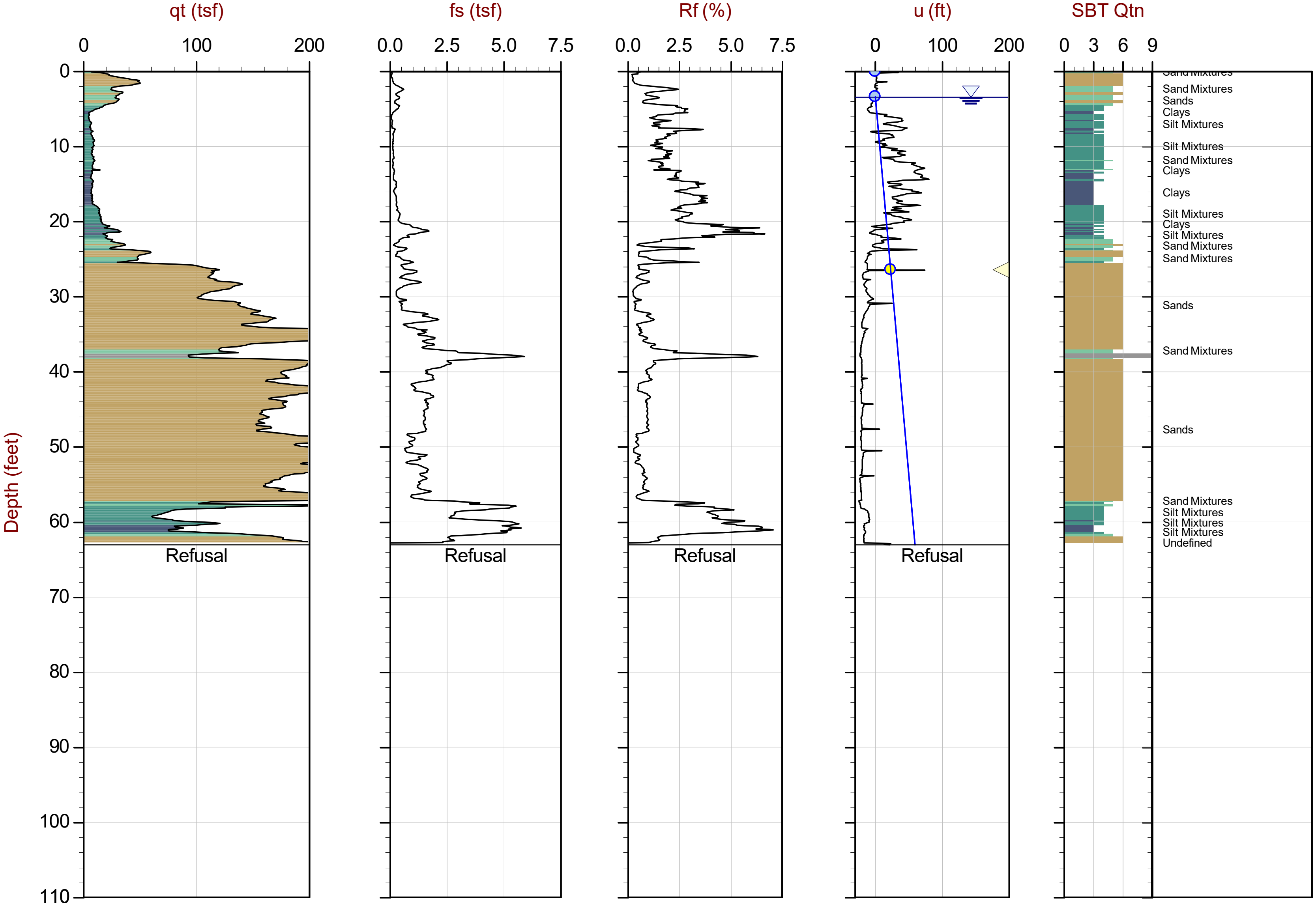
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-30 09:15
Site: Rio Vista Feasibility Study

Sounding: CPT-08
Cone: 446:T1500F15U500



Max Depth: 19.225 m / 63.07 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP08.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4226404m E: 615623m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq 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.

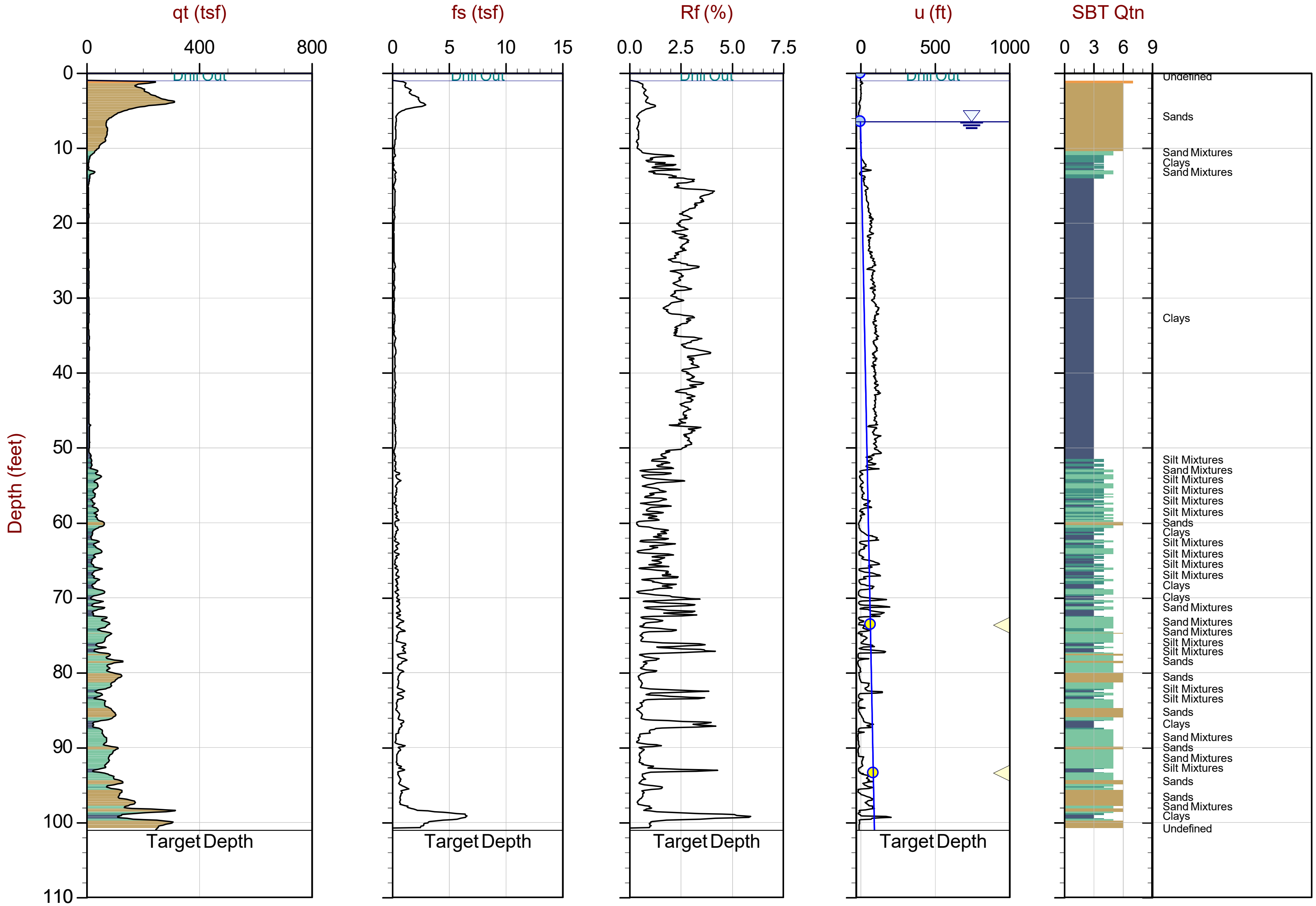
Cone Penetration Test Plots with Expanded Range

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 09:11
Site: Rio Vista Feasibility Study
Sounding: CPT-01
Cone: 446:T1500F15U500



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

File: 18-56035_CP01.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4223295m E: 614599m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

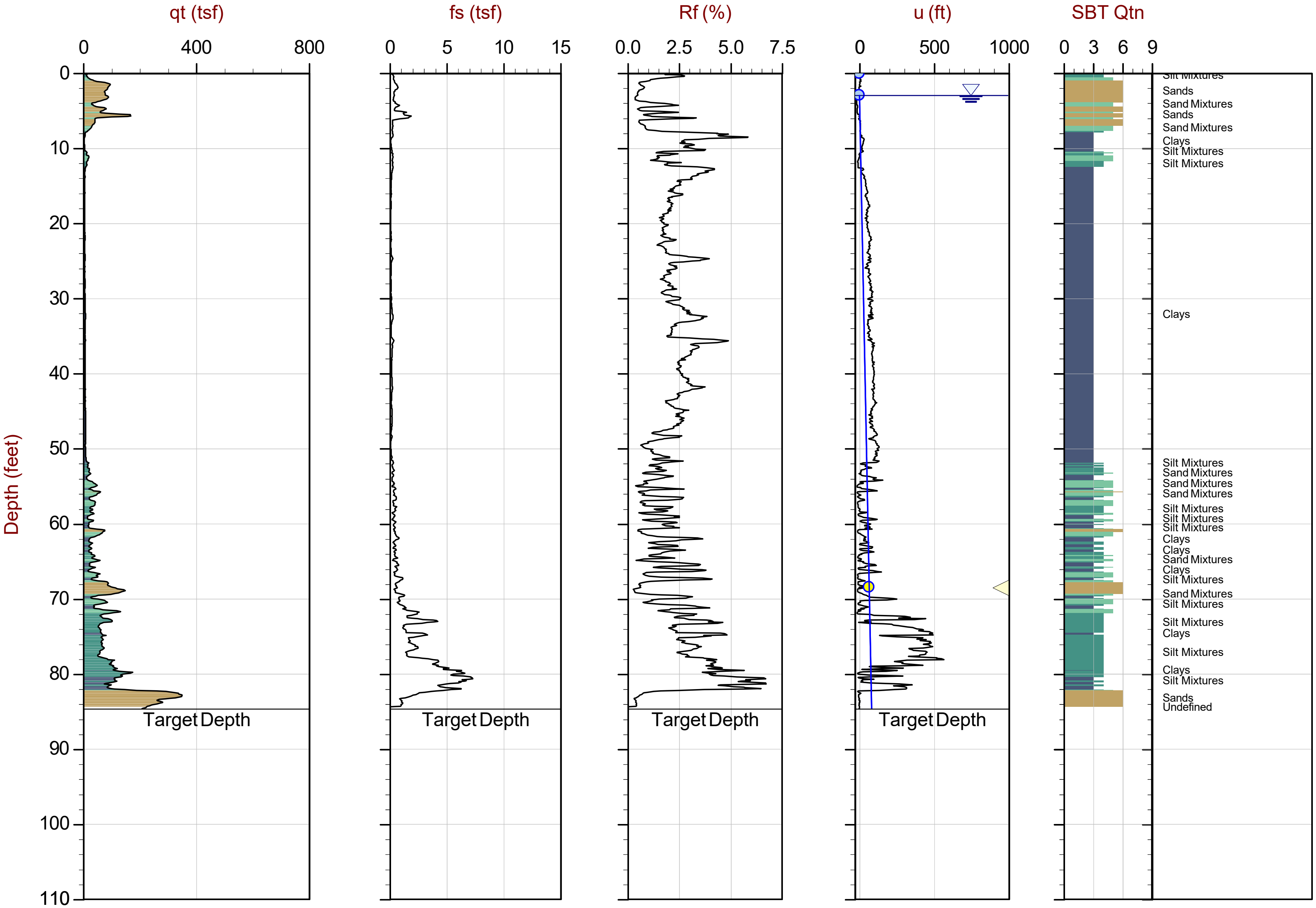
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 11:19
Site: Rio Vista Feasibility Study

Sounding: CPT-02
Cone: 446:T1500F15U500



Max Depth: 25.800 m / 84.64 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP02.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4223757m E: 614760m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

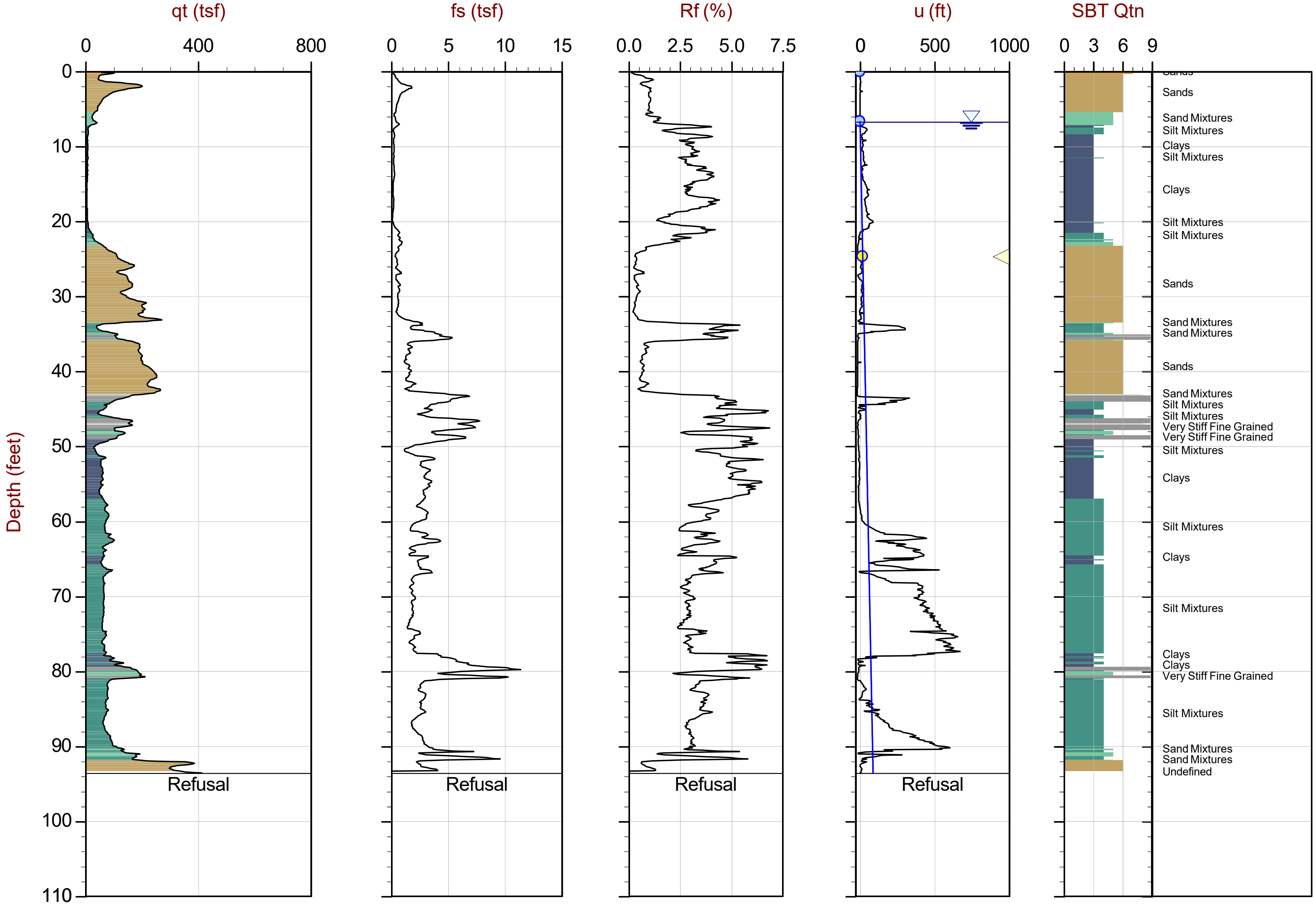
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 13:17
Site: Rio Vista Feasibility Study

Sounding: SCPT-03
Cone: 446:T1500F15U500



Max Depth: 28.525 m / 93.58 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_SP03.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4224299m E: 614979m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

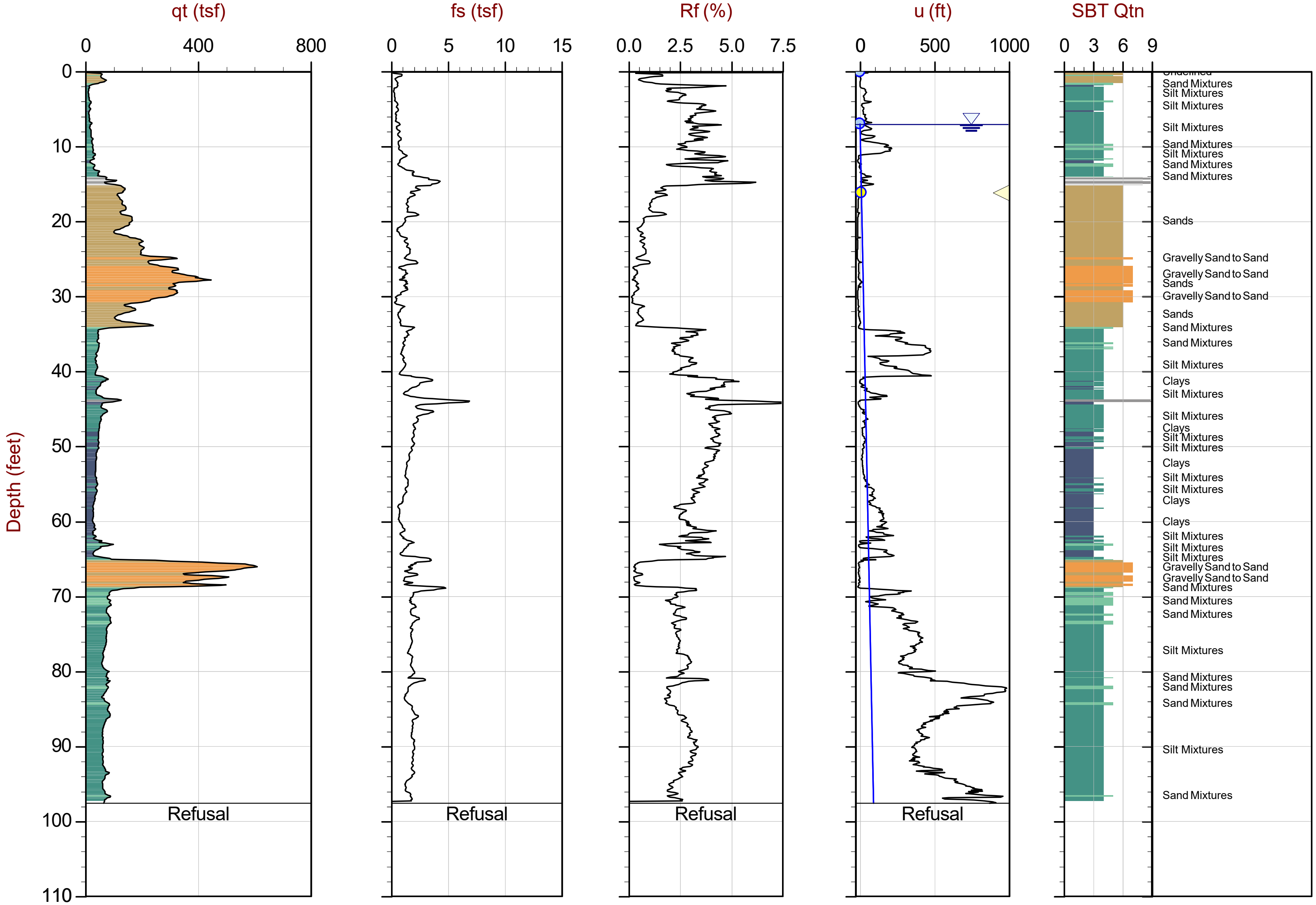
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 08:32
Site: Rio Vista Feasibility Study

Sounding: CPT-04
Cone: 446:T1500F15U500



Max Depth: 29.750 m / 97.60 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP04.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4224766m E: 615335m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

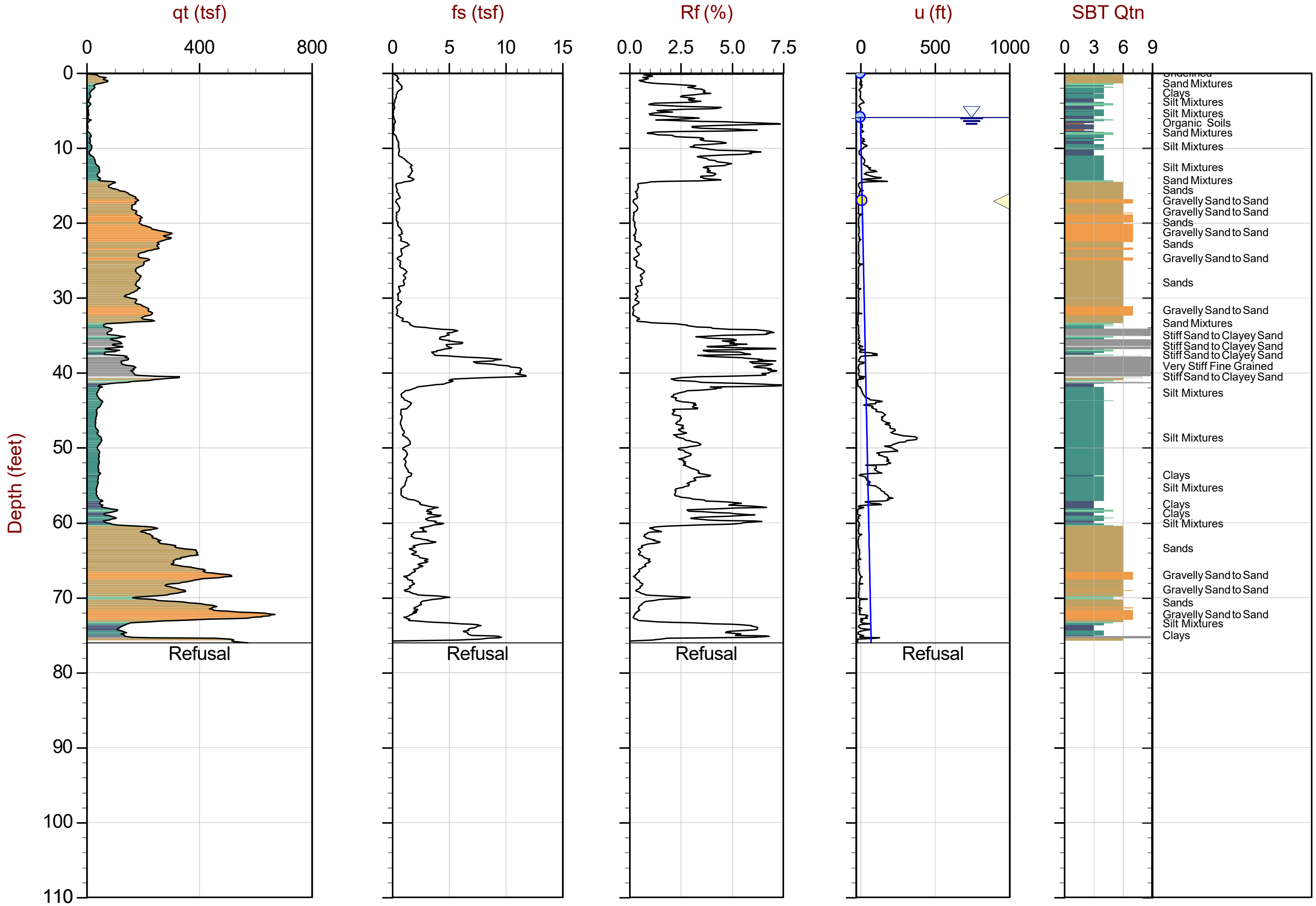
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 10:33
Site: Rio Vista Feasibility Study

Sounding: CPT-05
Cone: 446:T1500F15U500



Max Depth: 23.175 m / 76.03 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP05.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225232m E: 615571m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

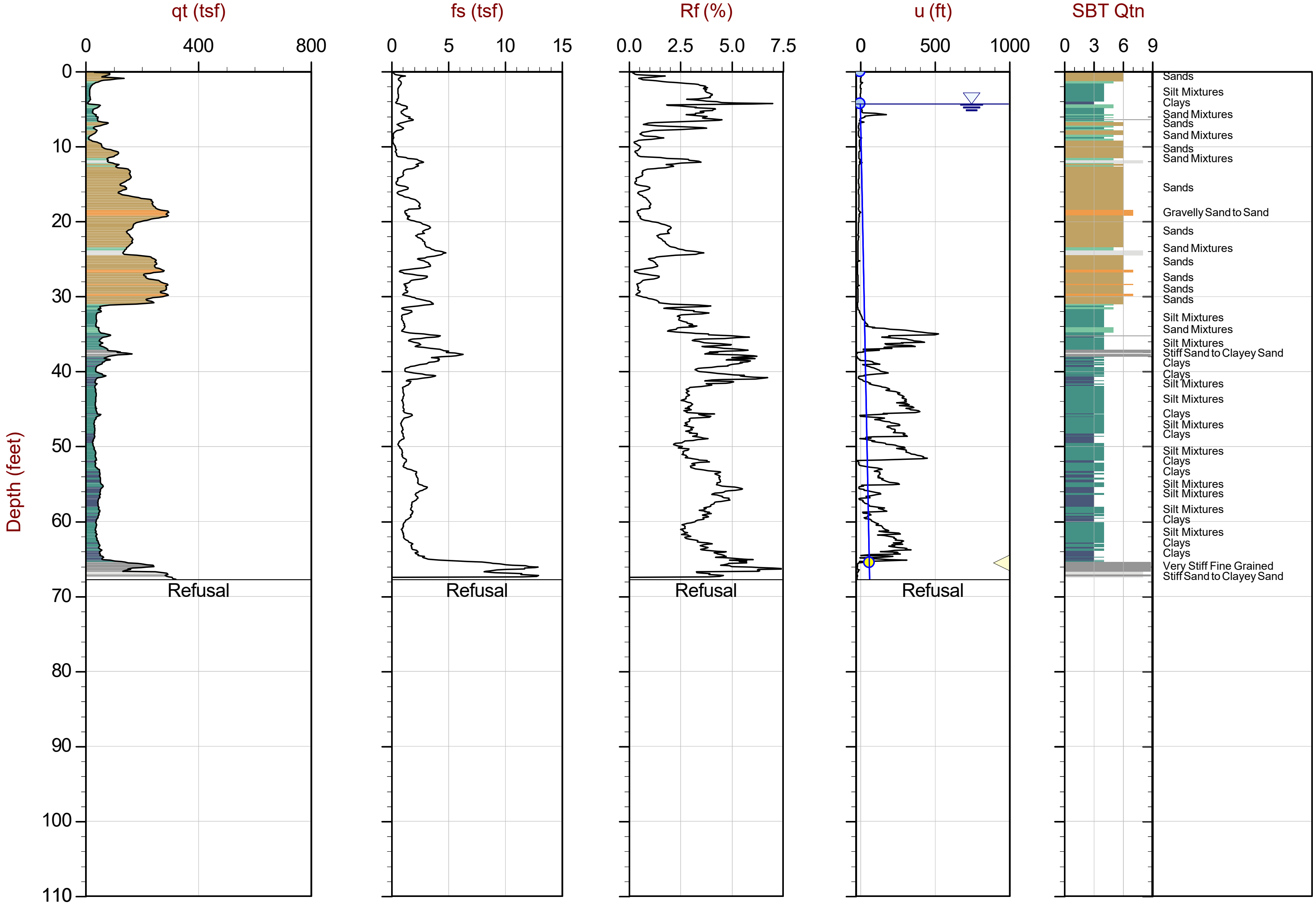
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 12:57
Site: Rio Vista Feasibility Study

Sounding: CPT-06
Cone: 446:T1500F15U500



Max Depth: 20.650 m / 67.75 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP06.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225584m E: 615760m
Sheet No: 1 of 1

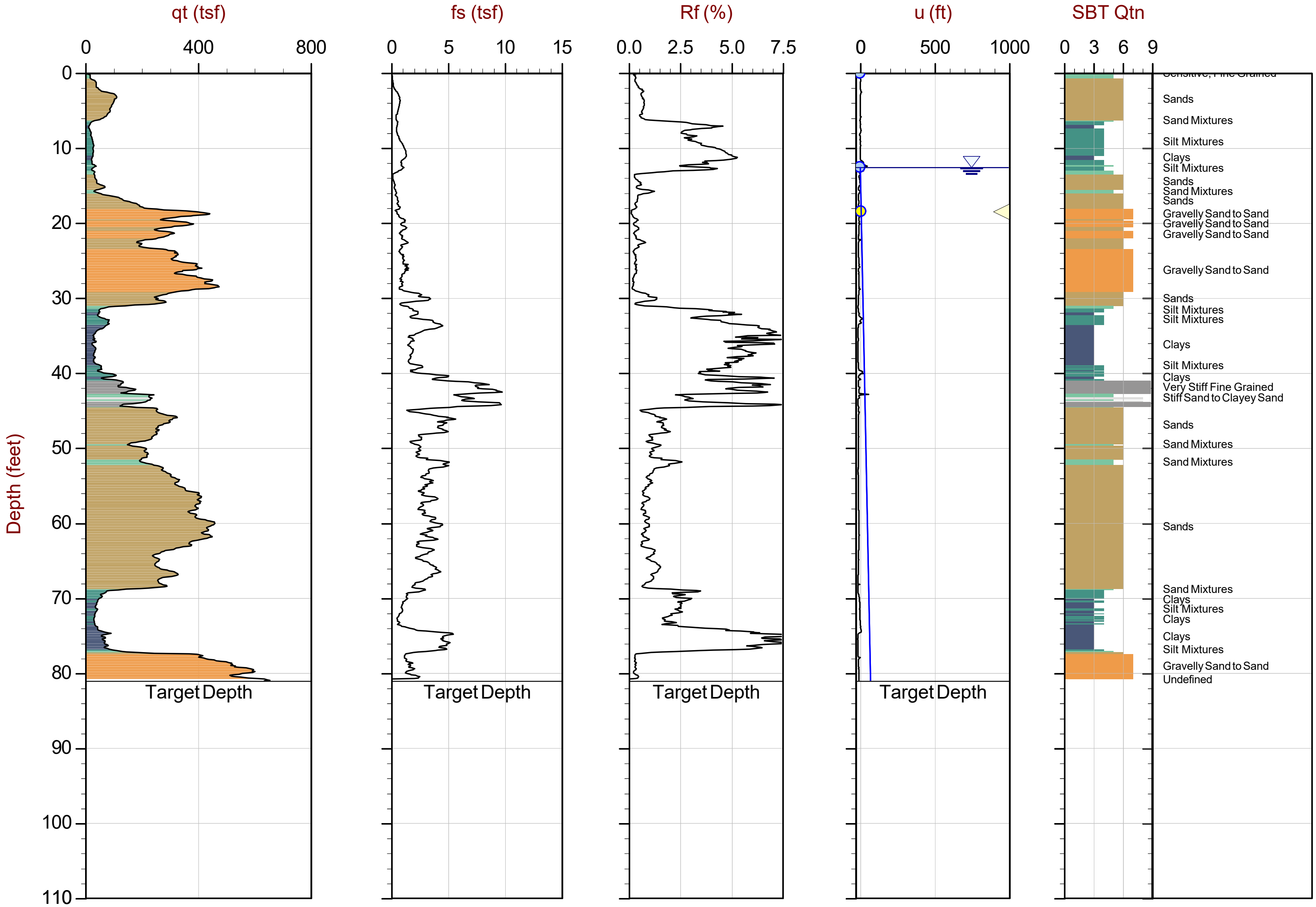
● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

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

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 14:45
Site: Rio Vista Feasibility Study
Sounding: CPT-07
Cone: 446:T1500F15U500



Max Depth: 24.700 m / 81.04 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP07.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4226047m E: 616002m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

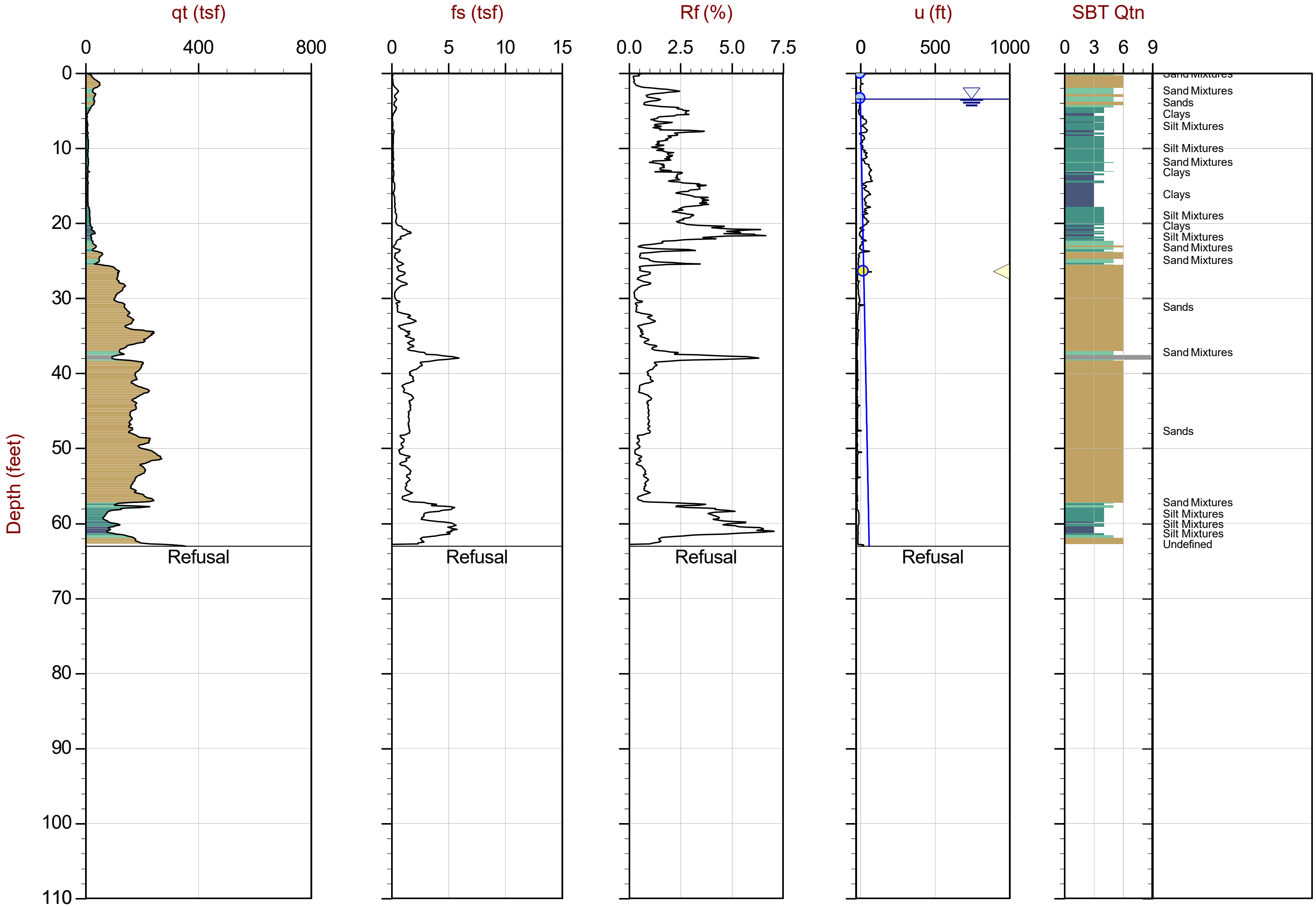
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-30 09:15
Site: Rio Vista Feasibility Study

Sounding: CPT-08
Cone: 446:T1500F15U500



Max Depth: 19.225 m / 63.07 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP08.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4226404m E: 615623m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq 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

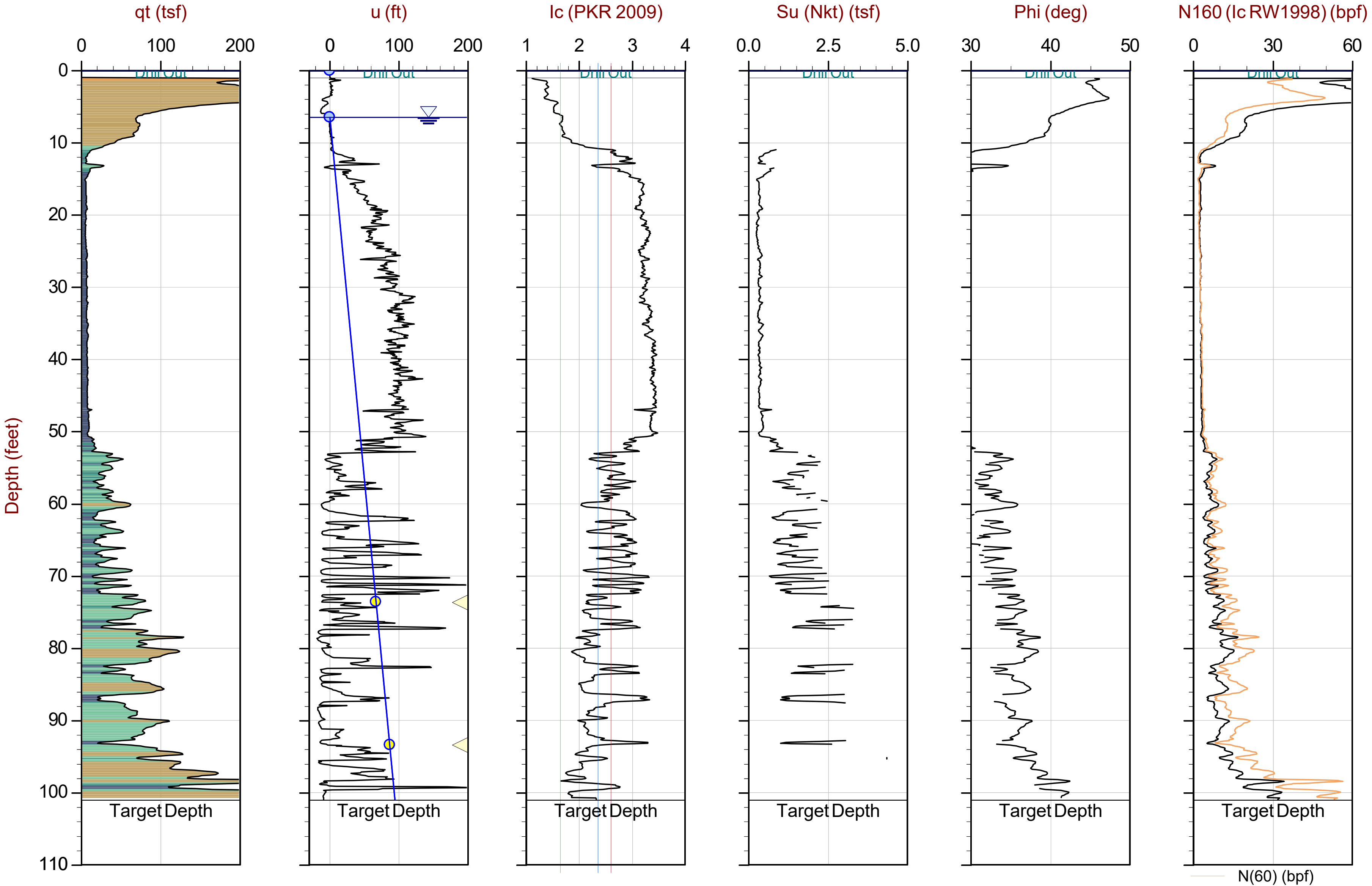
CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 09:11
Site: Rio Vista Feasibility Study

Sounding: CPT-01
Cone: 446:T1500F15U500



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

File: 18-56035_CP01.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4223295m E: 614599m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

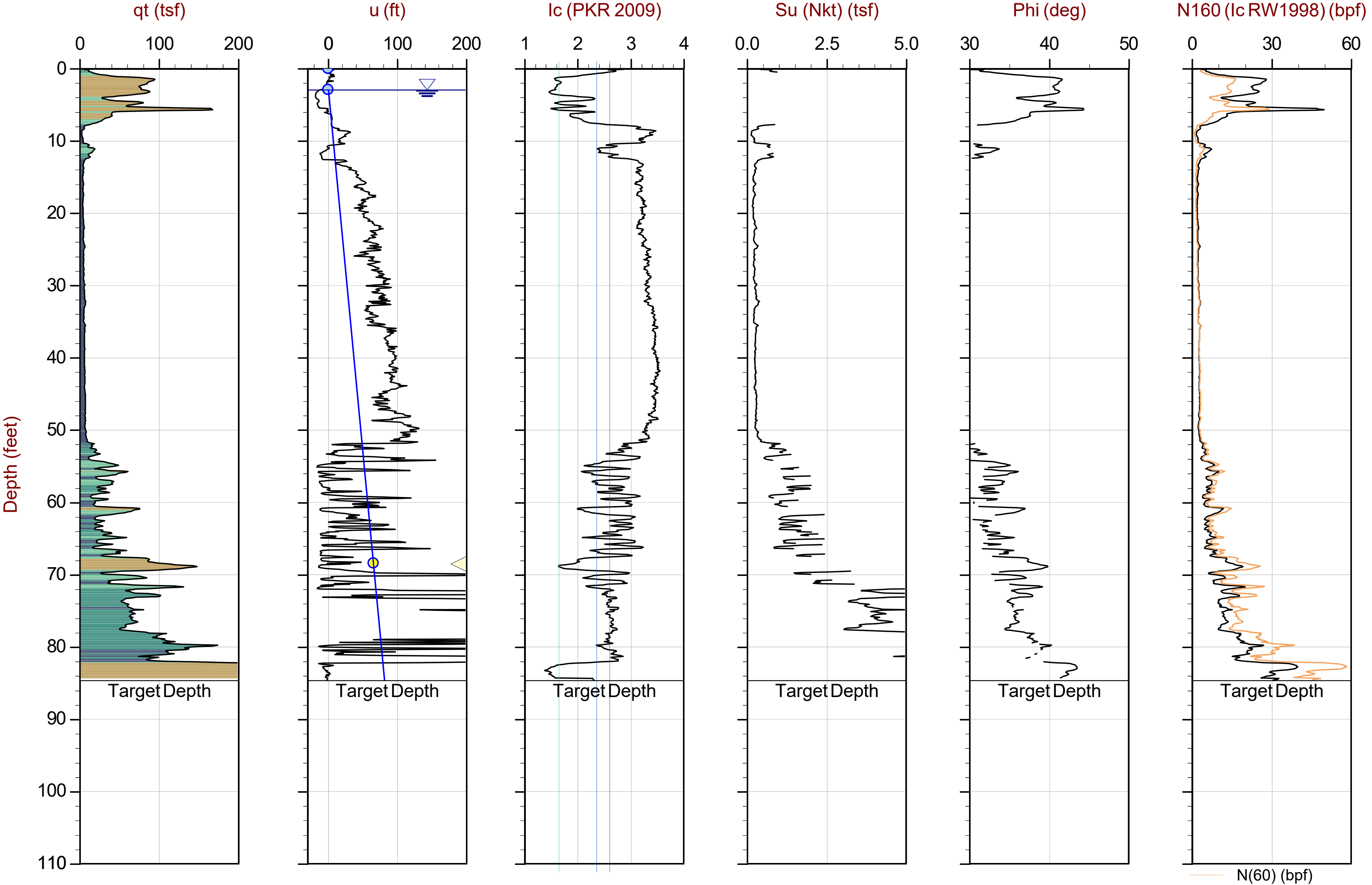
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 11:19
Site: Rio Vista Feasibility Study

Sounding: CPT-02
Cone: 446:T1500F15U500



Max Depth: 25.800 m / 84.64 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP02.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4223757m E: 614760m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq)   ● Assumed Ueq   ◁ Dissipation, Ueq achieved   — Hydrostatic Line

