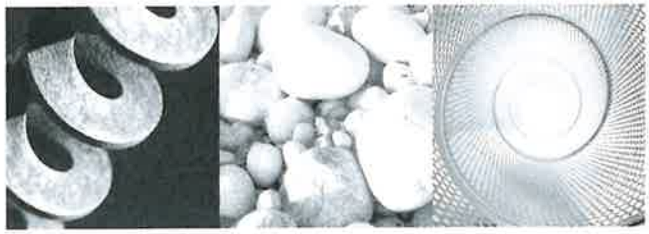
Geotechnical Data Report

NOVATO CREEK LEVEE EVALUATION

PREPARED FOR:

Marin County Flood Control and Water Conservation District

January 2020



GEI Consultants

Consulting
Engineers and
Scientists

Geotechnical Data Report

Novato Creek Levee Evaluation Project

Novato, California

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Table of Contents

Tables

Figures

Appendices

Abbreviations and Acronyms

ASTM	American Society for Testing and Materials
Cascade	Cascade Drilling, L.P.
CLE	CLE Engineering Inc
CPT	Cone Penetration Test
District	Marin County Flood Control and Water Conservation District
DWR	California Department of Water Resources
GDR	Geotechnical Data Report
GEI	GEI Consultants, Inc.
HASP	Health and Safety Plan
ID	Inner Diameter
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NFCP	Novato Flood Control Project
Novato Creek LB us 37	Novato Creek Left Bank Levee upstream of SR-37
OD	Outer Diameter
SMART Transit	Sonoma Marin Area Rail Transit
SPT	Standard Penetration Test
SR-37	State Route 37
USA	Underground Service Alert
USACE	United States Army Corps of Engineers
WGS 84	World Geodetic System 1984

1. Introduction

This Geotechnical Data Report (GDR) presents the results of a geotechnical investigation by GEI Consultants, Inc. (GEI) and summarizes results of pertinent previous investigations. This GDR will be used in support of alternatives evaluations for the Novato Creek levees.

1.1 Site Overview

The Novato Creek levees are located in the Novato Creek watershed within Flood Zone 1 of the Marin County Flood Control and Water Conservation District (District). The watershed is at the northwestern extent of San Pablo Bay and is the largest watershed in eastern Marin County (Figure 1). Novato Creek flows east through the City of Novato and empties into San Pablo Bay near the mouth of the Petaluma River.

The project levees are located along Duckbill Pond, Heron's Beak Pond between the Sonoma-Marin Area Transit (SMART) Railroad Bridge and State Route 37 (SR-37), the Pacheco Pond Levee, and the left bank of Novato Creek as shown in Figures 2 and 3.

The Novato Creek Left Bank Levee upstream of SR-37 (Novato Creek LB us 37) is approximately 8,500 feet long beginning at the SMART railroad bridge on the north side of Novato Creek and continues to the SR-37 bridge (Figure 2).

The Lynwood Levee adjacent to Duckbill and Heron's Beak Ponds extend approximately 6,800 feet between the SMART railroad bridge and SR-37 (Figure 2). It separates the 278-acre Lynwood stormwater detention basin on the west side from the two wildlife preserve ponds on the east. The Lynwood stormwater detention basin is owned by the State of California Department of Fish and Wildlife, is gravity-fed, and serves as both a stormwater detention area for a large portion of residential and commercial properties to the west and as a wildlife preserve.

Pacheco Pond is a stormwater detention basin and wildlife habitat pond located south of SR-37 (Figure 3). The pond is bordered by Bel Marin Keys Blvd to the north, the commercial Ignacio Industrial Park to the west, vacant City of Novato lands to the southwest and the State of California lands to the southeast. The eastern border of Pacheco Pond is held by an earthen levee approximately 3,400 linear feet in length. Pacheco Pond covers an area of approximately 120 acres and is fed by Pacheco Creek and Arroyo de San Jose.

1.2 Project Description

Field investigation for this GDR entailed performing additional subsurface investigation to supplement existing data. The new and existing geotechnical data will be used in support of a geotechnical evaluation of the Novato Creek LB us 37, Lynwood Levee, and Pacheco Pond Levee.

Existing information was reviewed to plan the field and laboratory investigations. A summary of previous relevant reports within the project area and current site conditions is provided in Appendix A.

This GDR summarizes data collection, subsurface investigations, and laboratory testing performed as part of this project. This report includes boring logs, laboratory test results, and maps showing current and historic exploration locations along the Novato Creek levee system and Pacheco Pond.

The scope of this GDR includes:

- Reviewing existing geotechnical information and summarizing pertinent data
- Completing six exploratory mud-rotary borings along the Novato Creek LB us 37, Lynwood Levee, and Pacheco Pond levee crowns
- Completing 19 cone penetration tests (CPTs) at the levee crown and landside levee toe along the Novato Creek LB us 37, Lynwood Levee, and Pacheco Pond Levee
- Geotechnical laboratory testing on selected soil samples collected during drilling
- Preparing this GDR

1.3 Elevation Datum, Horizontal Coordinates, and Levee Stationing

This GDR provides elevation references in feet, based on the North American Vertical Datum of 1988 (NAVD 88). Survey data, elevations and horizontal coordinates are provided in the California State Plane Coordinate System. The levee stationing is a project-specific stationing system developed by GEI. GEI stationing was developed to provide unique station alignments that the County can use for future projects. Separate stationing alignments were created for the Novato Creek LB us 37 (NCLB), Lynwood Levee (LL), Duck Bill Levee (DB), Heron's Beak Levee (HB), Deer Island Cross Levee (DI), and Pacheco Pond Levee (PP). As shown in Figures 2 and 3, the alignment stationing for the project levees are as follows:

- The Novato Creek LB us 37 starts at Station NCLB 225+36 (near SR-37) and ends at Station NCLB 310+00 (near the SMART railroad bridge).
- The Lynwood Levee starts at Station LL 242+16 (near SR-37) and ends at Station LL 310+00 (near the SMART railroad bridge).

- The Duck Bill Levee starts at Station DB 0+00 (near approximate Station LL 291+00) and ends at Station DB 28+81 (near the SMART railroad bridge).
- The Heron's Beak Levee starts at Station HB 0+00 (near approximate Station LL 243+50) and ends at Station HB 43+37 (near approximate Station LL 281+00).
- The Deer Island Cross Levee starts at Station DI 0+00 (near approximate Station NCLB 247+00) and ends at Station DI 6+39 (at the northeast end of the levee).
- The Pacheco Pond Levee starts at Station PP 10+00 (at the northwest end of the levee) and ends at Station PP 43+90 (at the southeast end of the levee).