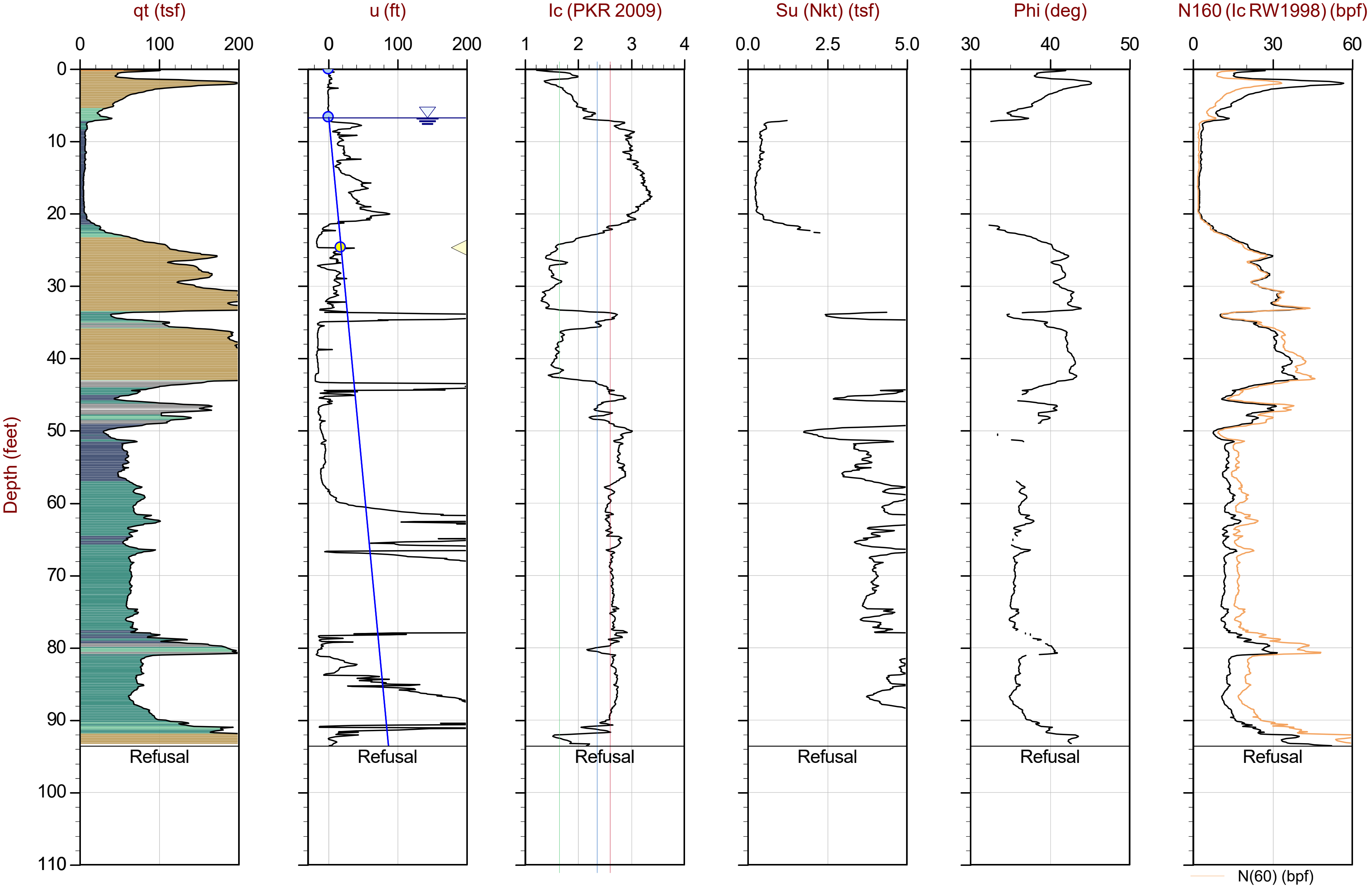
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 13:17
Site: Rio Vista Feasibility Study

Sounding: SCPT-03
Cone: 446:T1500F15U500



Max Depth: 28.525 m / 93.58 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_SP03.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4224299m E: 614979m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

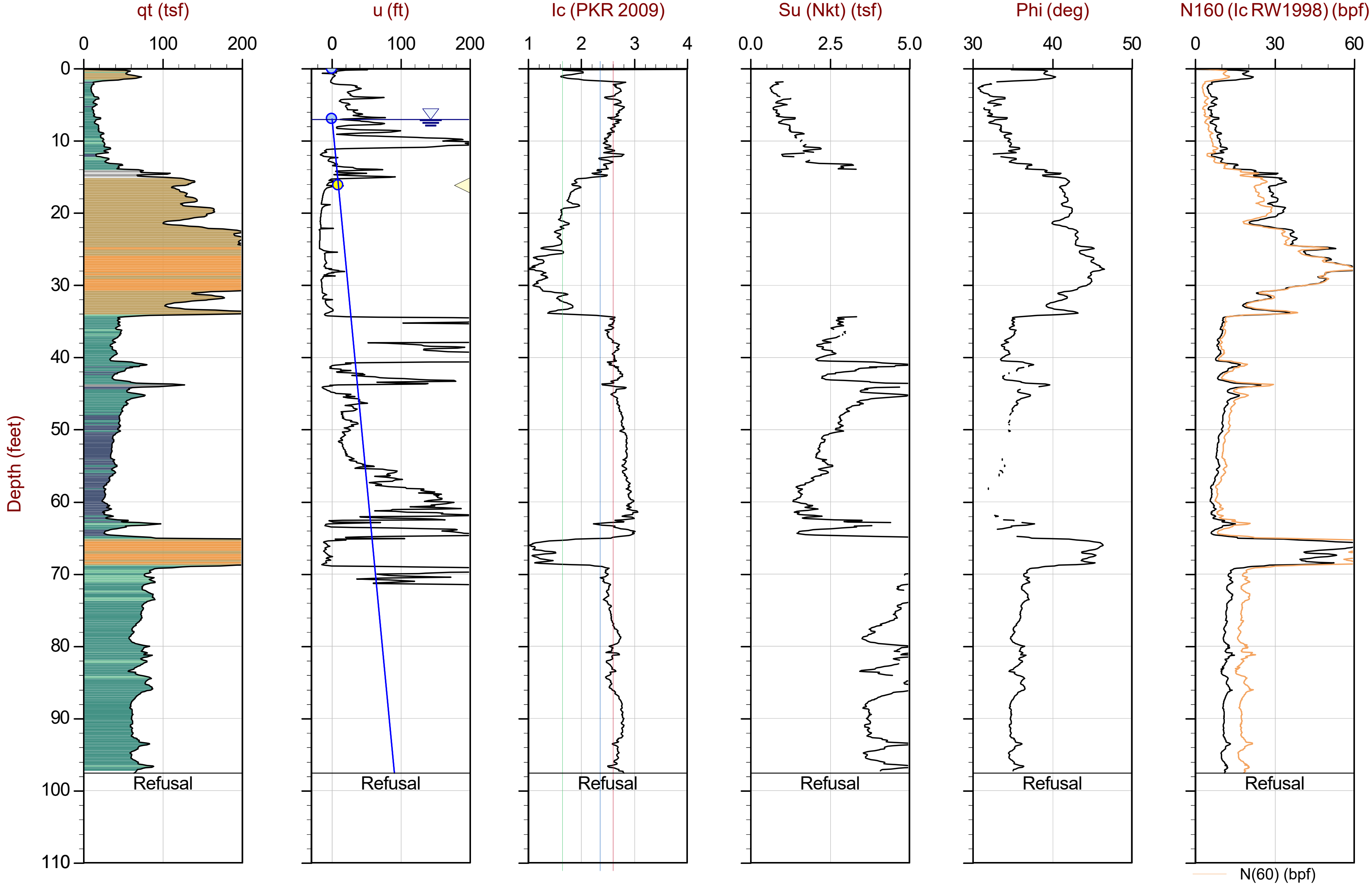
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 08:32
Site: Rio Vista Feasibility Study

Sounding: CPT-04
Cone: 446:T1500F15U500



Max Depth: 29.750 m / 97.60 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP04.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4224766m E: 615335m
Sheet No: 1 of 1

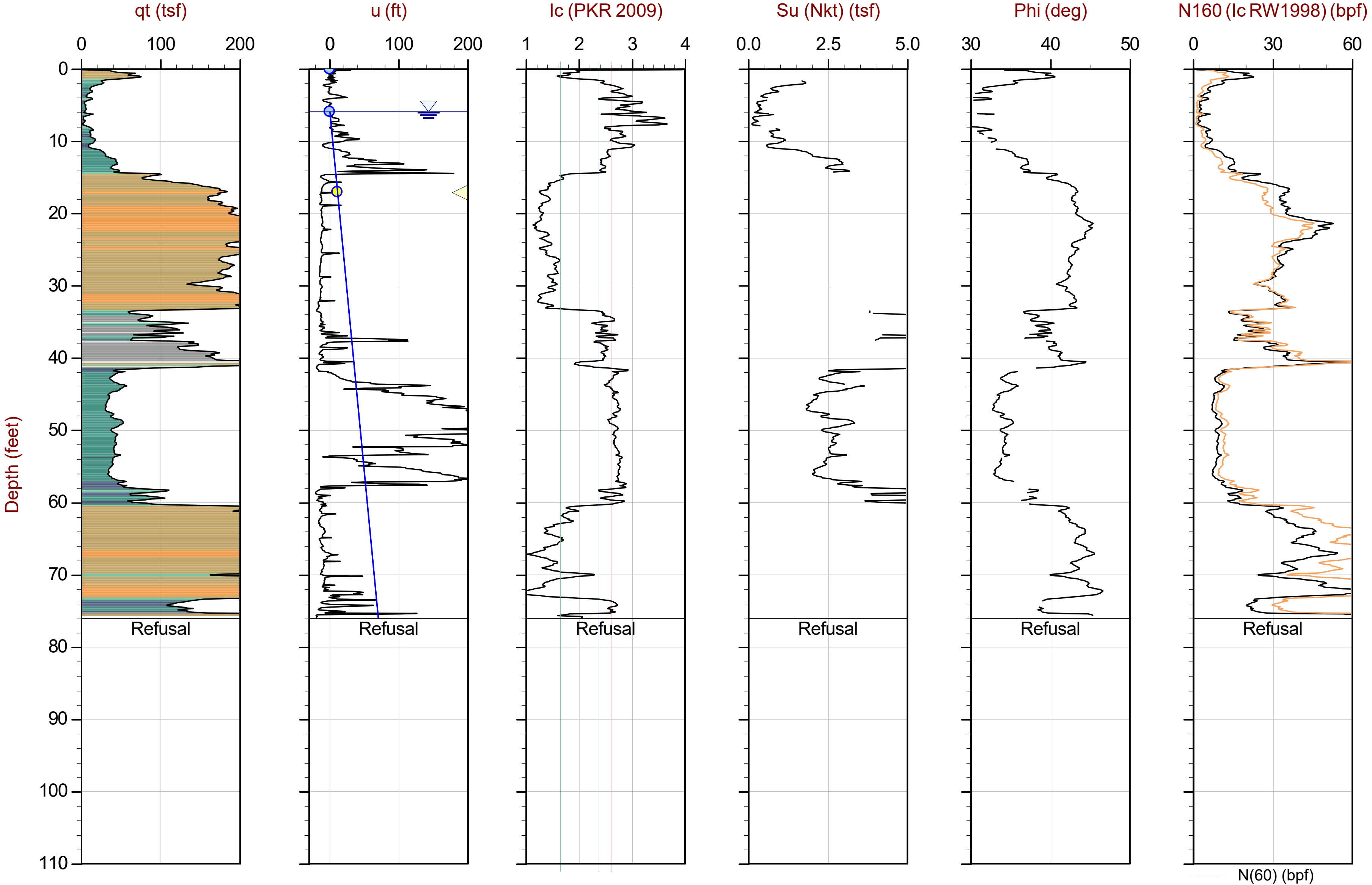
● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

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

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 10:33
Site: Rio Vista Feasibility Study

Sounding: CPT-05
Cone: 446:T1500F15U500



Max Depth: 23.175 m / 76.03 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP05.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225232m E: 615571m
Sheet No: 1 of 1

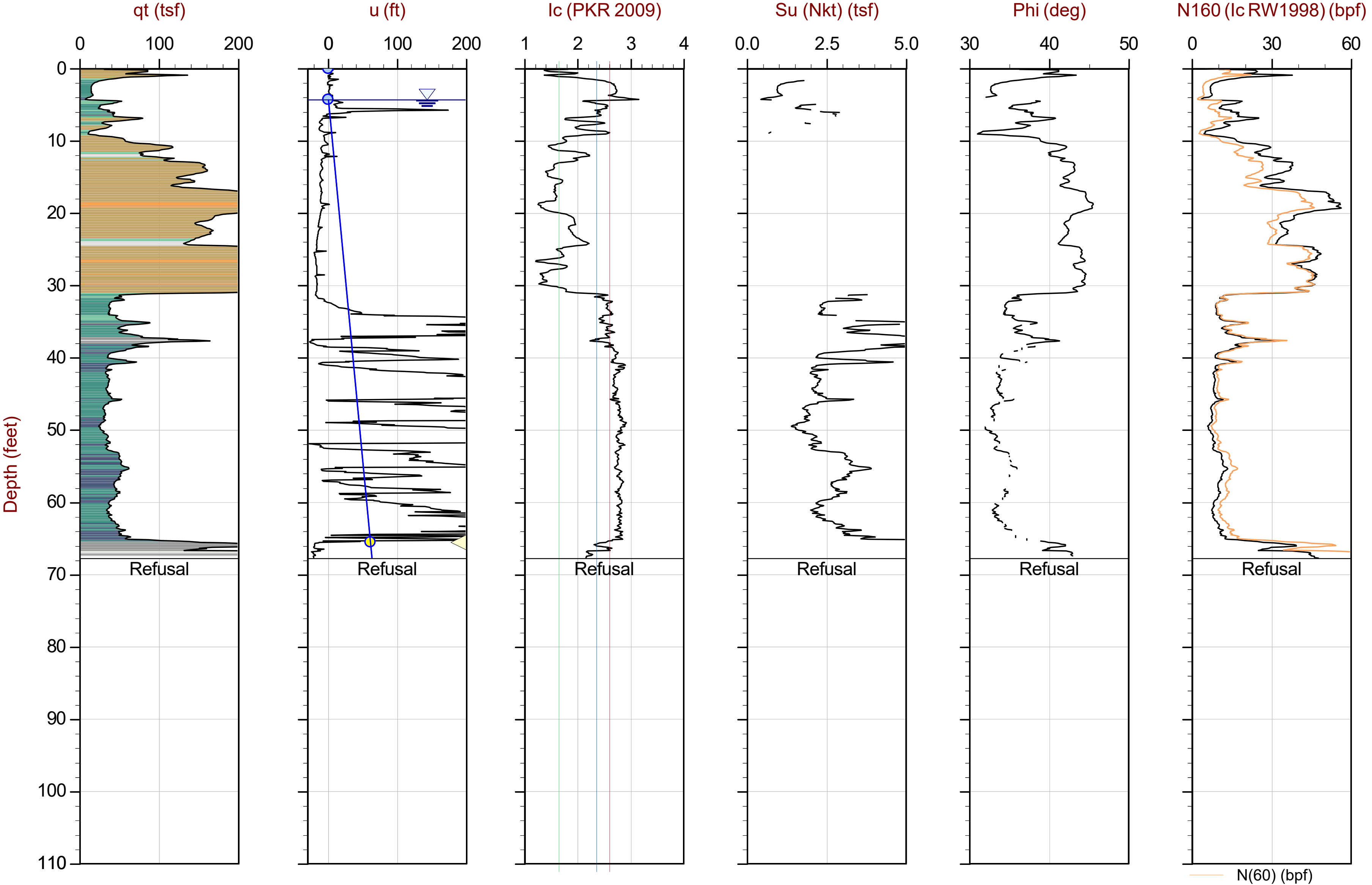
● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

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

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 12:57
Site: Rio Vista Feasibility Study
Sounding: CPT-06
Cone: 446:T1500F15U500



Max Depth: 20.650 m / 67.75 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP06.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4225584m E: 615760m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

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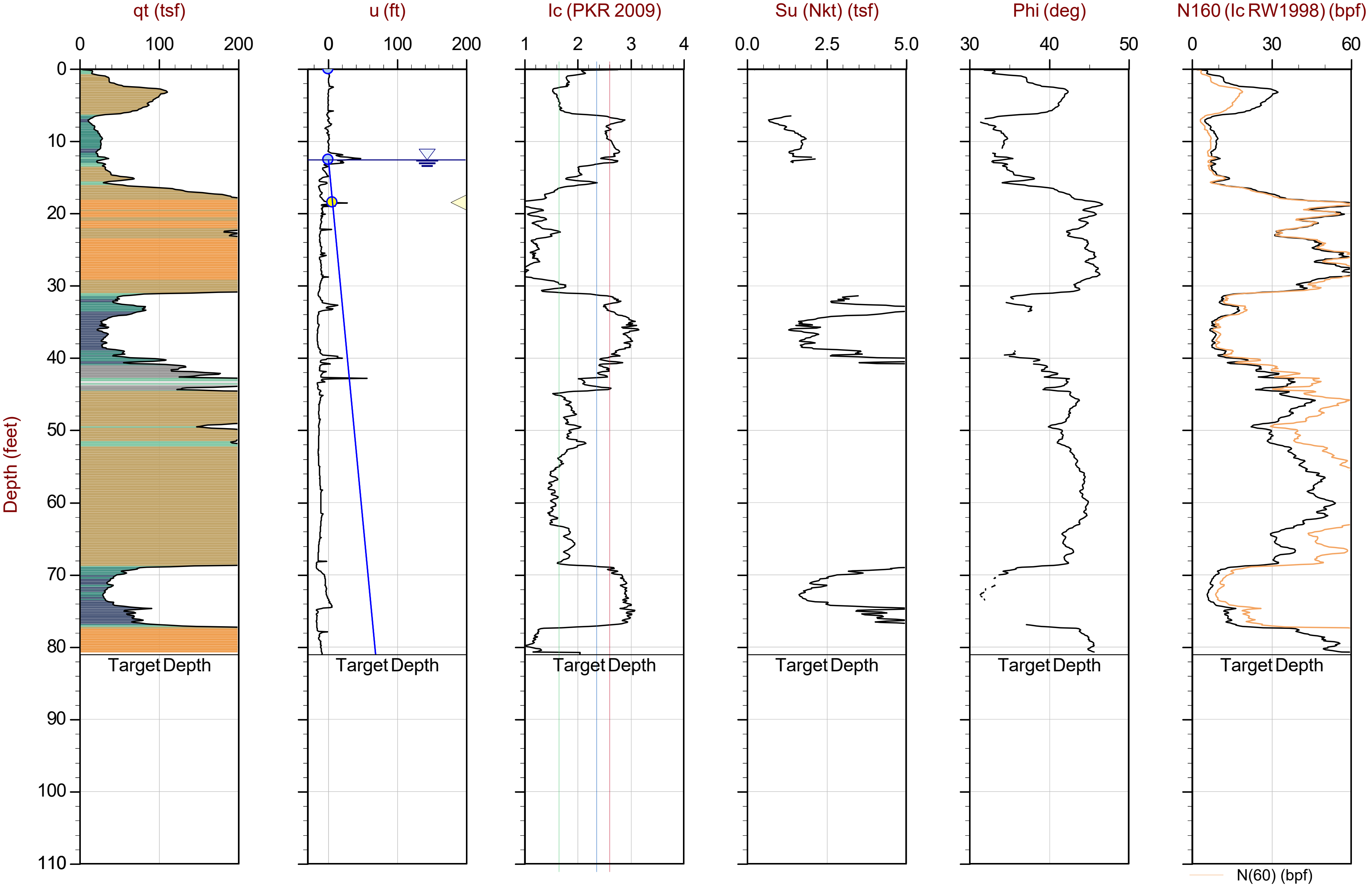
CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-29 14:45
Site: Rio Vista Feasibility Study

Sounding: CPT-07
Cone: 446:T1500F15U500



Max Depth: 24.700 m / 81.04 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP07.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4226047m E: 616002m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved — Hydrostatic Line

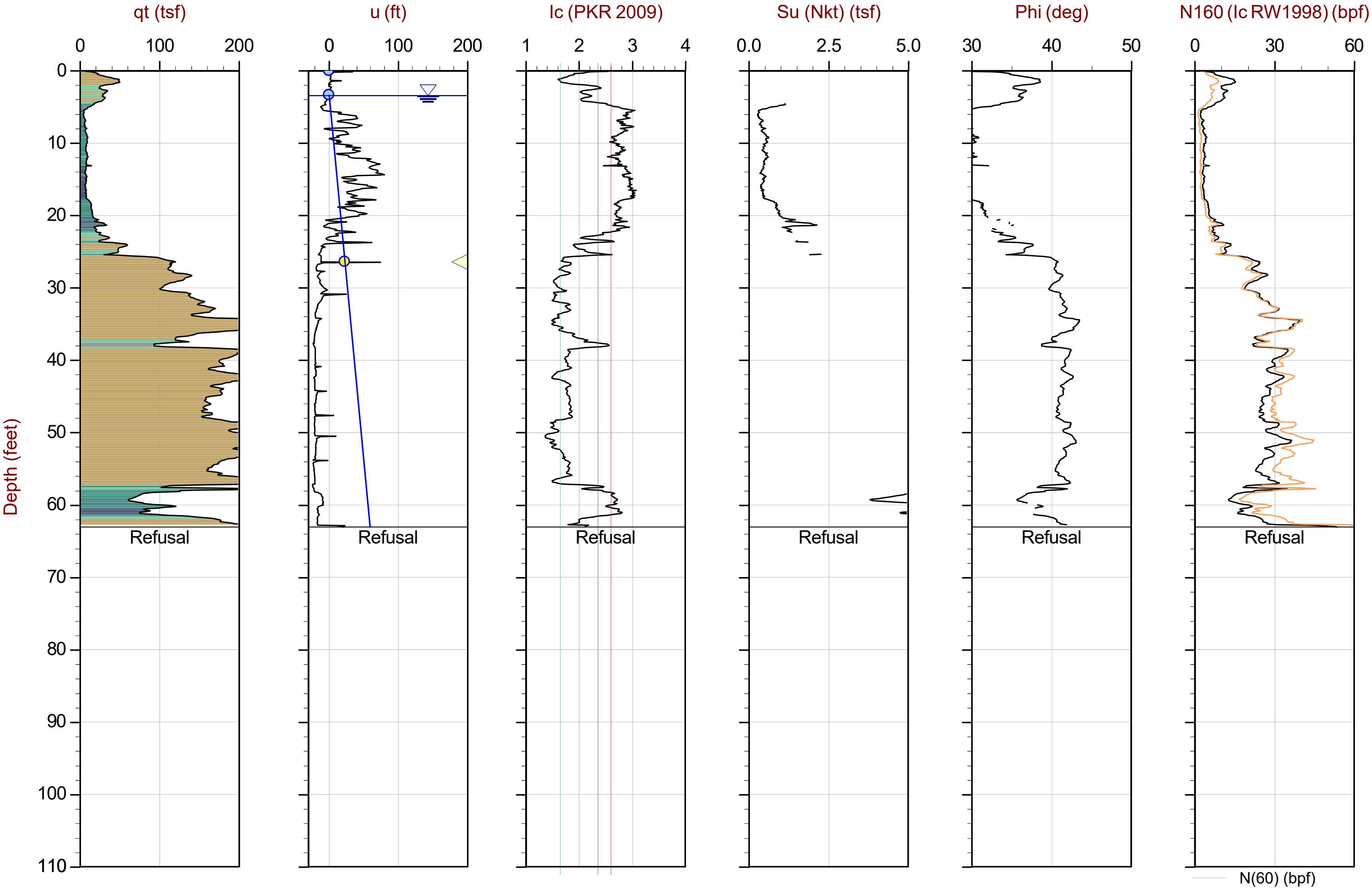
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-30 09:15
Site: Rio Vista Feasibility Study

Sounding: CPT-08
Cone: 446:T1500F15U500



Max Depth: 19.225 m / 63.07 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_CP08.COR
Unit Wt: SBTQtn (PKR2009)
Su Nkt: 15.0

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4226404m E: 615623m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq 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

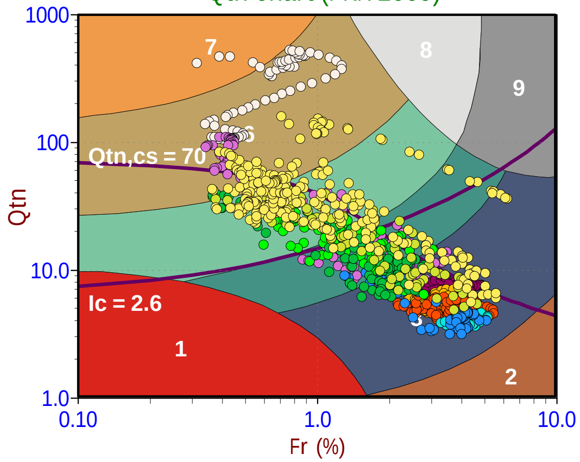
CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

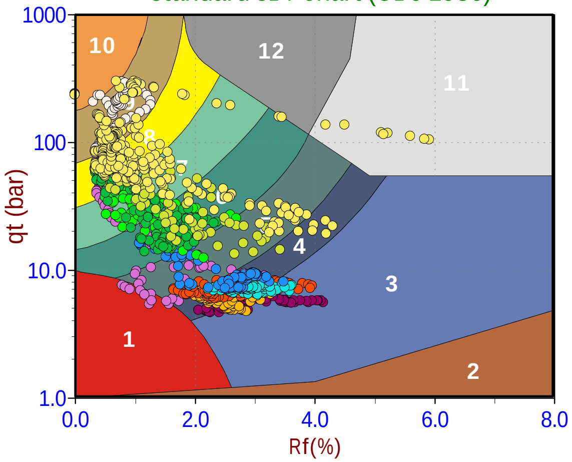
Job No: 18-56035
Date: 2018-03-28 09:11
Site: Rio Vista Feasibility Study

Sounding: CPT-01
Cone: 446:T1500F15U500

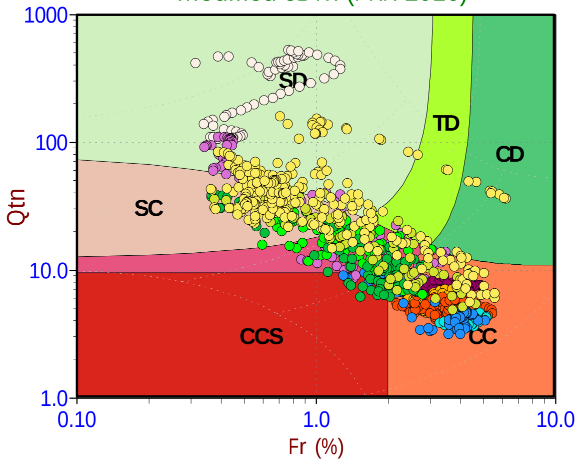
Qtn Chart (PKR 2009)



Standard SBT Chart (UBC 1986)



Modified SBTn (PKR 2016)



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

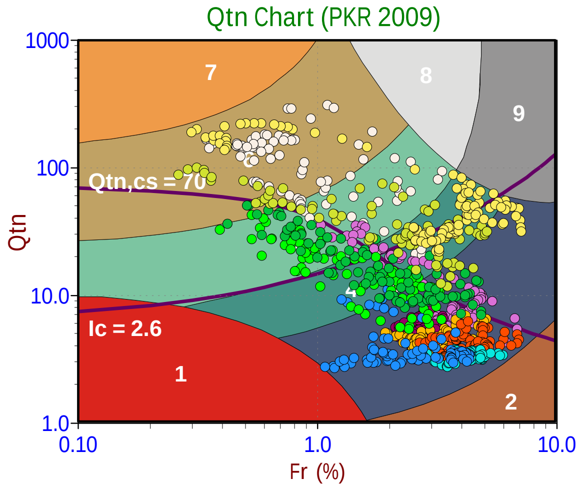
- ■ CCS (Cont. sensitive clay like)
- ■ CC (Cont. clay like)
- ■ TC (Cont. transitional)
- ■ SC (Cont. sand like)
- ■ CD (Dil. clay like)
- ■ TD (Dil. transitional)
- ■ SD (Dil. sand like)

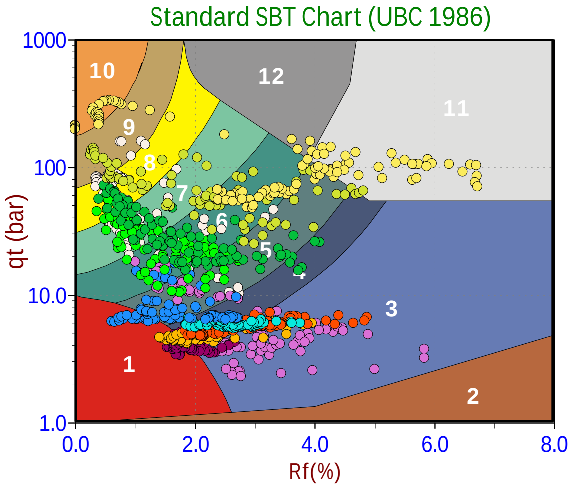
CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

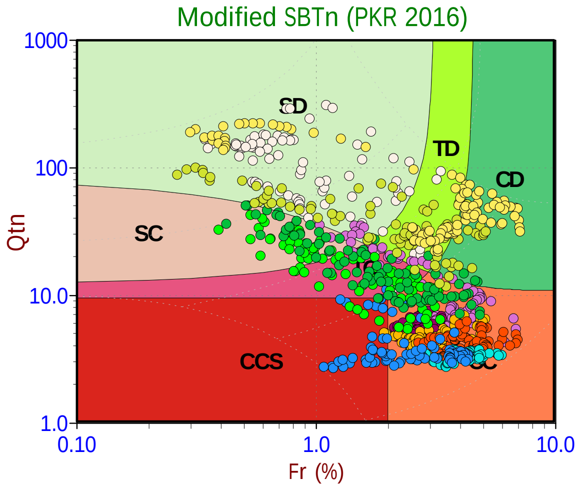
GEI Consultants

Job No: 18-56035
Date: 2018-03-28 11:19
Site: Rio Vista Feasibility Study

Sounding: CPT-02
Cone: 446:T1500F15U500


Qtn Chart (PKR 2009)


Standard SBT Chart (UBC 1986)


Modified SBTn (PKR 2016)

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

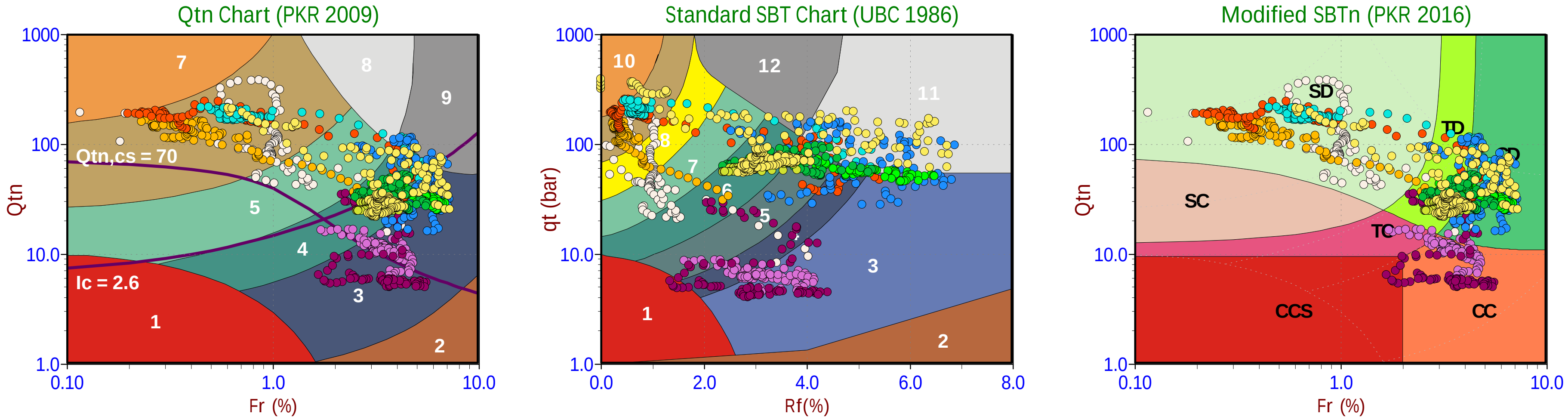
Legend
- 🟥 CCS (Cont. sensitive clay like)
- 🟧 CC (Cont. clay like)
- 🟥 TC (Cont. transitional)
- 🟫 SC (Cont. sand like)
- 🟩 CD (Dil. clay like)
- 🟩 TD (Dil. transitional)
- 🟩 SD (Dil. sand like)

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 13:17
Site: Rio Vista Feasibility Study

Sounding: SCPT-03
Cone: 446: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

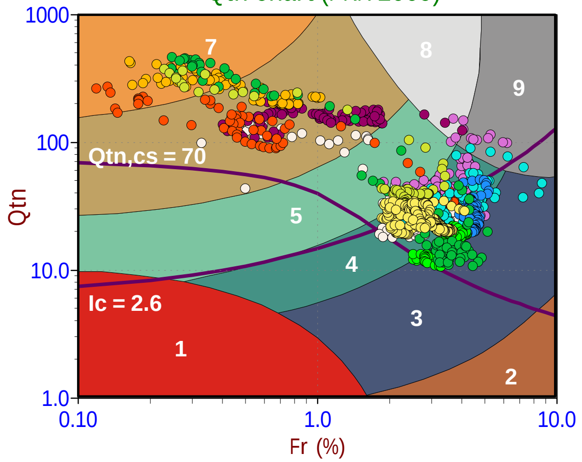
Legend
- 🟥 CCS (Cont. sensitive clay like)
- 🟧 CC (Cont. clay like)
- ■ TC (Cont. transitional)
- ■ SC (Cont. sand like)
- 🟩 CD (Dil. clay like)
- 🟩 TD (Dil. transitional)
- ■ SD (Dil. sand like)

GEI Consultants

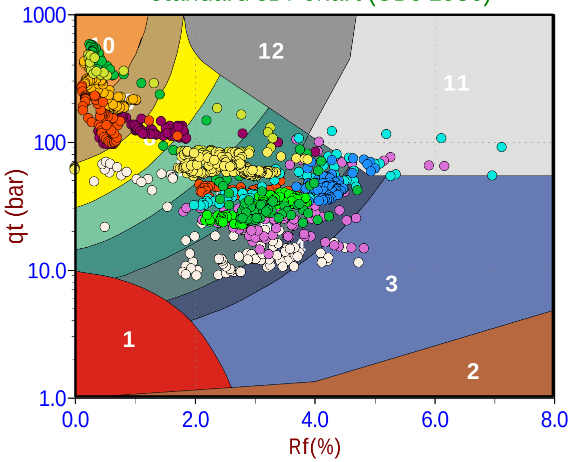
Job No: 18-56035
Date: 2018-03-29 08:32
Site: Rio Vista Feasibility Study

Sounding: CPT-04
Cone: 446:T1500F15U500

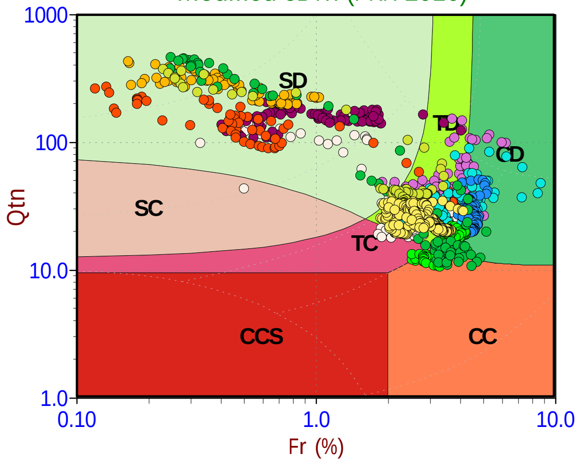
Qtn Chart (PKR 2009)



Standard SBT Chart (UBC 1986)



Modified SBTn (PKR 2016)



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

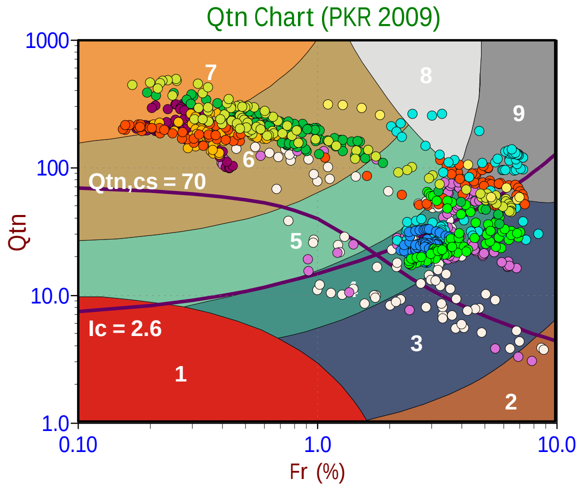
- 🟥 CCS (Cont. sensitive clay like)
- 🟧 CC (Cont. clay like)
- 🟥 TC (Cont. transitional)
- 🟫 SC (Cont. sand like)
- 🟩 CD (Dil. clay like)
- 🟩 TD (Dil. transitional)
- 🟩 SD (Dil. sand like)

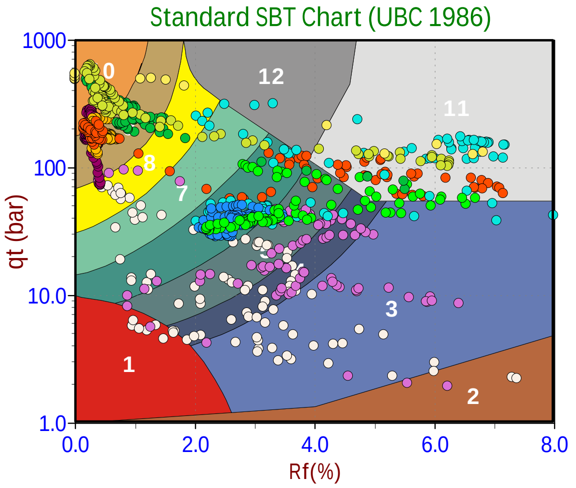
CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

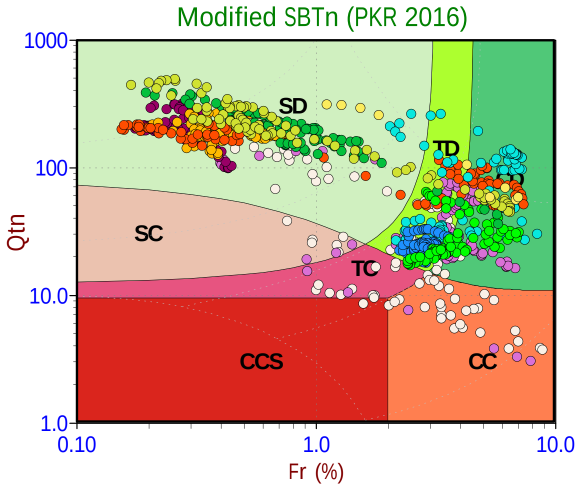
GEI Consultants

Job No: 18-56035
Date: 2018-03-29 10:33
Site: Rio Vista Feasibility Study

Sounding: CPT-05
Cone: 446:T1500F15U500


Qtn Chart (PKR 2009)


Standard SBT Chart (UBC 1986)


Modified SBTn (PKR 2016)

Depth Ranges
- ○ >0.0 to 7.5 ft
- ● >7.5 to 15.0 ft
- ● >15.0 to 22.5 ft
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- ● >52.5 to 60.0 ft
- ● >60.0 to 67.5 ft
- ● >67.5 to 75.0 ft
- ● >75.0 ft

Legend
- 🟥 Sensitive, Fine Grained
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- 🟦 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
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Legend
- 🟥 CCS (Cont. sensitive clay like)
- 🟧 CC (Cont. clay like)
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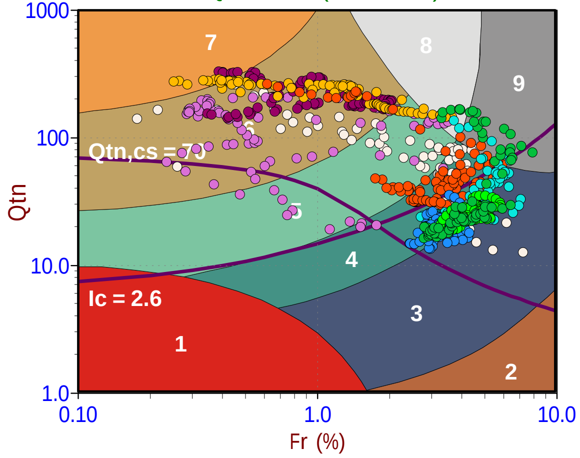
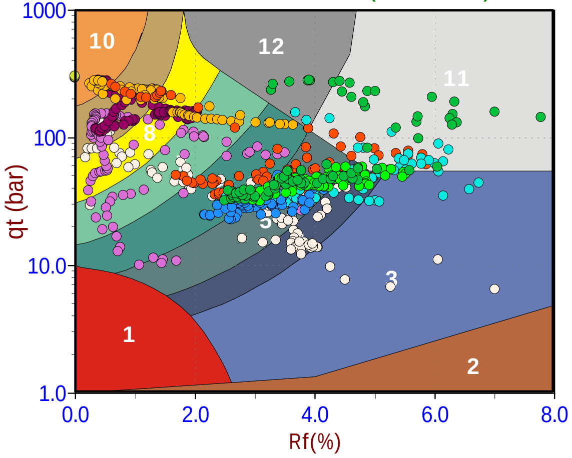
- 🟩 CD (Dil. clay like)
- 🟩 TD (Dil. transitional)
- 🟩 SD (Dil. sand like)

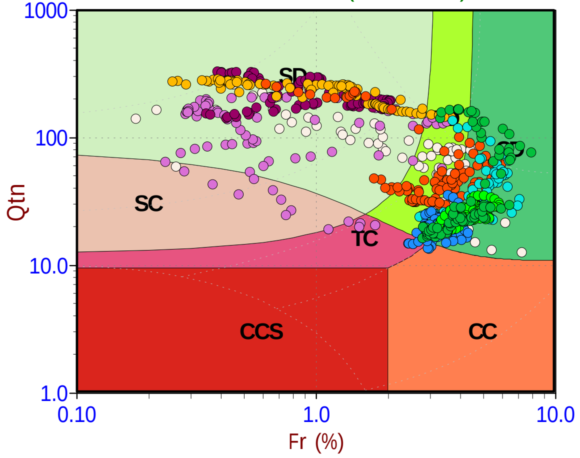
Qtn Chart (PKR 2009)



Standard SBT Chart (UBC 1986)



Modified SBTn (PKR 2016)



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
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Legend

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Legend

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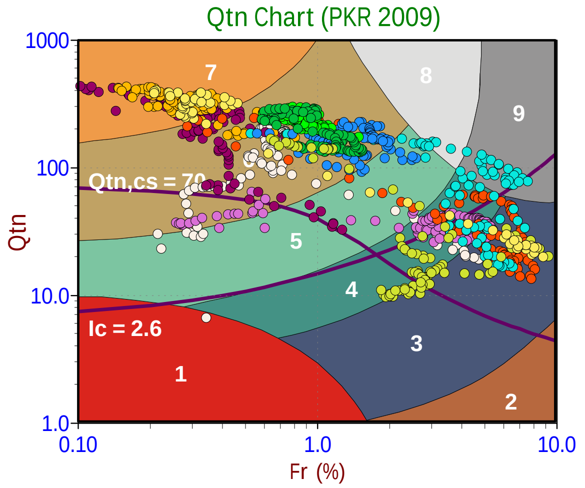
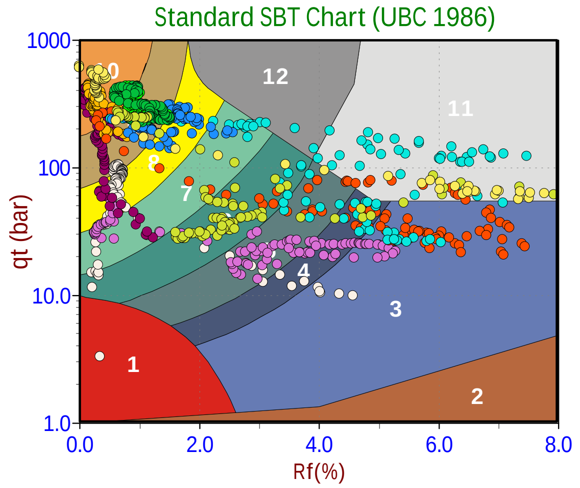
CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