2. Site Conditions

2.1 Introduction

As mentioned above, several previous geotechnical reports were reviewed by GEI prior to development of the *Geotechnical Exploration Work Plan, Novato Creek Levee Evaluation Project* (Work Plan) in Appendix B. These documents provide discussion of surface and subsurface conditions encountered during subsurface exploration, levee penetrations, and boring log and geotechnical laboratory testing data. A brief summary of this information, along with newly-collected information, is provided below in the existing data summary section. Refer to Appendix A for a more detailed discussion of these historical reports.

The locations of the new explorations and historical explorations by others are shown for reference in Figures 2 and 3. It should be noted that the stationing alignments included on these figures refer to GEI stationing developed for this evaluation project and not the original United States Army Corps of Engineers (USACE) channel centerline station alignment. GEI stationing was developed to provide unique station alignments to aid in developing this report and future analyses of potential levee remediations.

2.2 Topographic Data

The topographic data utilized for project evaluations was provided by the District. Three separate data sets were provided, which include:

- 2016 topographic survey data from CLE Engineering Inc., (CLE)
- 2018 topographic and bathymetric data from CLE (report can be found in Appendix C)
- County of Marin digital topographic-bathymetric surface model, Revision 2013.12.18.

Brief descriptions of these datasets are provided in the following sections.

2.2.1 2016 Topographic Survey from CLE Engineering Inc.

In 2016, CLE conducted a topographic survey along levees surrounding Deer Island, North Deer Island, and Lynwood Basin which included the Lynwood Levee, Novato Creek LB us 37 (excluding an approximate 2,200 feet section just north of SR-37), and the Deer Island Cross Levee.

2.2.2 2018 Topographic and Bathymetric Survey from CLE Engineering Inc.

In 2018, GEI contracted CLE to survey areas within project limits that were missing from CLE's 2016 topographic survey. CLE utilized a Leica System 1200 Real-Time Kinematic GPS system to collect topographic data along the Pacheco Pond Levee, Novato Creek LB us 37 (an approximate 2,200 feet section just north of SR-37), along Lynwood Basin Southwest

Levee (located outside project limits), and within Heron's Beak Pond. Only the crown along the Lynwood Basin Southwest Levee was surveyed since excessive vegetation prevented CLE personnel from accessing the side-slopes. CLE also utilized a Teledyne Odom CVM (200 kHz) single-beam echosounder system to collect bathymetric data within Novato Creek and Duckbill Pond. Survey data delivered by CLE was presented using the North American Datum 1983 (NAD 83) as the horizontal datum and NAVD 88 as the vertical datum. The Upper Novato Creek Bathymetric and Topographic Surveys report prepared by CLE can be found in Appendix C.

2.2.3 County of Marin Digital Topographic-Bathymetric Surface Model

The County of Marin digital topographic-bathymetric surface model, Revision 2013.12.18, is a 50 cm gridded surface exported from an ESRI Terrain Dataset which includes bare earth topographic and bathymetric elevation surfaces for Marin County and surrounding areas. The Terrain Dataset was developed from multiple source datasets including airborne LiDAR ground-classified points, and multi-beam sonar bathymetric grids. This surface is the fourth edition of an integrated county-wide terrain model of Marin County, California. Airborne LiDAR surveys were flown between 2007 and 2010 and multiple bathymetric datasets were fused into a single ESRI Terrain Dataset to develop a best-available surface. The coordinate system datum for this surface model is World Geodetic System 1984 (WGS 84, Geoid 2003) and the vertical datum is NAVD 88. Elevation values are provided in meters and were converted to feet (by GEI) for project use.

2.3 Surficial Geomorphic Assessment

The levees within the project site are interpreted to be underlain by Quaternary alluvium and marine deposits (Q) from the Pleistocene to Holocene age as shown in Figure 4. The soil is interpreted to be mostly alluvium, lake, playa, and terrace deposits that are unconsolidated or semi-consolidated. The area northeast of the project site contains soils that are interpreted to be Franciscan schist (KJfs) from the early Cretaceous period. The soil in this area is interpreted to be blueschist and semi-schist from the Franciscan complex which includes Cretaceous and Jurassic sandstone with smaller amounts of shale, chert, limestone, and conglomerate.

2.4 Description of Levees

The Novato Creek LB us 37 has a crown width that typically ranges from approximately 13.0 to 21.3 feet and ranges in elevation between 10.5 to 15.3 feet (NAVD 88). The waterside slope typically ranges between 1.3H:1V to 2.7H:1V but can have a slope as flat as 4.8H:1V. The landside slope typically ranges between 1.5 H:1V to 2.2 H:1V but can be as steep as 1.1 H:1V and have a slope slightly flatter with a 2.7 H:1V slope.

The Pacheco Pond Levee has a crown width that typically ranges from approximately 8.2 to 17.1 feet and ranges in elevation between 7.3 to 13.0 feet (NAVD 88). The waterside slope typically ranges between 3.6 H:1V to 4.2 H:1V, but can be as flat as 6.6 H:1V near the north end of the levee. The landside slope typically ranges between 1.9 H:1V to 2.7 H:1V, but can be flatter with a slope up to 3.9 H:1V near the north end of the levee.

The Lynwood Levee has a crown width that typically ranges from approximately 19.0 to 69.0 feet and ranges in elevation between 10.8 to 17.2 feet (NAVD 88). The waterside slope typically ranges between 1.5 H:1V to 2.6 H:1V, but can be as flat as 4.1 H:1V. The landside slope typically ranges between 1.4 H:1V to 2.2 H:1V, but can be as flat as 5.5.

2.5 Construction History

Flood Control Zone No. 1 (Zone) was formed in 1955 to address flooding issues in downtown Novato and surrounding areas and encompasses the entire City of Novato as well as a sizeable amount of unincorporated area around the City, making it the County's largest flood control zone. The Zone includes the entire watershed tributary to Novato and Rush Creeks, which includes the project levees (Novato Creek LB us 37, Lynwood levee, and Pacheco Pond Levee). This area has regularly experienced significant flooding, especially in the areas of Novato where two major creeks converge (Novato and Warner Creeks). In 1984, the residents of Novato voted to fund the Novato Flood Control Project (NFCP). The NFCP was implemented in eight phases that began in 1985 and was completed in 2006. In addition to these improvements, maintenance of lower Warner, Arroyo Avichi, and Novato Creek has required the District to conduct sediment removal operations comprising a range of 25,000-75,000 cubic yards of sediment removal every 4-years to provide the design-level (50-year) flood protection.