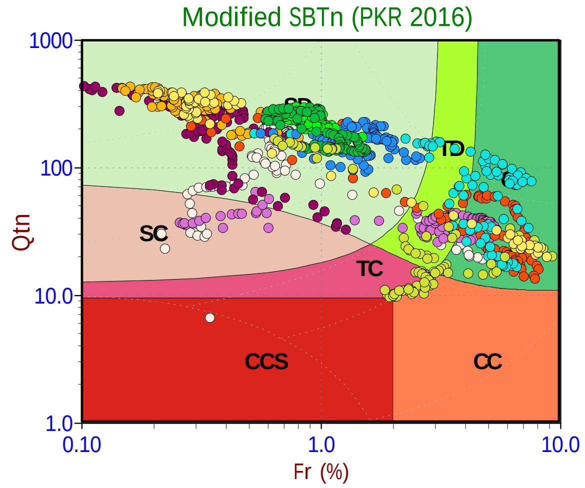
GEI Consultants

Job No: 18-56035
Date: 2018-03-29 14:45
Site: Rio Vista Feasibility Study

Sounding: CPT-07
Cone: 446:T1500F15U500







Depth Ranges
- ○ >0.0 to 7.5 ft
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Legend
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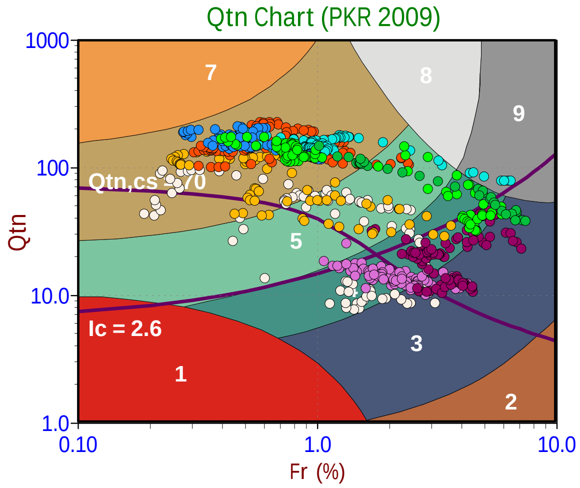
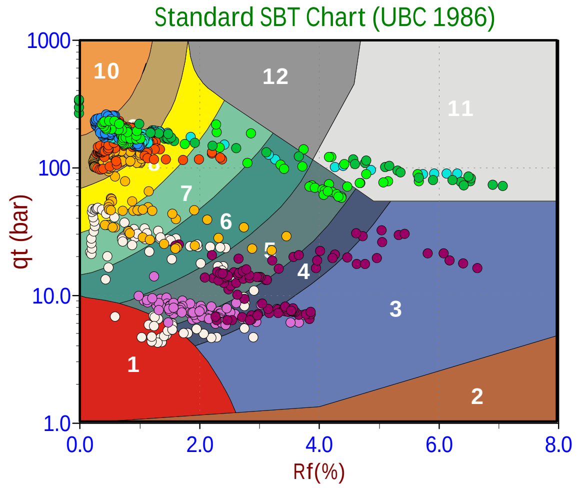
CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

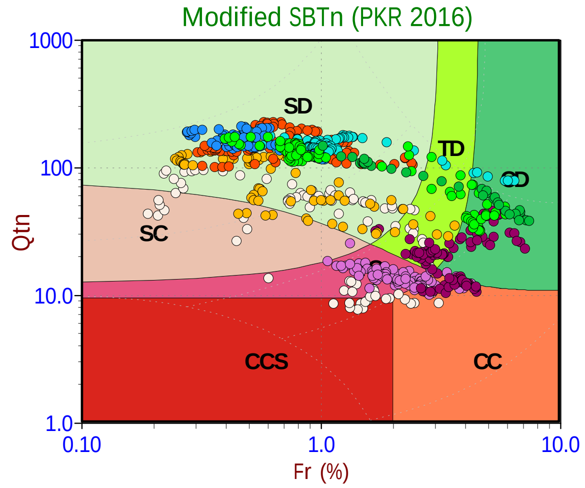
GEI Consultants

Job No: 18-56035
Date: 2018-03-30 09:15
Site: Rio Vista Feasibility Study

Sounding: CPT-08
Cone: 446:T1500F15U500







Depth Ranges
- ○ >0.0 to 7.5 ft
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Legend
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Legend
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- ■ SC (Cont. sand like)
- 🟩 CD (Dil. clay like)
- ■ TD (Dil. transitional)
- ■ SD (Dil. sand like)

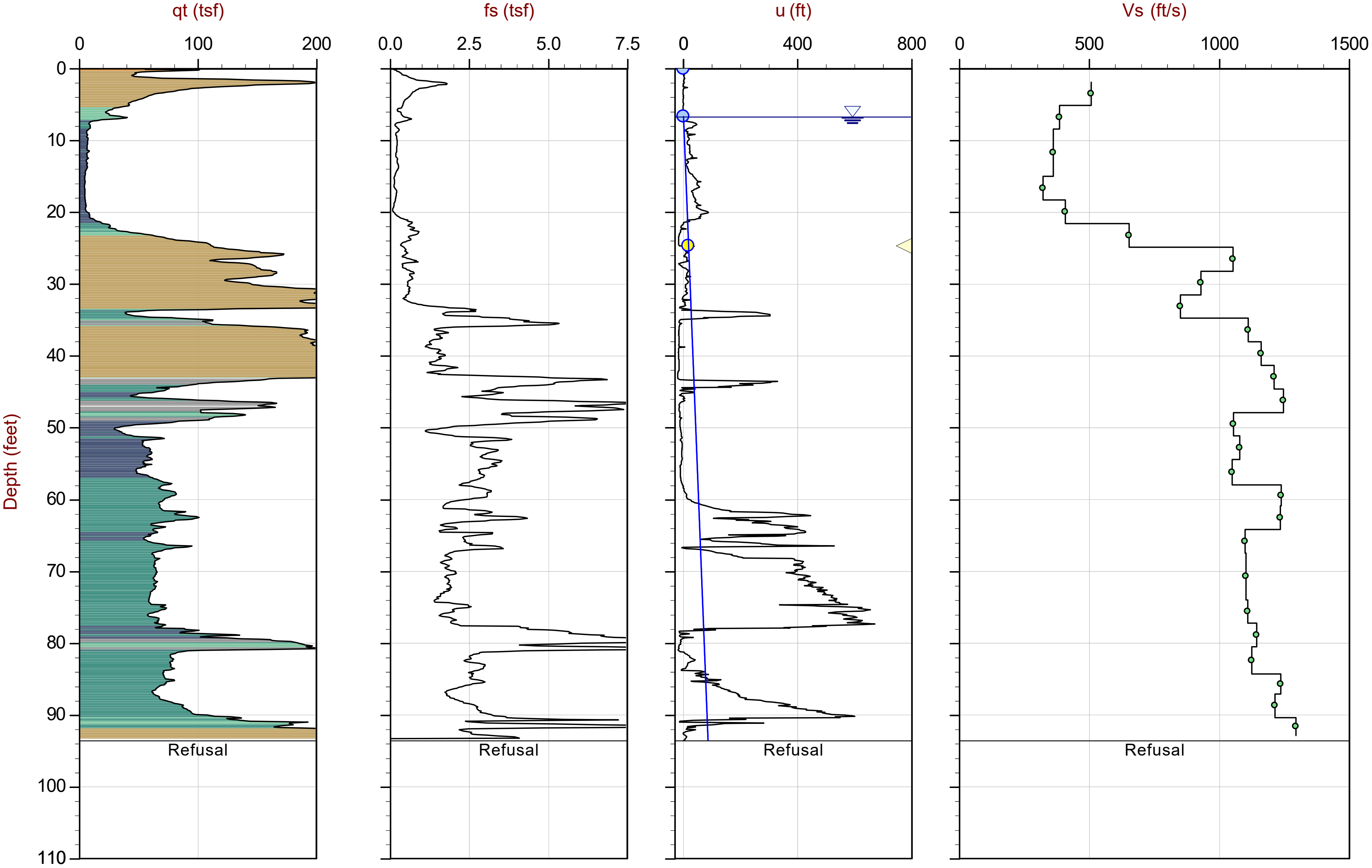
Seismic Cone Penetration Test Plots

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 2018-03-28 13:17
Site: Rio Vista Feasibility Study

Sounding: SCPT-03
Cone: 446:T1500F15U500



Max Depth: 28.525 m / 93.58 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-56035_SP03.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 4224299m E: 614979m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq 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.

Seismic Cone Penetration Test Tabular Results

Job No: 18-56035
Client: GEI Consultants Inc.
Project: Rio Vista Feasibility Study
Sounding ID: SCPT-03
Date: 28-Mar-2018

Seismic Source: Beam
Source Offset (ft): 1.9
Source Depth (ft): 0.0
Geophone Offset (ft): 0.66

SCPTu SHEAR WAVE VELOCITY TEST RESULTS - Vs

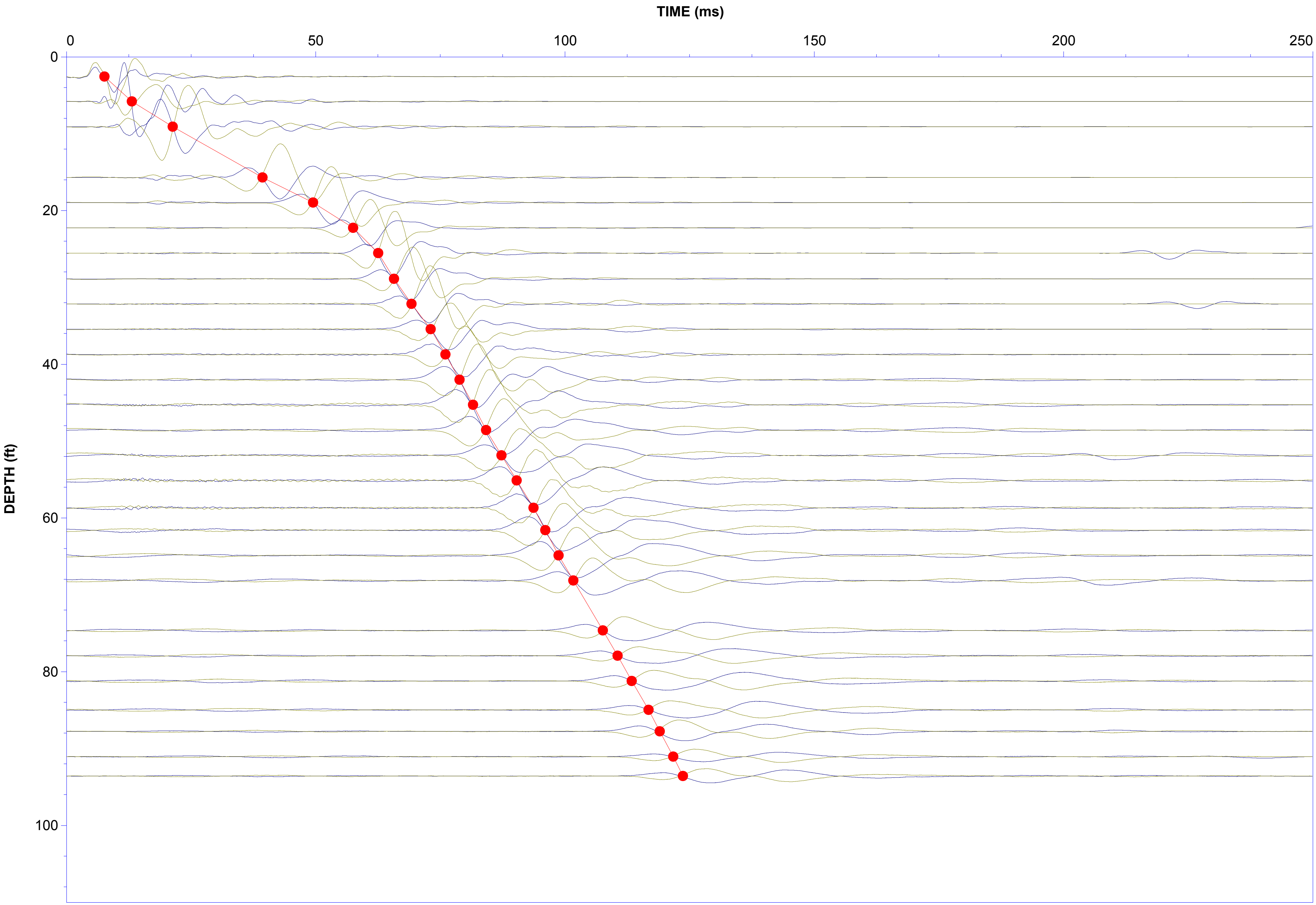
Tip Depth (ft)	Geophone Depth (ft)	Ray Path (ft)	Ray Path Difference (ft)	Travel Time Interval (ms)	Interval Velocity (ft/s)	Interval Velocity (m/s)
2.6	1.9	2.7				
5.8	5.2	5.5	2.8	5.5	508	155
9.1	8.4	8.6	3.2	8.2	385	117
15.7	15.0	15.1	6.5	18.0	361	110
19.0	18.3	18.4	3.3	10.1	321	98
22.2	21.6	21.7	3.3	8.0	407	124
25.5	24.9	24.9	3.3	5.0	653	199
28.9	28.2	28.3	3.3	3.2	1053	321
32.2	31.5	31.6	3.3	3.5	929	283
35.4	34.8	34.8	3.3	3.8	851	259
38.7	38.1	38.1	3.3	3.0	1111	339
42.0	41.3	41.4	3.3	2.8	1161	354
45.3	44.6	44.7	3.3	2.7	1210	369
48.6	47.9	47.9	3.3	2.6	1246	380
51.8	51.2	51.2	3.3	3.1	1055	322
55.1	54.5	54.5	3.3	3.0	1078	328
58.7	58.0	58.0	3.5	3.4	1050	320
61.6	60.9	61.0	2.9	2.4	1239	378
64.9	64.2	64.2	3.3	2.7	1234	376
68.1	67.5	67.5	3.3	3.0	1100	335
74.6	74.0	74.0	6.5	5.9	1102	336
77.9	77.3	77.3	3.3	3.0	1110	338
81.2	80.5	80.6	3.3	2.9	1144	349
85.0	84.3	84.3	3.8	3.4	1125	343
87.8	87.1	87.1	2.8	2.3	1237	377
91.0	90.4	90.4	3.3	2.7	1215	370
93.6	92.9	92.9	2.5	2.0	1295	395

Sheet 1 of 1

Seismic Cone Penetration Test Time Domain Traces

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

Job No: 18-56035 Client: GEI Consultants Project Title: Rio Vista Feasibility Study Filter: None Hole: SCPT-03



Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

Job No: 18-56035
Client: GEI Consultants Inc.
Project: Rio Vista Feasibility Study
Start Date: 28-Mar-2018
End Date: 30-Mar-2018

CPTu PORE PRESSURE DISSIPATION SUMMARY

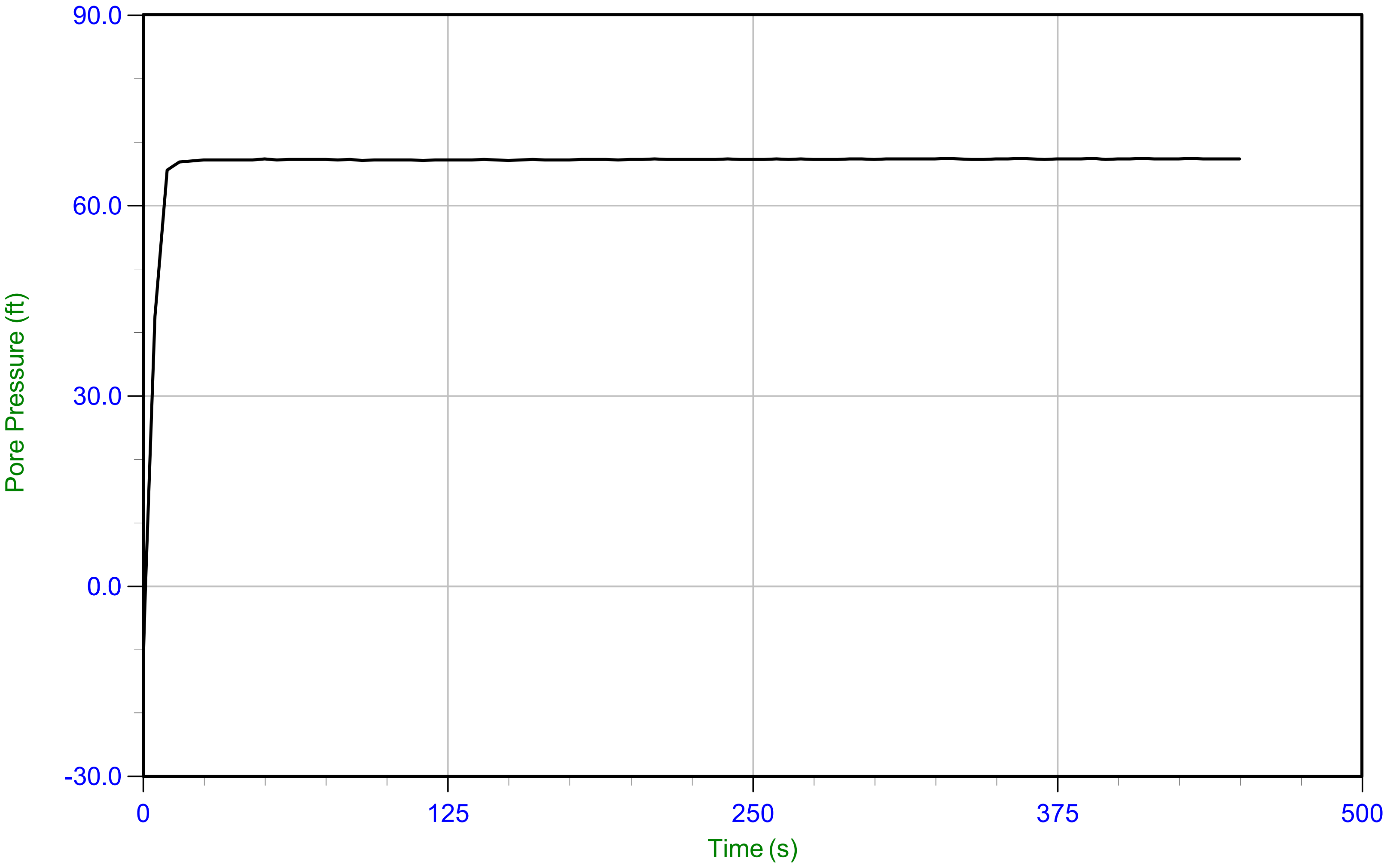
Sounding ID	File Name	Cone Area (cm^2)	Duration (s)	Test Depth (ft)	Estimated Equilibrium Pore Pressure U_{eq} (ft)	Calculated Phreatic Surface (ft)
CPT-01	18-56035_CP01	15	450	73.654	67.2	6.5
CPT-01	18-56035_CP01	15	150	93.421	87.1	6.4
CPT-02	18-56035_CP02	15	365	68.487	65.6	2.9
SCPT-03	18-56035_SP03	15	315	24.688	18.0	6.7
CPT-04	18-56035_CP04	15	310	16.158	9.1	7.0
CPT-05	18-56035_CP05	15	300	17.060	11.1	5.9
CPT-06	18-56035_CP06	15	300	65.534	61.2	4.3
CPT-07	18-56035_CP07	15	315	18.455	5.9	12.6
CPT-08	18-56035_CP08	15	375	26.410	23.0	3.4

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 03/28/2018 09:11
Site: Rio Vista Feasibility Study

Sounding: CPT-01
Cone: 446:T1500F15U500 Area=15 cm²

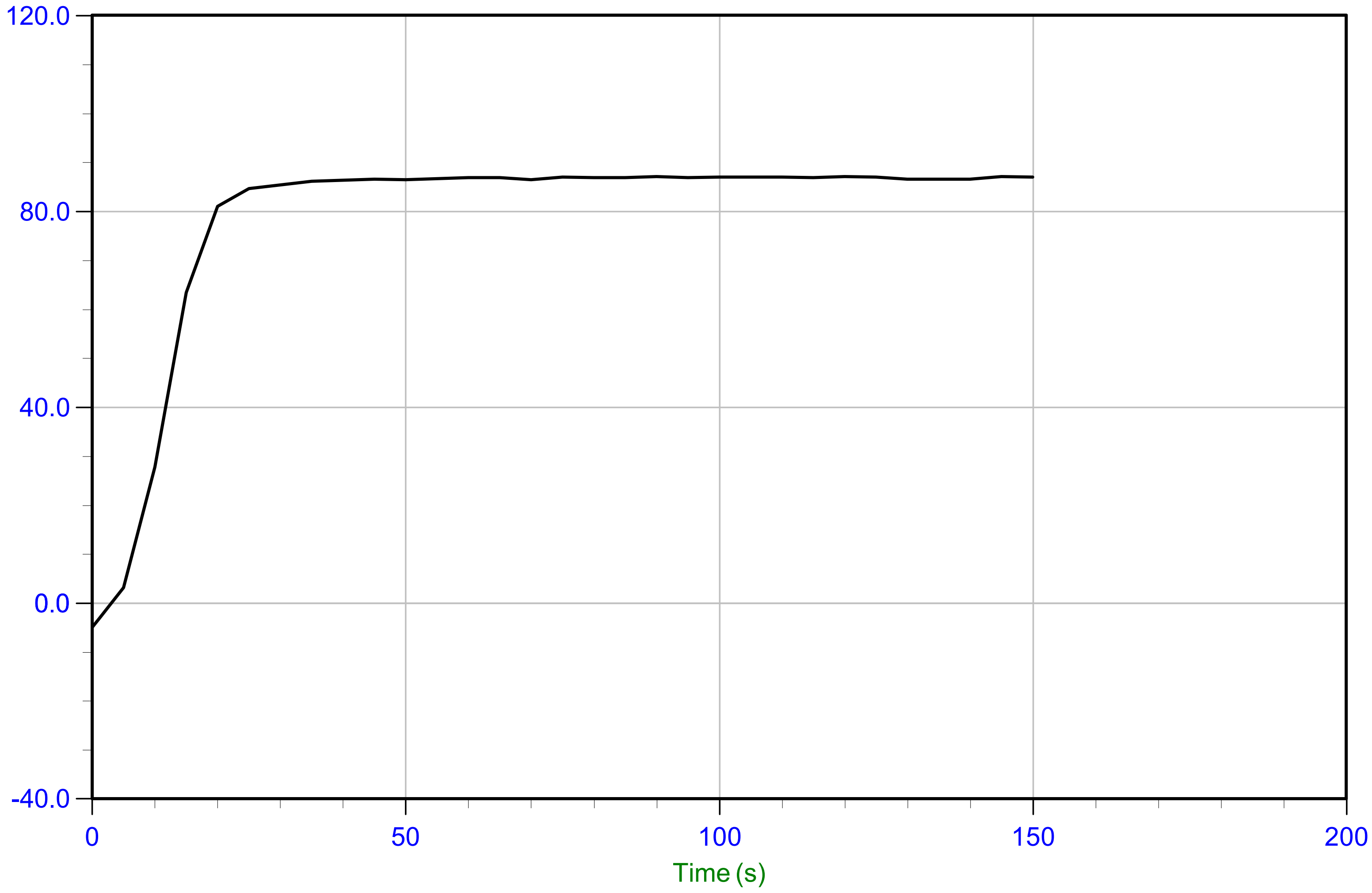


Trace Summary:	Filename: 18-56035_CP01.PPF	U Min: -11.7 ft	WT: 1.969 m / 6.460 ft
	Depth: 22.450 m / 73.654 ft	U Max: 67.4 ft	Ueq: 67.2 ft
	Duration: 450.0 s		

GEI Consultants

Job No: 18-56035
Date: 03/28/2018 09:11
Site: Rio Vista Feasibility Study

Sounding: CPT-01
Cone: 446:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 18-56035_CP01.PPF
Depth: 28.475 m / 93.421 ft
Duration: 150.0 s

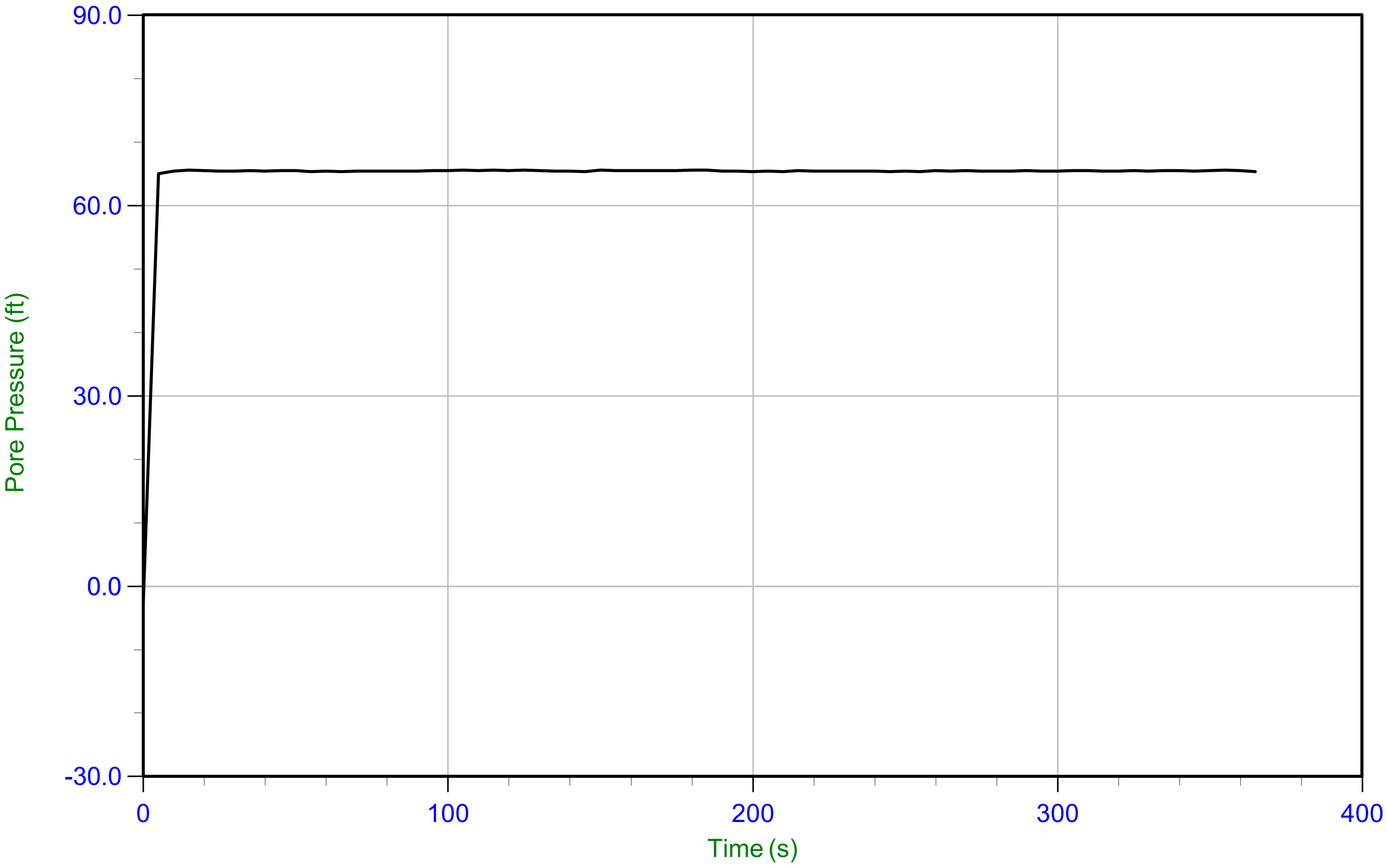
U Min: -4.9 ft
U Max: 87.0 ft

WT: 1.939 m / 6.363 ft
Ueq: 87.1 ft

GEI Consultants

Job No: 18-56035
Date: 03/28/2018 11:19
Site: Rio Vista Feasibility Study

Sounding: CPT-02
Cone: 446:T1500F15U500 Area=15 cm²



Trace Summary:

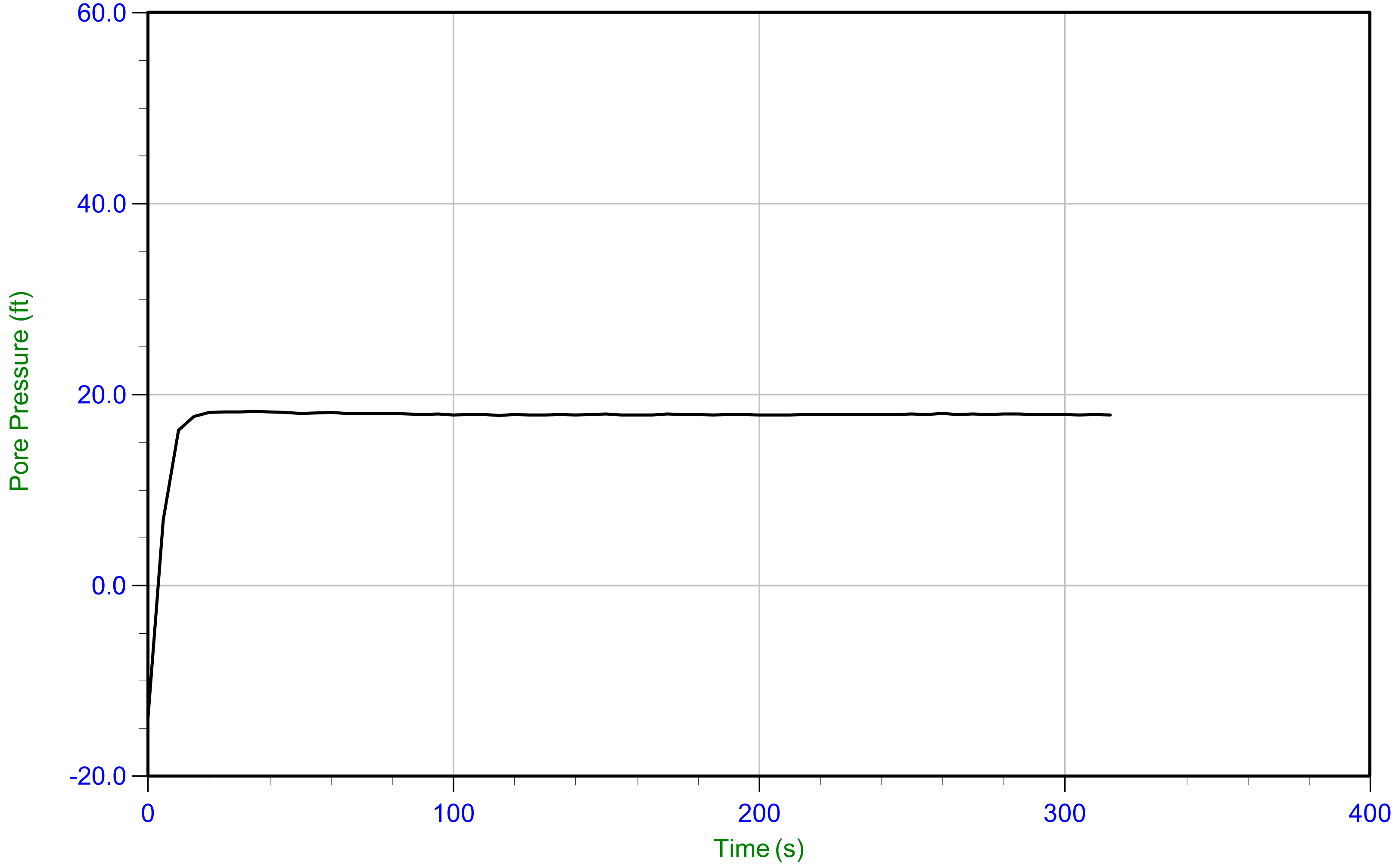
Filename: 18-56035_CP02.PPF
Depth: 20.875 m / 68.487 ft
Duration: 365.0 s

U Min: -2.6 ft
U Max: 65.6 ft

WT: 0.891 m / 2.922 ft
Ueq: 65.6 ft

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants	Job No: 18-56035 Date: 03/28/2018 13:17 Site: Rio Vista Feasibility Study	Sounding: SCPT-03 Cone: 446:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 18-56035_SP03.PPF
Depth: 7.525 m / 24.688 ft
Duration: 315.0 s

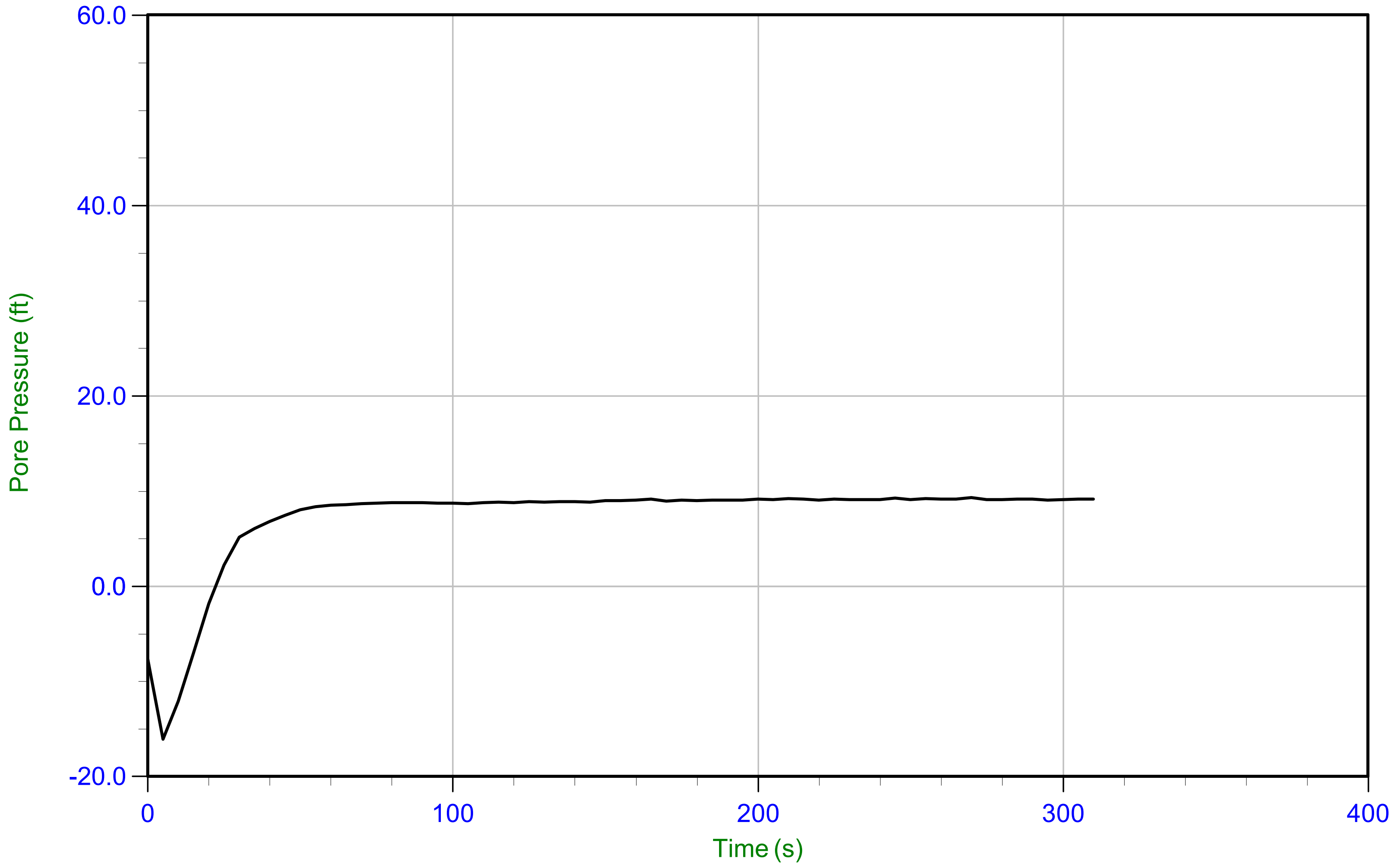
U Min: -13.9 ft
U Max: 18.2 ft

WT: 2.036 m / 6.679 ft
Ueq: 18.0 ft

GEI Consultants

Job No: 18-56035
Date: 03/29/2018 08:32
Site: Rio Vista Feasibility Study

Sounding: CPT-04
Cone: 446:T1500F15U500 Area=15 cm²

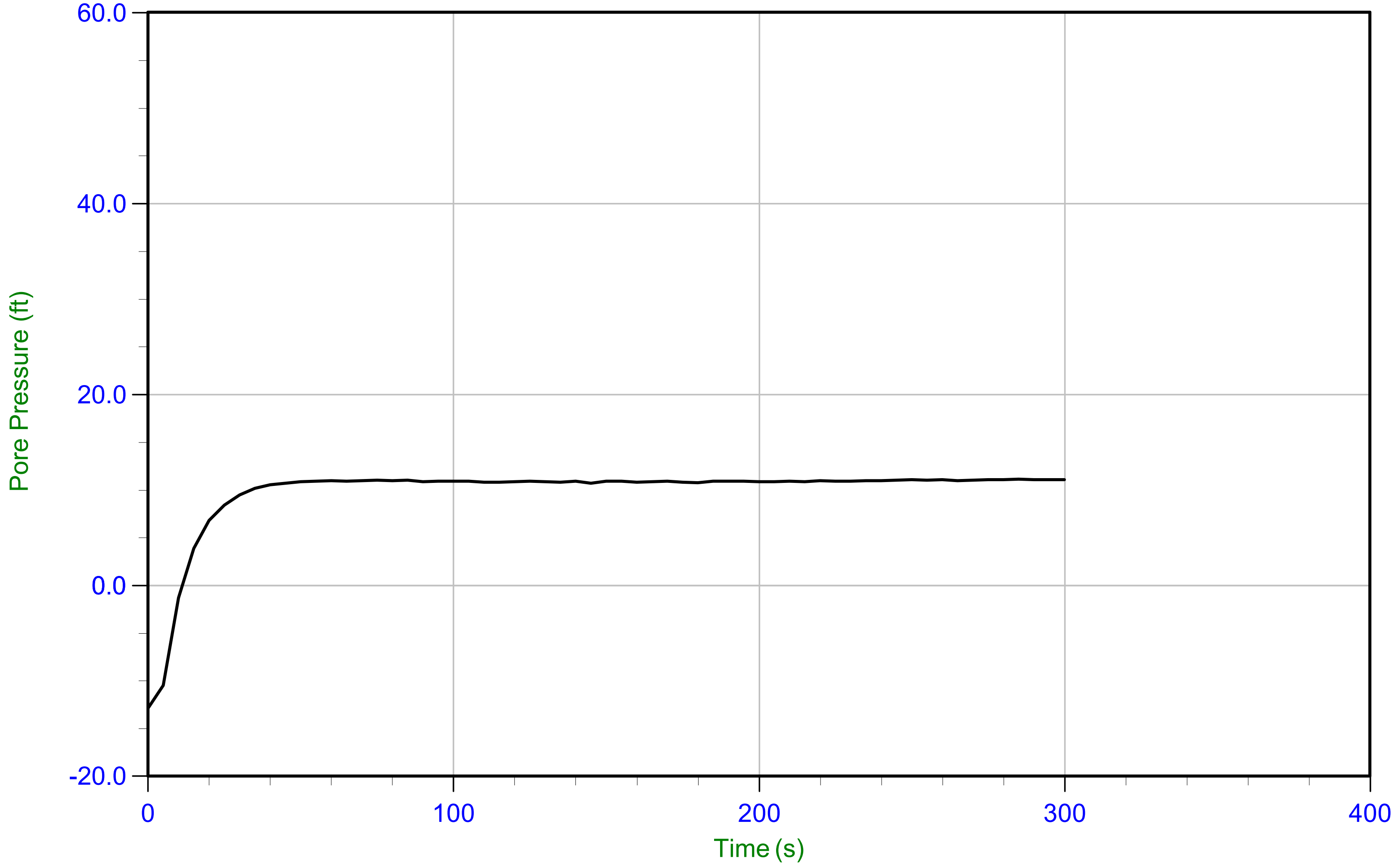


Trace Summary:
Filename: 18-56035_CP04.PPF
Depth: 4.925 m / 16.158 ft
Duration: 310.0 s
U Min: -16.1 ft
U Max: 9.3 ft
WT: 2.139 m / 7.018 ft
Ueq: 9.1 ft

GEI Consultants

Job No: 18-56035
Date: 03/29/2018 10:33
Site: Rio Vista Feasibility Study

Sounding: CPT-05
Cone: 446:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 18-56035_CP05.PPF
Depth: 5.200 m / 17.060 ft
Duration: 300.0 s

U Min: -12.9 ft
U Max: 11.1 ft

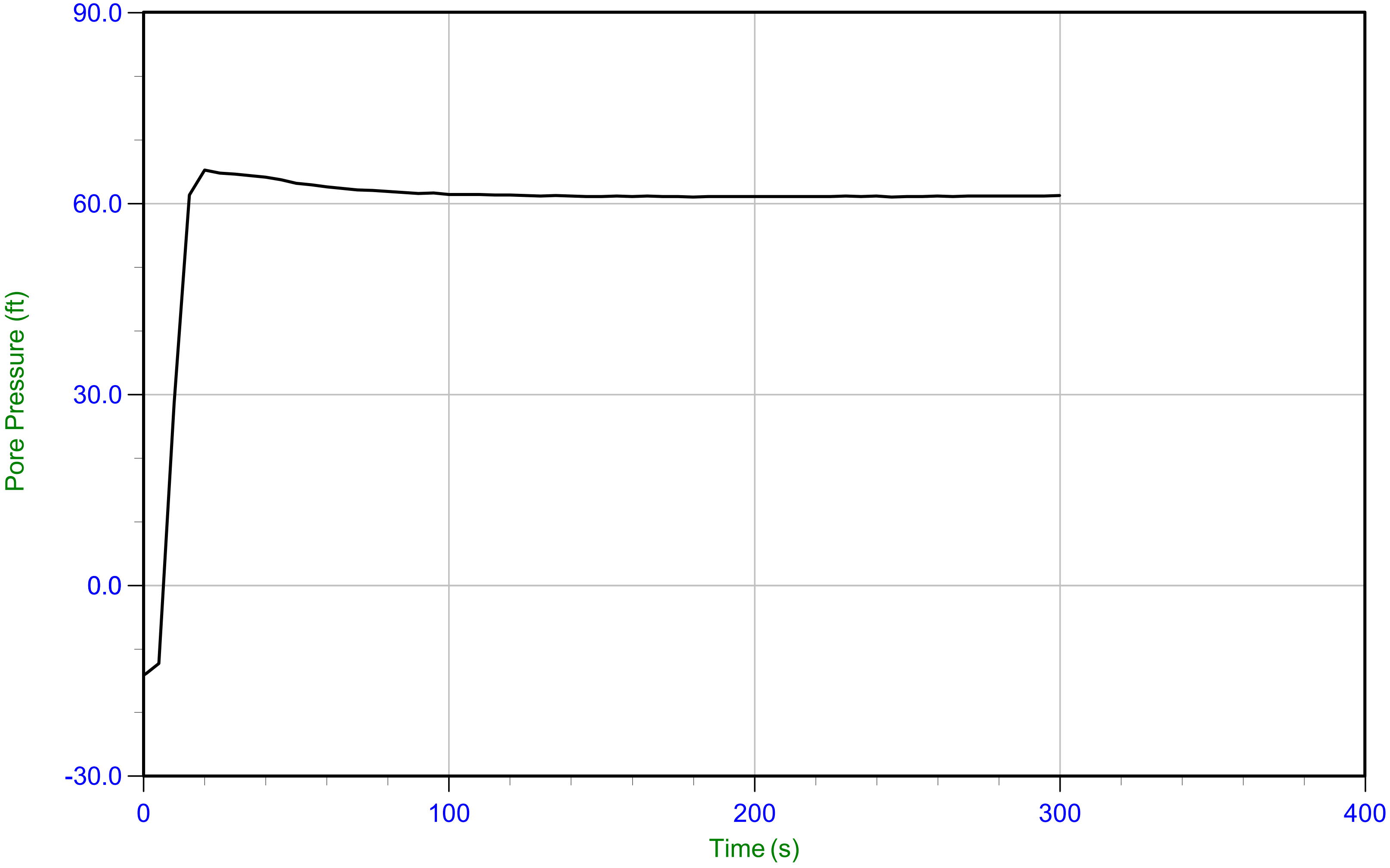
WT: 1.807 m / 5.929 ft
Ueq: 11.1 ft

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 03/29/2018 12:57
Site: Rio Vista Feasibility Study

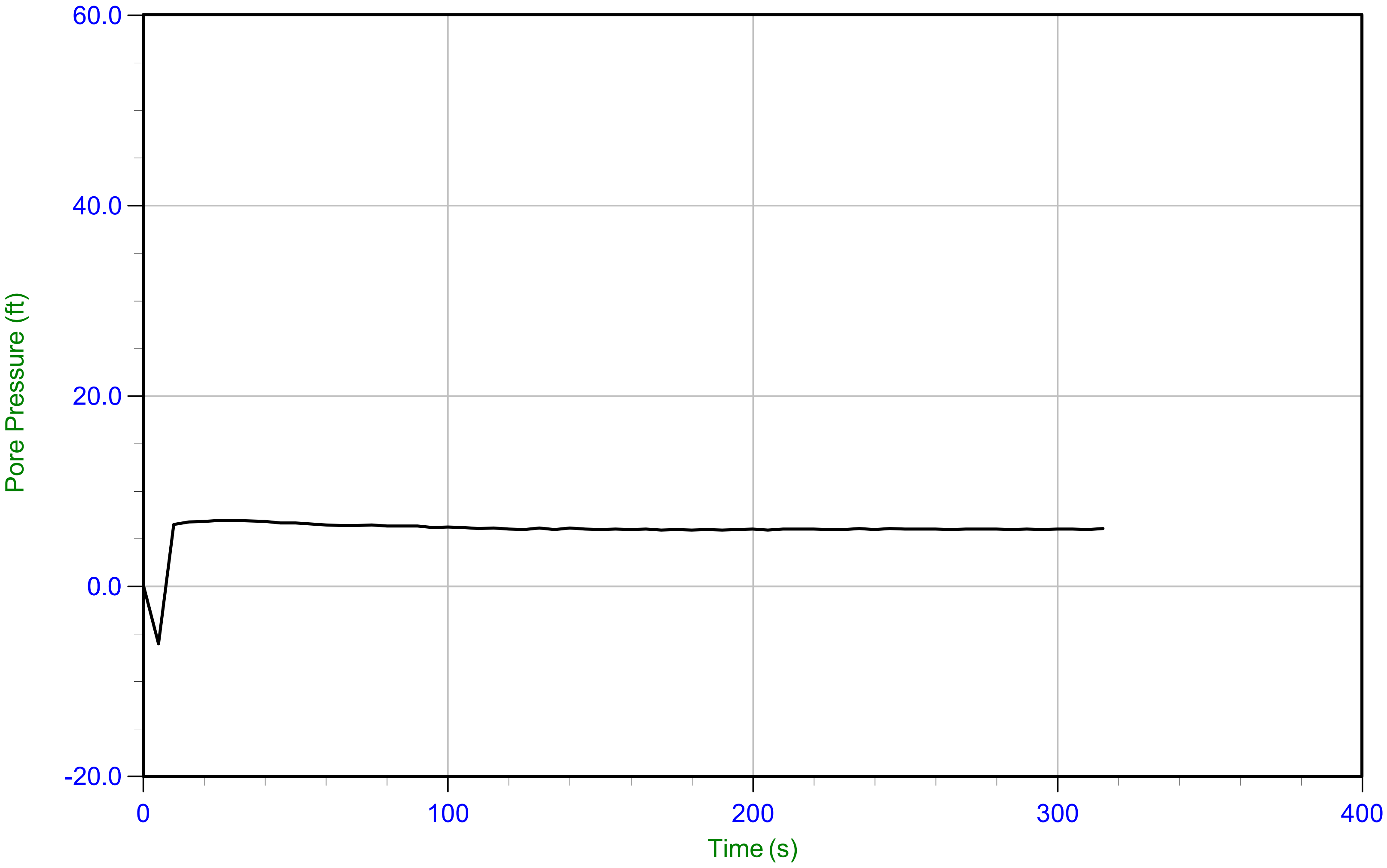
Sounding: CPT-06
Cone: 446:T1500F15U500 Area=15 cm²



	Filename: 18-56035_CP06.PPF	U Min: -14.2 ft	WT: 1.315 m / 4.313 ft
Trace Summary:	Depth: 19.975 m / 65.534 ft	U Max: 65.3 ft	Ueq: 61.2 ft
	Duration: 300.0 s		

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants	Job No: 18-56035 Date: 03/29/2018 14:45 Site: Rio Vista Feasibility Study	Sounding: CPT-07 Cone: 446:T1500F15U500 Area=15 cm²



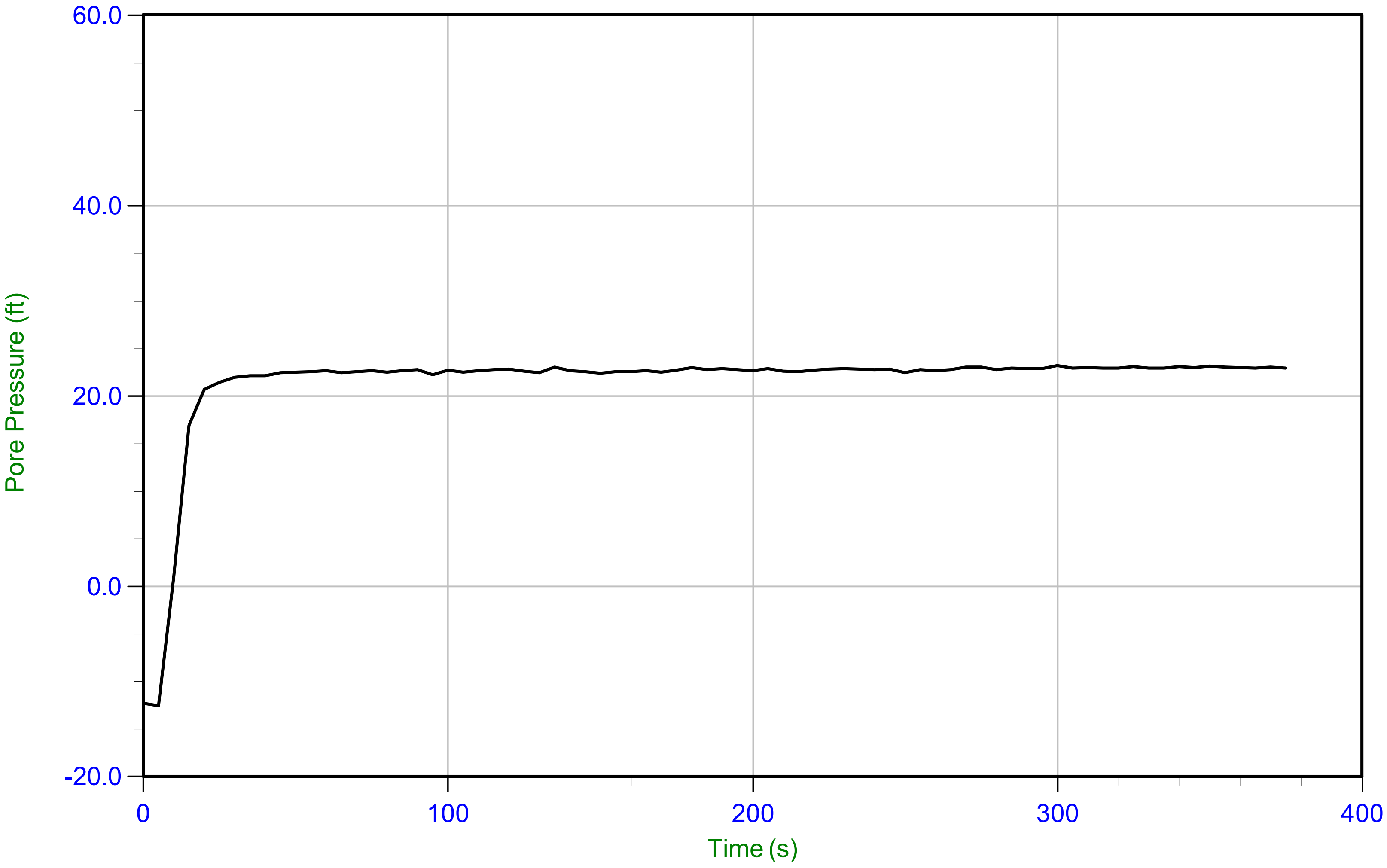
	Filename: 18-56035_CP07.PPF	U Min: -6.0 ft	WT: 3.832 m / 12.572 ft
Trace Summary:	Depth: 5.625 m / 18.454 ft	U Max: 6.9 ft	Ueq: 5.9 ft
	Duration: 315.0 s		

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

GEI Consultants

Job No: 18-56035
Date: 03/30/2018 09:15
Site: Rio Vista Feasibility Study

Sounding: CPT-08
Cone: 446:T1500F15U500 Area=15 cm²



Trace Summary:

Filename: 18-56035_CP08.PPF
Depth: 8.050 m / 26.410 ft
Duration: 375.0 s

U Min: -12.6 ft
U Max: 23.2 ft

WT: 1.039 m / 3.408 ft
Ueq: 23.0 ft

Appendix C – Laboratory Test Data from 2018 FCFS Geotechnical Exploration

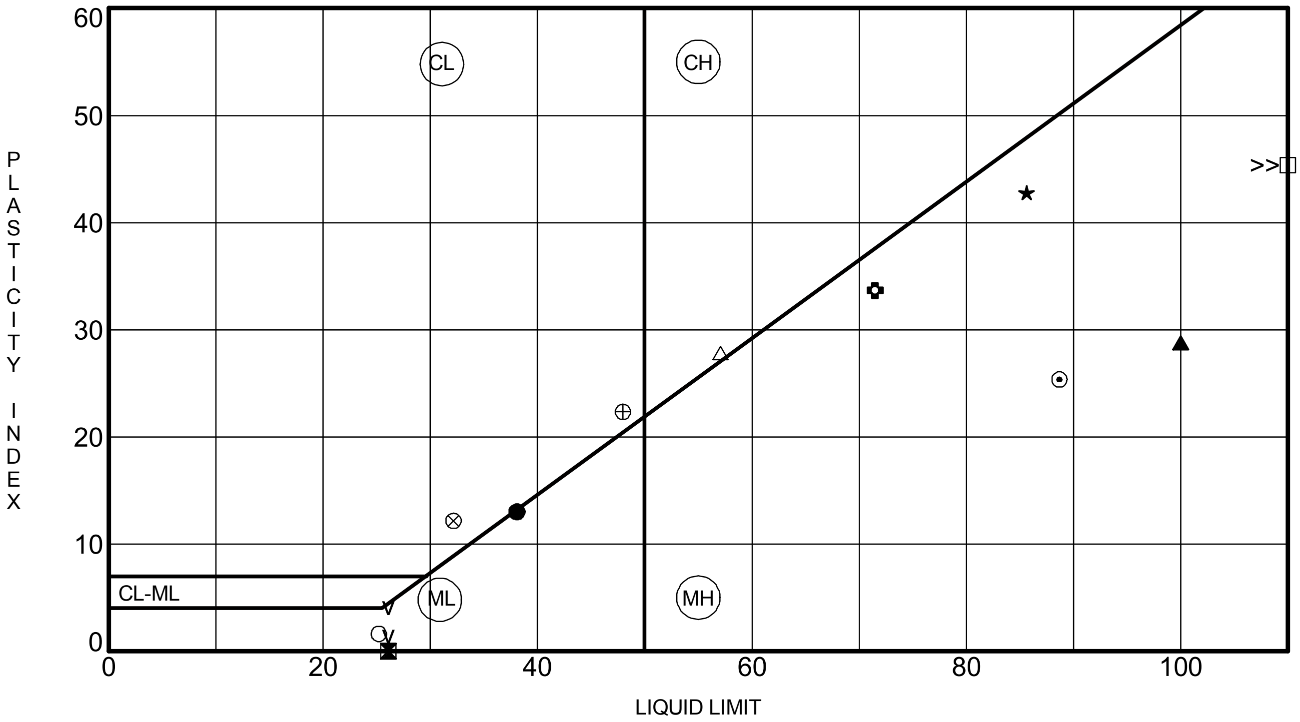
Sample ID	Depth (feet)	Liquid Limit	Plastic Limit	Plasticity Index	Maximum Size (mm)	%<#200 Sieve	Water Content (%)	Dry Density (pcf)
B1_S02A_003_004S	3	38	25	13	---	45.8		
B1_S03A_005_007S	5				---	7.5		
B1_S04A_010_012C	10	26	26	NP	---	49.8	37.4	86.3
B1_S06A_016_018T	16				---	80.4		
B1_S08A_022_024T	22	100	71	29	---	79.4		
B1_S09A_025_027S	25	86	43	43	---			
B1_S14A_038_040T	38	89	63	26	---	86.0		
B2_S02A_005_006C	5				---	9.2	11.9	89.6
B2_S05A_012_014T	12	71	38	33	---	68.7		
B2_S09A_023_025S	23				---	3.8		
B2_S12A_029_031S	29				---	5.4		
B3_S05A_010_012T	10	25	24	1	---	69.0		
B3_S07A_015_017S	15				---	6.0		
B3_S08A_020_022S	20				---	5.5		
B4_S03A_005_007T	5	57	29	28	---	95.7		
B4_S04A_008_010T	8	32	20	12	---	51.5		
B4_S05A_010_012T	10	48	26	22	---	99.2		
B4_S07A_015_017S	15	119	74	45	---	47.3		
B4_S15A_035_037S	35				---	9.4		
B4_S17A_045_047S	45				---	11.9		

LAB SUMMARY FOR GEI S1136-05-08 GEI RVFS.GPJ US_LAB.GDT 5/4/18

GEOCON
Geocon Consultants, Inc.
3160 Gold Valley Drive, Suite 800
Rancho Cordova, CA 95742
Telephone: 916-852-9118
Fax: 916-852-9132

Summary of Laboratory Results

Project: GEI Rio Vista Feasibility Study
Location:
Project Number: S1136-05-08



	Sample No. & Depth (ft.)	Liquid Limit	Plastic Limit	Plasticity Index	% Pass #200 Sieve	Unified Soil Classification Description	Preparation Method
●	**B1_S02A_003_004S 3**	**38**	**25**	**13**	**45.8**	**SILTY SAND(SM)**	**dry**
⧗	**B1_S04A_010_012C 10**	**26**	**26**	**NP**	**49.8**	**SILTY SAND(SM)**	**dry**
▲	**B1_S08A_022_024T 22**	**100**	**71**	**29**	**79.4**	**ELASTIC SILT with SAND(MH)**	**dry**
★	**B1_S09A_025_027S 25**	**86**	**43**	**43**			**dry**
⊙	**B1_S14A_038_040T 38**	**89**	**63**	**26**	**86.0**	**ELASTIC SILT(MH)**	**dry**
✿	**B2_S05A_012_014T 12**	**71**	**38**	**33**	**68.7**	**SANDY ELASTIC SILT(MH)**	**dry**
○	**B3_S05A_010_012T 10**	**25**	**24**	**1**	**69.0**	**SANDY SILT(ML)**	**dry**
△	**B4_S03A_005_007T 5**	**57**	**29**	**28**	**95.7**	**FAT CLAY(CH)**	**dry**
⊗	**B4_S04A_008_010T 8**	**32**	**20**	**12**	**51.5**	**SANDY LEAN CLAY(CL)**	**dry**
⊕	**B4_S05A_010_012T 10**	**48**	**26**	**22**	**99.2**	**LEAN CLAY(CL)**	**dry**
□	**B4_S07A_015_017S 15**	**119**	**74**	**45**	**47.3**	**Organic SILT or PEAT**	**dry**

PI FOR GEI S1136-05-08 GEI RVFS.GPJ US LAB.GDT 5/4/18

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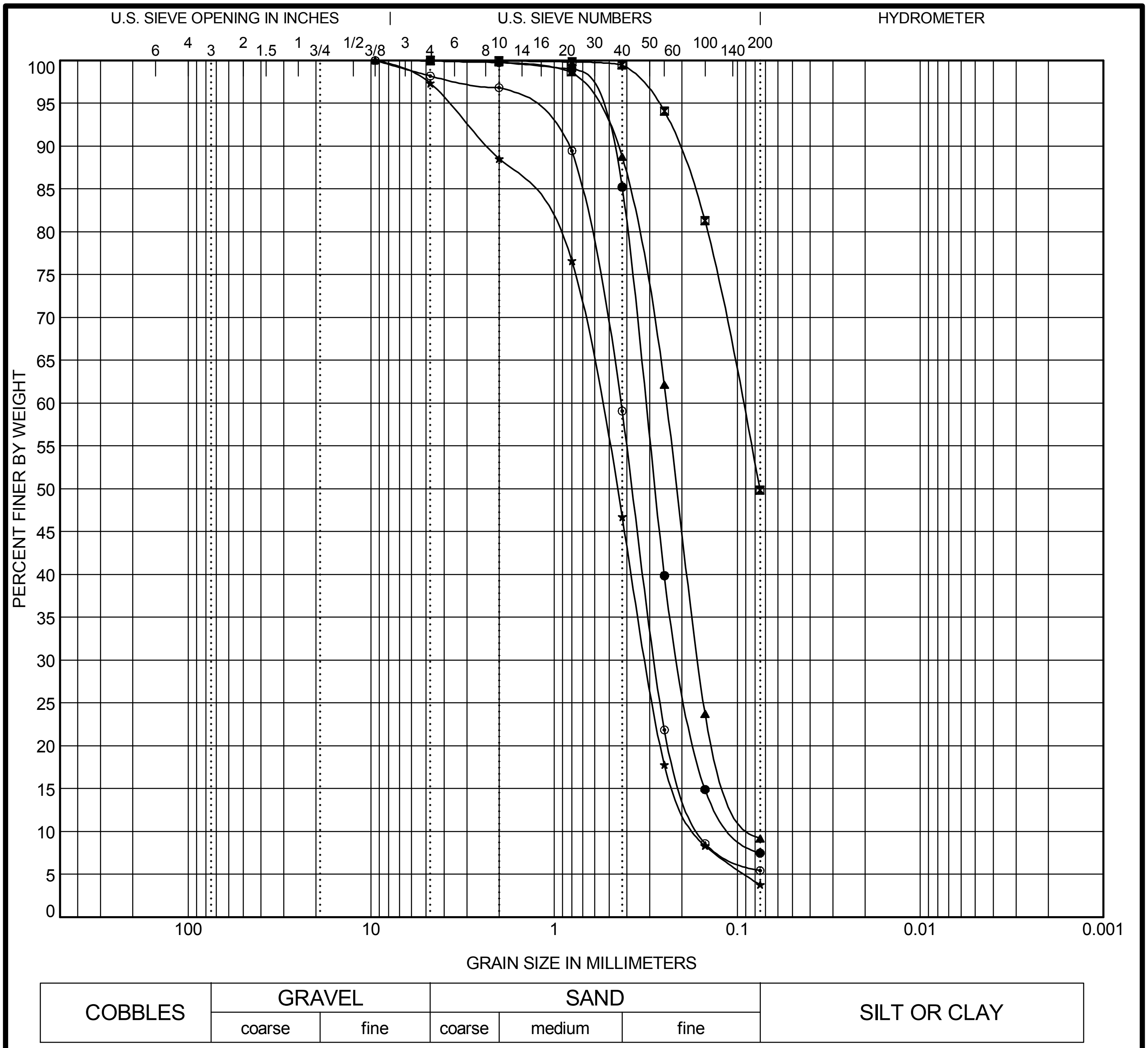
ATTERBERG LIMITS

Project: GEI Rio Vista Feasibility Study
Location:
Project Number: S1136-05-08



	Sample No.	Classification	LL	PL	PI	Cc	Cu
●	B1_S03A_005_007S 5					1.39	3.3
⊠	B1_S04A_010_012C 10	SILTY SAND(SM)	26	26	NP		
▲	B2_S02A_005_006C 5					1.40	3.1
★	B2_S09A_023_025S 23	POORLY GRADED SAND(SP)				1.06	3.4
⊙	B2_S12A_029_031S 29					1.15	2.7

	Sample No.	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	S03A_005_007S	4.75	0.316	0.204	0.095	0.0	92.5	7.5	
⊠	S04A_010_012C	4.75	0.094			0.0	50.2	49.8	
▲	S02A_005_006C	9.5	0.243	0.163	0.078	0.0	90.8	9.2	
★	S09A_023_025S	9.5	0.563	0.313	0.164	2.7	93.6	3.8	
⊙	S12A_029_031S	9.5	0.433	0.281	0.158	1.8	92.8	5.4	

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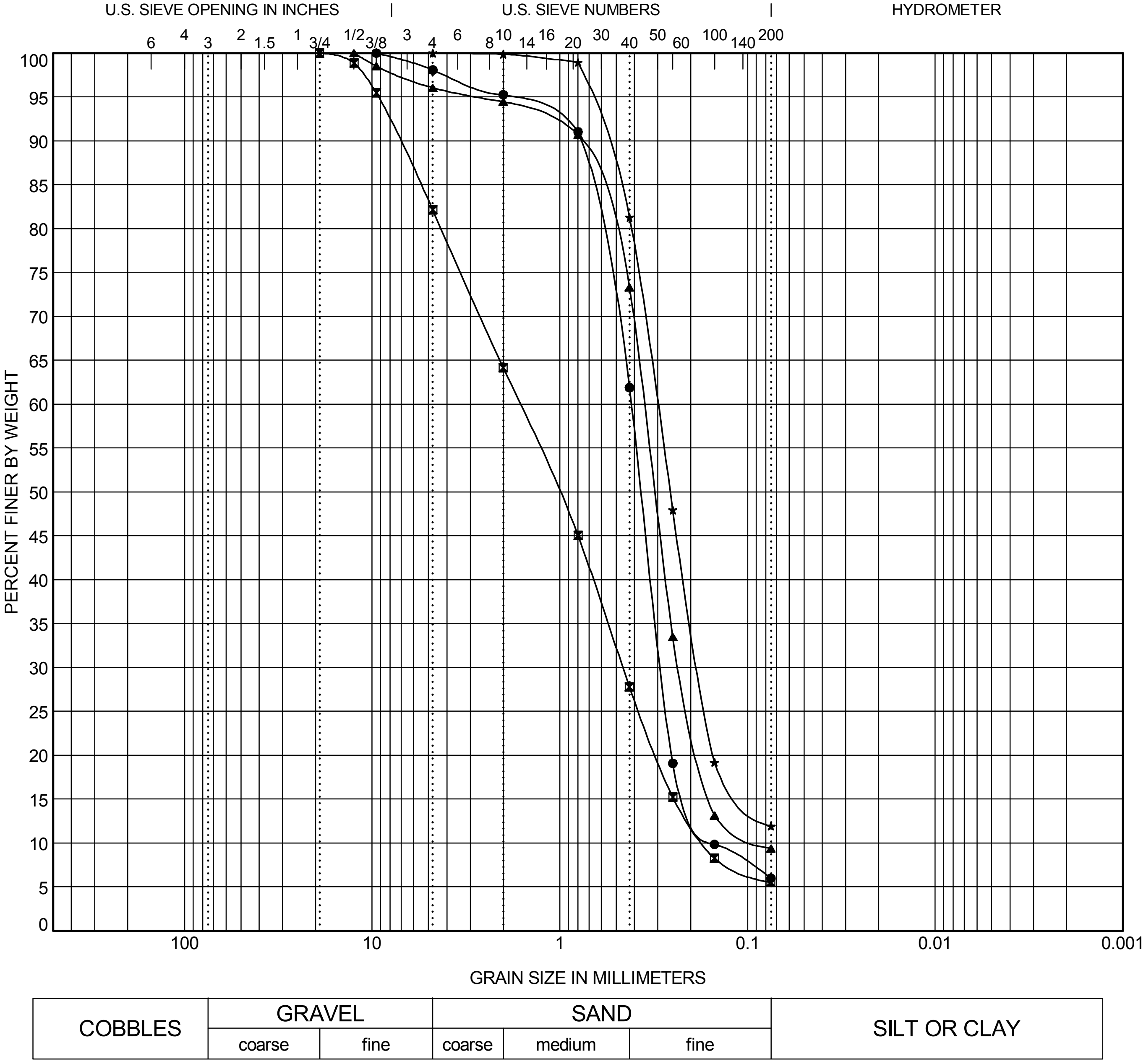
GRAIN SIZE DISTRIBUTION (ASTM D422, D6913)

Project: GEI Rio Vista Feasibility Study
Location:
Project Number: S1136-05-08

GRAIN SIZE FOR GEI S1136-05-08 GEI RVFS.GPJ US LAB.GDT 5/4/18



	Sample No.	Classification	LL	PL	PI	Cc	Cu
●	**B3_S07A_015_017S 15**					**1.30**	**2.7**
⊠	**B3_S08A_020_022S 20**					**0.76**	**9.6**
▲	**B4_S15A_035_037S 35**					**1.76**	**4.2**
★	**B4_S17A_045_047S 45**					**1.75**	**4.9**

	Sample No.	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**S07A_015_017S**	**9.5**	**0.415**	**0.286**	**0.151**	**1.9**	**92.1**	**6.0**	
⊠	**S08A_020_022S**	**19**	**1.639**	**0.461**	**0.17**	**17.9**	**76.6**	**5.5**	
▲	**S15A_035_037S**	**12.5**	**0.356**	**0.229**	**0.084**	**3.9**	**86.7**	**9.4**	
★	**S17A_045_047S**	**4.75**	**0.303**	**0.182**		**0.0**	**88.1**	**11.9**	

GRAIN SIZE FOR GEI S1136-05-08 GEI RVFS.GPJ US_LAB.GDT 5/15/18

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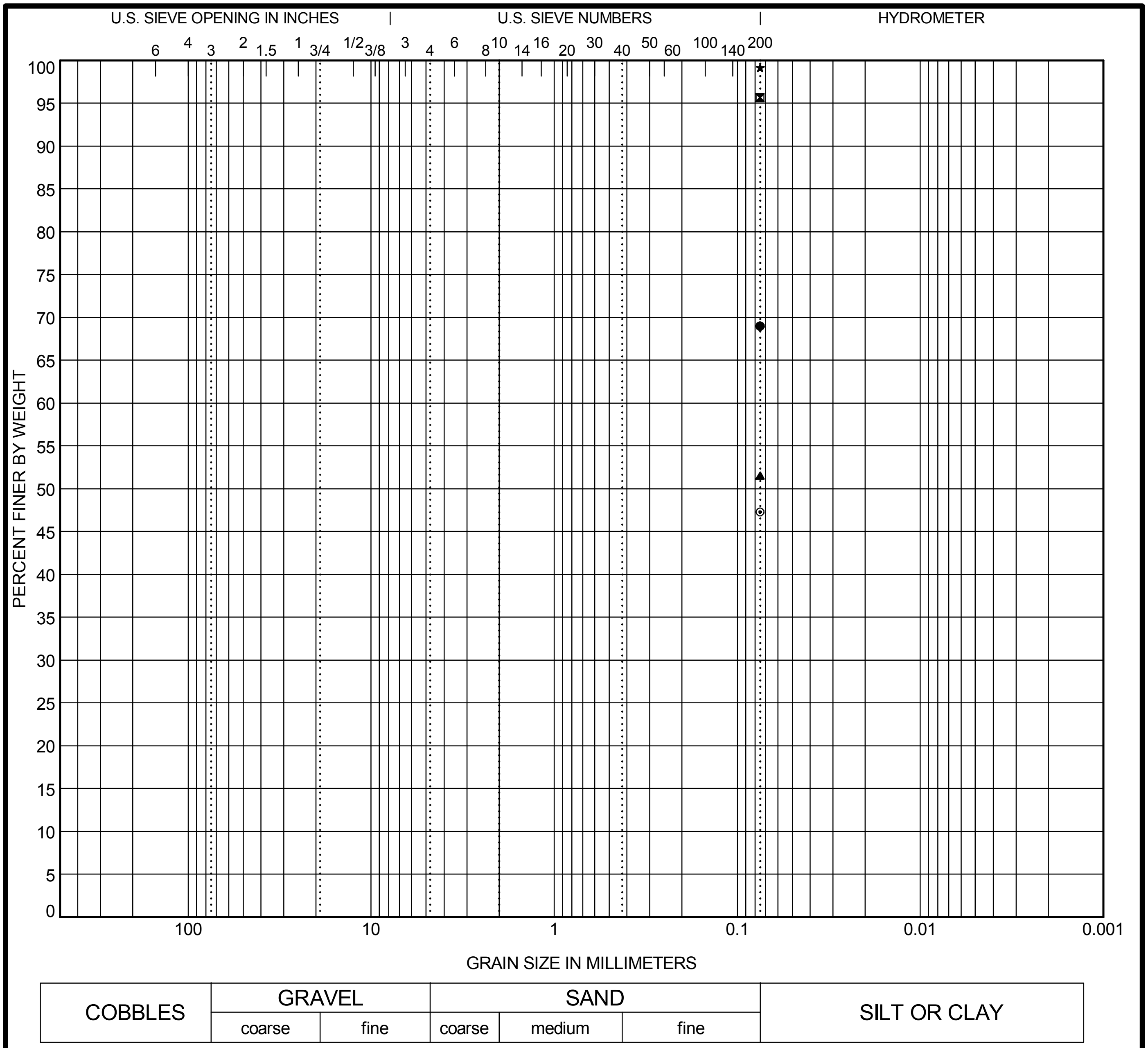
GRAIN SIZE DISTRIBUTION (ASTM D422, D6913)

Project: GEI Rio Vista Feasibility Study
Location:
Project Number: S1136-05-08



	Sample No.	Classification	LL	PL	PI	Cc	Cu
●	**B3_S05A_010_012T 10**	**SANDY SILT(ML)**	**25**	**24**	**1**		
☒	**B4_S03A_005_007T 5**	**FAT CLAY(CH)**	**57**	**29**	**28**		
▲	**B4_S04A_008_010T 8**	**SANDY LEAN CLAY(CL)**	**32**	**20**	**12**		
★	**B4_S05A_010_012T 10**	**LEAN CLAY(CL)**	**48**	**26**	**22**		
⊙	**B4_S07A_015_017S 15**	**Organic SILT or PEAT**	**119**	**74**	**45**		

	Sample No.	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**S05A_010_012T**	**0.075**				**0.0**	**0.0**	**69.0**	
☒	**S03A_005_007T**	**0.075**				**0.0**	**0.0**	**95.7**	
▲	**S04A_008_010T**	**0.075**				**0.0**	**0.0**	**51.5**	
★	**S05A_010_012T**	**0.075**				**0.0**	**0.0**	**99.2**	
⊙	**S07A_015_017S**	**0.075**				**0.0**	**0.0**	**47.3**	

GRAIN SIZE FOR GEI S1136-05-08 GEI RVFS.GPJ US_LAB.GDT 5/4/18

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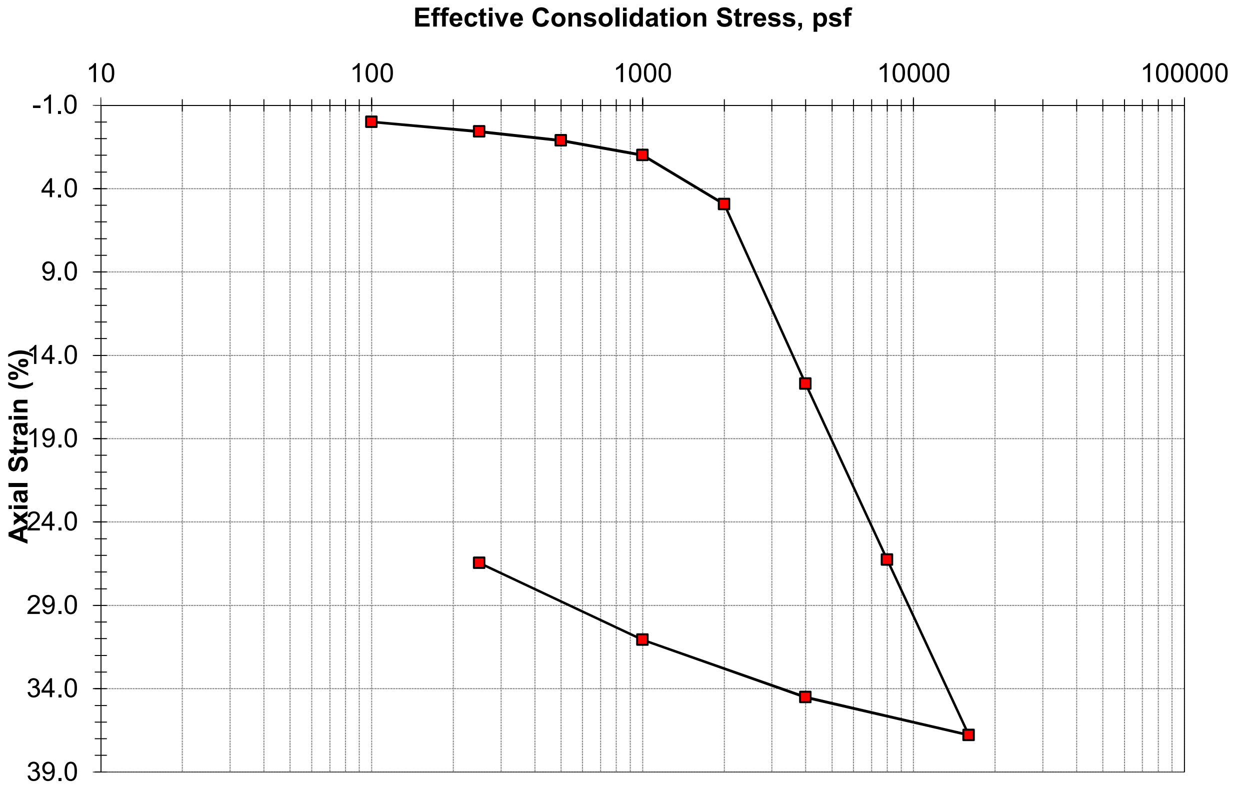
GRAIN SIZE DISTRIBUTION (ASTM D422, D6913)

Project: GEI Rio Vista Feasibility Study
Location:
Project Number: S1136-05-08

CONSOLIDATION TEST - ASTM D2435
STRESS VERSUS STRAIN

Project Name	GEI Rio Vista Feasibility Study
Geocon Project Number	S1136-05-08
Boring Number	B-1
Sample Number	S08A_022_024
Sample Description	Black Organic CLAY (3"BOT)



Axial Load, psf	Void Ratio	Axial Strain, %
initial	3.329	0.00
100	3.329	0.00
250	3.305	0.57
500	3.281	1.11
1000	3.243	2.00
2000	3.116	4.93
4000	2.650	15.70
8000	2.193	26.26
16000	1.737	36.78
4000	1.835	34.52
1000	1.984	31.07
250	2.184	26.45

Measurement	Initial	Final
Height (in.)	0.750	0.550
Moisture Content (%)	129.3	86.7
Dry Density (pcf)	36.1	49.2
Saturation (%)	97	100

Note:
Gs = 2.5 (assumed)

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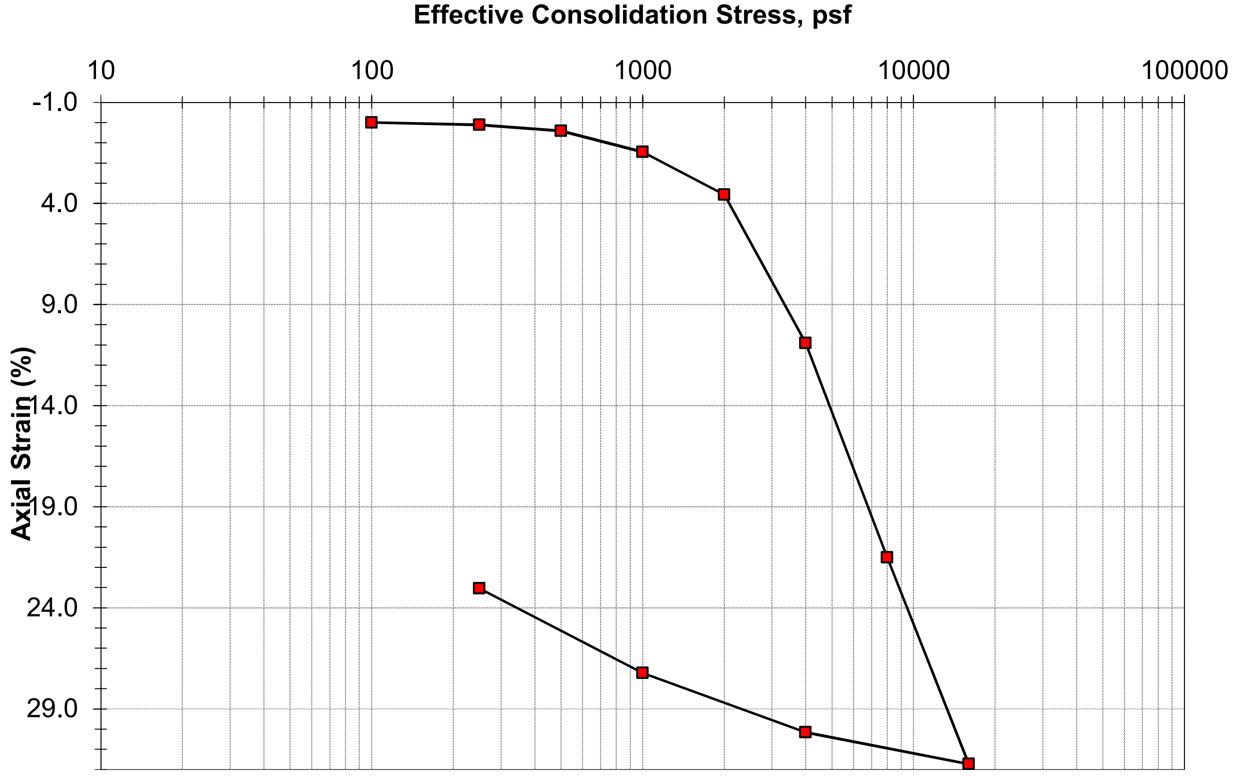
CONSOLIDATION TEST - ASTM D2435
STRESS VERSUS STRAIN

Project Name	GEI Rio Vista Feasibility Study
Geocon Project Number	S1136-05-08
Boring Number	B1
Sample Number	S14A_038_040T
Sample Description	Very Dark Gray Fat CLAY (3" BOT)



Axial Load, psf	Void Ratio	Axial Strain, %
initial	3.210	0.00
100	3.210	0.00
250	3.205	0.12
500	3.192	0.42
1000	3.149	1.45
2000	3.060	3.57
4000	2.751	10.90
8000	2.304	21.51
16000	1.874	31.73
4000	1.940	30.16
1000	2.064	27.23
250	2.240	23.04

Measurement	Initial	Final
Height (in.)	0.750	0.573
Moisture Content (%)	116.5	81.7
Dry Density (pcf)	40.0	52.5
Saturation (%)	98	100

Note:
Gs = 2.7 (assumed)

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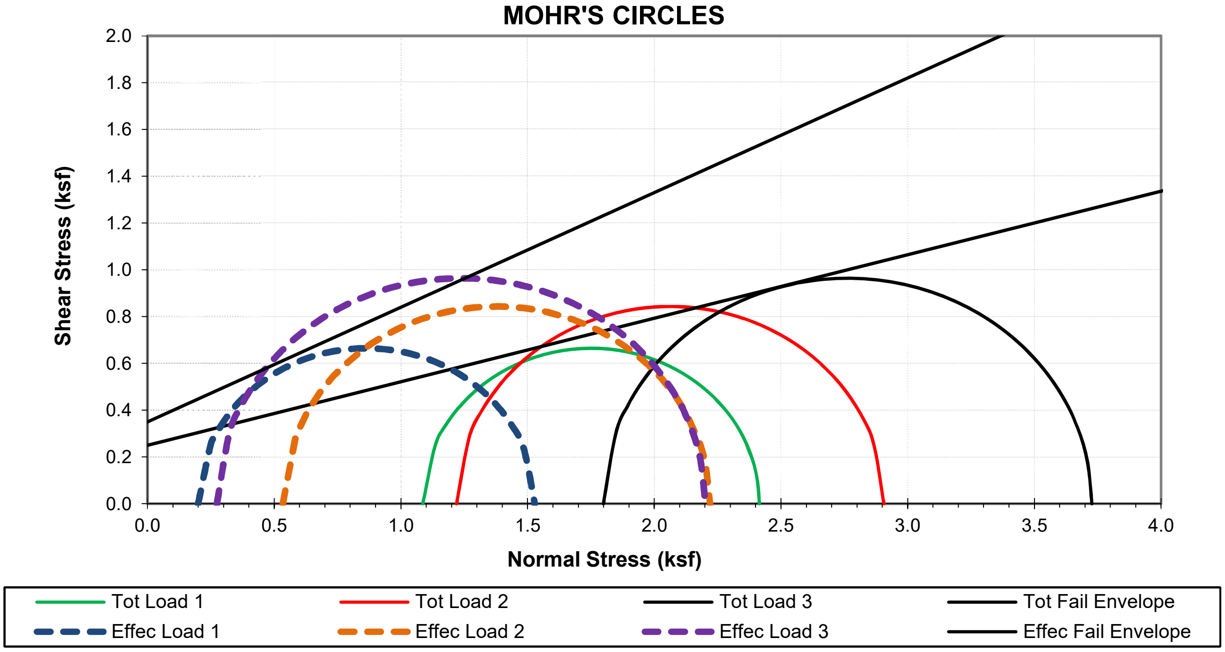
Page 1 of 3

Consolidated Undrained Triaxial Compression - ICU Test ASTM D4767

Sample IDs	**Specimen 1 =** B-1_S08A_022_024T (5-12" BOT), **Specimen 2 =** B-2_S05A_012_014T (5-10" BOT), **Specimen 3 =** B-1_S14A_038_040T (5-11" BOT)
Sample Description	**Specimen 1 =** Elastic SILT with sand, **Specimen 2 =** Sandy Elastic SILT, **Specimen 3 =** Elastic SILT



Test Results, At Maximum Principal Stress Ratio	Total	Effective
Friction Angle ϕ (degrees)	**15.2**	**26.1**
cohesion (psf)	**250**	**350**

Initial Conditions at Start of Test	specimen 1	specimen 2	specimen 3
Sample ID (psf), Initial Confining Pressure	**1100**	**1200**	**1800**
Height (inch)	4.880	4.880	4.890
Diameter (inch)	2.367	2.400	2.398
Moisture Content (%)	98.1	49.1	108.5
Dry Density (pcf)	46.1	71.5	42.5
Saturation (%)	101.4	95.4	95.4
After Saturation			
B Parameter	0.98	0.96	0.95
Dry Density (pcf)	46.1	71.5	42.5
After Consolidation			
Dry Density (pcf)	48.5	73.5	46.3
Shear Test Conditions			
Dry Density (pcf)	48.6	73.6	46.5
Moisture Content (%)	89.9	48.7	96.3
Saturation (%)	100.0	99.7	99.9
Strain rate (%/hr)	0.51	0.51	0.51
Cell pressure (psf)	8300	8400	7690
Initial Back Pressure (psf)	7210	7180	5890
Initial Effective Confining Pressure (psf)	1090	1220	1800
Total Major Principal Stress At Failure (psf)	2420	2910	3730
Effective Major Principal Stress At Failure (psf)	1530	2220	2200
Pore Pressure At Failure (psf)	890	690	1530
Effective Minor Princial Stress At Failure (psf)	200	530	270

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Triaxial Shear Strength - CU Test, ASTM D4767 with pore pressure measurements