The District constructed the Lynwood Levee with crest elevations of 14 to 15 feet (NAVD 88); 1 to 2 feet higher than Duck Bill Levee and Heron's Beak Levee. Essentially, the Lynwood Levee is a setback levee to the existing Duck Bill Levee and Heron's Beak Levee and may be the future primary flood protection structure on the right bank of Novato Creek. This levee protects homes, businesses and two pump stations operated and maintained by the District. Failure of the Lynwood Levee would likely cause upstream stormwater flooding and possibly tidal water to flow upstream through the system.

Pacheco Pond was created in 1980 as mitigation for construction of the adjacent Ignacio Industrial Park. The pond is fed by Arroyo de San Jose and Pacheco Creeks and is maintained both as a flood control basin and as wildlife habitat. These two creeks, which serve 18 percent of the Novato watershed drainage area, generate significant discharges to Novato Creek. Inflows from these large and steeply-sloped drainages have a relatively short travel time to Pacheco Pond, but can only flow to Novato Creek during periods of low tide when water levels in Pacheco Pond are higher than tidal elevations in Novato Creek. The tide gates also limit brackish water incursions into this predominantly freshwater pond and preserve Pacheco Pond for stormwater storage. Additionally, the tide gates accommodate creek flow from Pacheco Creek and Arroyo de San Jose that cannot drain against Novato Creek high tides.

2.6 Existing Data Summary

Historical geotechnical reports were reviewed by GEI prior to development of the Work Plan. These documents provide discussions of surface and subsurface conditions encountered during subsurface exploration as well as boring logs and geotechnical laboratory testing data. A summary of the relevant geotechnical reports reviewed is provided below.

- Kleinfelder, 2004: Geotechnical investigation for Lynwood Pump Station and Cheda Pump Station. Three borings were completed along the Lynwood Levee, within the current project area. Preliminary geotechnical evaluations for seismic site characterization were performed and recommendations were made for the geotechnical aspects of the proposed improvements.

- Kleinfelder, 2011: Geotechnical investigation for the preliminary engineering phase of the SMART Project. Borings and CPTs were performed as part of the investigation. Geotechnical recommendations were developed to support the engineering of various structures.

- Hultgren-Tillis, 2016: Geotechnical evaluation of dredge stockpiles at the Gnoss Field and Lynwood Levee for use in constructing a new detention basin along Novato Creek. The report includes boring and hand auger logs for borings along Heron's Beak Pond.

- Hultgren-Tillis, 2017: Geotechnical analysis and design for a planned detention basin levee for the North Deer Island Flood Protection Project. Tasks included borings and CPTs, geotechnical evaluations, and geotechnical recommendations for the construction of the basin levee and facilities. The report includes a geologic map of the current project area, a generalized subsurface profile, laboratory data, and seepage and stability analyses.

- Hultgren-Tillis, 2017: Geotechnical investigation for the Novato Creek Levee project located along the Novato Creek LB us 37 adjacent to the Deer Island Basin. This investigation was performed to evaluate a crack and slump that developed along the levee crest. Conclusions and recommendations for remediation were presented in the report.

The locations of the identified historic explorations by others are shown for reference on Figures 2 and 3, along with the 2018 GEI explorations.

2.7 Past Performance

Flooding has occurred in Flood Zone 1 with varying degrees of severity over 30 times in the last 150 years, with Novato Creek experiencing the most severe impacts. In recent history, the winter storms of 1970, 1973, 1982, 1983, 1986, 1998, 2005, 2006, 2014, and 2016/17 caused significant damage. Novato Creek in the northern part of the county historically has caused damage to large numbers of homes in the 1960's through the early 1980's until the initial phases of the Novato Flood Control Project were completed.

On December 10-11, 2014, a combination of high tides and high intensity rains resulted in overtopping of the right bank levee, a breach of Lynwood Levee into the Lynwood Basin, and one intentional breach of the Novato Creek LB us 37 into Deer Island Basin. The first two sites mentioned were repaired in 2015 as part of the Novato Creek Levee Repair Project, and the intentional breach was temporarily repaired after the storm event, and then more permanently repaired as part of the 2016 Novato Creek Sediment Removal Project. Additionally, the December 2014 storm/high tide event resulted in the Pacheco Pond water level coming within inches of overtopping its east levee, but no overtopping occurred. However, the Pacheco Pond Levee had reportedly breached several years ago at the southern-most end and was repaired by the District as a result. No District records of the levee failure cause or its repair have been located. Further detail of these failures as described by the district are outlined below:

- About 370-ft downstream of SMART Railroad Bridge (2014): A 20-foot-wide section of the Novato Creek LB us 37 was intentionally breached into Deer Island Basin during the December 2014 storm as an emergency measure to direct water away from downtown businesses and nearby subdivisions. In 2016 an approximate 100 linear foot section of the left bank levee was rebuilt to be self-eroding as designed by Hultgren & Tillis Engineering. The design is intended to allow the top two-feet of the levee/weir to erode at high flow conditions thereby relieving hydrologic pressures upstream. The geotechnical assessment shall maintain the erodible weir section to its current configuration.

- Between Lynwood Basin and Duck Bill Pond (2014): Approximately 230-ft downstream from the SMART Railroad Bridge a 20-foot concaved section of the Lynwood Levee between Duck Bill Pond and Lynwood Basin on the Lynwood-side blew out at an abandoned 60-inch culvert that once connected Duck Bill Pond and Lynwood Basin. Water had overtopped the Novato Creek right bank levee into Duckbill Pond filling the pond and creating enough head pressure to induce the blow-out. The abandoned culvert was removed, and the levee repaired in 2015.

- Between Novato Creek and Heron's Beak Pond (2014): A 450+/- feet section of Heron's Beak Levee overtopped into Heron's Beak Pond about 1,500 feet upstream from the SR-37 Bridge. In addition, 450+/- feet of Heron's Beak Levee had extensive piping at rodent holes in the levee. The piping and overtopping caused noticeable erosion, however the levee remained standing. In 2015 a section in the center of the levee was excavated and re-compacted to repair the damage caused by rodent holes.