Project: GEI Rio Vista Feasibility Study
Location:
Number: S1136-05-08
Figure: page 1 of 3

B-1_S08A_022_024T Before


B-1_S08A_022_024T After
Corporate Express
0
1
2
3
4
5
6
7
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

B-1_S14A_038_040T Before

B-1_S14A_038_040T After

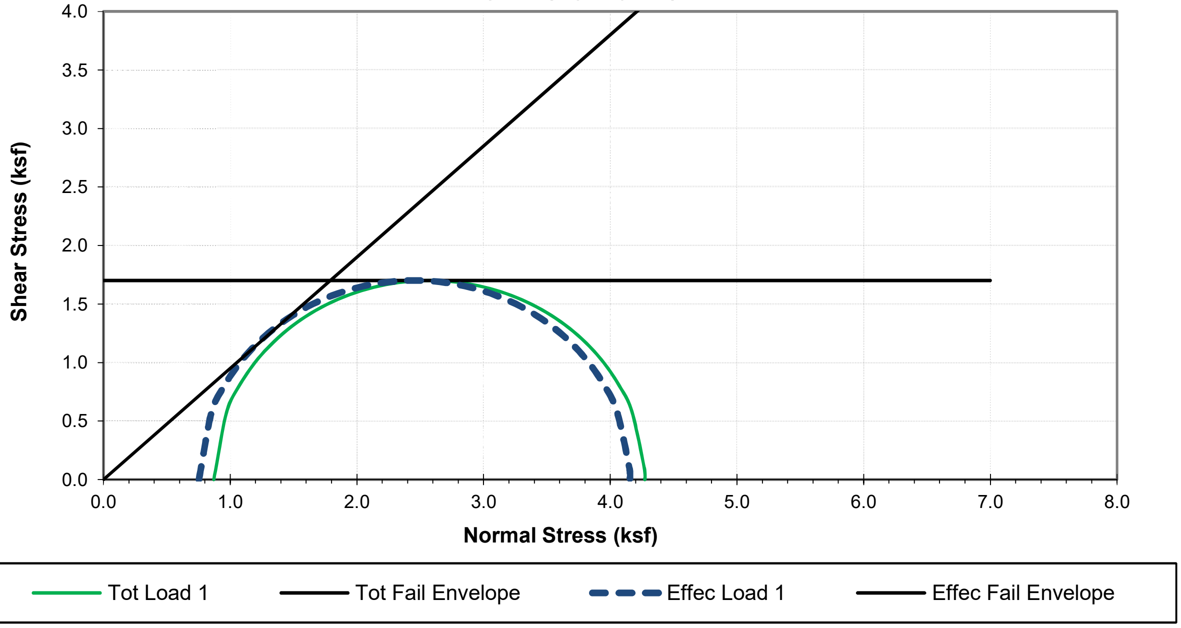
B-2_S05A_012_014T Before

B-2_S05A_012_014T After

Consolidated Undrained Triaxial Compression - ICU Test ASTM D4767

Boring Number	B-3
Sample Number	S05A_010_012T
Sample Description	Yellowish brown Sandy SILT

MOHR'S CIRCLES



Test Results, At Maximum Principal Stress Ratio	Total	Effective
Friction Angle ϕ (degrees)	**0.0**	**43.5**
cohesion (psf)	**1701**	**0**
Initial Conditions at Start of Test	specimen 1	
Sample ID (psf), Initial Confining Pressure	**870**	
Height (inch)	4.869	
Diameter (inch)	2.375	
Moisture Content (%)	36.6	
Dry Density (pcf)	85.3	
Saturation (%)	99.1	
After Saturation		
B Parameter	0.99	
Dry Density (pcf)	85.3	
After Consolidation		
Dry Density (pcf)	85.7	
Shear Test Conditions		
Dry Density (pcf)	85.7	
Moisture Content (%)	36.7	
Saturation (%)	100.3	
Strain rate (%/hr)	1.09	
Cell pressure (psf)	8180	
Initial Back Pressure (psf)	7310	
Initial Effective Confining Pressure (psf)	870	
Total Major Principal Stress At Failure (psf)	4270	
Effective Major Principal Stress At Failure (psf)	4150	
Pore Pressure At Failure (psf)	120	
Effective Minor Princial Stress At Failure (psf)	750	

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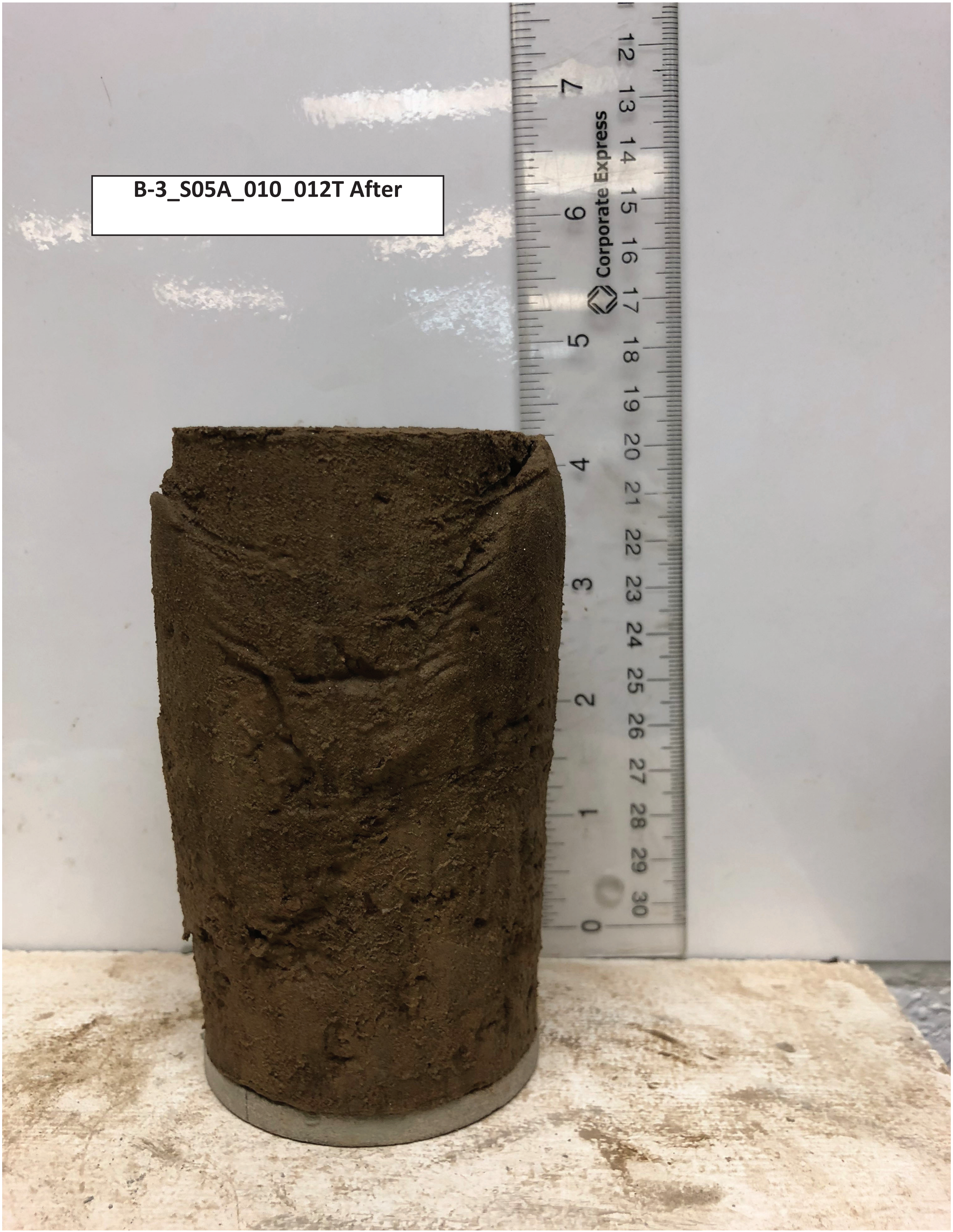
Triaxial Shear Strength - CU Test, ASTM D4767 with pore pressure measurements

Project: GEI Rio Vista Feasibility Study
Location:
Number: S1136-05-08
Figure: page 1 of 3

B-3_S05A_010_012T Before

B-3_S05A_010_012T After



Organic Content
ASTM 2974

Job Name:	GEI Rio Vista Feasibility Study
Job Number:	S1136-05-08
Tested by:	M. Repking
Method Type:	Method C, 440°C

Sample ID:	**B-4_S07A_015_017S**		**B-1_S08A_022_024T**		**B-1_S06A_016_018T**							
Dry soil + tare	187.82		180.59		191.36							
Dry Soil	20.59		13.38		24.16							
Tare weight	167.23		167.21		167.2							
	Time	**Weight + tare**	**Time**	**Weight + tare**	**Time**	**Weight + tare**	**Time**	**Weight + tare**	**Time**	**Weight + tare**	**Time**	**Weight + tare**
	11:49 AM	181.3	1:07 PM	175.5	8:07 AM	187.59						
	3:24 PM	181.04	8:49 AM	175.43	11:30 AM	187.59						
	8:48 AM	180.86	10:06 AM	175.40								
	9:48 AM	180.86	11:26 AM	175.40								
Final Weight + tare	180.86		175.4		187.59							
Final Weight	13.63		8.19		20.39							
Ash Content %	66.2		61.2		84.4							
Organic Content %	**33.8**		**38.8**		**15.6**							

Shelby Tube Log

Logged By: Mark Repking

Date: 4/27/18

Company Name: GEI Consultants

Project Name: Rio Vista Feasibility Study

Recovery: 21 of 21

Project No.: 1704795

Boring: B-4

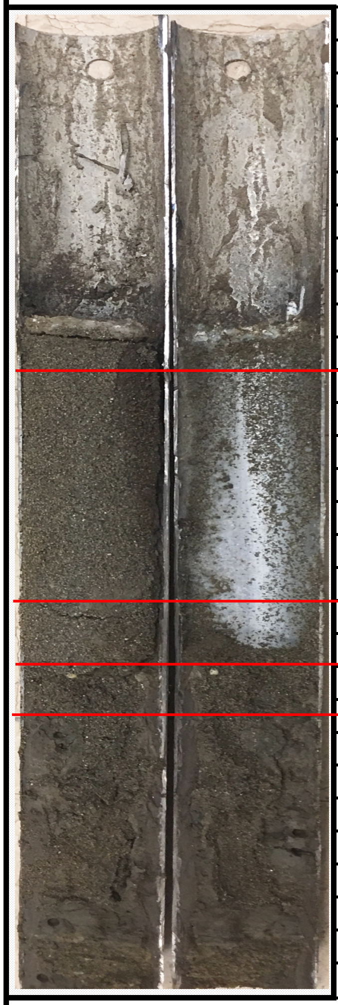
Sample: S03A_005_007T

Depth (ft.): 5-7

Top

30" Tube

Direct Push: 250 psi



Length (in.)	PP	
30		
29		
28		
27		
26		
25		
24		
23		
22		
21		Wax Top
20		Silty SAND (SM), dark brownish gray, very moist, trace gravel,
19		non-plastic
18		
17		
16		
15		
14		
13		Clayey SAND (SC), dark brownish gray, very moist, trace gravel,
12		slightly plastic
11		Silty SAND (SM), dark brownish gray, very moist, trace gravel, non-plastic
10		
9		Disturbed Material, mix of Lean CLAY (CL) and Silty SAND (SM)
8	0.25	Trace gravel coarse to fine grained, clay is moderately plastic
7		
6		
5		
4		
3		
2	1-1.25	
1		

Tip

B - BAGGED

NB - NOT BAGGED

NOTES:

Shelby Tube Log

Logged By: Mark Repking

Date: 4/27/18

Company Name: GEI Consultants

Project Name: Rio Vista Feasibility Study

Recovery: 20 of 20

Project No.: 1704795

Boring: B-4

Sample: S04A_008_010T

Depth (ft.): 8-10

Top

30" Tube

Direct Push: 150 psi

Length (in.)	PP	
30		
29		
28		
27		
26		
25		
24		
23		
22		Wax Top
21		Slough
20		
19		SILT (ML), dark yellowish brown, very moist, slightly plastic
18		
17	0.5	
16		
15		
14		
13	0.5	
12		
11		Silty CLAY (CL-ML), dark grayish brown, very moist, slight to moderately plastic
10		
9	0.25	SILT (ML), dark yellowish brown, dark greenish gray, very moist
8		slightly plastc
7		
6		
5	0	
4		Lean CLAY (CL), dark yellowish brown and dark greenish gray,
3	0	very moist, moderately plastic
2		
1		

Tip

B - BAGGED

NB - NOT BAGGED

NOTES:

Shelby Tube Log

Logged By: Mark Repking
Date: 4/27/18
Company Name: GEI Consultants
Project Name: Rio Vista Feasibility Study
Recovery: 17 of 21
Project No.: 1704795
Boring: B-1
Sample: S06A_016_018T
Depth (ft.): 16-18

Top
30" Tube

Direct Push: Not Listed psi

Length (in.)	PP	
30		
29		
28		
27		
26		
25		
24		
23		
22		Wax Top
21		
20		Organic CLAY (CH or OH), black, very moist, moderately to
19		highly plastic, visable organic matter
18	0	
17		
16		
15		
14	0.25	
13		
12		
11	0.5	
10		
9		
8	0.25	
7		
6		
5	0	
4		
3		
2		Wax Bottom and Void
1		

Tip

B - BAGGED
NB - NOT BAGGED

NOTES:

Appendix D – Preliminary Sheet Pile Wall Design Calculations Provided by Wood Rodgers, dated December 2018.

Sheet Pile Floodwall FW1 - Feasibility Study (PRELIMINARY)

STA XX+00.00 FWX - Line (start)
STA XX+XX.XX FWX - Line (end)

Geotechnical Design and Loading Parameters

$q_a := 63 \cdot pcf$	wall design pressure hydrostatic load case	$\gamma_S := 120 \cdot pcf$	soil weight
$q_{a1} := 45 \cdot pcf$	active pressure above GWT	$q_{p1} := 375 \cdot pcf$	passive pressure above GWT
$q_{a2} := 25 \cdot pcf$	active pressure below GWT	$q_{p2} := 190 \cdot pcf$	passive pressure below above GWT

$q_{n1} := q_{p1} - q_{a1} = 330\ pcf$ net pressure above point C

$q_{n2} := q_{p2} - q_{a2} = 165\ pcf$ net pressure below point C

$k_a := \dfrac{q_a}{\gamma_S} = 0.525$ $k_p := \dfrac{q_{p2}}{\gamma_S} = 1.583$

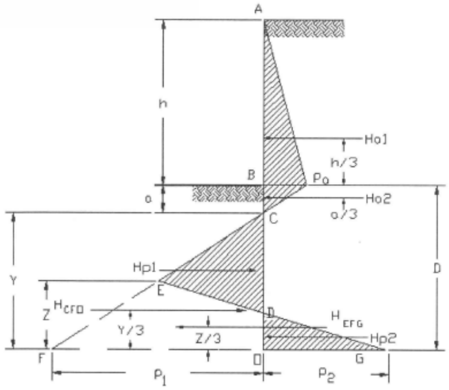
Sheet Pile Floodwall Geometry

$h_1 := 8.0 \cdot ft$ h_1 = wall height above finish grade (top of wall - EL 18.0')

$h_2 := 1.0 \cdot ft$ h_2 = height of retained soil (top of grade retained side - EL 10.0')

$h_3 := 1.0 \cdot ft$ h_2 = height of soil neglected for passive resistance

$h := h_1 + h_2 + h_3 = 10\ ft$



cantliever sheet pile wall in cohesionless soil

Determine Sheet Pile Depth

Calculate lateral earth pressure at base of sheet pile wall P_a and H_{a1}

$$P_a := q_a \cdot h = 630\ psf$$

$$H_{a1} := P_a \cdot \frac{h}{2} = 3150\ plf$$

Calculate depth a , and H_{a2}

$$a := \frac{P_a}{q_{n1}} = 1.909\ ft$$

$$H_{a2} := P_a \cdot \frac{a}{2} = 601.4\ plf$$

Assume a trial depth Y, calculate p_1 and p_2

$Y := 15.12729\ ft$ imput trial depth Y below point C

$$p_1 := q_{n2} \cdot Y = 2496\ psf$$

$$p_2 := \left(q_{p2} \cdot (h + a + Y)\right) - \left(q_{a2} \cdot (a + Y)\right) = 4711\ psf$$

Calculate depth Z

$$Z := \frac{(p_1 \cdot Y) - 2\ (H_{a1} + H_{a2})}{p_1 + p_2} = 4.198\ ft$$

Revise depth Y to make R=0, (equation depth variables are Y and Z)

$$R := \left(H_{a1} \cdot \left(\frac{h}{3} + a + Y\right) + H_{a2} \cdot \left(2 \cdot \frac{a}{3} + Y\right) - p_1 \cdot \frac{Y^2}{6} + (p_1 + p_2) \cdot \frac{Z^2}{6}\right) = 0\ \frac{lbf \cdot ft}{ft}$$

$D := Y + a + h_3 = 18\ ft$ (minimum embedment depth)

$L_P := (1.2 \cdot D) + h_1 + h_2 = 31\ ft$ (Total Pile Length)

Calculate maximum shear

$$V_{max} := H_{a1} + H_{a2} = 3.751\ \frac{kip}{ft}$$

Maximum shear force is usually located at point C where lateral earth pressure changes from active to passive

Calculate maximum moment

$$y := \left(2 \cdot \left(\frac{\left(H_{a1} + H_{a2}\right)}{q_{n2}}\right)\right)^{0.5} = 6.743\ ft$$

Maximum moment locates where shear stress equals to zero. Assume that maximum moment is loacated at a distance y below point C.

$$M_{max} := \left(H_{a1} \cdot \left(\frac{h}{3} + a + y\right) + H_{a2} \cdot \left(\frac{2 \cdot a}{3} + y\right) - \left(q_{n2}\right) \cdot \frac{y^3}{6}\right) = 34.1\ \frac{kip \cdot ft}{ft}$$

Sheet Pile Section and Properties

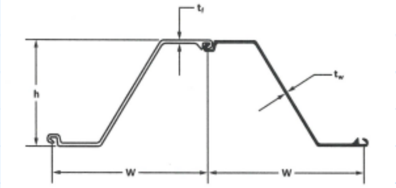
Use NZ 19 Hot Rolled Steel Sheet Pile

$h_{sheetpile} := 16.14 \cdot in$

$w_{sheetpile} := 27.56 \cdot in$

$A_{sheetpile} := 7.04 \cdot \frac{in^2}{ft}$

$S_{sheetpile} := 35.08 \cdot \frac{in^3}{ft}$



$I_{sheetpile} := 283.1 \cdot \frac{in^4}{ft}$

$F_y := 50 \cdot ksi$ *(ASTM A-572 Grade 50)*

$E := 29000 \cdot ksi$

Check Shear

$\Omega_v := 1.80$

0.6/1.80 = 0.33 (EM 1110-2-2504 Section 6-3)

$$V_n := 0.6 \cdot F_y \cdot A_{sheetpile} = 211.2\ \frac{kip}{ft}$$

$\frac{V_n}{\Omega_v} = 117.3\ \frac{kip}{ft}$

$\frac{V_n}{\Omega_v} > V_{max} = 1$

If equals 1 than OKAY,
If equals 0 then select larger section

Check Flexure

$\Omega_b := 2.0$

1.0/2.0 = 0.50 (EM 1110-2-2504 Section 6-3)

$M_n := F_y \cdot S_{sheetpile} = 146.2 \ \frac{kip \cdot ft}{ft}$

$\frac{M_n}{\Omega_b} = 73.083 \ \frac{kip \cdot ft}{ft}$

$\frac{M_n}{\Omega_b} > M_{max} = 1$

If equals 1 than OKAY,
If equals 0 then select larger section

Check Deflection

$$\Delta_{max} := \left(\frac{H_{a1} \cdot \left(\frac{h}{3} + a \right)^2}{6 \cdot E \cdot I_{sheetpile}} \cdot \left((3 \cdot (h+a)) - \left(\frac{h}{3} + a \right) \right) \right) + \left(\frac{H_{a2} \cdot \left(\frac{2 \cdot a}{3} \right)^2}{6 \cdot E \cdot I_{sheetpile}} \cdot \left((3 \cdot (h+a)) - \left(\frac{2 \cdot a}{3} \right) \right) \right) = 0.094 \ in$$

$\frac{2 \cdot (h+a)}{360} = 0.794 \ in$

$\frac{2 \cdot (h+a)}{360} > \Delta_{max} = 1$

If equals 1 than OKAY,
If equals 0 then select larger section

Attachment D: Local Runoff Conveyance Impacts TM

TECHNICAL MEMORANDUM

PREPARED FOR: Mr. Jeff M. Barich, P.E., Solano County Water Agency

PREPARED BY: Mr. Michael C. Nowlan, P.E., CFM, Wood Rodgers, Inc.
Mr. Kaveh Zamani, PhD, Wood Rodgers, Inc.

REVIEWED BY: Mr. Jesse J. Patchett, P.E., CFM, Wood Rodgers, Inc.

DATE: August 31, 2018

SUBJECT: Rio Vista Flood Control Feasibility Study –
Local Storm Runoff Conveyance Facility Impact Analysis

INTRODUCTION

The City of Rio Vista (City) and the Solano County Water Agency (SCWA) are in the process of developing the Rio Vista Flood Control Feasibility Study (Feasibility Study). The Feasibility Study is being prepared through a California Department of Water Resources (DWR) Small Communities Flood Risk Reduction (SCFRR) Program grant. The goal of the Feasibility Study is to identify a preferred alternative that will reduce the risk of flooding in Rio Vista and that is compatible with the City's Waterfront Specific Plan and the DWR Sacramento River Basin-Wide Feasibility Study (BWFS). The preferred alternative will be developed later in the Feasibility Study, but it is expected to consist of a levee, a floodwall, or a combination of the two. The area to be included in the Feasibility Study extends along the west bank of the Sacramento River at Rio Vista from Marina Creek to the Mellin Levee. An evaluation of the Mellin Levee is also included in the Feasibility Study. An overview of the project area is shown on **Figure 1** (attached).

A levee or floodwall along the Sacramento River has the potential to create a barrier to existing overland flow, as well as to present an impact to existing storm runoff conveyance facilities. Therefore, an evaluation needs to be conducted in order to assess the potential impact to local storm runoff conveyance facilities and to develop recommended improvements in order to mitigate the impacts.

This Draft Technical Memorandum (TM) describes the assumptions, approach, and results of the local storm runoff conveyance facility impact analyses. Recommendations for the improvements needed to mitigate identified impacts are also included, and will be a part of the Feasibility Study's overall cost estimates.

BACKGROUND

The City prepared a pre-feasibility study in January of 2015 to evaluate alternatives that would provide 200-year flood protection for the City. Local conveyance facilities' impacts were evaluated at that time using simplified estimating techniques. The effort behind this Feasibility Study builds upon the concepts and approach of the previous study, while providing more detailed hydrologic/hydraulic analyses using

Solano County (County) standards and the XPSWMM software platform. These analyses also account for updated design water surface elevations at the Sacramento River used in the Feasibility Study.

The existing and future Design Water Surface Elevations (DWSEs) in the Sacramento River are described in the March 15, 2018 TM titled *Rio Vista Flood Control Feasibility Study – Design Water Surface Elevation* (Reference 1, DWSE TM) prepared by Wood Rodgers, Inc. (Wood Rodgers) and MBK Engineers (MBK). The existing and future (i.e.: with sea level rise) 200-year design water surface elevations from the DWSE TM are presented below in **Table 1** and **Table 2**. The design water surface profile (future 200-year DWSE) along the entire project alignment is shown on **Figure 2** (attached). This was used to determine downstream tailwater conditions for proposed local storm runoff conveyance facilities.

TABLE 1 – Existing 200-Year DWSE

	Sacramento River at the Delta Marina (feet)	Sacramento River at California State Route 12 (SR 12) (feet)	Sacramento River at the Mellin Levee (feet)
Base 200-Year WSE	12.05	12.55	12.85
Uncertainty Adjustment	1.00	1.00	1.00
Adjusted DWSE	**13.05**	**13.55**	**13.85**

Note: Elevations are in North American Vertical Datum of 1988 (NAVD 88).

TABLE 2 – Future 200-Year DWSE

	Sacramento River at the Delta Marina (feet)	Sacramento River at SR 12 (feet)	Sacramento River at the Mellin Levee (feet)
200-Year WSE with SLR	12.77	13.22	13.49
Uncertainty Adjustment	1.00	1.00	1.00
Adjusted DWSE	**13.77**	**14.22**	**14.49**

Note: Elevations are in NAVD 88.

APPROACH AND METHODOLOGY

General

The local tributary areas currently draining to the Sacramento River contain land that is both above and below the future project design river levels. For land that is physically below the maximum river level, storm drainage must be collected and pumped over the proposed flood barrier to prevent flooding behind the barrier. For local tributary land that is physically above the maximum river level, gravity storm drains can be installed to continue gravity drainage, even when the river is elevated. To adequately size any proposed gravity and pumping facilities, Wood Rodgers evaluated the peak flow and coincident flow conditions between local runoff and the Sacramento River. Local storm runoff often occurs when the Sacramento River is not at peak stage. When the river is low, the system can be configured to drain all areas of the City by gravity, thereby limiting pumping costs. When the river is high, backflow prevention devices can be used to prevent the river's floodwaters from backing up into the City's low-lying areas. The maximum anticipated local stormwater can be collected and pumped to the river from low-lying areas while upstream land drains separately by gravity to the river.

Local Storm Runoff Hydrology and Conveyance Design Standards

The following documents were consulted in establishing the storm definitions, runoff parameters and design of the overall drainage system:

1. Solano County Water Agency Hydrology Manual 1999
2. Natural Resource Conservation Service Soil Survey Map for Solano County
3. City of Rio Vista Design Standards – Division 1, Section 4 – Storm Drainage

Modeling Platforms

Two computer modeling platforms were used to evaluate the hydrologic and hydraulic performance of watersheds. These are detailed below:

1. HEC-HMS: The Hydrologic Engineering Center's Hydraulic Modeling System (HEC-HMS) is a generalized hydrologic routing software created by the United States Army Corps of Engineers (USACE). The software allows users to employ many combinations of basic hydrologic processes to simulate the response of a watershed to rainfall and to route runoff through watersheds.
2. XPSWMM: XPSWMM (version 2017.1.1 by XP Software) is a comprehensive software package for modeling stormwater, sanitary sewer systems or river systems. XPSWMM is a dynamic, unsteady flow model platform that allows simultaneous simulation of hydrologic (storm event data and runoff) and hydraulic (conduit operation and hydraulic grade line data) conditions in real time, rather than a steady state or standard step model.

The proposed local storm runoff conveyance facilities were evaluated using XPSWMM v2017.1.1. XPSWMM provides the flexibility to model dual conveyances through overland flow in streets and conduits, while at the same time accounting for detention due to planned on-site storage and pumped discharge. Runoff hydrographs for each watershed from the proposed conditions HEC-HMS model were inserted and routed at the upstream inlet locations for gravity and pumped inflow using XPSWMM to iterate pipe sizing, detention pipe volume, and the outlet pipe conditions. Existing conditions were not evaluated as part of this study. The additions to the on-site drainage system were determined using the City of Rio Vista Design Standards as a minimum:

1. Manning's n= 0.015
2. Minimum velocity = 2.0 feet per second (fps) at design flow
3. 100-year Hydraulic Grade Line (HGL) from local flow is below ground (drainage inlet rim)

Peak Storm Coincidence

The storm runoff generated from local rainfall directly over Rio Vista will not produce elevated conditions in the Sacramento River by itself. The Sacramento River watershed is very large and slow in response compared to the rainfall/runoff response of Rio Vista land draining to the river during a storm. Elevated flow conditions in the lower Sacramento River are governed by large atmospheric river events encompassing much of the northern portion of California, and they generally take a minimum of 48 to 72 hours to reach peak flood stages after peak rainfall has occurred. The same precipitation event must travel eastward and must run down gradient through mountain streams, reservoirs, dams, and miles of major river before reaching Rio Vista. While such large rainfall events can impact Rio Vista directly, local rainfall generally occurs days before peak river conditions are created by the same rainfall event occurring over the rest of the watershed.

Because of this watershed dynamic, Rio Vista should be able to drain to the river by gravity before the river rises to its peak condition. The storm coincidence evaluation then becomes an analysis of the timing of separate subsequent rainfall events that may coincide with the delayed runoff from previous rainfall.

Limited rainfall data is available in the immediate area of Rio Vista. A rainfall gage was operated in Rio Vista from 1948 to 1977, and Wood Rodgers obtained the daily rainfall record for this gage from the Western Regional Climate Center (COOP Station 047446), which contains some small record gaps in July 1968, October 1969 and May 1964, as well as a longer gap from July 1953 to October 1959. To supplement our understanding of rainfall in this area, a second nearby gage in Lodi, also from the WRCC (COOP Station 045032) was evaluated. This gage was in operation from January 1948 to December 2008. Since 1948, the Lodi gage also contains small gaps in October 1979, May 1990, July 1992, February 1997, August 1997, and August 2000; and longer gaps from January 1988 to November 1988 and from April 2002 to July 2002. While there is no numerical correlation between the data from the Rio Vista gage and the Lodi gage, a brief analysis of the overlapping portion of the data shows that greater than 75 percent of the wet days in Rio Vista (1,094 total wet days) were also wet in Lodi. The magnitudes of each gage's record will vary as precipitation does not fall uniformly across the landscape and they are 23 miles apart. On approximately 73 percent of the days when rainfall occurred at both locations, the differences in their respective amounts were less than 0.5 inch.

While there is a stream gage for measuring stage levels located on the Sacramento River at Rio Vista, it only has post-2007 data available, and it will not provide sufficient information to establish long-term (peak conditions) correlations. The peak stages/events in the Sacramento River have been recorded more comprehensively over the last century at the I Street Bridge in Sacramento. Continuous daily stage information is available from 1984 to the present, with large flood events (historic crests) prior to 1984 uniquely recorded under Sacramento River at the I Street Bridge ("SACC1") on the National Weather Service Advanced Hydrologic Prediction Service website: https://water.weather.gov/ahps and at the United States Geological Survey (USGS) National Water Information System website: (https://waterdata.usgs.gov/ca/nwis/inventory/?site_no=11447500)

While peak stages at Rio Vista are affected by both the Sacramento River and the Yolo Bypass, the direct correlation of both of these waterways is very high, considering that the Yolo Bypass flows are generated from peak flow spilling from the Sacramento River at the Fremont Weir. If the Yolo Bypass is flooded, the Sacramento River is also flooded. Therefore, monitored peak conditions at I Street should provide a reasonable representation of the peak river conditions that are also experienced downstream at Rio Vista.

The oldest recorded peak stage at I Street was in 1909. As local rainfall records for this year are unavailable for both Rio Vista and Lodi, Wood Rodgers utilized daily rainfall from Sacramento to supplement this preliminary correlation analysis. **Table 3** (attached) summarizes the local rainfall occurring during the largest recorded river events since 1909.

As shown on Table 3, the correlation is very low, with the largest local storm event (Rio Vista rainfall gage) roughly equivalent to a 6-year event occurring three days prior to the January 15, 1952 peak river stage. The largest event to occur the on same day as the river's peak stage was a 4-year event (at the Lodi gage) during the December 23, 1955 flood. During the same flood date, only 1.31 inches fell in Sacramento, which is equivalent to less than a 1-year event. The vast majority of all daily rainfall occurring within a 6-day window (three days prior to two days after) for all 42 of the high-water events listed on Table 3 are less than 1-year rainfall. Only eight days out of the 252 days of recorded rainfall shown on Table 3 exceeded a 1-year event, with the largest being the 6-year event noted above. Eighty-two of the recorded days documented zero rainfall.

During the event on December 23, 1955 noted above, the rainfall depth was roughly equivalent to a 5-year storm in Lodi. The 5-year hypothetical design storm event used in the analysis applies the peak rainfall much more intensely. Therefore, the peak flow generated from a 5-year design storm is likely higher than what was experienced on December 23, 1955 in the very small Rio Vista watersheds. Without 5-minute interval rainfall recordings measured directly in the subject watersheds for the entire period of evaluated storms, there is no way of knowing for sure. Stormwater pumping rates necessary to evacuate the 5-year design storm event peak flow are assumed to be sufficient for handling local drainage when the river is at a stage where gravity discharge is not possible.

It is important to note that coincidence of local rainfall and river stages can be affected by reservoir regulation. Historical comparisons of data from the conditions recorded in the early 20th century to today's conditions (and the future) should account for changing system components and operations. As the larger river watersheds have been changing, it is extremely difficult to assign a single frequency distribution to represent the conditions in these rivers. It is for this reason that Wood Rodgers reported only the peak stage elevation rather than assigning a frequency to the river conditions. The largest and most extensive evaluation to date was performed under the Central Valley Hydrology Study (CVHS) which deregulated (removed dams and levees) the historical record, performed unregulated flow frequency estimates, and then estimated regulated conditions with "today's" system. Unfortunately, even this analysis did not evaluate relative timing of local downstream rainfall storms, but focused primarily on river flow/stage frequency.

While reservoir flood releases may change portions of the flood hydrograph in the future, it should also be noted that peak flow conditions in the major river systems are still considerably governed by the unregulated portions of these same watersheds, downstream of reservoirs. Considering this aspect of the hydrology, the peak evaluations for today are still reasonable. If peak flows are delayed more by reservoir storage, or if operational releases are made earlier (significantly prior to events), then Wood Rodgers recommends that local rainfall coincidence evaluations treat these events as independent of one another, and perform combined probability assessments, as the system is no longer behaving as a natural watershed.

Water Quality and Hydromodification

No assessments were made with respect to installing new or retrofitting existing stormwater quality facilities in order to comply with US Environmental Protection Agency (EPA) National Pollution Discharge Elimination System (NPDES) requirements. Most of the City area that will be draining through the proposed storm drains is currently developed. If small infill areas are permitted by the City, this study assumes that each parcel will need to meet its obligations for stormwater quality treatment on-site, on a case-by-case basis. Finally, no estimation of, or effort to address US EPA NPDES Hydromodification requirements were made as part of this analysis. Because the Sacramento River is tidally influenced at this location, it is assumed that the City would be exempt from these requirements. Even so, with the proposed project, the peak flow reaching the river should be reduced because of the proposed detention and pumping strategies envisioned by this analysis. When the river is low, gravity flow conditions should be the same as existing conditions and should create no adverse impact to the river from a peak flow perspective.

WATERSHED CHARACTERISTICS

Topography and Existing Local Storm Runoff Conveyance Facilities

Local watershed elevations directly affecting the project site range from approximately Elevation 173 to Elevation 5 (NAVD 88). The City generally slopes and drains from the northwest to the southeast toward the Sacramento River, draining through Industrial Creek, Marina Creek and underground storm drains. **Figures 3a** and **3b** (attached) depict the topography for the watersheds utilized for the Feasibility Study. Watersheds that potentially could be impacted by a proposed flood barrier along the Sacramento River are shown in **Figure 4** (attached). The existing local drainage system is shown in **Figure 5** (attached).

Soils

Soil classifications for the project site were taken from the published Natural Resources Conservation Service (NRCS) soil survey, which have been accepted by the County. The project site is split into four main hydrologic soil groups: Type “A”, Type “B”, Type “C”, and Type “D”. **Figure 6** shows the soils types at the project site, which are associated with assumed constant infiltrative soil losses within the hydrologic analysis.

Land Use

Proposed conditions land use affecting the project site were provided by Solano County and based on the current zoning of parcels tributary to the project. **Figure 7** shows the land use types for the proposed conditions watersheds. These land uses were translated to estimate imperviousness within each sub-watershed, also using existing aerial photography available through Google Earth®

DESIGN SCENARIOS

The Rio Vista system was evaluated under two separate scenarios to determine which scenario would govern the design/sizing of the proposed drainage system improvements. When riverine conditions are near peak flood (design water surface) conditions, and pumping is required for low-lying areas, the local rainfall (storm) that must drain to the river was considered to be a 5-year 24-hour storm event, based on the discussion above. The definition of this storm event was based on the depth/duration/frequency rainfall tables from the Solano County Hydrology Manual, with a temporal hyetograph distribution which "nests" the peak 5-minute duration storm within the peak 10-minute duration storm, within each subsequent duration up to the 24-hour duration. Using this rainfall hyetograph, all 5-year duration events are evaluated at one time, which will generate the highest expected peak flow and volume conditions for assessing gravity-drained (upper) and pumped (lower) portions of the watersheds under evaluation.

The second scenario evaluated the same hydraulic system with a local 100-year 24-hour storm event (also defined with a nested rainfall distribution) occurring while the Sacramento River conditions are low, to gravity drain all of the local watershed areas to the river without backing up behind the proposed flood barrier. When the river is low, the pump system does not need to be enabled. Modeling for both scenarios has been provided with this report.

RESULTS AND DISCUSSION

A proposed flood barrier along the Sacramento River has the potential to impact the drainage of 19 watersheds, with upstream areas contributing to the peak runoff at each point of discharge to the river. The proposed conditions HEC-HMS watershed parameters and results are included in **Appendix A**.

Taking into account that all of the subject watersheds currently discharge to the Sacramento River unattenuated and untreated, and also that the project is not increasing the current development level or imperviousness, the conclusion was that hydromodification and stormwater treatment issues were considered not applicable. Two additional watersheds were evaluated for potential runoff to the river. Watersheds 20 and 16 topographically drain to low points within their respective sheds, which must fill up before overflowing and discharging to other areas.

Watershed 20 (12.12 acres) drains to the Rio Vista Business Park Storm Basin, which is located northeast of the intersection of St. Francis Way and Poppy House Road. Wood Rodgers contacted the City of Rio Vista and requested basin design information relating to infiltration and discharge to ground, as this basin has no direct gravity outlet/discharge to the river. The City has contacted the design engineer of record and, for the purposes of this study, it is assumed that this area sufficiently holds and infiltrates the local 100-year design storm runoff, as designed. The NRCS Hydrologic Soil Group A designation indicates that this area is highly infiltrative. Based on an analysis of the terrain and the watershed area, the basin has enough capacity to hold 7 inches of runoff generated from the entire watershed area. With a conservative infiltrative capacity of 0.3 inch/hour, there should be sufficient capacity to handle most of the storm runoff. The bottom area of the basin is approximately 1.25 acres which can evacuate 7.2 inches of stored volume in one day, and that equates to 0.6 inch of excess runoff from the entire watershed area per day.

Watershed 16 (271.09 acres) is primarily made up of open space and has sufficient surface storage to hold the local 100-year annual storm runoff without overtopping. Without accounting for infiltration or evaporation, Wood Rodgers conservatively calculated the volume of the 100-year annual rainfall (30.78 inches) from the published Solano County rainfall depth/duration/frequency tables and determined that this very conservative volume could be contained within the watershed storage. The majority of the watershed is open space, with a small percentage of the watershed now being used for aggregate storage (piles) along the eastern, southern and western boundaries. Wood Rodgers, therefore, assumes that this area is not draining overland to the river through the proposed flood barrier alignment.

A summary of the 5-year 24-hour storm volumes for the upstream watersheds is presented in **Table 4** (below). The results of this analysis were used to develop recommendations for a combination of storage and/or pumping to mitigate impacts of a proposed flood barrier along the Sacramento River.

TABLE 4
Estimated Upstream 5-Year 24-Hour Storm Volumes

Watershed Label	Area (ac)	5-Year 24-Hour Storm Volume (ac-ft)
1	45.21	4.72
2	57.28	4.58
3	34.33	2.73
4	52.83	5.22
5	42.75	7.34
6	11.36	1.92
7	11.15	1.96
8	9.17	1.63
9	76.26	13.23
10	20.28	3.58
11	52.5	9.13
12	40.41	7.02
13	14.81	2.71
14	6.34	1.13
15	3.63	0.64
16	271.09	11.51
17	19.43	1.21
18	9.3	1.58
19	2.65	0.18
20	23.87	1.47
21	837.97	53.45

RECOMMENDATIONS

Based on the results of this analysis, a series of storm drains and pump stations has been proposed in order to mitigate runoff impacts associated with a proposed flood barrier along the Sacramento River. The recommended facilities are shown graphically on **Figure 8** (attached).

The proposed runoff conveyance facilities were designed as a direct conduit system to the river that could maintain hydraulic grade profiles above ground levels (under pressure) when the river is elevated without flooding low-lying areas (which would require backflow prevention devices and pumping). Therefore, it will be important for the future design of these facilities to account for this pressure flow condition.

Wherever possible, the proposed storm drains were located within existing streets or unoccupied/paved spaces. There are nine overall proposed outfall locations where a storm drain would penetrate the proposed flood barrier structure. Three locations (Watershed 1, Watershed 2, and Watershed 3) drain low-lying areas only, with everything directed through pump station sumps before discharging to the river. Two locations (Watershed 9 and Watershed 17) convey only upstream gravity flow to the river. The four remaining locations combine both upstream gravity flow and downstream pumped flow through a "single" conduit in order to reduce the number of penetrations through the flood barrier. A summary of the watersheds and storm drain penetrations is shown on Figure 8.

The drainage network designed for this Draft TM is made up of conduits ranging in size from 18 inches to 72 inches in diameter, with the XPSWMM model results provided in Appendix A. Flow hydrographs at the outfall location for each storm event modeled are provided in the Appendix A model output.

No assessments were made as part of this study regarding flow depths in existing streets and pipes upstream of the proposed new inlets and storm drains. Any flooding upstream of new facilities is assumed to be an existing condition that is unaffected by the project, as all flow reaching new inlets will have 100-year flow capacity within underground conduits downstream.

Enclosures:

Tables:
- Table 3 – Local Rainfall and River Stage Coincidence

Figures:
- Figure 1 – Location Map
- Figure 2 – DWSE Profile
- Figure 3A – Topographic Map
- Figure 3B – Topographic Digital Elevation Model
- Figure 4 – Watersheds Impacted by a Proposed Flood Barrier Along the Sacramento River
- Figure 5 – Existing Storm Drainage Facilities
- Figure 6 – NRCS Hydrologic Soil Data Map
- Figure 7 – Land Use
- Figure 8 – Proposed Local Runoff Conveyance Facilities

Appendix A (Electronic data & model files on CD)
- GIS Base Data
- HEC-HMS Input/Output; XPSWMM Input/Output

TABLE 3 - RIO VISTA FLOOD CONTROL FEASIBILITY STUDY - LOCAL RAINFALL AND RIVER STAGE COINCIDENCE

			1.) Rio Vista or, 2.) Lodi or 3.) Sacramento Daily Precipitation (in) and Estimated Recurrence Interval (yrs)											
			-3 days		-2 days		-1 day		Same Day		+1 day		+2 days	
Sacramento River Event Date	I Street Peak River Stage (ft)	Rainfall Gage	Depth (in)	Estimated Recurrence (yrs)	Depth (in)	Estimated Recurrence (yrs)	Depth (in)	Estimated Recurrence (yrs)	Depth (in)	Estimated Recurrence (yrs)	Depth (in)	Estimated Recurrence (yrs)	Depth (in)	Estimated Recurrence (yrs)
2/19/1986	30.58	Lodi	0.8	<1	2.54	5	0.65	<1	0.87	<1	0.12	<1	0.05	<1
1/3/1997	30.38	Lodi	0.06	<1	1.36	<1	1.28	<1	0	<1	0	<1	0	<1
11/21/1950	30.14	Rio Vista	1.7	1	0.62	<1	0.82	<1	0.28	<1	0.01	<1	0	<1
2/9/2017	29.89	Sacramento	1.15	<1	0.87	<1	0.39	<1	1.06	<1	0.08	<1	0	<1
1/17/1909	29.6	Sacramento	1.28	<1	1.03	<1	0.32	<1	0.12	<1	0	<1	0.29	<1
1/11/2017	29.59	Sacramento	1.96	2	0.18	<1	2.16	3	0.19	<1	0.12	<1	0	<1
12/25/1964	29.36	Rio Vista	0.8	<1	0.19	<1	0	<1	0	<1	0.4	<1	0.58	<1
12/23/1955	28.673	Lodi	0.33	<1	0.08	<1	1.77	1	2.42	4	0.33	<1	0	<1
2/1/1963	28.52	Rio Vista	0.9	<1	0.86	<1	1.53	<1	0	<1	0	<1	0	<1
1/24/1970	28.24	Rio Vista	1.74	1	0.76	<1	0	<1	0.21	<1	0.22	<1	0	<1
1/21/1969	28.18	Lodi	0.52	<1	0.7	<1	0.43	<1	0.41	<1	0.05	<1	0.03	<1
12/31/2005	27.7	Lodi	0.28	<1	0.01	<1	0.7	<1	1.8	2	0.25	<1	1.75	1
4/7/1958	27.62	Lodi	0.51	<1	0	<1	0.42	<1	0.29	<1	0	<1	0	<1
1/31/1967	27.4	Rio Vista	0	<1	1.44	<1	0.6	<1	0.45	<1	0	<1	0	<1
1/26/1997	27.39	Lodi	0.1	<1	0.38	<1	0.68	<1	0	<1	0.67	<1	0	<1
4/5/2006	27.27	Lodi	0	<1	1.04	<1	0.96	<1	0.2	<1	0	<1	0	<1
2/4/1998	27.27	Lodi	0.68	<1	0.82	<1	2.05	2	0.06	<1	0.31	<1	0.33	<1
3/11/1995	27.22	Lodi	0.18	<1	1.08	<1	1.24	<1	0.65	<1	0.02	<1	0.31	<1
1/21/1974	27.18	Rio Vista	0.17	<1	0	<1	0	<1	0	<1	0	<1	0	<1
12/22/1982	27.1	Lodi	0.02	<1	0.24	<1	1.48	<1	1.16	<1	0.02	<1	0	<1
1/15/1952	26.843	Rio Vista	2.57	6	0.2	<1	0.64	<1	0.58	<1	0.28	<1	0.32	<1
1/19/1973	26.74	Rio Vista	1.38	<1	0.26	<1	1.15	<1	0	<1	0.08	<1	0.28	<1
1/12/1995	26.66	Lodi	0.02	<1	1.53	<1	0.03	<1	0.25	<1	0.08	<1	0.35	<1
2/25/1917	26.4	Sacramento	0	<1	0.62	<1	1.82	2	0.06	<1	0.02	<1	0	<1
3/6/1957	25.75	Lodi	0.32	<1	0.15	<1	0.59	<1	0.03	<1	0	<1	0	<1
2/7/1996	25.6	Lodi	0.82	<1	0.1	<1	0	<1	0	<1	0.02	<1	0	<1
3/25/2011	25.53	Sacramento	0.05	<1	0.37	<1	1.11	<1	0.02	<1	0.5	<1	0	<1
1/21/1953	25.463	Rio Vista	0.04	<1	0.1	<1	0	<1	0.04	<1	0	<1	0	<1
2/15/2000	25.32	Lodi	1.12	<1	1.25	<1	0.78	<1	0	<1	0.52	<1	0.09	<1
4/17/2006	25.24	Lodi	0	<1	0	<1	0.25	<1	0.01	<1	0	<1	0	<1
2/18/1999	25.24	Lodi	0	<1	0.05	<1	0.35	<1	0.1	<1	0	<1	0.23	<1
3/21/2011	25.23	Sacramento	0.78	<1	0.42	<1	0.32	<1	0	<1	0.05	<1	0.37	<1
2/15/1998	25.23	Lodi	0.6	<1	0.03	<1	1.15	<1	0.02	<1	0.26	<1	0.26	<1
5/6/1995	24.67	Lodi	0	<1	0	<1	0.02	<1	0	<1	0	<1	0	<1
2/10/1999	24.64	Lodi	1.4	<1	0.35	<1	0.66	<1	0	<1	0.02	<1	0	<1
2/7/1950	24.553	Rio Vista	0.94	<1	0.29	<1	0.24	<1	0	<1	0	<1	0	<1
3/15/2016	24.08	Sacramento	0.71	<1	0.44	<1	0.11	<1	0	<1	0	<1	0	<1
3/11/1954	23.733	Lodi	0.14	<1	0.51	<1	0.05	<1	0	<1	0	<1	0	<1
5/22/2005	22.99	Lodi	0.01	<1	0	<1	0	<1	0	<1	0	<1	0	<1
2/12/1993	22.98	Lodi	0.16	<1	0	<1	0.2	<1	0	<1	0	<1	0	<1
12/22/2010	22.7	Sacramento	0.98	<1	0.01	<1	0.03	<1	0.43	<1	0	<1	0	<1
1/23/1993	22.19	Lodi	0.76	<1	0.44	<1	0.47	<1	0	<1	0	<1	0	<1

Solano County Water Agency
Rio Vista Flood Control Feasibility Study
Location Map

SOURCES:
California DWR - State-Federal Levees
ESRI - City/County Boundary
Microsoft Virtual Earth - Aerial Background

PRELIMINARY

WOOD RODGERS

J:\Jobs\8246-Solano County Water Agency\8246.007 Rio Vista Pre-Feasibility Study\GIS\Tasks\Floodwall\FIG_01_LocationMap_20160927_V2.mxd 10/17/2016 03:13:46 PM jpatchett

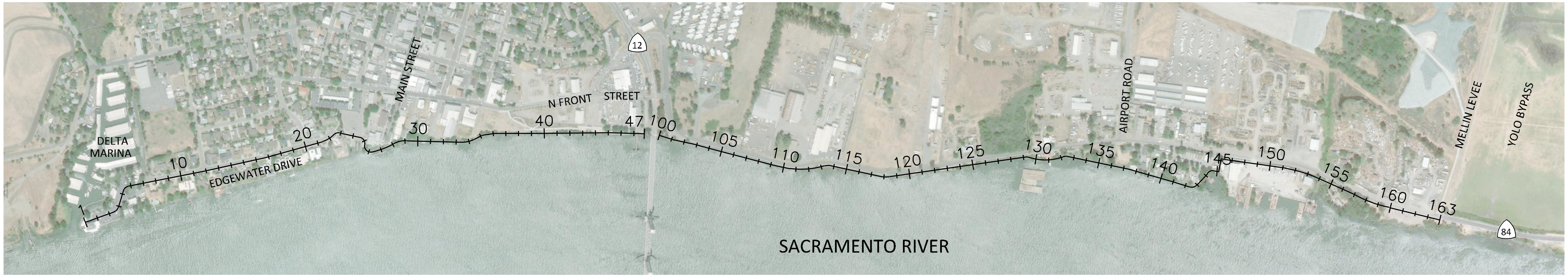
FIGURE 1

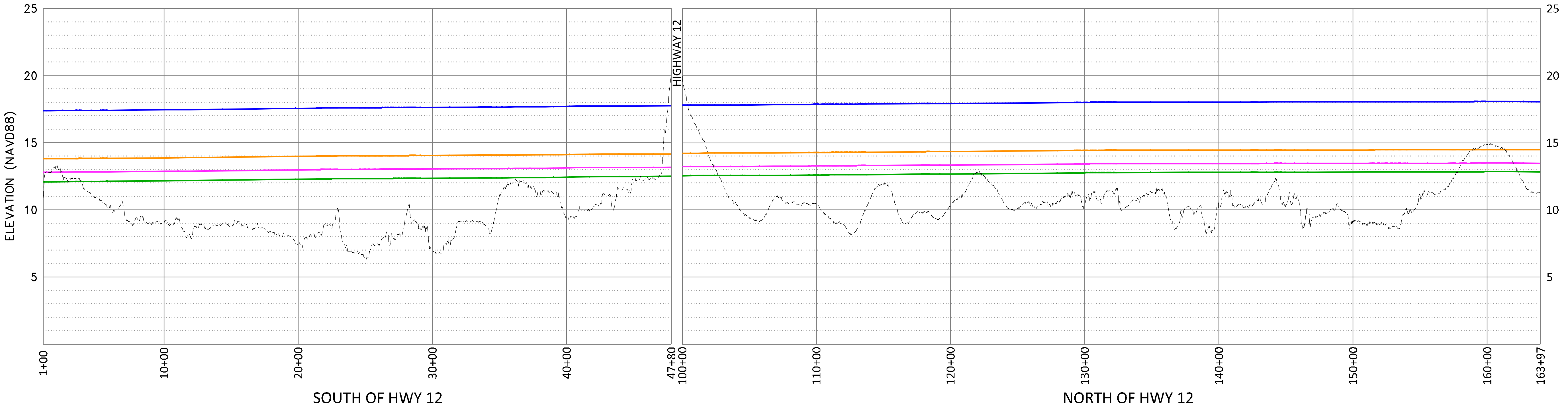
SOLANO COUNTY WATER AGENCY
RIO VISTA FLOOD PROTECTION FEASIBILITY STUDY
WATER SURFACE ELEVATION PROFILE

FEBRUARY, 2018

0' 200' 400' 800'
HORIZ. SCALE: 1" = 800'

0' 1' 2' 4'
VERT. SCALE: 1" = 4'





NOTES:
1. WATER SURFACE ELEVATIONS WERE BASED ON INFORMATION PROVIDED BY MBK ENGINEERS DATED JANUARY 2018.

Recommended DWSE, Adjustment Factors, and MTOL

Scenario	Location Sacramento River at the Delta Marina (feet)	Sacramento River at State Highway 12 (feet)	Sacramento River at the Mellin Levee (feet)
Base 200-year WSE	12.05	12.55	12.85
200-year WSE with SLR (Year 2062)	12.77	13.22	13.49
Uncertainty Adjustment	1	1	1
Adjusted DWSE	**13.77**	**14.22**	**14.49**
Settlement	0.58	0.58	0.58
Wind / Wave / Freeboard Adjustment	3	3	3
Recommended MTOL	**17.35**	**17.8**	**18.07**

LEGEND

🟦	200-YR WSE +SLR +1' UNCERTAINTY +3' FB (MTOL)
🟧	200-YR WSE +SLR +1' UNCERTAINTY
🟪	200-YR WSE +SLR
🟩	200-YR WSE
- - - - - -	EXISTING GROUND

MBK ENGINEERS
CONSULTING ENGINEERS

WOOD RODGERS
BUILDING RELATIONSHIPS ONE PROJECT AT A TIME
3301 C ST, BLDG. 100-B TEL 916.341.7760
SACRAMENTO, CA 95816 FAX 916.341.7767

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FIGURE 2

SOLANO COUNTY WATER AGENCY

RIO VISTA FLOOD CONTROL FEASIBILITY STUDY

TOPOGRAPHICS MAP

RIO VISTA, CA - JULY, 2018

Source: Esri Topographic Map

NORTH

0 1,000 2,000

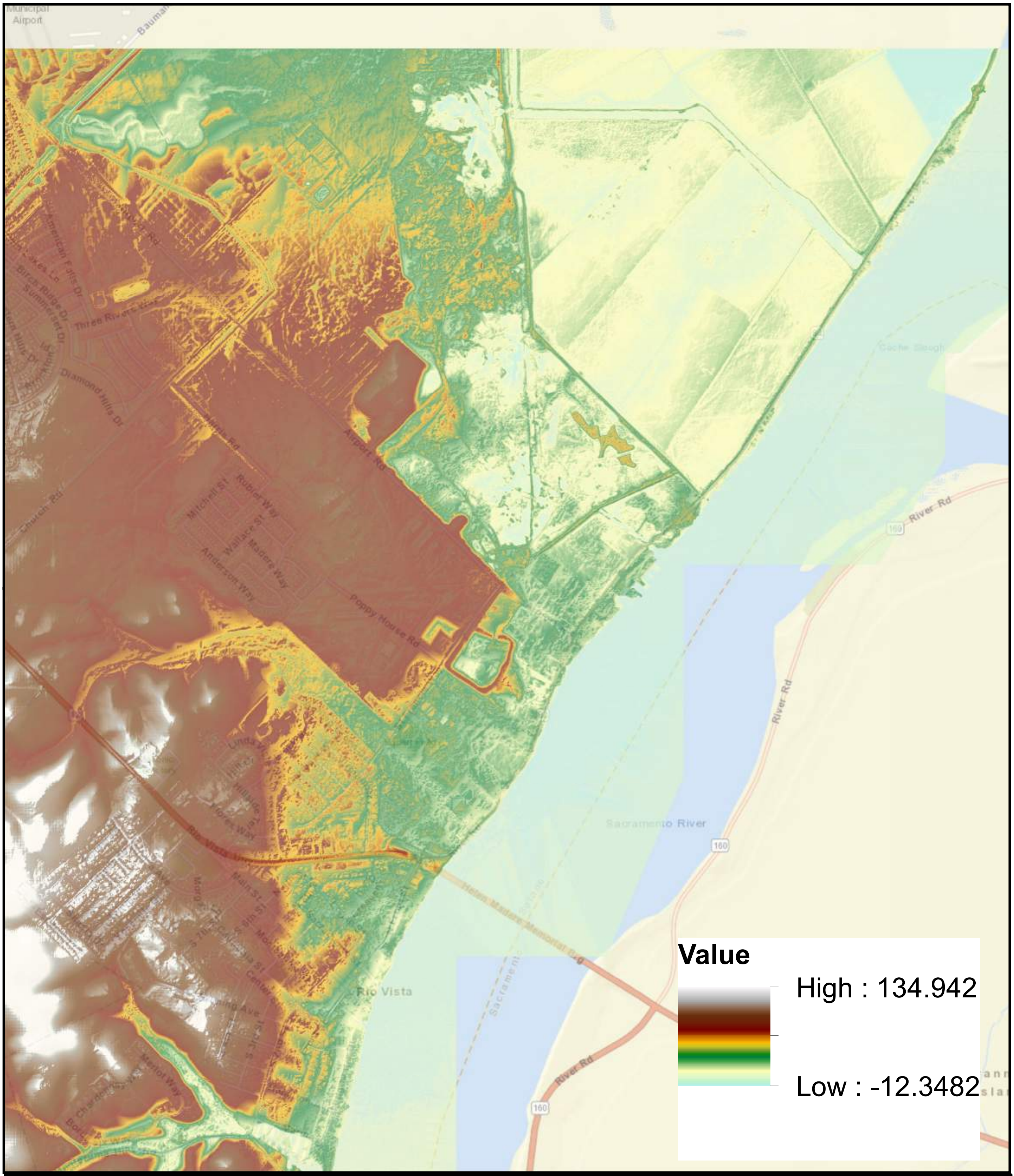
Feet

PRELIMINARY

WOOD RODGERS

J:\Jobs\8246-Solano County Water Agency\8246008 Rio Vista Feasibility Study\GIS\Output\MXD\Figure_4A.mxd 7/6/2018 4:11:00 PM jpriest

FIGURE 3A



SOLANO COUNTY WATER AGENCY
RIO VISTA FLOOD CONTROL FEASIBILITY STUDY
TOPOGRAPHIC DIGITAL ELEVATION MODEL
RIO VISTA, CA - JUNE 2018

NORTH

0 1,000 2,000
Feet

PRELIMINARY

WOOD RODGERS

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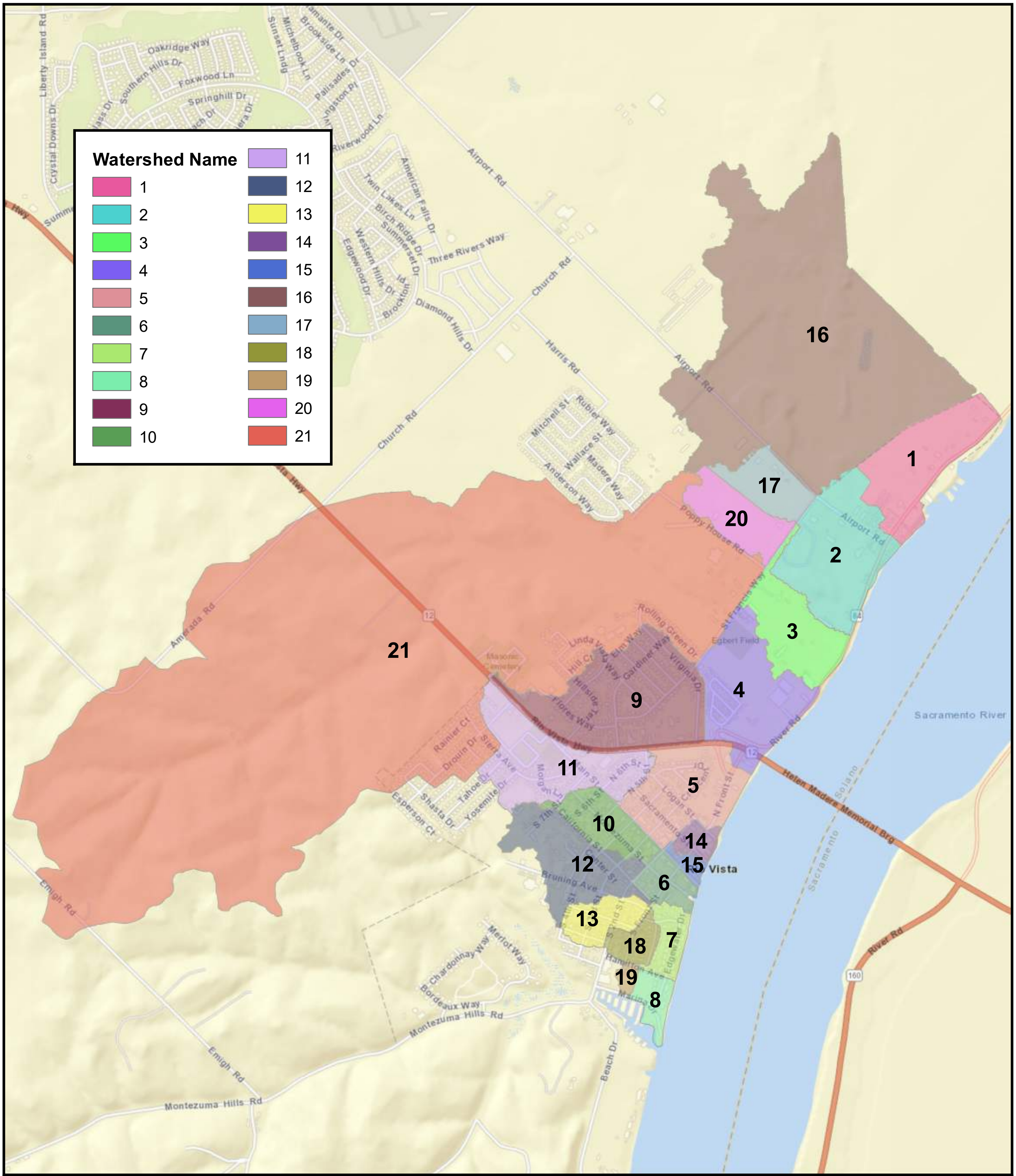
FIGURE 3B



SOLANO COUNTY WATER AGENCY

RIO VISTA FLOOD CONTROL FEASIBILITY STUDY

WATERSHEDS IMPACTED BY A PROPOSED FLOOD BARRIER

RIO VISTA, CA - JUNE 2018

NORTH

0 1,000 2,000

Feet

PRELIMINARY

WOOD RODGERS

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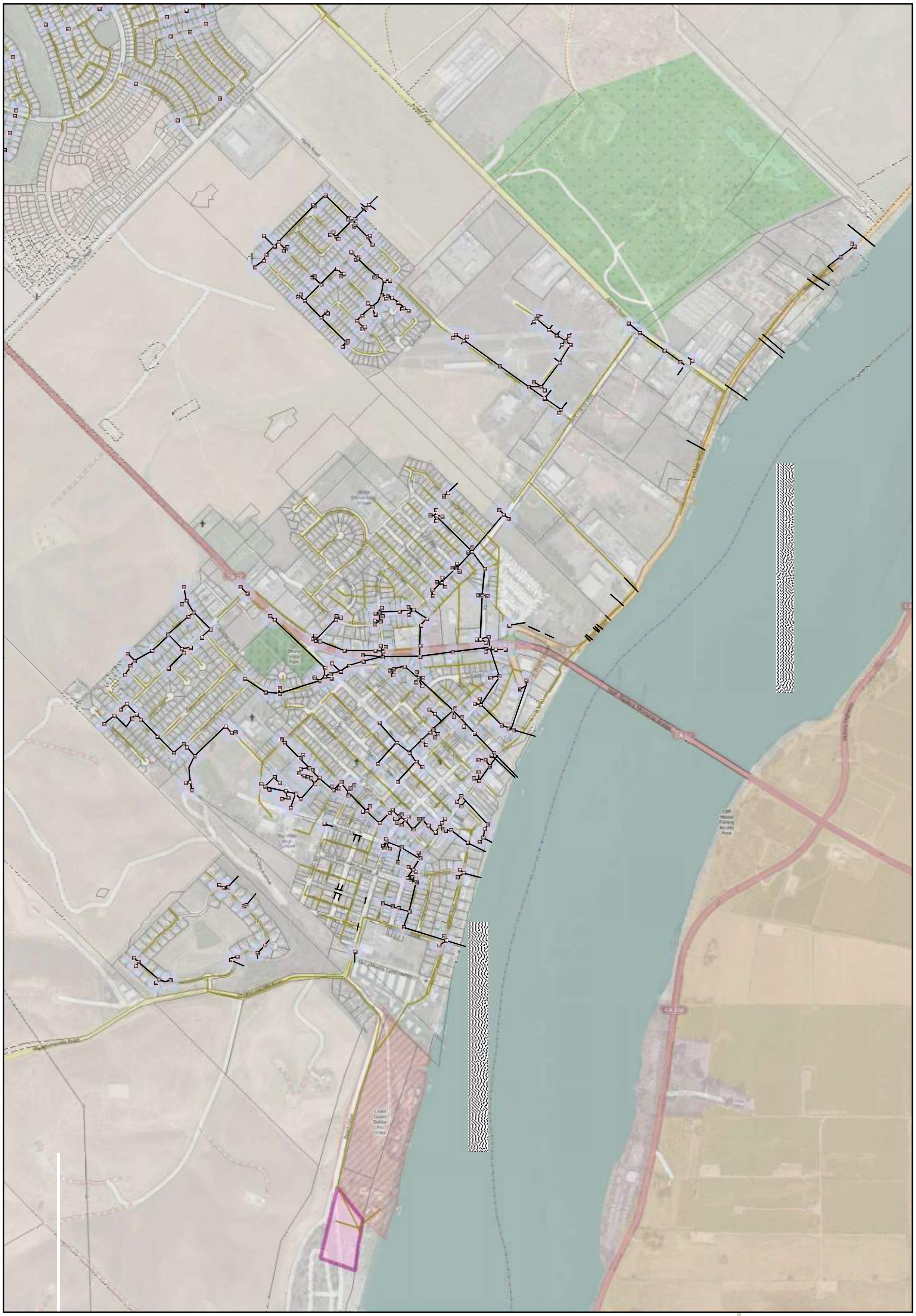
FIGURE 4



SOLANO COUNTY WATER AGENCY
RIO VISTA FLOOD PROTECTION FEASIBILITY STUDY
Existing Storm Drainage Facilities
RIO VISTA, CA - JUNE 2018

Source: West Yost Associates, Beach Area Prioritization Project, 2013

N

0 500 1,000
Scale in Feet

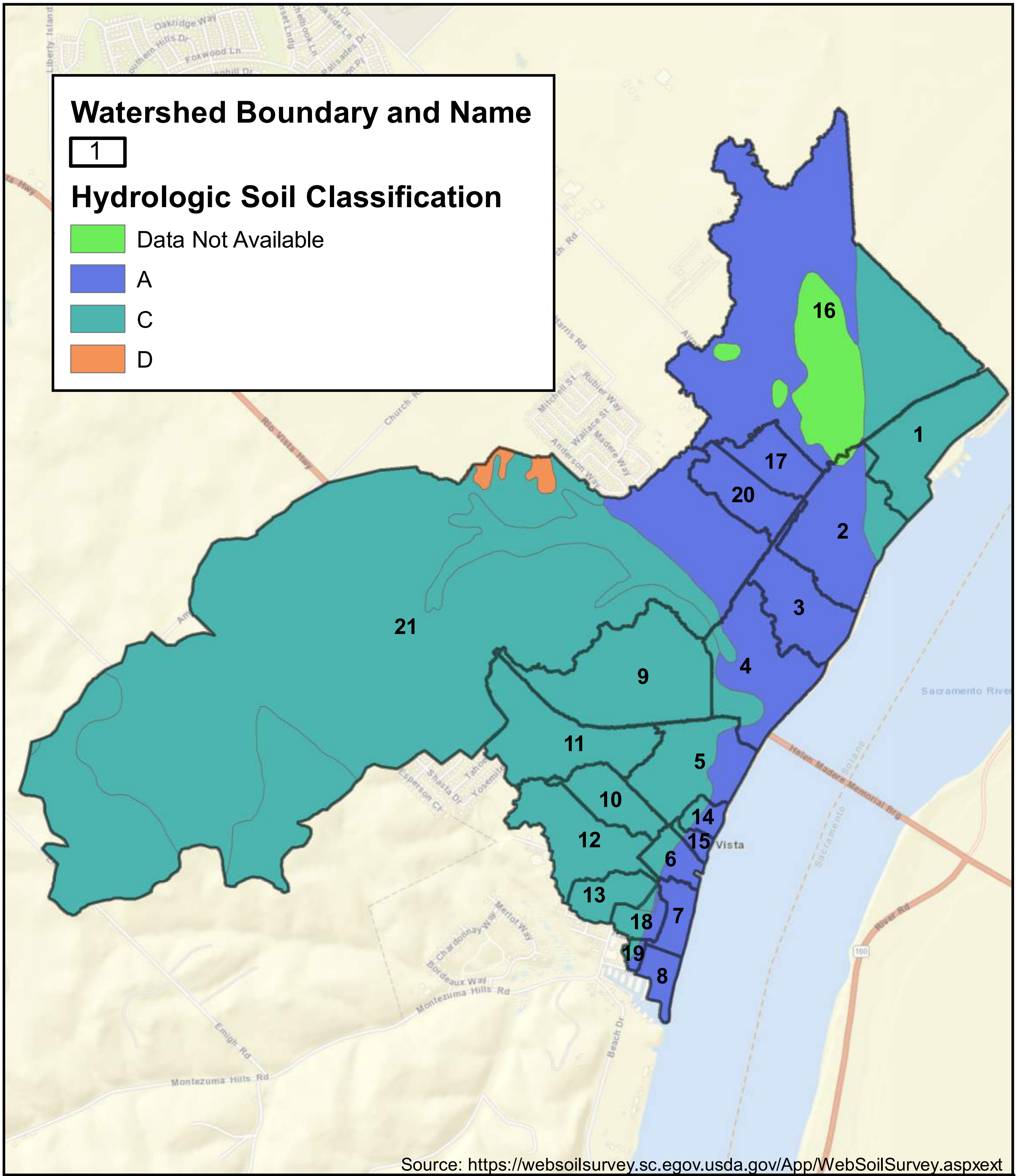
LEGEND

▪	Storm Sewer Nodes
—	Storm Sewer Lines
🟥	50' Storm Drain Buffer
🟦	100' Storm Drain Buffer

PRELIMINARY

WOOD RODGERS

FIGURE 5



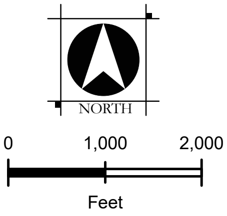
Source: https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspxext

SOLANO COUNTY WATER AGENCY

RIO VISTA FLOOD CONTROL FEASIBILITY STUDY

NRCS HYDROLOGIC SOIL DATA

RIO VISTA, CA - JULY 2018



PRELIMINARY

WOOD RODGERS

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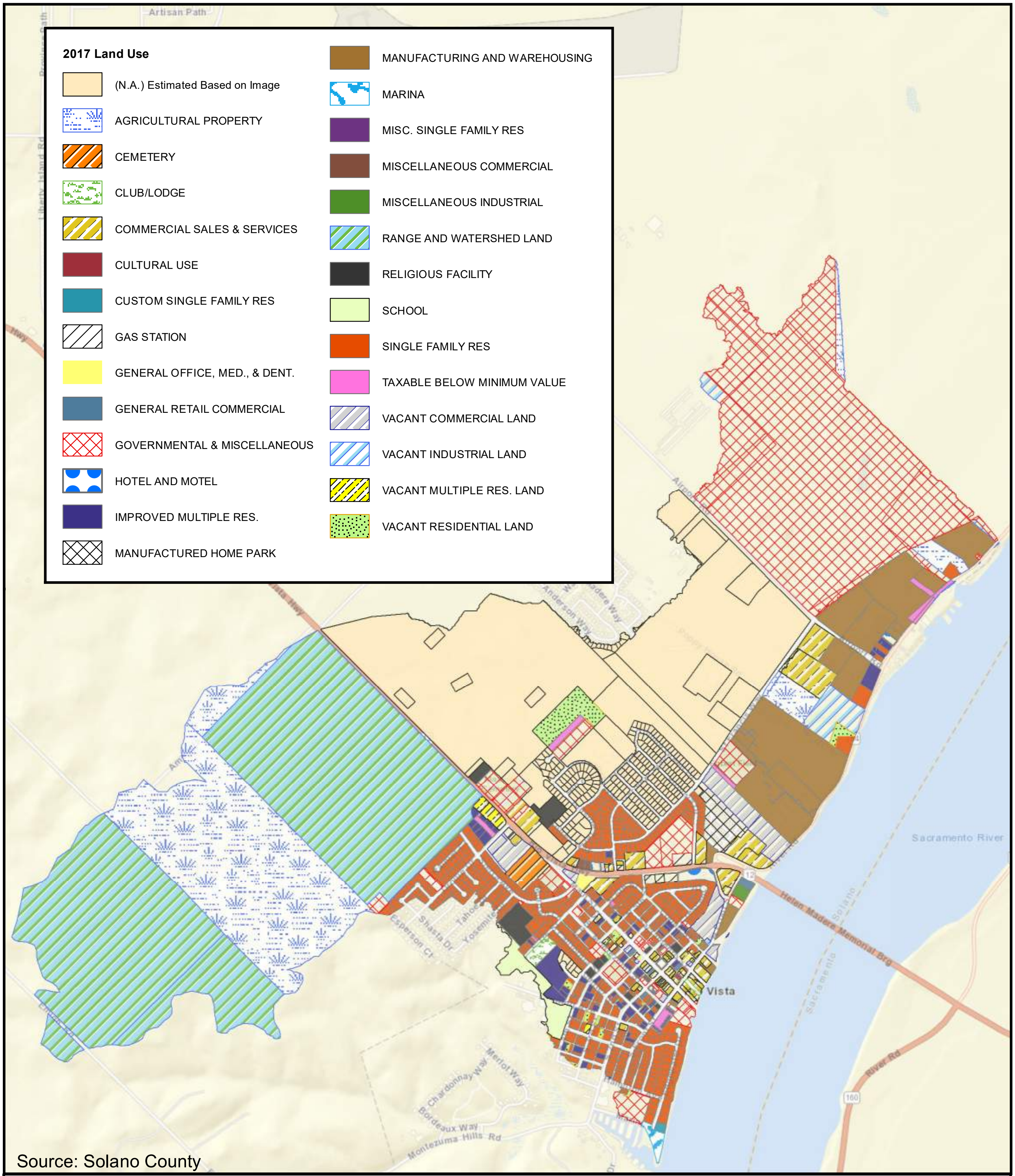
FIGURE 6



Source: Solano County

SOLANO COUNTY WATER AGENCY
RIO VISTA FLOOD CONTROL FEASIBILITY STUDY
RIO VISTA LAND USE DATA
RIO VISTA, CA - JUNE 2018

NORTH

0 1,000 2,000

Feet

PRELIMINARY

WOOD RODGERS

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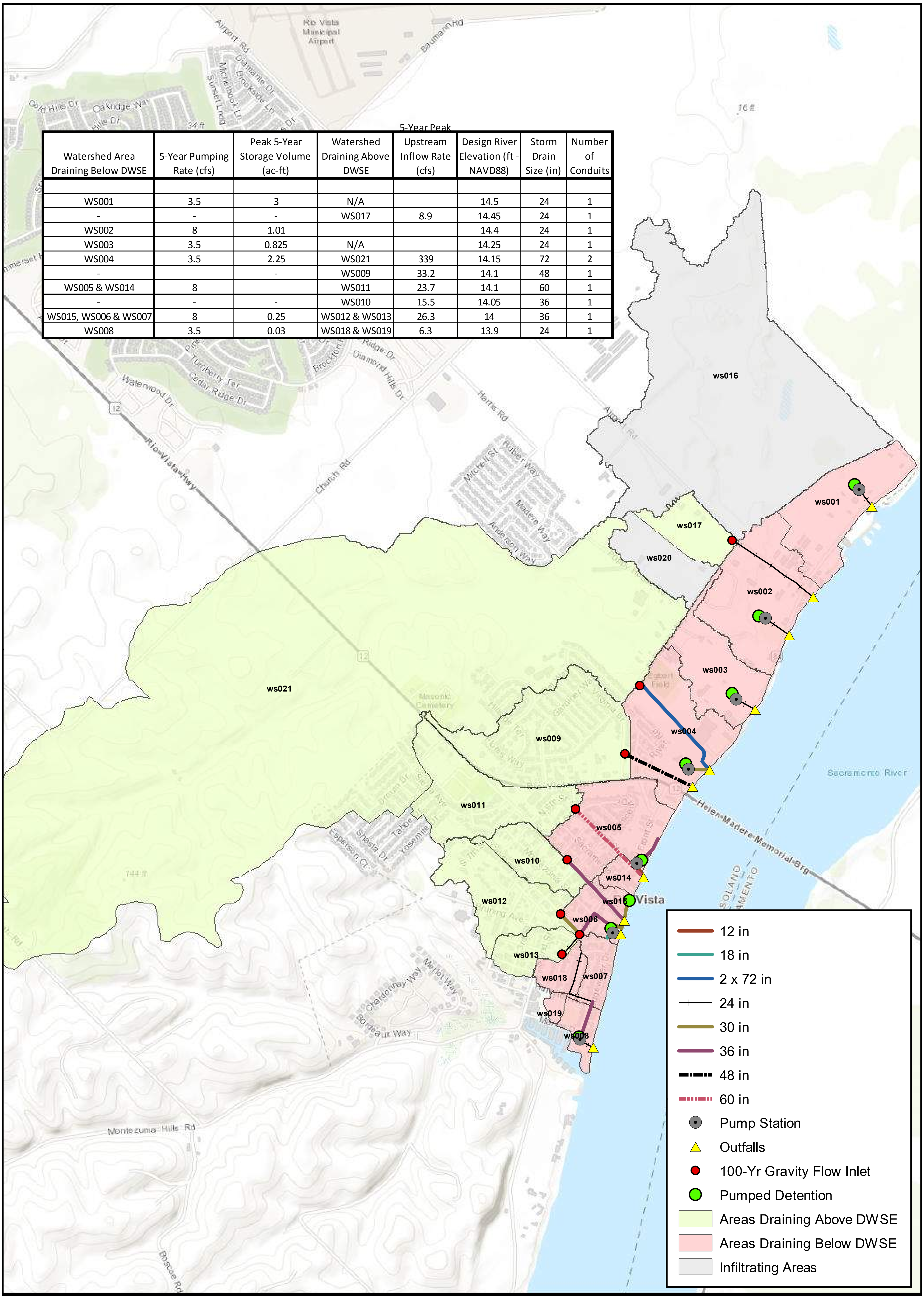
FIGURE 7

Watershed Area Draining Below DWSE	5-Year Pumping Rate (cfs)	Peak 5-Year Storage Volume (ac-ft)	Watershed Draining Above DWSE	5-Year Peak Upstream Inflow Rate (cfs)	Design River Elevation (ft - NAVD88)	Storm Drain Size (in)	Number of Conduits
WS001	3.5	3	N/A		14.5	24	1
-	-	-	WS017	8.9	14.45	24	1
WS002	8	1.01			14.4	24	1
WS003	3.5	0.825	N/A		14.25	24	1
WS004	3.5	2.25	WS021	339	14.15	72	2
-		-	WS009	33.2	14.1	48	1
WS005 & WS014	8		WS011	23.7	14.1	60	1
-	-	-	WS010	15.5	14.05	36	1
WS015, WS006 & WS007	8	0.25	WS012 & WS013	26.3	14	36	1
WS008	3.5	0.03	WS018 & WS019	6.3	13.9	24	1



SOLANO COUNTY WATER AGENCY
RIO VISTA FLOOD CONTROL FEASIBILITY STUDY
PROPOSED STORM DRAINAGE LAYOUT
RIO VISTA, CA - JULY, 2018

PRELIMINARY

WOOD RODGERS

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FIGURE 8

Attachment E: Multi-Benefit Assessment and Permitting Needs TM

Memo

To:	Jeff Barich, Solano County Water Agency
From:	Lynn Hermansen and Eric Htain
cc:	Graham Bradner; Jesse Patchett, Wood Rodgers
Date:	June 6, 2018
Re:	Multi-benefit Opportunities Rio Vista Flood Control Feasibility Study Solano County, CA GEI Project 1704795

GEI Consultants, Inc. (GEI), subconsultant to Wood Rodgers, Inc. (Wood Rodgers), is assisting the Solano County Water Agency in conducting a feasibility study to evaluate structural and non-structural actions to reduce the risk of flooding to the City of Rio Vista (City). The feasibility study is being funded under the California Department of Water Resources (DWR) Small Communities Flood Risk Reduction Program. As part of this feasibility design, GEI identified potential permitting implications and constraints, and compiled potential multi-benefit opportunities for the proposed project. This Draft Technical Memorandum (TM) summarizes initial findings. Identified opportunities will be refined with the project team to represent those most suitable to include in the project. Refined opportunities, permitting implications, and constraints will be summarized in the Feasibility Study Report.

Constraints and Opportunities Analysis Methodology

To identify potential multi-benefit opportunities and project constraints, a baseline conditions assessment was conducted. Existing conditions reviewed included: topography (Wood Rodgers 2018), land use and infrastructure (Wood Rodgers 2015), soils (NRCS 2018), vegetation (CDFW and CSU Chico 2013), current lists of special-status species known to occur and/or having the potential to occur (USFWS 2018, CNPS 2018, and CDFW 2018), and records of historic and pre-historic resources.

The cultural resources record search was conducted at the Northwest Information Center on February 16, 2018. The record search provided records and studies for known historic and pre-historic resources within ¼ mile of the study area.

A reconnaissance-level site survey was conducted on February 16, 2018 to assess the potential for sensitive biological resources and field conditions, and identify multi-benefit opportunities. The survey area included: the study area, a 250-foot buffer and the upstream drainages and tributaries extending beyond the study area.

Relevant regional documentation was also reviewed to identify current and proposed restoration projects and conservation actions within and adjacent to the study area. These resources will be documented in the Feasibility Study Report.

Project Location and Setting

Rio Vista is located along the west bank of the Sacramento River in Solano County, California, just downstream of the confluence of the Yolo Bypass and Sacramento Deep Water Ship Channel, Steamboat Slough, and the Sacramento River. The study area includes approximately 2 miles of frontage along the Sacramento River right bank, from Marina Creek northeast to the Mellin Levee, and approximately 0.6 mile of the existing Mellin Levee embankment (**Figure 1**). There are two major roadways running through the study area; CA-84 is located on the west bank of the Sacramento River. CA-12 crosses the Sacramento River, bisecting the study area and a portion of the City.

Current land use designations within the study area are: residential, commercial, industrial, and public. The south end of the study area includes: Delta Marina Yacht Harbor; residences that extend north to Main Street; and a combination of commercial, residential, and public land use extending to the Rio Vista Bridge/CA-12. Public facilities located south of the Rio Vista Bridge/CA-12 include: the City Waterfront Promenade park, a boat launch ramp, and fishing pier. North of the Rio Vista Bridge/CA-12, land use is primarily industrial comprised of manufacturing and service companies located along River Road intermixed with scattered residences and the Rio Vista RV park.

Biological Resources

Elevations in the study area along the river bank vary from approximately 5 to 10 feet. The Mellin levee represents the highest topographical point at approximately 16 feet.

According to the Natural Resource Conservation Service (NRCS 2018), three soil types intersect the study area boundary (**Figure 2**). Tujunga fine sand, an alluvial soil composed of fine sands and silts and typically free of gravels, is found throughout most of the study area. Valdez silt loam, drained, 0 to 2 percent slopes, is found at the northeast end of the study area. Valdez soils are poorly drained alluvial silt loam to fine sandy loam with low permeability. A very small amount of Diablo-Ayar clay, 2 to 9 percent slopes, is found adjacent to the Rio Vista Bridge/CA-12.

The Sacramento River is the primary aquatic feature within the study area. Two creeks, Industrial Creek and Marina Creek, flow through the study area to the Sacramento River. Industrial Creek, located approximately 500 feet to the north of Rio Vista Bridge/CA-12, enters the river through a pipe. Marina Creek, located at the southern end of the study area, flows through the Delta Marina Yacht Harbor and into the Sacramento River. There are two other irrigation drainages, one directly north of Airport Road, and one approximately 0.18 mile south of the Mellin Levee. The northern portion of the study area, north of Airport Road, lies within the boundary of the legal Delta.

Vegetation

Along the Sacramento River there are areas of floating vegetation on the water surface including water primrose (*Ludwigia peploides*) and water hyacinth (*Eichhornia crassipes*). Most of the waterside bank slope is covered with rip rap and has little to no emergent vegetation. To the north of the Rio Vista Bridge/CA-12, where the bank is gentler and water is shallower, patches of freshwater marsh dominated by tules (*Schoenoplectus* spp.) are present.

Along the river's edge, primarily between Main Street and the Rio Vista Bridge/ CA-12, are remnant patches of Great Valley mixed riparian forest dominated by white alder (*Alnus rhombifolia*). Native tree species also include: Fremont cottonwood (*Populus fremontii*), valley oak (*Quercus lobata*), and Oregon ash (*Fraxinus latifolia*). Native trees are intermixed with patches of non-native trees and shrubs including: stands of giant reed (*Arrundo donax*), Himalayan blackberry (*Rubus armeniacus*) and isolated patches of mature eucalyptus trees dominated by blue gum (*Eucalyptus globulus*). A large stand of blue gum is located adjacent to the Rio Vista Bridge/CA-12 and west of the Mellin levee. North of the bridge, the overstory is limited with fewer native trees and larger stands of giant reed. The understory in these areas is dominated by non-native herbaceous vegetation including non-native annual grasses, Bermuda grass (*Cynodon dactylon*), and annual yellow sweetclover (*Melilotus indicus*). Within or just above the rip rap edge, are occurrences of native herbaceous species including: common rush (*Juncus effusus*), salt marsh baccharis (*Baccharis glutinosa*), and common horsetail (*Equisetum arvense*).

Residential landscaped areas within the study area include: backyard lawns, ornamental plantings, and small structures (e.g., retaining walls, planters, stairs) along the edge of the river. These areas are characterized by a mix of ornamental and native species. This is also true within the public recreation facilities with the exception of the Waterfront Promenade. Located just north of the Rio Vista Bridge/CA-12 bridge, this park has been landscaped with native vegetation including native bunchgrasses and shrubs such as California rose (*Rosa californica*).

Areas of ruderal vegetation are found adjacent to buildings, Highway 84 and other roadways, and drainage ditches. In these areas, most of the native vegetation has been completely removed. Weedy species commonly encountered include: Bermuda grass, bur-clover (*Medicago polymorpha*), wild radish (*Raphanus sativus*), wild oats (*Avena fatua*), yellow star-thistle (*Centaurea solstitialis*), and umbrella sedge (*Cyperus eragrostis*), among others.

Special-Status Species

Review of CNDDB occurrences and other biological data resources show 42 special-status plant species and 38 special-status wildlife species that are documented or have potential to occur in the study area (**Appendix A Table 1 and 2**). **Figure 3** depicts CNDDB occurrences of special-status plant and wildlife species within 3 miles of the study area. There are 19 special-status plant species with moderate potential to occur in the vicinity. One species, Suisun Marsh aster (*Symphyotricum lentum*), has a high potential to occur, with multiple CNDDB occurrences within the study area.