- Between Novato Creek and Heron's Beak Pond (2017): During the storms of 2017, approximately 1,000-ft downstream of the Lynwood Pump Station outfall, the Heron's Beak Levee breached. On a post-storm inspection, the six-foot wide breach was noted to have been likely caused by rodent piping. Water from Novato Creek then flowed into Heron's Beak Pond. The District installed an emergency temporary repair of the breach with an inner rock core, and earthen fill over the rock and plastic cover-sheeting.

- Leveroni Levee Downstream of Hwy 37 (2017): Two levee breach-points occurred on the Leveroni Levee about 1,500 feet downstream of SR-37 during strong storm and high tides events in 2017. The breaches largely contributed to flooding and subsequent closure of SR-37. As-Built information from Caltrans is available if needed to the selected Consultant. Although the right bank levee where the breaches occurred is privately owned and maintained, the District owns and maintains the left bank levee along the same reach. As a result, there is a strong desire to conduct a condition analysis on the District-owned Novato Creek Left Bank Levee downstream of SR-37.

- Sections of Heron's Beak Levee (2017): A small section of levee, approximately 1,000 feet downstream from the Lynwood Pump Station outfalls, along the Heron's Beak Levee failed sometime during storm events in January 2017. Upon investigation of the breach, District engineers determined that the breach was caused by rodent boring holes resulting in piping at high water flow of Novato Creek. Repairs were completed in February 2017.

- Sections of Lynwood Levee on the inside bank within Heron's Beak Pond: Following the Heron's Beak Levee breach in early 2017, District Engineers conducted a visual inspection of the Duck Bill Levee, Heron's Beak Levee, and the Lynwood Levee. Several points on the Pond-side of the levees were noted to have sustained erosion leaving near vertical bank cuts in several locations. Initial repairs to the Lynwood Levee embankments within the pond were completed in the summer of 2017, and repairs were completed in 2018.

Accelerated bank erosion was noted in 2016-2017 along portions of Lynwood Levee and the Heron's Beak Levee. These levees are maintained by the District, which completed temporary repairs after the storm using private contractors. Another levee breach that occurred during the 2016-17 storms included the Leveroni Levee about 1,000-ft downstream of SR-37. This is a privately-owned and maintained levee.

More recently, on February 14, 2019, two levees were breached during a storm. The first levee breach occurred along the Novato Creek Left Bank Levee downstream of SR-37 (located outside of project limits) as shown in Figure 2. Novato Creek was flowing at full capacity as Northwest Pacific Railroad tracks were left suspended above flood waters due to significant levee failure as a field to the south of SR-37 became flooded. The second levee breach occurred along the Pacheco Pond Levee between Station PP 31+00 and PP 32+00 as shown in Figure 3. Approximately 75 to 100 feet of levee was blown out in an area just north of the location of GEI_005B. In addition to the levee breaches, a portion of the Novato Creek LB us 37 (from approximate Station NCLB 225+36 to NCLB 235+00) and Lynwood Levee (from approximate Station LL 242+16 to LL 247+50) overtopped during the same storm event as shown in Figure 2.

2.8 General Subsurface Conditions

Marin County is located in the Coast Ranges Geomorphic Province of Northern California. The region consists of bedrock materials of the Franciscan formation subjected to faulting and folding overlain by younger alluvial, fluvial, and Bay Mud deposits. The alluvial materials vary in depths up to about 60 feet below ground surface.

The project site is generally underlain by Bay Mud, which consists of silt and clay with peat, organics, and fine sands. The Bay Mud varies in thickness and is estimated to be about 5 to 60 feet thick. The project levees were constructed with Bay Mud. Below the Bay Mud are alluvial soils consisting of interbedded silt, clay, sand, and gravel. Franciscan Formation bedrock in the area varies between about 35 to 75 feet below ground surface.

2.9 Groundwater Conditions

Our 2018 explorations encountered groundwater at elevations ranging from approximately -5.0 to 6.4 feet NAVD 88 (Table 1). Our review of historical boring logs only revealed two boring logs with depths to groundwater listed. These two borings (B1 and B2) were completed in 2017 near Station NCLB 250+00 along the Novato Creek LB us 37 (Figure 2) as part of a longitudinal levee crack study and encountered groundwater at an elevation of 0.4 feet NAVD88 (B1) and -4.2 feet NAVD88 (B2).

3. Field Investigation

3.1 General

The field exploration program summarized in this report was generally performed as described in the Work Plan (Appendix B).

The selection of subsurface exploration locations, sampling intervals, sample types, and exploration depths was based on several factors, including available geotechnical data from past investigations, and USACE guidance as described in the *Geotechnical Levee Practice*, REFP10L0 (USACE, 2008). Table 1 summarizes the subsurface explorations performed as part of this investigation. Figures 2 and 3 show an aerial image of the Novato Creek levee system, the levee alignment and GEI levee stationing, recent and historical exploration locations, and areas of past performance issues. Project boring logs are included in Appendix D of this report and the CPT report and logs are included in Appendix E as part of the ConeTec report.

Review of the historical subsurface investigations provided information on the subsurface materials at the site. This knowledge allowed the project team to evaluate conditions and to select the appropriate exploration strategy and equipment. Specific considerations relative to the investigation approach included:

- The presence of soft bay mud deposits generally increasing in stiffness with depth below the levee fill material;
- Areas of fill including the levee embankment and landside areas;
- The depth to bedrock below soft bay mud deposits;
- The presence of organics within soft bay mud deposits.

Based on these considerations, an investigation program was developed utilizing mud rotary and auger borings and CPTs through the levee crown and levee toe.

Prior to the start of field investigations, the goals and challenges of the exploration program were identified through discussion and site reconnaissance with District staff and exploration subcontractors. Because this project involved exploration activities in a number of parcels owned by the California Department of Water Resources (DWR) and the District, site access agreements in these areas were coordinated during the investigation program planning by GEI personnel. Other significant considerations of the exploration program included:

- Project goals and objectives;

- Project Health and Safety Plan (HASP)
- The scope of field investigations;
- Sampling procedures and sample requirements;
- Specific sampling targets and strategies to optimize sampling methods;
- Exploration depth targets;
- Site access and contact information;
- Utility clearance and permits;
- Site security and noise;
- Backfill requirements;
- Disposal of cuttings;
- Site restoration requirements;
- Applicable standards (DWR Division of Flood Management *Soil and Rock Logging, Classification, Description and Presentation Manual,* September 2009, American Society for Testing and Materials (ASTM) standards, and USACE guidance).