The study area supports suitable habitat for several special-status fish species. The following fish species are considered to have a high potential to occur: green sturgeon—southern DPS (*Acipenser medirostris*), Delta smelt (*Hypomesus transpacificus*), longfin smelt (*Spirinchus thaleichthys*), California Central Valley steelhead DPS (*Oncorhynchus mykiss irideus*), Chinook Salmon—Sacramento River winter–run, Chinook Salmon—Central Valley spring–run (*Oncorhynchus tshawytascha*), and Sacramento splittail (*Pogonichthys macrolepidotus*). Wildlife species with high potential and/or observed during the field survey are Northern harrier (*Circus cyaneus*), American peregrine falcon (*Falco peregrinus anatum*), and Mexican free-tailed bat (*Tadarida brasiliensis*). An additional nine special-status wildlife species have a moderate potential to occur in the vicinity (**Appendix A**).

Cultural Resources

A total of 20 historic resources and four potentially historic properties were identified during the record search and are located within the 1/4-mile buffer of the study area. These resources include one vessel or vessel-like structure located under water in the Sacramento River that has been evaluated and determined to be eligible under the National Register of Historic Places. This resource is located just north of the Marina Creek confluence with the Sacramento River. There are an additional 19 resources and four buildings that require additional investigation and evaluation for potential eligibility under the National Register of Historic Places if project work could impact these resources.

Multi-benefit Opportunities

Based on the analysis conducted, an initial list of existing recreation features and potential multi-benefit opportunities were identified. Existing recreation features may represent potential constraints because retaining these features would be important to stakeholders. There may also be opportunity to improve and/or expand these facilities as part of the project. Potential restoration opportunities include proposed projects associated with other regional planning efforts that are currently in the planning phase and other more localized opportunities. Both are shown on **Figure 4**.

Opportunities within the study area include habitat enhancement and/or restoration along the Sacramento River, Industrial Creek, and at the south end of the Waterfront Promenade. Benefits associated with wetland creation would potentially include groundwater recharge and/or flood attenuation. North of the study area there is opportunity for habitat enhancement and/or restoration within the Powell Property north of the Mellin Levee and restoration of Little Egbert Tract. The initial opportunities shown in **Figure 4** may change or be revised as further screening and evaluation of project flood control alternatives is developed.

Regional Related Proposed Projects

There are many ongoing state, federal, and regional conservation and flood planning processes within the Yolo Bypass, Delta, and along the Sacramento River. As a result, there are also many current or proposed projects within the vicinity that may provide additional restoration opportunities that could be contributed to and/or may require coordination with the project. These opportunities will be further identified in the Feasibility Study Report.

Initial planning for Little Egbert Tract, located approximately 1 mile north of the study area, is currently underway to assess the feasibility of restoring tidal inundation to a portion of the property. The project goals include maximizing continued agricultural production and contributing to regional flood risk reduction. Opportunities to collaborate and/or coordinate adjacent restoration efforts may be feasible.

Within the project vicinity are two large restoration projects currently underway by DWR: Decker Island and Prospect Island. Both projects are fully funded by the State Water Project and are intended to fulfill mitigation requirements for long-term coordinated operations. While these do not represent a current restoration opportunity, they are a relevant planning consideration. The Decker Island project, located approximately 4 miles south of the study area in Solano County, will restore tidal action to140 acres of emergent wetland. The project on Prospect Island, located approximately 5 miles north of the study area, will restore between 1,000 and 1,500 acres of tidal and subtidal habitat.

References

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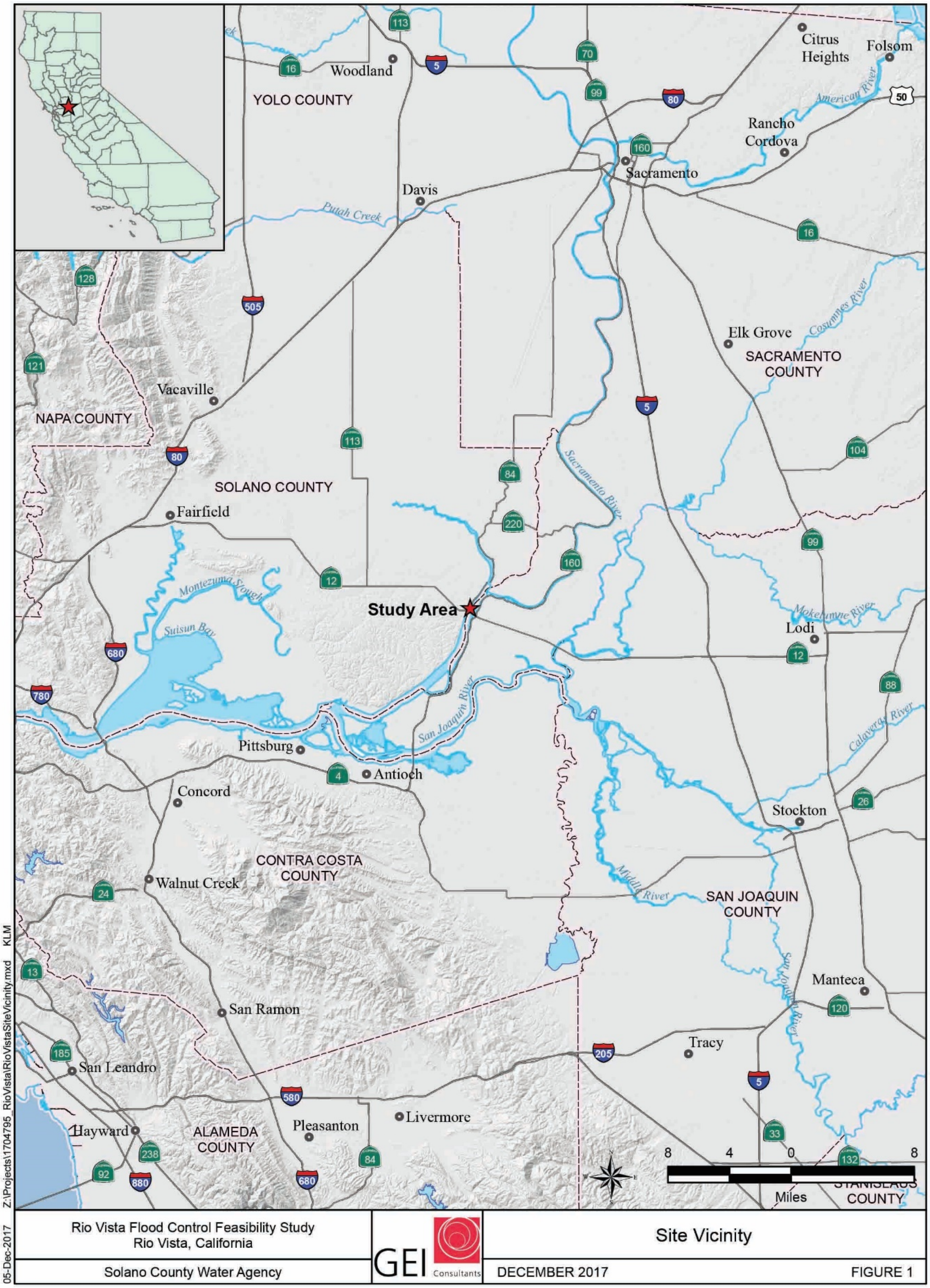


Rio Vista Flood Control Feasibility Study
Rio Vista, California

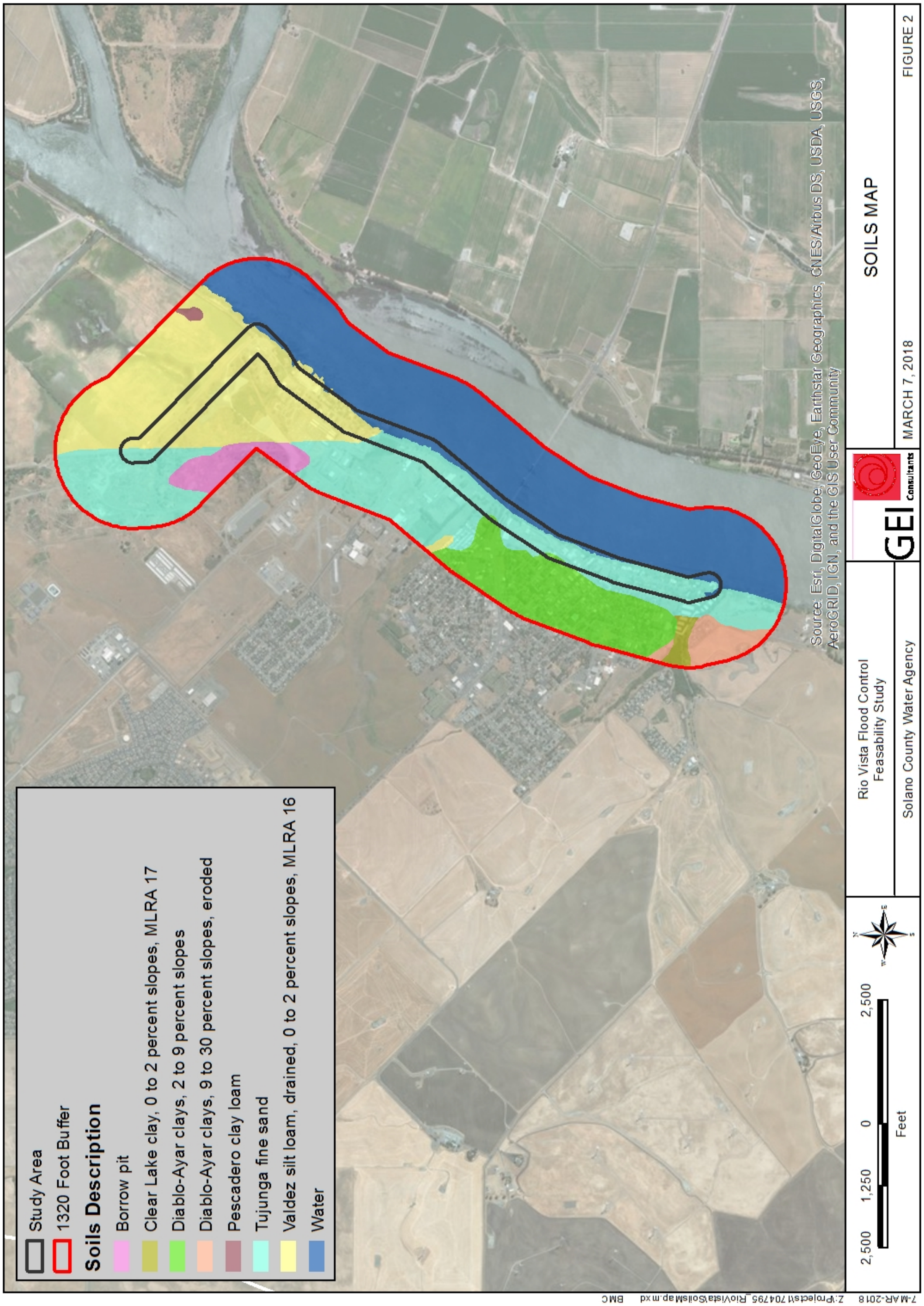
Solano County Water Agency

GEI Consultants

Site Vicinity

DECEMBER 2017

FIGURE 1



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Rio Vista Flood Control
Feasability Study

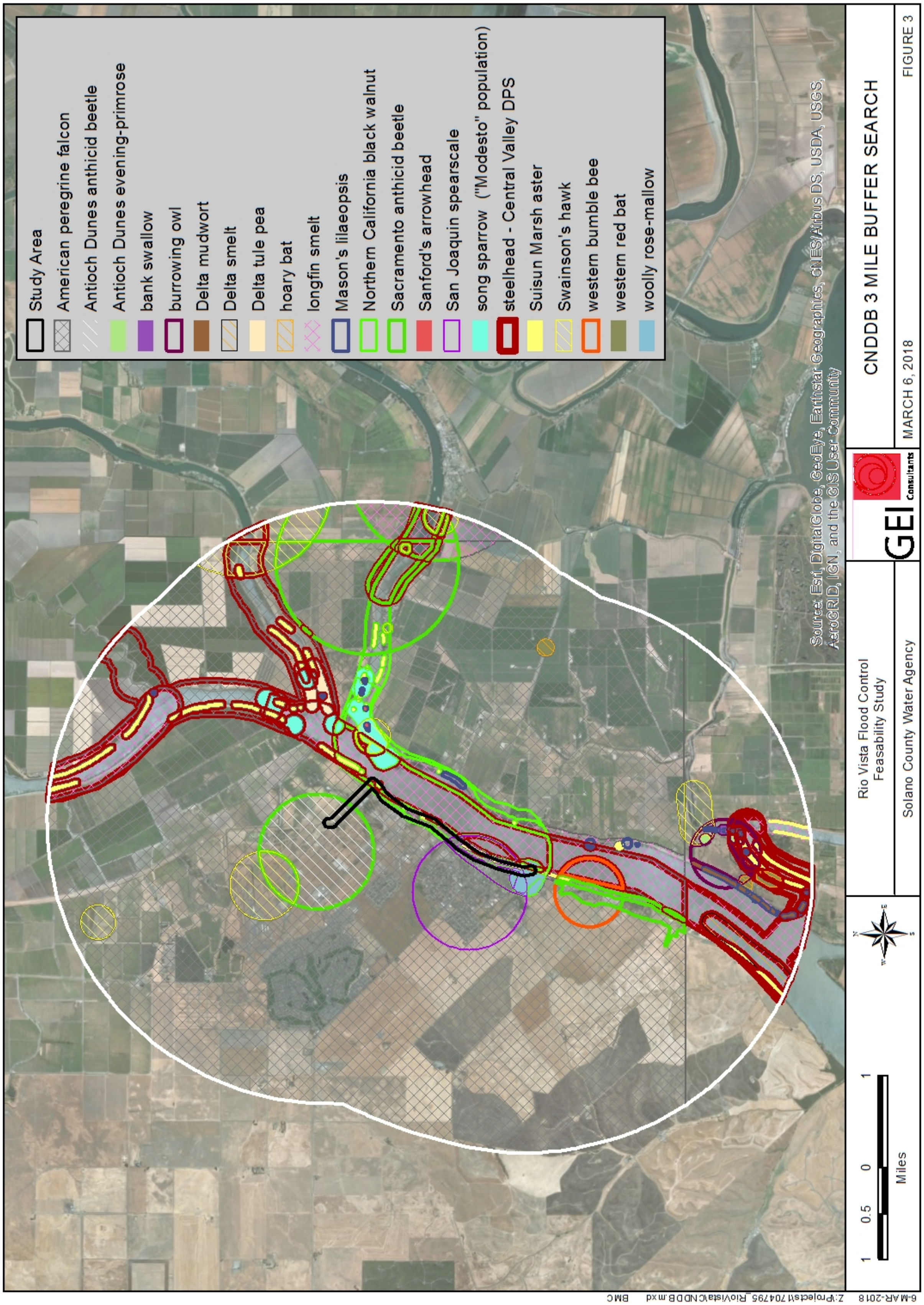
Solano County Water Agency

MARCH 7, 2018

SOILS MAP

FIGURE 2

7-MAR-2018 Z:\Projects\1704795_RioVista\SoilsMap.mxd BMC



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

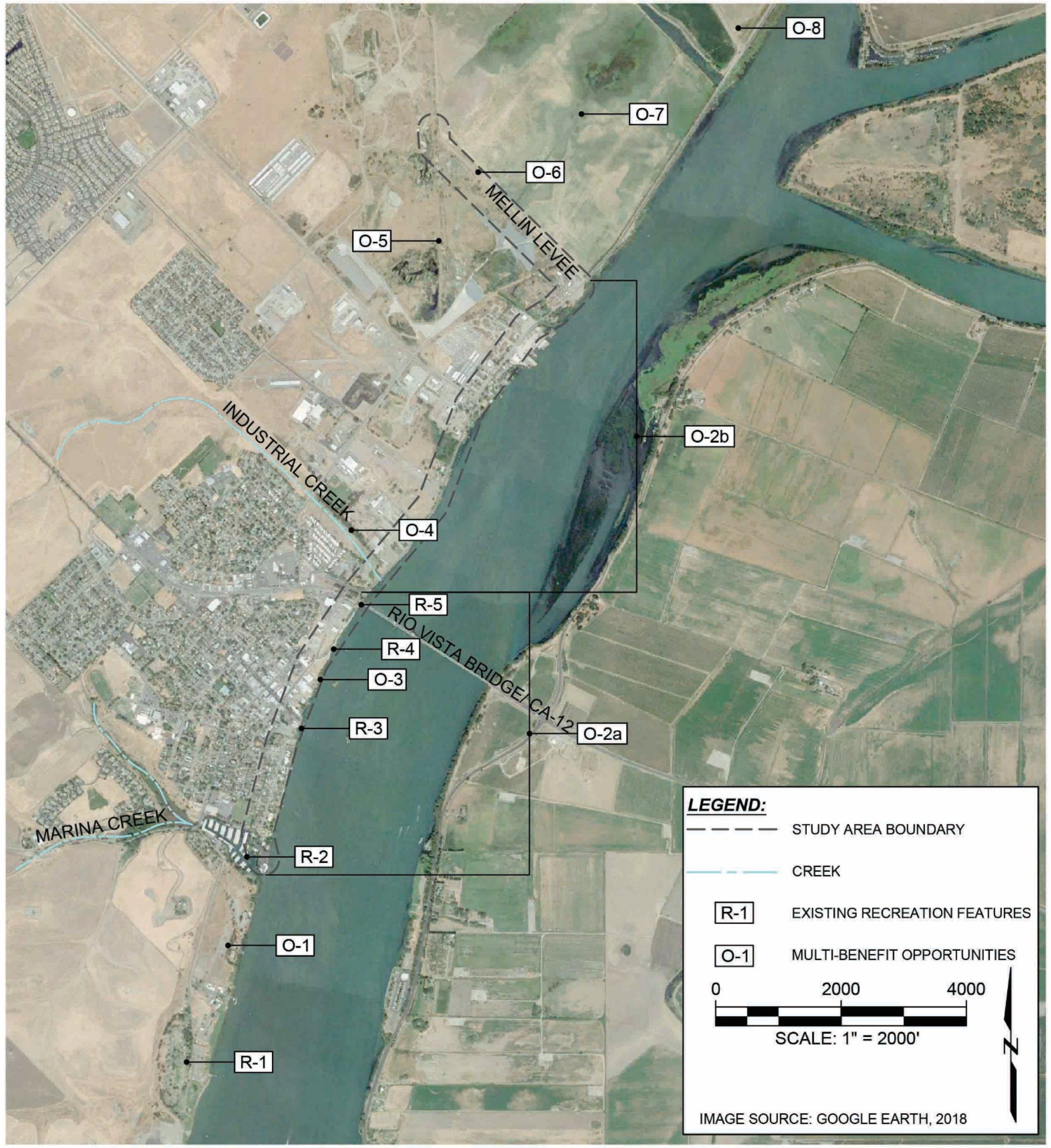


IMAGE SOURCE: GOOGLE EARTH, 2018

PUBLIC RECREATION EXISTING FEATURES

R-1 **Sandy Beach County Park** - boat launch, fishing, camping, picnic area, and swimming

R-2 **Delta Marina Yacht Harbor** - boat launch, fishing, RV park, and picnic area

R-3 **Municipal Boat Launch** - boat launch, fishing, and picnic area

R-4 **Waterfront Park and Promenade** - picnic area and waterfront trail

R-5 **Rio Vista Fishing Pier** -fishing

RESTORATION OPPORTUNITIES

O-1 **Rio Vista Estuarine Research Center** - The decommissioned Rio Vista Army Base, located approximately 0.25 mile south of the study area, is slated for the Rio Vista Estuarine Research Center. Creating or enhancing tidal marsh and/or riparian habitat may be feasible in conjunction with project planning and construction.

O-2a **Sacramento River Enhancement South** - Opportunities for creating and/or enhancing habitat include: replacing riprap slope with bioengineered structures, incorporating riparian plantings on the waterside to create shaded riverine aquatic habitat, removing invasive species, and removing foreign debris that may be hazardous to wildlife.

O-2b **Sacramento River Enhancement North** -In addition to those opportunities identified in O-2a, in areas north of the Rio Vista Bridge/CA-12 opportunities include: incorporating in-stream large woody material, constructing tule benches, and enhancing shallow water habitat.

O-3 **Waterfront Park and Promenade -** Pending land ownership, this location provides potential to create a small area of tidal marsh and/or expanded riparian habitat.

O-4 **Industrial Creek -** Enhancing Industrial Creek could include floodplain expansion to provide better attenuation and/or better connectivity to the river to create emergent marsh and/or riparian scrub habitat.

O-5 **CVFPB Dredge Disposal Site -** This site provides opportunities for creating and/or enhancing wetlands and riparian habitat including providing better connection to the Sacramento River.

O-6 **Mellin Levee Wind-Wave Buffer -** Establishing a riparian wind-wave buffer on the north side of the levee could reduce wave height and increase protection of the levee from erosive forces.

O-7 **Powell Property -** Provides a potential opportunity to re-establish connection to the river and create tidal marsh habitat.

O-8 **Little Egbert Tract -** In conjunction with regional planning efforts for this area, establish tidal marsh habitat within the Little Egbert tract.

Solano County Water Agency
City of Rio Vista Flood Control Feasibility Study
Rio Vista, California

GEI Consultants

MULTIBENEFIT
OPPORTUNITIES

March 2018 Fig. #20180307

\\sac1v-fs01\ \\sac1v-fs01\data\WR\Wood Rodgers\Projects\1704795 Rio Vista Feasibility Study\Task 3 - Problem Identification & Data Gathering\3.6 - ID Mult-Benefit Opp. and Constraints\CAD Exhibit\Drawing1_recover.dwg - 3/9/2018

Appendix A. Tables

Table 1. Special-Status Plant Species with Potential to Occur within the Survey Area

Species	Blooming Period	Status[1]			Habitat Associations	Potential for Occurrence in the Survey Area
		Federal	State	CRPR		
Ferris' milk-vetch *Astragalus tener* var. *ferrisiae*	Apr–May	–	–	1B.1	Vernal pools, meadows and seeps. Valley and foothill grassland in subalkaline flats.	Moderate: suitable habitat present adjacent to survey area.
Alkali milk-vetch *Astragalus tener* var. *tener*	Mar—June	–	–	1B.2	Vernal pools; playa; valley and foothill grassland.	None; survey area lacks alkaline soils.
Heartscale *Atriplex codulata* var. *cordulata*	April–Oct	–	–	1B.2	Saline or alkaline soils; chenopod scrub, meadows and seeps, valley and foothill grassland.	None; survey area lacks suitable soils.
Brittlescale *Atriplex depressa*	April–Oct	–	–	1B.2	Alkaline, clay; chenopod scrub, meadows and seeps, playa, valley and foothill grassland, vernal pools.	None; survey area lacks suitable soils.
Vernal pool smallscale *Atriplex persistens*	Jun—Sept	–	–	1B.2	Vernal pools with alkaline soils.	None; survey area lacks alkaline soil.
Big tarplant *Blepharizonia plumosa*	Jul—Oct	–	–	1B.1	Clay soils; valley and foothill grassland.	Moderate; suitable habitat adjacent to survey area.
Watershield *Brasenia schreberi*	Jun—Sept	–	–	2B.3	Marshes and swamps.	Moderate; suitable habitat adjacent to survey area.
Bristly sedge *Carex comosa*	May—Sept	–	–	2B.1	Coastal prairie; marshes and swamps, valley and foothill grassland.	Moderate; suitable habitat adjacent to survey area.
Pappose tarplant *Centromadia parryi* ssp. *parryi*	May—Nov	–	–	1B.2	Often found in alkaline soils; chaparral, coastal prairie, meadows and seeps, marshes and swamps.	Low; suitable habitat adjacent to survey area; however, suitable soil lacking in survey area.
Soft bird's-beak *Chloropyron molle* ssp. *molle*	Jun—Nov	–	–	1B.2	Marshes and swamps (coastal salt)	Low; suitable habitat adjacent to survey area; however, suitable soil lacking in survey area.
Bolander's water-hemlock *Cicuta maculata* var. *bolanderi*	Jul—Sept	–	–	2B.1	Marshes and swamps; Coastal, fresh or brackish water.	Moderate; suitable habitat adjacent to survey area.
Dwarf downingia *Downingia pusilla*	Mar—May	–	–	2B.2	Valley and foothill grassland in mesic soils; vernal pools.	Low; suitable habitat adjacent to survey area; however, suitable soil lacking in survey area.
Antioch Dunes buckwheat	Jul—Oct	–	–	1B.1	Inland dunes.	None; survey area lacks suitable habitat.

Table 1. Special-Status Plant Species with Potential to Occur within the Survey Area

Species	Blooming Period	Status[1]			Habitat Associations	Potential for Occurrence in the Survey Area
		Federal	State	CRPR		
Eriogonus nudum var. *psychicola*						
Mt. Diablo buckwheat *Eriogonum truncatum*	April-Dec	–	–	1B.1	Sandy soils; chaparral, coastal scrub, valley and foothill grassland.	Moderate; suitable habitat adjacent to survey area.
Contra Costa wallflower *Erysimum capitatum* var. *angustatum*	Mar—Jul	–	–	1B.1	Inland dunes.	None; survey area lacks suitable habitat.
Diamond-petaled California poppy *Eschscholzia rhombipetala*	Mar—Apr	–	–	1B.1	Valley and foothill grassland; alkaline, clay soil.	Low; suitable habitat adjacent to survey area; however, alkaline soils are absent from survey area.
San Joaquin spearscale *Etriplex joaquiana*	April–Oct	–	–	1B.2	Alkali grassland and alkali meadow, or on margins of alkali scrub; on clay soils.	None; survey area lacks alkaline soils.
Fragrant fritillary *Fritillaria liliacea*	Feb—April	–	–	1B.2	Often serpentine soil; cismontane woodland, coastal prairie, coastal scrub, valley and foothill grassland.	Low; suitable habitat adjacent to survey area; however, serpentine soils are absent from survey area.
Boggs lake hedge-hyssop *Gratiola heterosepala*	Apr—Aug	–	–	1B.2	Clay soils; Marshes and swamps, vernal pools.	Moderate; suitable habitat adjacent to survey area.
Carquinez goldenbush *Isocoma arguta*	Aug—Dec	–	–	1B.1	Alkaline soils; valley and foothill grassland.	None; survey area lacks alkaline soils.
Contra Costa goldfields	Mar—Jun	–	–	1B.1	Mesic soil; cismontane woodland, alkaline playas, valley and foothill grassland, vernal pools.	Low; suitable habitat adjacent to survey area; however, suitable soils are absent from survey area.
Woolly rose-mallow *Hibiscus lasiocarpos* var. *occidentalis*	June–Sep	–	–	1B.2	Freshwater wetlands, wet banks, marshes below 300 feet; often in riprap on sides of levees.	Moderate; rip rap and other suitable habitat present in the survey area.
Northern California black walnut *Juglans hindsii*	Apr–May	–	–	1B.1	Riparian forest, riparian woodland; along streams and rivers.	None; Native stock extirpated from survey area.
Delta tule pea *Lathyrus jepsonii* var. *jepsonii*	May–Sep	–	–	1B.2	Coastal and estuarine marshes, freshwater marsh slopes, and tidal river banks.	Moderate; suitable habitat present in survey area.
Legenere	April—Jun	–	–	1B.1	Vernal pools; shallow, acidic clays.	Low; suitable clay present; however,

Table 1. Special-Status Plant Species with Potential to Occur within the Survey Area

Species	Blooming Period	Status[1]			Habitat Associations	Potential for Occurrence in the Survey Area
		Federal	State	CRPR		
Legenere limosa						suitable habitat may be absent from survey area.
Heckard's peppergrass *Lepidium latipes* var. *heckardii*	March—May	–	–	1B.2	Alkaline flats; valley and foothill grassland.	None: suitable soils are absent from survey area.
Mason's lilaeopsis *Liliaeopsis masonii*	April–Nov	–	–	1B.1	Brackish and freshwater marshes and streambanks; regularly inundated tidal zones, on mud-banks and flat along erosional creek-banks, sloughs, and rivers.	Moderate; suitable habitat present in survey area and known occurrences located across Sacramento River on the east bank, approximately 0.5 miles.
Delta mudwort *Limosella australis*	May– Aug	–	–	2B.1	Muddy or sandy intertidal flats, brackish water.	Moderate; suitable habitat present in survey area and known occurrences located across Sacramento River on the east bank, approximately 0.5 miles.
Showy golden madia *Madia radiata*	Mar-May	–	–	1B.1	Valley and foothill grassland; cismontane woodland.	Low; suitable habitat adjacent to survey area; however, habitat is poor.
Baker's navarretia *Navarretia leucocephala* ssp. *bakeri*	Apr-Jul	–	–	1B.1	Mesic soils; cismontane woodland, meadows and seeps, valley and foothills grassland, vernal pools	Moderate; suitable habitat present in survey area.
Colusa grass *Neostapfia colusana*	May—Aug	–	–	1B.1	Adobe soils; Vernal pools	None; suitable soils are absent from survey area.
Antioch Dunes evening-primrose *Oenothera deltoides* ssp. *howelli*	March—Sep	–	–	1B.1	Inland dunes.	None; suitable habitat absent from survey area.
Bearded popcornflower *Plagiobothrys hystriculus*	April—May	–	–	1B.1	Vernal swales; valley and foothill grassland, vernal pool margins	Moderate; suitable habitat present adjacent to survey area.
Eel-grass pondweed *Potamogeton zosteriformis*	Jun—Jul	–	–	2B.2	Freshwater and brackish marshes and swamps.	Moderate; suitable habitat present in survey area.
California alkali grass *Puccinellia simplex*	March—May	–	–	1B.2	Alkaline soils, vernally mesic soil; meadows and seeps, valley and foothill grassland, vernal pools	None; suitable soils absent from survey area.

Table 1. Special-Status Plant Species with Potential to Occur within the Survey Area

Species	Blooming Period	Status[1]			Habitat Associations	Potential for Occurrence in the Survey Area
		Federal	State	CRPR		
Sanford's arrowhead *Sagittaria sanfordii*	May–Nov	–	–	1B.2	Slow-moving or standing freshwater ponds, marshes, and ditches.	Moderate; suitable habitat present in survey areaand known occurrences located across Sacramento River on the east bank, approximately 0.5 miles.
Marsh skullcap *Scutellaria galericulata*	Jun—Sept	–	–	2B.2	Meadows and seeps, marshes and swamps, lower montane coniferous forest.	Moderate; suitable habitat present in the survey area.
Side-flowering skullcap *Scutellaria lateriflora*	July—Sept	–	–	2B.2	Meadows and seeps, marshes and swamps.	Moderate; suitable habitat present in the survey area.
Keck's checkerbloom *Sidalcea keckii*	April—June	–	–	1B.1	Serpentine soils; valley and foothill grassland.	None; suitable soil absent from survey area.
Suisun Marsh aster *Symphyotricum lentun*	April–Nov	–	–	1B.2	Brackish or freshwater marshes and along streambanks and sloughs.	High; multiple CNDDB occurrences within the survey area.
Saline clover *Trifolium hydrophilum*	April-Jun	–	–	2B.2	Valley and foothill grassland, marshes and swamps, vernal pools.	Moderate; suitable habitat present adjacent to the survey area.
Crampton's tuctoria *Tuctoria mucronata*	April-Aug	–	–	1B.1	Valley and foothill grassland, vernal pools.	Moderate; suitable habitat present adjacent to the survey area.

[1] Status Definitions
Federal Listing Categories (U.S. Fish and Wildlife Service)
FT = Threatened
FE = Endangered
– = No status
State Listing Categories (California Department of Fish and Wildlife)
ST = Threatened
SE = Endangered
– = No status
California Rare Plant Ranks
1B = Plants rare, threatened, or endangered in California and elsewhere
2B = Plants rare, threatened, or endangered in California, but more common elsewhere
Extensions:
.1 = Seriously threatened in California (>80% of occurrences threatened/high degree and immediacy of threat)
.2 = Moderately threatened in California (20–80% of occurrences threatened/moderate degree and immediacy of threat)
.3 = Not very threatened in California (<20% of occurrences threatened/low degree and immediacy of threat or no current threats)
Sources: CDFW 2018; CNPS 2018; USFWS 2018; based on data collected and compiled by GEI Consultants, Inc. in 2018

Table 2. Special-Status Wildlife Species with Potential to Occur in or Adjacent to the Survey Area

Species	Status[1]		Habitat Associations	Potential for Occurrence in the Project Area
	Federal	State		
Invertebrates				
Conservancy fairy shrimp *Branchinecta conservatio*	E	–	Large, cool-water vernal pools with moderately turbid water.	Moderate; seasonal wetlands in the survey area provide potentially suitable habitat.
Vernal pool fairy shrimp *Branchinecta lynchi*	T	–	Vernal pools, including a wide range of sizes and depths	Moderate; seasonal wetlands in the survey area provide potentially suitable habitat.
San Bruno elfin butterfly *Callophrys mossii bayensis*	E	–	Rocky outcrops and cliffs in coastal scrub on the San Francisco Peninsula	None; outside of the extant range.
Valley elderberry longhorn beetle *Desmocerus californicus dimorphus*	T	–	Closely associated with elderberry, which is an obligate host for the beetle larvae.	Low; elderberry shrubs were not observed in and adjacent to the survey area.
Delta green ground beetle *Elaphrus viridis*	T	–	Open habitats in grassland-playa pool matrix, along edges of pools, trails, roads and ditches.	Low; suitable habitat is present in the survey area; however, habitat conditions are poor.
Vernal pool tadpole shrimp *Lepidurus packardi*	E	–	Vernal pools, typically medium to large.	Moderate: seasonal wetlands in the survey area provide potentially suitable habitat.
Fish				
Green Sturgeon—southern DPS *Acipenser medirostris*	T	--	Anadromous; Estuaries and bays; spawn in deep pools or “holes” in large, turbulent, freshwater river mainstems.	High; suitable habitat present in and adjacent to the survey area.
Sacramento perch *Archoplites interruptus*	–	SSC	Heavily vegetated water of slough and lakes throughout the Central Valley.	None; suitable habitat is absent from survey area.
Delta smelt *Hypomesus transpacificus*	T	E	Semi-anadromous; typically restricted to the Delta and the lower Sacramento River downstream of Isleton	High; suitable habitat present in and adjacent to the survey area.
California Central Valley DPS Steelhead *Oncorhynchus mykiss irideus*	T	–	Anadromous; typically found in the Sacramento-San Joaquin Delta.	High, suitable habitat present in and adjacent to the survey area.
Chinook Salmon—Sacramento River winter–run ESU (*Oncorhynchus tshawytcha*)	E	--	Anadromous; typically found in deep, large streams.	High; suitable habitat present in and adjacent to the survey area.

Table 2. Special-Status Wildlife Species with Potential to Occur in or Adjacent to the Survey Area

Species	Status[1]		Habitat Associations	Potential for Occurrence in the Project Area
	Federal	State		
Chinook Salmon—Central Valley spring–run ESU ESU (*Oncorhynchus tshawytscha*)	T	–	Anadromous; typically found in deep, large streams.	High; suitable habitat present in and adjacent to the survey area.
Sacramento splittail *Pogonichthys macrolepidotus*	–	SSC	Backwaters and pools of rivers, lakes, slow-moving waters and slough of main rivers and Delta.	High; suitable habitat present in and adjacent to the survey area.
Longfin smelt *Spirinchus thaleichthys*	–	T	Anadromous; typically found in the San Francisco Estuary and the Sacramento-San Joaquin Delta.	High; suitable habitat present in and adjacent to the survey area.
Amphibians				
California tiger salamander *Ambystoma californiense*	T	T	Grassland and low foothills with pools or ponds; vernal pool or stock ponds	Low; seasonal wetlands in the survey area provide potentially suitable habitat.
California red-legged frog *Rana draytonii*	T	SSC	Lowlands and foothill areas, in or near permanent deep water with dense, shrubby or emergent riparian vegetation	Low; suitable habitat is present in the survey area; nearest CNDDB occurrence 15 miles southwest of survey area.
Reptiles				
Northern California legless lizard *Anniella pulchra*	–	SSC	Burrows in loose soils, typically in sand dunes along the coast.	None; suitable habitat is not present on or adjacent to the survey area.
California glossy snake *Arizona elegans occidentalis*	–	SSC	Barren to sparse shrubby desert, sagebrush flats, grassland, sandhills, coastal scrub, and chaparral slopes.	None; suitable habitat is absent from survey area
Western pond turtle *Emys marmorata*	–	SSC	Permanent or nearly permanent water bodies in various habitats, including ponds, marshes, rivers, streams, and ditches.	Moderate; survey area provides suitable aquatic habitat and upland areas; however, nearest known occurrences within 6 miles of the survey area.
Giant garter snake *Thamnophis gigas*	T	T	Open water and emergent vegetation in marshes, sloughs, and other aquatic habitats; also requires open upland habitat for basking and underground refuge.	Low; suitable habitat present in the survey area; however, no suitable upland habitat is present along the survey area.
Birds				
Tricolored blackbird *Agelaius tricolor*	–	SSC	Nests and forages in wetlands with cattails,	Moderate; suitable habitat present in and adjacent to the

Table 2. Special-Status Wildlife Species with Potential to Occur in or Adjacent to the Survey Area

Species	Status[1]		Habitat Associations	Potential for Occurrence in the Project Area
	Federal	State		
			bulrushes, and willows, and occasionally agricultural fields.	survey area, but no nesting colonies in the vicinity.
Burrowing owl *Athene cunicularia*	–	SSC	Nests and forages in grasslands, agricultural lands, open shrublands, and open woodlands with natural or artificial burrows or friable soils.	Low; potentially suitable habitat is present in and adjacent to the survey area, but no California ground squirrels or suitable burrows were observed during the 2018 survey.
Swainson's hawk *Buteo swainsoni*	–	T	Nests in riparian forest and scattered trees; forages in grasslands and agricultural fields.	Moderate; scattered trees adjacent to survey area provides suitable nest habitat, agriculture in the vicinity of the survey area provide foraging habitat in the southern portion, provide suitable nest sites.
Mountain plover *Charadrius montanus*	–	SSC	Fallow agricultural fields, grazed grasslands, alkali flats, and other sparsely vegetated open habitats.	Low; grazed grassland in northern portion of survey area provides potentially suitable habitat, but higher quality habitat is available elsewhere in the region.
Northern harrier *Circus cyaneus*	–	SSC	Nests and forages in grasslands, agricultural fields, and marshes; nests on the ground in patches of dense, often tall, vegetation in undisturbed areas.	High; grasslands and marsh habitat in and adjacent to undeveloped portions of the survey area provide suitable foraging yet marginal nesting habitat; observed during 2018 reconnaissance survey.
Western yellow-billed cuckoo *Coccyzus americanus occidentalis*	T	E	Wooded riparian habitat with dense cover and water nearby; dense thickets along streams and marshes.	Low; marginal quality foraging habitat for migrant individuals is present adjacent to the survey area, but the area is outside the current breeding range of the species.
White-tailed kite *Elanus leucurus*	–	FP	Savanna, open woodland, marshes, and cultivated fields. Nests in isolated trees, or at edge of forest.	Moderate; potentially suitable habitat is present adjacent to the survey area.
American peregrine falcon *Falco peregrinus anatum*	–	FP	Open country near water where shorebirds feed. May nest in high cliffs near rivers, wetlands, lakes, and human-made structures; forages in grasslands, open woodland, and agricultural areas.	High; river and human-made structures on and adjacent to the survey area provide suitable nesting and foraging habitat; CNDDB occurrence in 2015 within survey area.
Saltmarsh common yellowthroat	–	SSC	Fresh to saltwater marsh and riparian woodland and swamp.	Low; habitat in the survey area is marginally suitable, but the recognized range of this

Table 2. Special-Status Wildlife Species with Potential to Occur in or Adjacent to the Survey Area

Species	Status[1]		Habitat Associations	Potential for Occurrence in the Project Area
	Federal	State		
Geothlpis trichas sinuosa				subspecies does not extend east into the Delta.
California black rail *Laterallus jamaicensis coturniculus*	–	T	Wet meadows and shallow freshwater to saltwater marshes with dense vegetation.	None; no suitable habitat is present in or adjacent to the survey area.
Modesto Song sparrow *Melospiza melodia*	–	SSC	Nests and forages in dense vegetation in marsh, riparian forest and scrub, and along irrigation and drainage canals.	Moderate; potentially suitable habitat is present on and adjacent to the survey area.
Samuels song sparrow *Melospiza melodia samuelis*	–	SSC	Tidal salt marsh.	None; no suitable habitat is present in or adjacent to the survey area; does not occur east of San Pablo Bay.
California Ridgeway's rail *Rallus obsoletus obsoletus*	E	FP	Salt water and brackish marshes traversed by tidal slough near the San Francisco Bay; typically associated with pickleweed and cordgrass.	None; no suitable habitat is present in or adjacent to the survey area; not known to occur east of Suisun Marsh.
Bank swallow *Riparia riparia*	–	T	Burrow in sandy, vertical bluff or riverbanks, streams, coastal bluff and sand and gravel pits.	None; suitable habitat is not present on or adjacent to the survey area.
Mammals				
Western red bat *Lasiurus blossevillii*	–	SSC	Roosts in broad leaved trees, especially cottonwood and willows from sea level up through foothills and lower mountains. Forages in grasslands, shrublands, open woodland and forests, and croplands.	Moderate; suitable roosting habitat in and adjacent to the survey area.
Salt-marsh harvest mouse *Reithrodontomys raviventris*	–	FP	Salt and brackish marshes, dense vegetation cover, associated with pickleweed and *Atriplex* ssp.	None; no suitable habitat is present in or adjacent to the study area, and the species does not occur in the Delta.
Mexican free-tailed bat *Tadarida brasiliensis*	–	SSC	Roosts in caves, in structures such as ceiling or walls, hollows of trees, and beneath fronds of palm trees.	High; suitable roosting habitat in and adjacent to the survey area. Roosting population observed in abandoned structure immediately south of Rio Vista Bridge (Highway 12) during 2018 survey.

Table 2. Special-Status Wildlife Species with Potential to Occur in or Adjacent to the Survey Area

Species	Status[1]		Habitat Associations	Potential for Occurrence in the Project Area
	Federal	State		
American badger *Taxidea taxus*	–	SSC	Grasslands, shrublands, and other open habitats.	Low; marginally suitable habitat present adjacent to the survey area, but more suitable and less disturbed habitat is present elsewhere in the region

Notes: CDFW = California Department of Fish and Wildlife; CNDDB = California Natural Diversity Database; ESU = NMFS = National Marine Fisheries Service; USFWS = U.S. Fish and Wildlife Service

[1] Status Definitions:

Federal Listing Categories (NMFS/USFWS)
T = Threatened
E = Endangered
SC = Species of concern
– = No status

State Listing Categories (CDFW)
T = Threatened
E = Endangered
R = Rare
SSC = Species of special concern
FP = Fully Protected
– = No status

CDFW California Rare Plant Ranks
1B = Plants rare, threatened, or endangered in California and elsewhere
2B = Plants rare, threatened, or endangered in California, but more common elsewhere

Extensions:
.1 = Seriously endangered in California (>80% of occurrences are threatened and/or high degree and immediacy of threat)
.2 = Fairly endangered in California (20–80% of occurrences are threatened)

Sources: CDFW 2018; CNPS 2018; USFWS 2018; based on data collected and compiled by GEI in 2018.

Attachment F: Cost Estimates

Solano County Water Agency (SCWA)
Rio Vista Flood Protection Measures Feasibility Study
Alternative S-1A

Item	Quantity	Unit	Unit Price	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Lands							
Land Acquisition	1.00	LS	$165,000	$165,000	30%	$49,500	$214,500
Subtotal - Lands				***$165,000***		***$50,000***	***$215,000***
Relocations							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Urban)	1	%	3.0%	$0	30%	$0	$0
Remove Existing Concrete		SF	$8.00	$0	30%	$0	$0
Utility Pole Relocation	0	EA	$15,000.00	$0	30%	$0	$0
Misc Dock/Debri Removal		LS	$10,000.00	$0	30%	$0	$0
Subtotal - Relocations				***$0***		***$0***	***$0***
Mitigation - Fish and Wildlife							
Environmental Mitigation	1	%	7.0%	$2,512,510	30%	$753,753	$3,266,263
Subtotal - Mitigation				***$2,513,000***		***$754,000***	***$3,267,000***
Structure Raising							
Raising Less than 2-feet	3	EA	150,000	$450,000	30%	$135,000	$585,000
Raising Between 2 and 4 feet	9	EA	175,000	$1,575,000	30%	$472,500	$2,047,500
Raising Between 4 and 6 feet	24	EA	200,000	$4,800,000	30%	$1,440,000	$6,240,000
Raising Between 6 and 8 feet	1	EA	250,000	$250,000	30%	$75,000	$325,000
Subtotal - Structure Raising				***$7,075,000***		***$2,123,000***	***$9,198,000***
Interior Drainage							
Mobilization and Demobilization	1	%	5.0%	$236,265	30%	$70,880	$307,145
Traffic Control (Rural)	1	%	1.0%	$46,785	30%	$14,036	$60,821
Drainage Swale / Ditch	0	LF	$20.00	$0	30%	$0	$0
Pump Station (3.5 cfs)	0	EA	$1,400,000.00	$0	30%	$0	$0
Pump Station (8 cfs)	2	EA	$1,800,000.00	$3,600,000	30%	$1,080,000	$4,680,000
Outfall Structure	4	EA	$0.00	$0	30%	$0	$0
Gravity Flow Inlet	5	EA	$3,500.00	$17,500	30%	$5,250	$22,750
Pumped Detention	3	EA	$0.00	$0	30%	$0	$0
12" Storm Drain	220	LF	$75.00	$16,500	30%	$4,950	$21,450
18" Storm Drain	150	LF	$100.00	$15,000	30%	$4,500	$19,500
24" Storm Drain	400	LF	$125.00	$50,000	30%	$15,000	$65,000
30" Storm Drain	970	LF	$150.00	$145,500	30%	$43,650	$189,150
36" Storm Drain	2,680	LF	$175.00	$469,000	30%	$140,700	$609,700
48" Storm Drain	0	LF	$200.00	$0	30%	$0	$0
60" Storm Drain	1,460	LF	$250.00	$365,000	30%	$109,500	$474,500
2x72" Storm Drain	0	LF	$600.00	$0	30%	$0	$0
Subtotal - Interior Drainage				***$4,962,000***		***$1,488,465***	***$6,450,015***
Earthwork							
Mobilization and Demobilization	1	%	5.0%	$3,815	30%	$1,145	$4,960
Traffic Control (Rural)	1	%	1.0%	$756	30%	$227	$983
Levee Fill (for Pad up to Elev 12')	7,553	CY	$10.00	$75,534	30%	$22,660	$98,194
Subtotal - Earthwork				***$81,000***		***$25,000***	***$105,000***
Floodwalls, Levees, Stoplogs							
Mobilization and Demobilization	1	%	5.0%	$1,124,270	30%	$337,281	$1,461,551
Traffic Control (Rural)	1	%	1.0%	$222,628	30%	$66,788	$289,416
Stripping		CY	$4.00	$0	30%	$0	$0
Clearing and Grubbing		AC	$3,250.00	$0	30%	$0	$0
Borrow Site Excavation		CY	$3.00	$0	30%	$0	$0
Borrow Site Hauling Level 2		CY	$5.50	$0	30%	$0	$0
Borrow Site Restoration		AC	$4,000.00	$0	30%	$0	$0
Sheetpile Floodwall	243,518.7	SF	$85.00	$20,699,091	30%	$6,209,727	$26,908,818
Concrete Cap	281.8	CY	$2,000.00	$563,667	30%	$169,100	$732,767
Active Floodwall - Materials	0.0	SF	$520.00	$0	30%	$0	$0
Active Floodwall - Installation	0.0	SF	$520.00	$0	30%	$0	$0
Steel Railing		LF	$185.00	$0	30%	$0	$0
Dewatering		LF	$75.00	$0	30%	$0	$0
Existing Floodwall to be Raised/Improved		LF	$200.00	$0	30%	$0	$0
Levee Fill		CY	$10.00	$0	30%	$0	$0
Berm Fill		CY	$10.00	$0	30%	$0	$0
Soil- Bentonite Cutoff Wall		SF	$20.00	$0	30%	$0	$0
Rip Rap - Wall		CY	$225.00	$0	30%	$0	$0
Rip Rap - Levee		CY	$225.00	$0	30%	$0	$0
Stoplog Structure	2	LS	$500,000.00	$1,000,000	30%	$300,000	$1,300,000
Subtotal - Levees				***$23,610,000***		***$7,083,000***	***$30,693,000***
ESTIMATED ALTERNATIVE TOTAL				**$38,406,000**		**$11,523,465**	**$49,928,015**

Solano County Water Agency (SCWA)
Rio Vista Flood Protection Measures Feasibility Study
Alternative S-1B

Item	Quantity	Unit	Unit Price	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Lands							
Land Acquisition	1.00	LS	$14,089,000	$14,089,000	30%	$4,226,700	$18,315,700
Subtotal - Lands				***$14,089,000***		***$4,227,000***	***$18,316,000***
Relocations							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Urban)	1	%	3.0%	$0	30%	$0	$0
Remove Existing Concrete		SF	$8.00	$0	30%	$0	$0
Utility Pole Relocation	0	EA	$15,000.00	$0	30%	$0	$0
Misc Dock/Debri Removal		LS	$10,000.00	$0	30%	$0	$0
Subtotal - Relocations				***$0***		***$0***	***$0***
Mitigation - Fish and Wildlife							
Environmental Mitigation	1	%	7.0%	$4,158,000	30%	$1,247,400	$5,405,400
Subtotal - Mitigation				***$4,158,000***		***$1,248,000***	***$5,406,000***
Structure Raising							
Raising Less than 2-feet	3	EA	150,000	$450,000	30%	$135,000	$585,000
Raising Between 2 and 4 feet	9	EA	175,000	$1,575,000	30%	$472,500	$2,047,500
Raising Between 4 and 6 feet	24	EA	200,000	$4,800,000	30%	$1,440,000	$6,240,000
Raising Between 6 and 8 feet	1	EA	250,000	$250,000	30%	$75,000	$325,000
Subtotal - Structure Raising				***$7,075,000***		***$2,123,000***	***$9,198,000***
Interior Drainage							
Mobilization and Demobilization	1	%	5.0%	$409,707	30%	$122,912	$532,619
Traffic Control (Rural)	1	%	1.0%	$81,130	30%	$24,339	$105,469
Drainage Swale / Ditch	0	LF	$20.00	$0	30%	$0	$0
Pump Station (3.5 cfs)	1	EA	$1,400,000.00	$1,400,000	30%	$420,000	$1,820,000
Pump Station (8 cfs)	3	EA	$1,800,000.00	$5,400,000	30%	$1,620,000	$7,020,000
Outfall Structure	5	EA	$0.00	$0	30%	$0	$0
Gravity Flow Inlet	5	EA	$3,500.00	$17,500	30%	$5,250	$22,750
Pumped Detention	4	EA	$0.00	$0	30%	$0	$0
12" Storm Drain	220	LF	$75.00	$16,500	30%	$4,950	$21,450
18" Storm Drain	150	LF	$100.00	$15,000	30%	$4,500	$19,500
24" Storm Drain	1,660	LF	$125.00	$207,500	30%	$62,250	$269,750
30" Storm Drain	970	LF	$150.00	$145,500	30%	$43,650	$189,150
36" Storm Drain	3,120	LF	$175.00	$546,000	30%	$163,800	$709,800
48" Storm Drain	0	LF	$200.00	$0	30%	$0	$0
60" Storm Drain	1,460	LF	$250.00	$365,000	30%	$109,500	$474,500
2x72" Storm Drain	0	LF	$600.00	$0	30%	$0	$0
Subtotal - Interior Drainage				***$8,604,000***		***$2,581,151***	***$11,184,988***
Earthwork							
Mobilization and Demobilization	1	%	5.0%	$5,694	30%	$1,708	$7,402
Traffic Control (Rural)	1	%	1.0%	$1,128	30%	$338	$1,466
Levee Fill (for Pad up to Elev 12')	11,273	CY	$10.00	$112,734	30%	$33,820	$146,554
Subtotal - Earthwork				***$120,000***		***$36,000***	***$156,000***
Floodwalls, Levees, Stoplogs							
Mobilization and Demobilization	1	%	5.0%	$1,742,234	30%	$522,670	$2,264,904
Traffic Control (Rural)	1	%	1.0%	$344,997	30%	$103,499	$448,496
Stripping		CY	$4.00	$0	30%	$0	$0
Clearing and Grubbing		AC	$3,250.00	$0	30%	$0	$0
Borrow Site Excavation		CY	$3.00	$0	30%	$0	$0
Borrow Site Hauling Level 2		CY	$5.50	$0	30%	$0	$0
Borrow Site Restoration		AC	$4,000.00	$0	30%	$0	$0
Sheetpile Floodwall	387,482.5	SF	$85.00	$32,936,011	30%	$9,880,803	$42,816,814
Concrete Cap	281.8	CY	$2,000.00	$563,667	30%	$169,100	$732,767
Active Floodwall - Materials	0.0	SF	$520.00	$0	30%	$0	$0
Active Floodwall - Installation	0.0	SF	$520.00	$0	30%	$0	$0
Steel Railing		LF	$185.00	$0	30%	$0	$0
Dewatering		LF	$75.00	$0	30%	$0	$0
Existing Floodwall to be Raised/Improved		LF	$200.00	$0	30%	$0	$0
Levee Fill		CY	$10.00	$0	30%	$0	$0
Berm Fill		CY	$10.00	$0	30%	$0	$0
Soil- Bentonite Cutoff Wall		SF	$20.00	$0	30%	$0	$0
Rip Rap - Wall		CY	$225.00	$0	30%	$0	$0
Rip Rap - Levee		CY	$225.00	$0	30%	$0	$0
Stoplog Structure	2	LS	$500,000.00	$1,000,000	30%	$300,000	$1,300,000
Subtotal - Levees				***$36,587,000***		***$10,977,000***	***$47,563,000***
ESTIMATED ALTERNATIVE TOTAL				**$63,558,000**		**$19,069,151**	**$91,823,988**

Solano County Water Agency (SCWA)
Rio Vista Flood Protection Measures Feasibility Study
Alternative S-2

WOOD RODGERS

Item	Quantity	Unit	Unit Price	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Lands							
Land Acquisition	1.00	LS	$1,014,000	$1,014,000	30%	$304,200	$1,318,200
Subtotal - Lands				***$1,014,000***		***$305,000***	***$1,319,000***
Relocations							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Urban)	1	%	3.0%	$0	30%	$0	$0
Remove Existing Concrete		SF	$8.00	$0	30%	$0	$0
Utility Pole Relocation	0	EA	$15,000.00	$0	30%	$0	$0
Misc Dock/Debri Removal		LS	$10,000.00	$0	30%	$0	$0
Subtotal - Relocations				***$0***		***$0***	***$0***
Mitigation - Fish and Wildlife							
Environmental Mitigation	1	%	7.0%	$2,587,270	30%	$776,181	$3,363,451
Subtotal - Mitigation				***$2,588,000***		***$777,000***	***$3,364,000***
Structure Raising							
Raising Less than 2-feet	3	EA	150,000	$450,000	30%	$135,000	$585,000
Raising Between 2 and 4 feet	9	EA	175,000	$1,575,000	30%	$472,500	$2,047,500
Raising Between 4 and 6 feet	24	EA	200,000	$4,800,000	30%	$1,440,000	$6,240,000
Raising Between 6 and 8 feet	1	EA	250,000	$250,000	30%	$75,000	$325,000
Subtotal - Structure Raising				***$7,075,000***		***$2,123,000***	***$9,198,000***
Interior Drainage							
Mobilization and Demobilization	1	%	5.0%	$236,265	30%	$70,880	$307,145
Traffic Control (Rural)	1	%	1.0%	$46,785	30%	$14,036	$60,821
Drainage Swale / Ditch	0	LF	$20.00	$0	30%	$0	$0
Pump Station (3.5 cfs)	0	EA	$1,400,000.00	$0	30%	$0	$0
Pump Station (8 cfs)	2	EA	$1,800,000.00	$3,600,000	30%	$1,080,000	$4,680,000
Outfall Structure	4	EA	$0.00	$0	30%	$0	$0
Gravity Flow Inlet	5	EA	$3,500.00	$17,500	30%	$5,250	$22,750
Pumped Detention	3	EA	$0.00	$0	30%	$0	$0
12" Storm Drain	220	LF	$75.00	$16,500	30%	$4,950	$21,450
18" Storm Drain	150	LF	$100.00	$15,000	30%	$4,500	$19,500
24" Storm Drain	400	LF	$125.00	$50,000	30%	$15,000	$65,000
30" Storm Drain	970	LF	$150.00	$145,500	30%	$43,650	$189,150
36" Storm Drain	2,680	LF	$175.00	$469,000	30%	$140,700	$609,700
48" Storm Drain	0	LF	$200.00	$0	30%	$0	$0
60" Storm Drain	1,460	LF	$250.00	$365,000	30%	$109,500	$474,500
2x72" Storm Drain	0	LF	$600.00	$0	30%	$0	$0
Subtotal - Interior Drainage				***$4,962,000***		***$1,488,465***	***$6,450,015***
Earthwork							
Mobilization and Demobilization	1	%	5.0%	$3,815	30%	$1,145	$4,960
Traffic Control (Rural)	1	%	1.0%	$756	30%	$227	$983
Levee Fill (for Pad up to Elev 12')	7,553	CY	$10.00	$75,534	30%	$22,660	$98,194
Subtotal - Earthwork				***$81,000***		***$25,000***	***$105,000***
Floodwalls, Levees, Stoplogs							
Mobilization and Demobilization	1	%	5.0%	$1,134,690	30%	$340,407	$1,475,097
Traffic Control (Rural)	1	%	1.0%	$224,692	30%	$67,408	$292,100
Stripping		CY	$4.00	$0	30%	$0	$0
Clearing and Grubbing		AC	$3,250.00	$0	30%	$0	$0
Borrow Site Excavation		CY	$3.00	$0	30%	$0	$0
Borrow Site Hauling Level 2		CY	$5.50	$0	30%	$0	$0
Borrow Site Restoration		AC	$4,000.00	$0	30%	$0	$0
Sheetpile Floodwall	243,518.7	SF	$85.00	$20,699,091	30%	$6,209,727	$26,908,818
Concrete Cap	281.8	CY	$2,000.00	$563,667	30%	$169,100	$732,767
Active Floodwall - Materials	0.0	SF	$520.00	$0	30%	$0	$0
Active Floodwall - Installation	0.0	SF	$520.00	$0	30%	$0	$0
Steel Railing		LF	$185.00	$0	30%	$0	$0
Dewatering		LF	$75.00	$0	30%	$0	$0
Existing Floodwall to be Raised/Improved		LF	$200.00	$0	30%	$0	$0
Levee Fill	20,635	CY	$10.00	$206,350	30%	$61,905	$268,255
Berm Fill		CY	$10.00	$0	30%	$0	$0
Soil- Bentonite Cutoff Wall		SF	$20.00	$0	30%	$0	$0
Rip Rap - Wall		CY	$225.00	$0	30%	$0	$0
Rip Rap - Levee		CY	$225.00	$0	30%	$0	$0
Stoplog Structure	2	LS	$500,000.00	$1,000,000	30%	$300,000	$1,300,000
Subtotal - Levees				***$23,829,000***		***$7,149,000***	***$30,978,000***
ESTIMATED ALTERNATIVE TOTAL				**$39,549,000**		**$11,867,465**	**$51,414,015**

Solano County Water Agency (SCWA)
Rio Vista Flood Protection Measures Feasibility Study
Alternative S-3

Item	Quantity	Unit	Unit Price	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Lands							
Land Acquisition	1.00	LS	$165,000	$165,000	30%	$49,500	$214,500
Subtotal - Lands				***$165,000***		***$50,000***	***$215,000***
Relocations							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Urban)	1	%	3.0%	$0	30%	$0	$0
Remove Existing Concrete		SF	$8.00	$0	30%	$0	$0
Utility Pole Relocation	0	EA	$15,000.00	$0	30%	$0	$0
Misc Dock/Debri Removal		LS	$10,000.00	$0	30%	$0	$0
Subtotal - Relocations				***$0***		***$0***	***$0***
Mitigation - Fish and Wildlife							
Environmental Mitigation	1	%	7.0%	$3,262,280	30%	$978,684	$4,240,964
Subtotal - Mitigation				***$3,263,000***		***$979,000***	***$4,241,000***
Structure Raising							
Raising Less than 2-feet	3	EA	150,000	$450,000	30%	$135,000	$585,000
Raising Between 2 and 4 feet	9	EA	175,000	$1,575,000	30%	$472,500	$2,047,500
Raising Between 4 and 6 feet	24	EA	200,000	$4,800,000	30%	$1,440,000	$6,240,000
Raising Between 6 and 8 feet	1	EA	250,000	$250,000	30%	$75,000	$325,000
Subtotal - Structure Raising				***$7,075,000***		***$2,123,000***	***$9,198,000***
Interior Drainage							
Mobilization and Demobilization	1	%	5.0%	$236,265	30%	$70,880	$307,145
Traffic Control (Rural)	1	%	1.0%	$46,785	30%	$14,036	$60,821
Drainage Swale / Ditch	0	LF	$20.00	$0	30%	$0	$0
Pump Station (3.5 cfs)	0	EA	$1,400,000.00	$0	30%	$0	$0
Pump Station (8 cfs)	2	EA	$1,800,000.00	$3,600,000	30%	$1,080,000	$4,680,000
Outfall Structure	4	EA	$0.00	$0	30%	$0	$0
Gravity Flow Inlet	5	EA	$3,500.00	$17,500	30%	$5,250	$22,750
Pumped Detention	3	EA	$0.00	$0	30%	$0	$0
12" Storm Drain	220	LF	$75.00	$16,500	30%	$4,950	$21,450
18" Storm Drain	150	LF	$100.00	$15,000	30%	$4,500	$19,500
24" Storm Drain	400	LF	$125.00	$50,000	30%	$15,000	$65,000
30" Storm Drain	970	LF	$150.00	$145,500	30%	$43,650	$189,150
36" Storm Drain	2,680	LF	$175.00	$469,000	30%	$140,700	$609,700
48" Storm Drain	0	LF	$200.00	$0	30%	$0	$0
60" Storm Drain	1,460	LF	$250.00	$365,000	30%	$109,500	$474,500
2x72" Storm Drain	0	LF	$600.00	$0	30%	$0	$0
Subtotal - Interior Drainage				***$4,962,000***		***$1,488,465***	***$6,450,015***
Earthwork							
Mobilization and Demobilization	1	%	5.0%	$3,815	30%	$1,145	$4,960
Traffic Control (Rural)	1	%	1.0%	$756	30%	$227	$983
Levee Fill (for Pad up to Elev 12')	7,553	CY	$10.00	$75,534	30%	$22,660	$98,194
Subtotal - Earthwork				***$81,000***		***$25,000***	***$105,000***
Floodwalls, Levees, Stoplogs							
Mobilization and Demobilization	1	%	5.0%	$1,634,291	30%	$490,287	$2,124,578
Traffic Control (Rural)	1	%	1.0%	$323,622	30%	$97,087	$420,709
Stripping		CY	$4.00	$0	30%	$0	$0
Clearing and Grubbing		AC	$3,250.00	$0	30%	$0	$0
Borrow Site Excavation		CY	$3.00	$0	30%	$0	$0
Borrow Site Hauling Level 2		CY	$5.50	$0	30%	$0	$0
Borrow Site Restoration		AC	$4,000.00	$0	30%	$0	$0
Sheetpile Floodwall	226,523.7	SF	$85.00	$19,254,517	30%	$5,776,355	$25,030,872
Concrete Cap	281.8	CY	$2,000.00	$563,667	30%	$169,100	$732,767
Active Floodwall - Materials	11,100.0	SF	$520.00	$5,772,000	30%	$1,731,600	$7,503,600
Active Floodwall - Installation	11,100.0	SF	$520.00	$5,772,000	30%	$1,731,600	$7,503,600
Steel Railing		LF	$185.00	$0	30%	$0	$0
Dewatering		LF	$75.00	$0	30%	$0	$0
Existing Floodwall to be Raised/Improved		LF	$200.00	$0	30%	$0	$0
Levee Fill		CY	$10.00	$0	30%	$0	$0
Berm Fill		CY	$10.00	$0	30%	$0	$0
Soil- Bentonite Cutoff Wall		SF	$20.00	$0	30%	$0	$0
Rip Rap - Wall		CY	$225.00	$0	30%	$0	$0
Rip Rap - Levee		CY	$225.00	$0	30%	$0	$0
Stoplog Structure	2	LS	$500,000.00	$1,000,000	30%	$300,000	$1,300,000
Subtotal - Levees				***$34,321,000***		***$10,297,000***	***$44,617,000***
ESTIMATED ALTERNATIVE TOTAL				**$49,867,000**		**$14,962,465**	**$64,826,015**

Alternative S-4

Item	Quantity	Unit	Unit Price	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Structure Raising							
Raising Less than 2-feet	71	EA	150,000	$10,650,000	30%	$3,195,000	$13,845,000
Raising Between 2 and 4 feet	29	EA	175,000	$5,075,000	30%	$1,522,500	$6,597,500
Raising Between 4 and 6 feet	32	EA	200,000	$6,400,000	30%	$1,920,000	$8,320,000
Raising Between 6 and 8 feet	3	EA	250,000	$750,000	30%	$225,000	$975,000
Subtotal - Structure Raising				***$22,875,000***		***$6,863,000***	***$29,738,000***
ESTIMATED ALTERNATIVE TOTAL				**$22,875,000**		**$6,863,000**	**$29,738,000**

Solano County Water Agency (SCWA)
Rio Vista Flood Protection Measures Feasibility Study
Alternative S-5

Item	Quantity	Unit	Annual Premium	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Purchasing Flood Insurance in Lieu of Improvements							
Number of Policies for Structures in the FEMA 100-year Floodplain	20	EA	$4,480	$89,600	30%	$26,880	$116,480
Number of Policies for Structures in the FEMA 500-year Floodplain	20	EA	$4,400	$88,000	30%	$26,400	$114,400
Number of Policies for Structures outside of the FEMA 500-year Floodplain	114	EA	$4,400	$501,600	30%	$150,480	$652,080
Subtotal - Flood Insurance				***$680,000***		***$204,000***	***$883,000***
ESTIMATED ALTERNATIVE TOTAL				**$680,000**		**$204,000**	**$883,000**

Solano County Water Agency (SCWA)
Rio Vista Flood Protection Measures Feasibility Study
Alternative N-1

Item	Quantity	Unit	Unit Price	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Lands							
Land Acquisition	1.00	LS	$4,964,000	$4,964,000	30%	$1,489,200	$6,453,200
Subtotal - Lands				***$4,964,000***		***$1,490,000***	***$6,454,000***
Relocations							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Urban)	1	%	3.0%	$0	30%	$0	$0
Remove Existing Concrete		SF	$8.00	$0	30%	$0	$0
Utility Pole Relocation	0	EA	$15,000.00	$0	30%	$0	$0
Misc Dock/Debri Removal	0	LS	$10,000.00	$0	30%	$0	$0
Subtotal - Relocations				***$0***		***$0***	***$0***
Mitigation - Fish and Wildlife							
Environmental Mitigation	1	%	7.0%	$2,906,400	30%	$871,920	$3,778,320
Subtotal - Mitigation				***$2,907,000***		***$872,000***	***$3,779,000***
Structure Raising							
Raising Less than 2-feet	0	EA	150,000	$0	30%	$0	$0
Raising Between 2 and 4 feet	0	EA	175,000	$0	30%	$0	$0
Raising Between 4 and 6 feet	0	EA	200,000	$0	30%	$0	$0
Raising Between 6 and 8 feet	0	EA	250,000	$0	30%	$0	$0
Subtotal - Structure Raising				***$0***		***$0***	***$0***
Interior Drainage							
Mobilization and Demobilization	1	%	5.0%	$385,820	30%	$115,746	$501,566
Traffic Control (Rural)	1	%	1.0%	$76,400	30%	$22,920	$99,320
Drainage Swale / Ditch	0	LF	$20.00	$0	30%	$0	$0
Pump Station (3.5 cfs)	3	EA	$1,400,000.00	$4,200,000	30%	$1,260,000	$5,460,000
Pump Station (8 cfs)	1	EA	$1,800,000.00	$1,800,000	30%	$540,000	$2,340,000
Outfall Structure	6	EA	$0.00	$0	30%	$0	$0
Gravity Flow Inlet	3	EA	$3,500.00	$10,500	30%	$3,150	$13,650
Pumped Detention	4	EA	$0.00	$0	30%	$0	$0
12" Storm Drain	0	LF	$75.00	$0	30%	$0	$0
18" Storm Drain	0	LF	$100.00	$0	30%	$0	$0
24" Storm Drain	2,540	LF	$125.00	$317,500	30%	$95,250	$412,750
30" Storm Drain	320	LF	$150.00	$48,000	30%	$14,400	$62,400
36" Storm Drain	0	LF	$175.00	$0	30%	$0	$0
48" Storm Drain	1,130	LF	$200.00	$226,000	30%	$67,800	$293,800
60" Storm Drain	0	LF	$250.00	$0	30%	$0	$0
2x72" Storm Drain	1,730	LF	$600.00	$1,038,000	30%	$311,400	$1,349,400
Subtotal - Interior Drainage				***$8,103,000***		***$2,430,666***	***$10,532,886***
Earthwork							
Mobilization and Demobilization	1	%	5.0%	$14,021	30%	$4,206	$18,227
Traffic Control (Rural)	1	%	1.0%	$2,777	30%	$833	$3,610
Levee Fill (for Pad up to Elev 12')	27,764	CY	$10.00	$277,643	30%	$83,293	$360,936
Subtotal - Earthwork				***$295,000***		***$89,000***	***$383,000***
Floodwalls, Levees, Stoplogs							
Mobilization and Demobilization	1	%	5.0%	$1,340,840	30%	$402,252	$1,743,092
Traffic Control (Rural)	1	%	1.0%	$265,513	30%	$79,654	$345,167
Stripping		CY	$4.00	$0	30%	$0	$0
Clearing and Grubbing		AC	$3,250.00	$0	30%	$0	$0
Borrow Site Excavation		CY	$3.00	$0	30%	$0	$0
Borrow Site Hauling Level 2		CY	$5.50	$0	30%	$0	$0
Borrow Site Restoration		AC	$4,000.00	$0	30%	$0	$0
Sheetpile Floodwall	299,854.2	SF	$85.00	$25,487,606	30%	$7,646,282	$33,133,888
Concrete Cap	281.8	CY	$2,000.00	$563,667	30%	$169,100	$732,767
Active Floodwall - Materials	0.0	SF	$520.00	$0	30%	$0	$0
Active Floodwall - Installation	0.0	SF	$520.00	$0	30%	$0	$0
Steel Railing		LF	$185.00	$0	30%	$0	$0
Dewatering		LF	$75.00	$0	30%	$0	$0
Existing Floodwall to be Raised/Improved		LF	$200.00	$0	30%	$0	$0
Levee Fill		CY	$10.00	$0	30%	$0	$0
Berm Fill		CY	$10.00	$0	30%	$0	$0
Soil- Bentonite Cutoff Wall		SF	$20.00	$0	30%	$0	$0
Rip Rap - Wall		CY	$225.00	$0	30%	$0	$0
Rip Rap - Levee		CY	$225.00	$0	30%	$0	$0
Stoplog Structure	1	LS	$500,000.00	$500,000	30%	$150,000	$650,000
Subtotal - Levees				***$28,158,000***		***$8,448,000***	***$36,605,000***
ESTIMATED ALTERNATIVE TOTAL				**$44,427,000**		**$13,329,666**	**$57,753,886**

Solano County Water Agency (SCWA)
Rio Vista Flood Protection Measures Feasibility Study
Alternative N-2

Item	Quantity	Unit	Unit Price	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Lands							
Land Acquisition	1.00	LS	$16,507,000	$16,507,000	30%	$4,952,100	$21,459,100
Subtotal - Lands				***$16,507,000***		***$4,953,000***	***$21,460,000***
Relocations							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Urban)	1	%	3.0%	$0	30%	$0	$0
Remove Existing Concrete		SF	$8.00	$0	30%	$0	$0
Utility Pole Relocation	0	EA	$15,000.00	$0	30%	$0	$0
Misc Dock/Debri Removal	0	LS	$10,000.00	$0	30%	$0	$0
Subtotal - Relocations				***$0***		***$0***	***$0***
Mitigation - Fish and Wildlife							
Environmental Mitigation	1	%	7.0%	$4,047,190	30%	$1,214,157	$5,261,347
Subtotal - Mitigation				***$4,048,000***		***$1,215,000***	***$5,262,000***
Structure Raising							
Raising Less than 2-feet	18	EA	150,000	$2,700,000	30%	$810,000	$3,510,000
Raising Between 2 and 4 feet	1	EA	175,000	$175,000	30%	$52,500	$227,500
Raising Between 4 and 6 feet	29	EA	200,000	$5,800,000	30%	$1,740,000	$7,540,000
Raising Between 6 and 8 feet	10	EA	250,000	$2,500,000	30%	$750,000	$3,250,000
Subtotal - Structure Raising				***$11,175,000***		***$3,353,000***	***$14,528,000***
Interior Drainage							
Mobilization and Demobilization	1	%	5.0%	$385,820	30%	$115,746	$501,566
Traffic Control (Rural)	1	%	1.0%	$76,400	30%	$22,920	$99,320
Drainage Swale / Ditch	0	LF	$20.00	$0	30%	$0	$0
Pump Station (3.5 cfs)	3	EA	$1,400,000.00	$4,200,000	30%	$1,260,000	$5,460,000
Pump Station (8 cfs)	1	EA	$1,800,000.00	$1,800,000	30%	$540,000	$2,340,000
Outfall Structure	6	EA	$0.00	$0	30%	$0	$0
Gravity Flow Inlet	3	EA	$3,500.00	$10,500	30%	$3,150	$13,650
Pumped Detention	4	EA	$0.00	$0	30%	$0	$0
12" Storm Drain	0	LF	$75.00	$0	30%	$0	$0
18" Storm Drain	0	LF	$100.00	$0	30%	$0	$0
24" Storm Drain	2,540	LF	$125.00	$317,500	30%	$95,250	$412,750
30" Storm Drain	320	LF	$150.00	$48,000	30%	$14,400	$62,400
36" Storm Drain	0	LF	$175.00	$0	30%	$0	$0
48" Storm Drain	1,130	LF	$200.00	$226,000	30%	$67,800	$293,800
60" Storm Drain	0	LF	$250.00	$0	30%	$0	$0
2x72" Storm Drain	1,730	LF	$600.00	$1,038,000	30%	$311,400	$1,349,400
Subtotal - Interior Drainage				***$8,103,000***		***$2,430,666***	***$10,532,886***
Earthwork							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Rural)	1	%	1.0%	$0	30%	$0	$0
Levee Fill (for Pad up to Elev 12')	0	CY	$10.00	$0	30%	$0	$0
Subtotal - Earthwork				***$0***		***$0***	***$0***
Floodwalls, Levees, Stoplogs							
Mobilization and Demobilization	1	%	5.0%	$1,049,126	30%	$314,738	$1,363,864
Traffic Control (Rural)	1	%	1.0%	$207,748	30%	$62,324	$270,072
Stripping		CY	$4.00	$0	30%	$0	$0
Clearing and Grubbing		AC	$3,250.00	$0	30%	$0	$0
Borrow Site Excavation		CY	$3.00	$0	30%	$0	$0
Borrow Site Hauling Level 2		CY	$5.50	$0	30%	$0	$0
Borrow Site Restoration		AC	$4,000.00	$0	30%	$0	$0
Sheetpile Floodwall	223,417.0	SF	$85.00	$18,990,445	30%	$5,697,134	$24,687,579
Concrete Cap	281.8	CY	$2,000.00	$563,667	30%	$169,100	$732,767
Active Floodwall - Materials	0.0	SF	$520.00	$0	30%	$0	$0
Active Floodwall - Installation	0.0	SF	$520.00	$0	30%	$0	$0
Steel Railing		LF	$185.00	$0	30%	$0	$0
Dewatering		LF	$75.00	$0	30%	$0	$0
Existing Floodwall to be Raised/Improved		LF	$200.00	$0	30%	$0	$0
Levee Fill	72,065	CY	$10.00	$720,650	30%	$216,195	$936,845
Berm Fill		CY	$10.00	$0	30%	$0	$0
Soil- Bentonite Cutoff Wall		SF	$20.00	$0	30%	$0	$0
Rip Rap - Wall		CY	$225.00	$0	30%	$0	$0
Rip Rap - Levee		CY	$225.00	$0	30%	$0	$0
Stoplog Structure	1	LS	$500,000.00	$500,000	30%	$150,000	$650,000
Subtotal - Levees				***$22,032,000***		***$6,610,000***	***$28,642,000***
ESTIMATED ALTERNATIVE TOTAL				**$61,865,000**		**$18,561,666**	**$80,424,886**

Solano County Water Agency (SCWA)
Rio Vista Flood Protection Measures Feasibility Study
Alternative N-3

Item	Quantity	Unit	Unit Price	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Structure Raising							
Raising Less than 2-feet	68	EA	150,000	$10,200,000	30%	$3,060,000	$13,260,000
Raising Between 2 and 4 feet	84	EA	175,000	$14,700,000	30%	$4,410,000	$19,110,000
Raising Between 4 and 6 feet	51	EA	200,000	$10,200,000	30%	$3,060,000	$13,260,000
Raising Between 6 and 8 feet	15	EA	250,000	$3,750,000	30%	$1,125,000	$4,875,000
Subtotal - Structure Raising				***$38,850,000***		***$11,655,000***	***$50,505,000***
ESTIMATED ALTERNATIVE TOTAL				**$38,850,000**		**$11,655,000**	**$50,505,000**

Alternative N-4

Item	Quantity	Unit	Annual Premium	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Purchasing Flood Insurance in Lieu of Improvements							
Number of Policies for Structures in the FEMA 100-year Floodplain	123	EA	$4,480	$551,040	30%	$165,312	$716,352
Number of Policies for Structures in the FEMA 500-year Floodplain	0	EA	$4,400	$0	30%	$0	$0
Number of Policies for Structures outside of the FEMA 500-year Floodplain	95	EA	$4,400	$418,000	30%	$125,400	$543,400
Subtotal - Flood Insurance				***$970,000***		***$291,000***	***$1,260,000***
ESTIMATED ALTERNATIVE TOTAL				**$970,000**		**$291,000**	**$1,260,000**

Solano County Water Agency (SCWA)
Rio Vista Flood Protection Measures Feasibility Study
Alternative M-1

WOOD RODGERS

Item	Quantity	Unit	Unit Price	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Lands							
Land Acquisition	1.00	LS	$735,000	$735,000	30%	$220,500	$955,500
Subtotal - Lands				***$735,000***		***$221,000***	***$956,000***
Relocations							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Urban)	1	%	3.0%	$0	30%	$0	$0
Remove Existing Concrete		SF	$8.00	$0	30%	$0	$0
Utility Pole Relocation	0	EA	$15,000.00	$0	30%	$0	$0
Misc Dock/Debri Removal	0	LS	$10,000.00	$0	30%	$0	$0
Subtotal - Relocations				***$0***		***$0***	***$0***
Mitigation - Fish and Wildlife							
Environmental Mitigation	1	%	7.0%	$167,580	30%	$50,274	$217,854
Subtotal - Mitigation				***$168,000***		***$51,000***	***$218,000***
Roads							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Urban)	1	%	3.0%	$0	30%	$0	$0
AC Paving Removal	0	SY	$20.00	$0	30%	$0	$0
AC Paving Replacement	0	SY	$130.00	$0	30%	$0	$0
Striping & Signage	0	LF	$3.00	$0	30%	$0	$0
Subtotal - Roads				***$0***		***$0***	***$0***
Interior Drainage							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Rural)	1	%	1.0%	$0	30%	$0	$0
Drainage Swale / Ditch	0	LF	$20.00	$0	30%	$0	$0
Pump Station (3.5 cfs)	0	EA	$1,400,000.00	$0	30%	$0	$0
Pump Station (8 cfs)	0	EA	$1,800,000.00	$0	30%	$0	$0
Outfall Structure	0	EA	$0.00	$0	30%	$0	$0
Gravity Flow Inlet	0	EA	$3,500.00	$0	30%	$0	$0
Pumped Detention	0	EA	$0.00	$0	30%	$0	$0
12" Storm Drain	0	LF	$75.00	$0	30%	$0	$0
18" Storm Drain	0	LF	$100.00	$0	30%	$0	$0
24" Storm Drain	0	LF	$125.00	$0	30%	$0	$0
30" Storm Drain	0	LF	$150.00	$0	30%	$0	$0
36" Storm Drain	0	LF	$175.00	$0	30%	$0	$0
48" Storm Drain	0	LF	$200.00	$0	30%	$0	$0
60" Storm Drain	0	LF	$250.00	$0	30%	$0	$0
2x72" Storm Drain	0	LF	$600.00	$0	30%	$0	$0
Subtotal - Interior Drainage				***$0***		***$0***	***$0***
Earthwork							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Rural)	1	%	1.0%	$0	30%	$0	$0
Levee Fill (for Pad up to Elev 12')	0	CY	$10.00	$0	30%	$0	$0
Subtotal - Earthwork				***$0***		***$0***	***$0***
Floodwalls, Levees, Stoplogs							
Mobilization and Demobilization	1	%	5.0%	$78,982	30%	$23,695	$102,677
Traffic Control (Rural)	1	%	1.0%	$15,640	30%	$4,692	$20,332
Stripping		CY	$4.00	$0	30%	$0	$0
Clearing and Grubbing		AC	$3,250.00	$0	30%	$0	$0
Borrow Site Excavation		CY	$3.00	$0	30%	$0	$0
Borrow Site Hauling Level 2		CY	$5.50	$0	30%	$0	$0
Borrow Site Restoration		AC	$4,000.00	$0	30%	$0	$0
Sheetpile Floodwall	0.0	SF	$85.00	$0	30%	$0	$0
Concrete Cap	0.0	CY	$2,000.00	$0	30%	$0	$0
Active Floodwall - Materials	0.0	SF	$520.00	$0	30%	$0	$0
Active Floodwall - Installation	0.0	SF	$520.00	$0	30%	$0	$0
Steel Railing		LF	$185.00	$0	30%	$0	$0
Dewatering		LF	$75.00	$0	30%	$0	$0
Existing Floodwall to be Raised/Improved		LF	$200.00	$0	30%	$0	$0
Levee Fill	98,900	CY	$10.00	$989,000	30%	$296,700	$1,285,700
Berm Fill	57,500	CY	$10.00	$575,000	30%	$172,500	$747,500
Soil- Bentonite Cutoff Wall		SF	$20.00	$0	30%	$0	$0
Rip Rap - Wall		CY	$225.00	$0	30%	$0	$0
Rip Rap - Levee		CY	$225.00	$0	30%	$0	$0
Stoplog Structure	0	LS	$500,000.00	$0	30%	$0	$0
Subtotal - Levees				***$1,659,000***		***$498,000***	***$2,157,000***
ESTIMATED ALTERNATIVE TOTAL				**$2,562,000**		**$770,000**	**$3,331,000**

Solano County Water Agency (SCWA)
Rio Vista Flood Protection Measures Feasibility Study
Alternative M-2

Item	Quantity	Unit	Unit Price	Cost	Contingency (%)	Contingency ($)	Cost w/Contingency
Lands							
Land Acquisition	1.00	LS	$462,000	$462,000	30%	$138,600	$600,600
Subtotal - Lands				***$462,000***		***$139,000***	***$601,000***
Relocations							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Urban)	1	%	3.0%	$0	30%	$0	$0
Remove Existing Concrete		SF	$8.00	$0	30%	$0	$0
Utility Pole Relocation	0	EA	$15,000.00	$0	30%	$0	$0
Misc Dock/Debri Removal	0	LS	$10,000.00	$0	30%	$0	$0
Subtotal - Relocations				***$0***		***$0***	***$0***
Mitigation - Fish and Wildlife							
Environmental Mitigation	1	%	7.0%	$145,950	30%	$43,785	$189,735
Subtotal - Mitigation				***$146,000***		***$44,000***	***$190,000***
Roads							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Urban)	1	%	3.0%	$0	30%	$0	$0
AC Paving Removal	0	SY	$20.00	$0	30%	$0	$0
AC Paving Replacement	0	SY	$130.00	$0	30%	$0	$0
Striping & Signage	0	LF	$3.00	$0	30%	$0	$0
Subtotal - Roads				***$0***		***$0***	***$0***
Interior Drainage							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Rural)	1	%	1.0%	$0	30%	$0	$0
Drainage Swale / Ditch	0	LF	$20.00	$0	30%	$0	$0
Pump Station (3.5 cfs)	0	EA	$1,400,000.00	$0	30%	$0	$0
Pump Station (8 cfs)	0	EA	$1,800,000.00	$0	30%	$0	$0
Outfall Structure	0	EA	$0.00	$0	30%	$0	$0
Gravity Flow Inlet	0	EA	$3,500.00	$0	30%	$0	$0
Pumped Detention	0	EA	$0.00	$0	30%	$0	$0
12" Storm Drain	0	LF	$75.00	$0	30%	$0	$0
18" Storm Drain	0	LF	$100.00	$0	30%	$0	$0
24" Storm Drain	0	LF	$125.00	$0	30%	$0	$0
30" Storm Drain	0	LF	$150.00	$0	30%	$0	$0
36" Storm Drain	0	LF	$175.00	$0	30%	$0	$0
48" Storm Drain	0	LF	$200.00	$0	30%	$0	$0
60" Storm Drain	0	LF	$250.00	$0	30%	$0	$0
2x72" Storm Drain	0	LF	$600.00	$0	30%	$0	$0
Subtotal - Interior Drainage				***$0***		***$0***	***$0***
Earthwork							
Mobilization and Demobilization	1	%	5.0%	$0	30%	$0	$0
Traffic Control (Rural)	1	%	1.0%	$0	30%	$0	$0
Levee Fill (for Pad up to Elev 12')	0	CY	$10.00	$0	30%	$0	$0
Subtotal - Earthwork				***$0***		***$0***	***$0***
Floodwalls, Levees, Stoplogs							
Mobilization and Demobilization	1	%	5.0%	$77,263	30%	$23,179	$100,442
Traffic Control (Rural)	1	%	1.0%	$15,300	30%	$4,590	$19,890
Stripping		CY	$4.00	$0	30%	$0	$0
Clearing and Grubbing		AC	$3,250.00	$0	30%	$0	$0
Borrow Site Excavation		CY	$3.00	$0	30%	$0	$0
Borrow Site Hauling Level 2		CY	$5.50	$0	30%	$0	$0
Borrow Site Restoration		AC	$4,000.00	$0	30%	$0	$0
Sheetpile Floodwall	0.0	SF	$85.00	$0	30%	$0	$0
Concrete Cap	0.0	CY	$2,000.00	$0	30%	$0	$0
Active Floodwall - Materials	0.0	SF	$520.00	$0	30%	$0	$0
Active Floodwall - Installation	0.0	SF	$520.00	$0	30%	$0	$0
Steel Railing		LF	$185.00	$0	30%	$0	$0
Dewatering		LF	$75.00	$0	30%	$0	$0
Existing Floodwall to be Raised/Improved		LF	$200.00	$0	30%	$0	$0
Levee Fill	98,900	CY	$10.00	$989,000	30%	$296,700	$1,285,700
Berm Fill	0	CY	$10.00	$0	30%	$0	$0
Soil- Bentonite Cutoff Wall	27,048	SF	$20.00	$540,960	30%	$162,288	$703,248
Rip Rap - Wall		CY	$225.00	$0	30%	$0	$0
Rip Rap - Levee		CY	$225.00	$0	30%	$0	$0
Stoplog Structure	0	LS	$500,000.00	$0	30%	$0	$0
Subtotal - Levees				***$1,623,000***		***$487,000***	***$2,110,000***
ESTIMATED ALTERNATIVE TOTAL				**$2,231,000**		**$670,000**	**$2,901,000**