3.2 Health and Safety

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

3.3 Marin County Drilling Permits

A Marin County "permit for test holes/soil borings" was issued by the Environmental Health Services Department. The permit is applicable for one year, beginning on September 5, 2018. The permit requires that field operations follow all Marin County rules, regulations, codes, laws and statutes as per County well drilling procedures. Exploration permit documentation is contained in Appendix F.

3.4 Utility Clearance

Each exploration location was initially chosen after a review of available maps and plans containing utility information. The locations were visually observed for the presence of overhead and underground utilities and then outlined in white paint as required by Underground Service Alert (USA). USA was then contacted a minimum of 48 hours before subsurface investigation of the site. A USA ticket number as well as the clearance date, expiration date and extension date were obtained for the work area and documented in the project file.

3.5 Exploratory Program Description

Historical geotechnical exploration data was evaluated during preparation of the subsurface investigation work plan for Novato Creek. Based on this review, subsurface exploration locations were chosen to:

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

Table 1 summarizes the subsurface explorations completed by GEI in 2018.

Auger and mud rotary borings were drilled by Cascade Drilling, L.P., (Cascade) of West Sacramento, California. CPT explorations were conducted by ConeTec of San Leandro, California. GEI personnel coordinated and observed the drilling program, logged the borings, and collected and transported the soil samples to the laboratory.

The exploration program consisted of 25 explorations and 21 of the explorations were located on the levee crest with four located along the landside toe. The 25 explorations consisted of six geotechnical borings and 19 CPTs. The CPTs were completed between September 24, 2018 and October 2, 2018, prior to the start of drilling activities so that we would have additional data to help plan the drilling program. Hollow stem auger/mud rotary drilling followed, with the intent of focused sampling based on information from the CPT explorations. Drilling occurred between November 5, 2018 and November 12, 2018. Exploration types, locations, and depths are summarized in Table 1, and are shown in Figures 2 through 4.

Sampling of the subsurface material was performed using Shelby tube samplers and Standard Penetration Test (SPT) samplers. The type of sampler used at each sampling depth interval was determined by the sampling protocol and/or the material encountered or expected. Drive samples were driven using an automatic trip 140-pound hammer with a free fall of 30 inches.

The relatively undisturbed samples in the thin-walled Shelby tubes were labeled in the field and carefully transported from the site in an upright position to preserve the sample integrity. The samples were submitted to Geocon Consultants, Inc., in Rancho Cordova, California for testing and analysis.

3.5.1 Rationale for Project Explorations

3.6 Cone Penetration Testing

CPT is a direct-push technology where an instrumented cone is pushed into the ground at a constant rate. Sensors in the cone provide essentially continuous measurements of tip resistance, sleeve friction, and dynamic pore pressure. From this data, engineering parameters can be derived or estimated using correlations, including friction ratio, undrained shear strength, equivalent blow counts, and soil behavior type (a proxy to textural identification).

CPT soundings were performed in general accordance with ASTM D5778 using truck-mounted rigs with either a 20-ton ram or a 30-ton ram along the Novato Creek LB us 37 and Lynwood Levee and a track rig along the Pacheco Pond Levee. The conventional instrumented cone assembly was used, which includes a cone tip with a 60-degree apex and a base area of 15 square centimeters (cm^2), a sleeve segment with a surface area of 225 cm^2, and a pore pressure transducer near the base (shoulder) of the cone tip.

During the test, the instrumented cone was hydraulically pushed into the ground at a rate of about 2 centimeters per second (cm/s), and readings of cone tip resistance, sleeve friction, and pore pressure were digitally recorded every second. As the cone tip advanced, additional cone rods were added so that a "string" of rods continuously advanced through the soil. As the test progressed, the CPT operator monitored the cone resistance and its deviation from vertical alignment. A log of the CPT sounding was produced on a real-time basis.

Pore pressure dissipation tests were conducted during each CPT sounding, typically within granular materials below the water table. The test results were used to estimate the depth to groundwater. In a dissipation test, the CPT sounding is advanced to the estimated test depth, or as directed by the field inspector, and then paused. The changes in the “dynamic” pressures is then monitored. Pore pressure data during the test are digitally recorded for subsequent analyses. After the dissipation test data are recorded, cone advancement is resumed. The interpreted depth to groundwater from the pore pressure dissipation tests is summarized in Table 1.

Following completion of each CPT sounding, the CPT rods (which contain the wiring for the cone) were removed from the hole and replaced with tremie pipe for backfilling the hole with neat cement grout to ground surface.

The exploration plan included 19 CPTs, 15 of the CPTs were advanced through the levee crown and the remaining four were advanced at the landside toe of the levee. It is important to note that GEI_005C_Toe was attempted twice since the first attempt was stopped early as the CPT rig anchors began to slip once the cone reached an approximate depth of 22 feet and could not be advanced any further. The second attempt for GEI_005C_Toe (denominated as CPT-TOE-05B by ConeTec) was approximately five feet away from the location of the first attempt (CPT-TOE-05) but also faced anchor slippage at a similar cone depth and was stopped. Note that ConeTec's report (found in Appendix E) refers to the CPT explorations as "CPT-XX" or "CPT-TOE-XX" while this GDR refers to the same explorations as "GEI-0XXC" or "GEI-0XXC_Toe" where XX indicates the exploration number (between 01 and 15). It is also important to note that proposed CPT location GEI_016C was not completed due to refusal in near-surface concrete rubble/fill. This proposed CPT location was replaced with a geotechnical boring more capable of penetrating the near-surface materials. Boring GEI_006B was completed at the Pacheco Pond Levee to replace proposed CPT GEI_016C (Figures 3 and 4).

A complete report on the CPT soundings, which includes a detailed description of the methods and equipment used to advance the soundings, as well as profiles of the CPTs and the results of the pore pressure dissipation tests, is included in Appendix E.

3.7 Hollow-Stem Auger and Mud Rotary Drilling

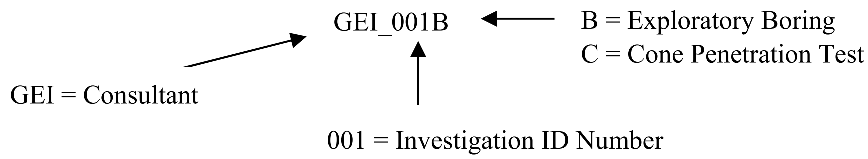
The borings for this project were completed using a combination of hollow-stem auger and mud-rotary drilling methods. Each location was hand-augured by Cascade to a depth of one to five feet prior to drilling. Hollow-stem augers were then used to advance the boring to the base of the levee, at which time mud-rotary drilling methods were used to drill and sample to total depth. A Diedrich D50 Turbo track-mounted drill rig was used for all the soil borings. All the borings were advanced to a minimum depth of approximately four times the levee height.

A total of five borings were planned for the investigation (GEI, 2018). However, six borings were completed. As described above, the additional, sixth boring (GEI_006B) was completed at the Pacheco Pond Levee to replace proposed CPT GEI_016C. All the borings were advanced through the levee crown. Groundwater was not observed during drilling in most of the borings due to the mud rotary drilling method, except for at boring GEI_006B, where groundwater was encountered at a depth of about 15 feet during hollow-stem auger drilling. Soil sampling and logging was completed as the borings were advanced.

The hollow-stem auger portions of each boring were drilled using approximately 6-inch diameter hollow-stem augers. The deeper, mud-rotary portions of each boring were completed using a 3.75-inch diameter tri-cone bit at the end of NWJ-size rods, or, in the case of GEI_006B, a 6-inch diameter face-discharging bit.

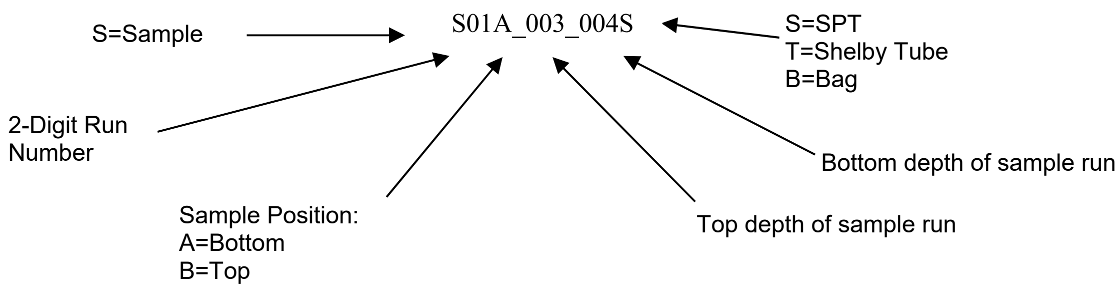
3.7.1 Naming of Explorations

Exploration locations were named by listing GEI first (Consultant), followed by a boring identification number and the type of exploration performed. An example of the exploration naming scheme is provided below:



3.7.2 Geotechnical Sampling within Soil Borings

For hollow-stem auger/mud-rotary borings, soil samples were collected within the levee embankment and foundation using drive and push samplers at 2.5-foot intervals. Samples were numbered as shown below. Note that sample depths used in the numbering protocols are rounded up to the nearest 1-foot interval.



3.8 Soil Sampling and Classification

Soil materials were sampled using drive samplers and push sampling methods. Drive sampling was performed using a SPT 1.375-inch inner diameter (ID) and 2.0-inch outer diameter (OD) sampler without liners. Relatively undisturbed samples of fine-grained materials were collected using 2.87-inch ID, 3-inch OD, 30-inch or 36-inch long Shelby tube samplers. The rig pull-down pressure was monitored during sampling with the Shelby tube and recorded on the boring logs. Drive sampling was performed in general accordance with ASTM D1586, ASTM D1587, and ASTM D6066.

The SPT samplers were driven using NWJ rods and a 140-pound automatic trip hammer falling from a height of 30 inches. In most cases, the sampler was driven 18 inches and the number of hammer blows needed to drive the sampler every 6 inches of the 18-inch-drive were recorded and are shown at the corresponding sample location on the boring logs.

A field boring log was completed for each boring. Soil logging generally conformed to the Work Plan (Appendix B). Soil classifications were refined using the laboratory test results in general accordance with ASTM D2487. Final boring logs and a boring log explanation sheet are presented in Appendix D.

Subsurface conditions observed in soil samples and drill cuttings or perceived through the performance of the drill rig (e.g., ease or difficulty of drilling, rig chatter) were described in the “Remarks” column on the log. Besides descriptions of individual soil samples, the boring logs show the top and bottom of soil layers. Descriptions were included for each soil layer, with horizontal lines drawn to separate subjacent layers.

Following completion of drilling and sampling activities, boreholes and CPT holes were backfilled with neat cement grout. Grout was placed into the borehole through a tremie pipe with its tip placed at the bottom of the borehole. The end of the tremie pipe was kept in the grout as it filled the borehole. When the grout appeared at the surface, the tremie pipe was withdrawn. As the tremie pipe was withdrawn, additional grout was added to make up for the lost volume.

Fluid used during drilling was contained and recirculated in an above-ground steel mud tub. The cuttings/fluid were transferred to 55-gallon drums and disposed of by Cascade.

3.9 Documentation of Exploration Locations

Field personnel used a handheld Trimble Geo7X global positioning system (GPS) unit to record the location of each boring. ConeTec personnel recorded each of the CPT sounding locations using a GPS unit. Horizontal coordinates are provided in terms of latitude and longitude. Topographic survey data was used to estimate the ground surface elevations at the exploration locations. The vertical datum is NAVD 88.

3.10 Site Restoration

Drill sites were cleaned and restored as closely as practicable to pre-drilling conditions. At the completion of drilling, all equipment and materials, tools and unused materials were removed, and trash was disposed of offsite.

4. Geotechnical Laboratory Testing

Geotechnical laboratory tests were performed on selected samples obtained from the explorations to assist with characterization of the geotechnical engineering properties of the subsurface materials. The geotechnical laboratory testing was performed by Geocon Consultants, Inc. of Rancho Cordova, California.

Geotechnical laboratory testing included the following tests:

- Sieve analysis and sieve analysis with hydrometer, ASTM D422 and D6913
- Moisture content and density of soils, ASTM D2216 and ASTM D7263
- Atterberg limits using dry preparation methods, ASTM D4318
- One-dimensional consolidation testing of soils using incremental loading, ASTM D2435
- Consolidated undrained triaxial compression, ASTM D4767

Laboratory test results are presented in Appendix G and summarized in Table 2. Index test results are also summarized on the boring logs.

5. Quality Assurance and Quality Control

5.1 Hammer Energy

Cascade performed energy measurements of the automatic-trip hammer used to drive the samples for the field exploration. The hammer energy measurements were conducted in accordance with ASTM D4633 using a pile driving analyzer manufactured by PAK. The average hammer energy value of 77 percent is noted on the first page of each boring log in the remarks area. A copy of the hammer energy measurement report is provided in Appendix H.

5.2 Boring Logs

GEI personnel were responsible for collecting and transporting soil samples to the soil testing laboratory, processing laboratory test results, and adjusting field boring logs based on laboratory test data.

Boring log development for this project included:

- Field sampling, soil classifications in general accordance with ASTM D2488, and soil sample and layer descriptions for the field boring logs.
- Quality check of field observations.
- Preparation of a draft gINT log.
- Laboratory tests were performed on samples recovered from borings. Soil classifications and descriptions were refined as appropriate based on test results in accordance with ASTM D2487.
- Final boring logs were prepared based on adjustments for laboratory tests and subsequent quality checks.

Final logs in gINT format were reviewed by a Senior Engineer designated by the Project Manager and any necessary final adjustments were made prior to inclusion in this data report.

5.3 Cone Penetration Test and Data Quality Control

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

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

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

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

5.4 Laboratory Testing and Test Results

Laboratory index test results were reviewed by project team engineers to gauge conformance with field boring logs. If laboratory results conflicted with the field boring log information, the matter was typically resolved through a visual check and classification of a sample of the soil in question by the Senior Engineer or Project Geologist designated by the Project Manager.

6. Key Participants

The work presented in this GDR is was completed by a team of engineers and geologists from GEI with significant assistance from Cascade, ConeTec, and Geocon Consultants, Inc. The Project team and roles included:

- GEI – prime consultant leading the coordination, field logging, and geotechnical engineering
- Cascade Drilling – performed drilling and sampling
- ConeTec – Performed the CPT soundings
- Geocon Consultants, Inc – performed geotechnical laboratory testing

The GEI Project team included personnel involved with field activities, report preparation, report review, quality assurance, and quality control. Personnel associated with the Project are listed below along with their Project roles:

Field Personnel

- Project Manager – Graham Bradner, PG, CEG, CHG
- Field Explorations Manager – Nichole Tollefson, PMP
- Field Logger and CPT Oversight – Eduardo Cerna Alvarez, PE

Report Preparation Personnel

- Justin Zumbro, PG
- Nichole Tollefson, PMP
- Eduardo Cerna Alvarez, PE

Senior Review

- Matt Weil, GE, PE

7. 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 data and information presented in this report was collected for the Study described in this GDR only and is intended only for use by Marin County Flood Control and Water Conservation District and their agents.

No warranty, either express or implied, is made in the furnishing of this report. GEI makes no warranty that actual encountered site and subsurface conditions will conform to the conditions described herein. Variations in subsurface conditions will exist between exploration locations, and GEI may not be able to identify all adverse conditions in the levee and/or its foundation.

GEI does not attest to the accuracy, completeness, or reliability of geotechnical borings and other subsurface data by others that are included in this report; an independent validation or verification of data by others has not been performed.

8. References

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Tables

TABLE 1. SUMMARY OF SUBSURFACE EXPLORATIONS

Table 1: Summary of Subsurface Explorations
Novato Creek Levee Evaluation
Marin County, California

Exploration ID	Exploration Area	Exploration Type	Exploration Location	Levee Station (ft)	Approximate Coordinates[1]		Ground Surface Elevation[2]	Approximate Depth to Groundwater (ft)	Exploration Depth (ft)
					Latitude	Longitude			
GEI_001B	Novato Creek LB us 37	Hollow Stem Auger and Mud Rotary	Crown - Paired	300+89	38.096663	-122.553286	15.6	NA	46.0
GEI_001C	Novato Creek LB us 37	Cone Penetration Test	Crown - Paired	300+86	38.096637	-122.553271	15.7	13.0	45.4
GEI_001C_TOE	Novato Creek LB us 37	Cone Penetration Test	Toe	297+06	38.097165	-122.552196	4.0	4.2	51.8
GEI_002C	Novato Creek LB us 37	Cone Penetration Test	Crown	289+51	38.097381	-122.549754	15.1	13.6	51.9
GEI_003C	Novato Creek LB us 37	Cone Penetration Test	Crown	279+19	38.094674	-122.549006	15.2	13.3	51.6
GEI_004C	Novato Creek LB us 37	Cone Penetration Test	Crown	266+90	38.093075	-122.545618	14.2	11.8	51.8
GEI_005C	Novato Creek LB us 37	Cone Penetration Test	Crown	255+12	38.093637	-122.541794	14.6	8.2	42.0
GEI_006C	Novato Creek LB us 37	Cone Penetration Test	Crown	246+75	38.092025	-122.539751	13.4	7.9	41.8
GEI_002C_TOE	Novato Creek LB us 37	Cone Penetration Test	Toe	0+68	38.092187	-122.539625	8.1	6.4	48.6
GEI_007C	Novato Creek LB us 37	Cone Penetration Test	Crown	231+38	38.089548	-122.535536	12.5	9.5	81.4
GEI_002B	Lynwood Levee	Hollow Stem Auger and Mud Rotary	Crown	303+89	38.095188	-122.553658	17.0	NA	55.0
GEI_008C	Lynwood Levee	Cone Penetration Test	Crown	294+50	38.094284	-122.550640	15.6	13.8	55.1
GEI_009C	Lynwood Levee	Cone Penetration Test	Crown	283+50	38.092407	-122.547675	15.0	11.2	65.0
GEI_010C	Lynwood Levee	Cone Penetration Test	Crown	271+42	38.091652	-122.543597	14.5	13.5	74.7
GEI_003B	Lynwood Levee	Hollow Stem Auger and Mud Rotary	Crown - Paired	260+68	38.090817	-122.540059	12.9	NA	46.5
GEI_011C	Lynwood Levee	Cone Penetration Test	Crown - Paired	260+94	38.090900	-122.540100	12.3	11.6	58.3
GEI_012C	Lynwood Levee	Cone Penetration Test	Crown	250+16	38.088958	-122.537273	10.7	9.7	81.4
GEI_013C	Pacheco Pond	Cone Penetration Test	Crown	14+41	38.076995	-122.526950	6.1	10.0	47.2
GEI_005C_TOE	Pacheco Pond	Cone Penetration Test	Toe	14+39	38.077031	-122.526847	-3.1	0.0	22.8
GEI_004B	Pacheco Pond	Hollow Stem Auger and Mud Rotary	Crown - Paired	23+27	38.074713	-122.525940	10.3	NA	41.5
GEI_014C	Pacheco Pond	Cone Penetration Test	Crown - Paired	23+24	38.074720	-122.525927	10.9	9.0	56.3
GEI_003C_TOE	Pacheco Pond	Cone Penetration Test	Toe/Ramp	23+21	38.074710	-122.525745	-0.2	4.0	47.4
GEI_005B	Pacheco Pond	Hollow Stem Auger and Mud Rotary	Crown - Paired	33+22	38.072343	-122.524640	10.4	NA	50.5
GEI_015C	Pacheco Pond	Cone Penetration Test	Crown - Paired	33+37	38.072308	-122.524609	10.7	4.3	46.1
GEI_006B	Pacheco Pond	Hollow Stem Auger and Mud Rotary	Crown	39+78	38.071516	-122.522639	10.0	15.0	45.5

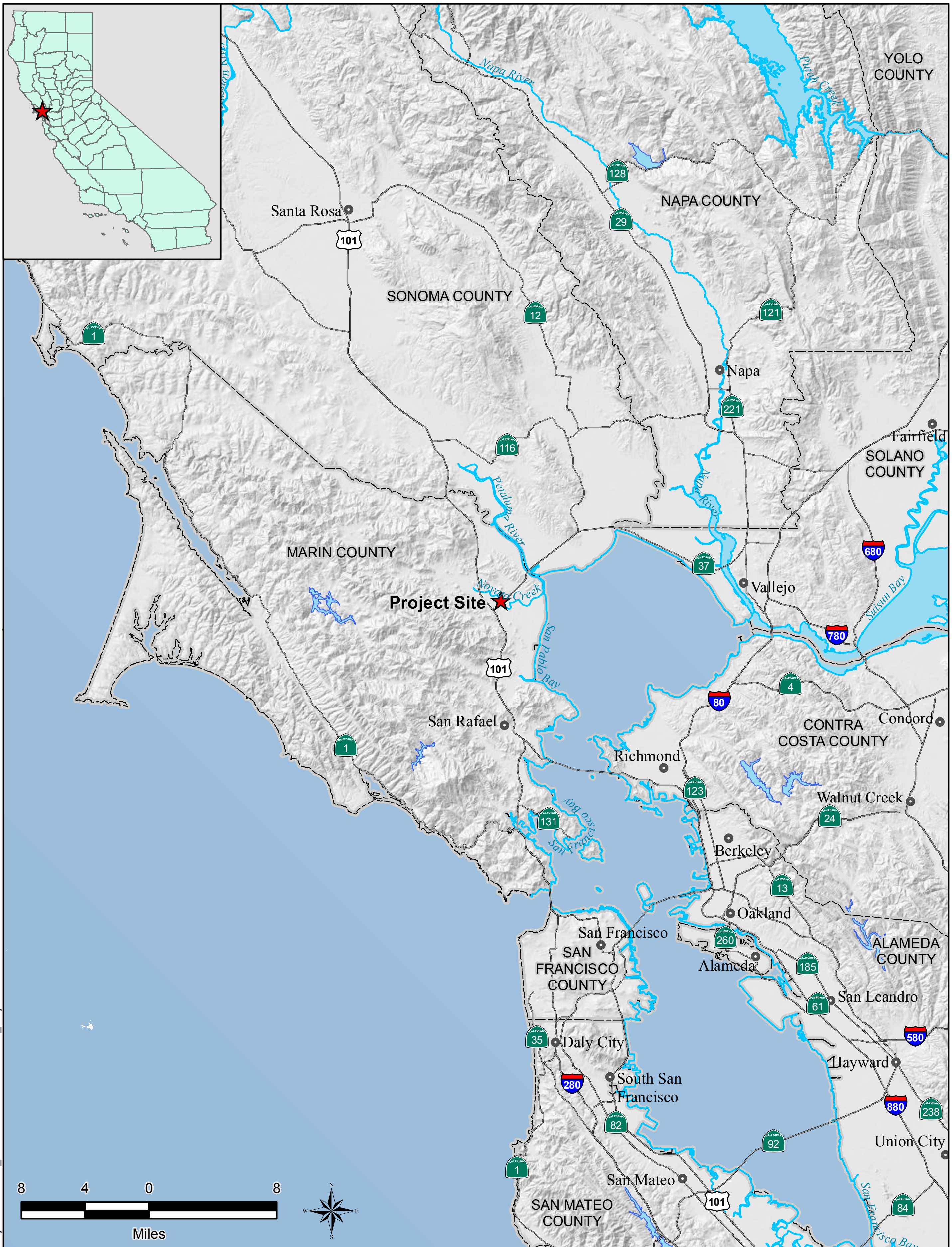
(1) Locations are approximate - based on field GPS and GIS tools. Horizontal datum is NAD 83.
(2) Elevations are approximate - based on GIS tools. Vertical datum is NAVD 88

TABLE 2. SUMMARY OF LABORATORY TEST DATA

Sample Information					Atterberg Limits			Particle Size Analysis								
Exploration ID	GEI Sample ID	Laboratory Sample ID	Sampler Type	Sample Depth Interval (feet)	Liquid Limit	Plastic Limit	Plasticity Index	Gravel (%)	Sand (%)	<#200 Sieve (%)	Silt (%)	Clay (%)	Water Content (%)	Dry Density (pcf)	Organic Content (%)	Other Tests
GEI_001B	S02A_004_005S	GEI_001B_S02A_3.5-5	SPT	3.5-5	37	21	16	13.5	36.6	49.9						
	S06A_014_015S	GEI_001B_S06A_13.5-15	SPT	13.5-15	45	26	19			81.7						
	S08A_019_021S	GEI_001B_S08A_19-20.5	SPT	19-20.5	97	36	61			98.3						
	S10A_024_026S	GEI_001B_S10A_24-25.5	SPT	24-25.5	112	39	73						93.9			
	S11A-026_028T	GEI_001B_S11A_26-28.25	Shelby Tube	26-28.25	122	43	79									CU, CN
	S13A_032_034S	GEI_001B_S13A_32-33.5	SPT	32-33.5	109	41	68			98.7			88.0			
	S15A_037_039S	GEI_001B_S15A_37-38.5	SPT	37-38.5				1.2	61.2	37.6	19.4	18.2				
GEI_002B	S01A_001_003S	GEI_002B_S01A_1-2.5	SPT	1-2.5	49	34	15			74.2						
	S02A_004_005S	GEI_002B_S02A_3.5-5	SPT	3.5-5						45.8						
	S03A_006_008S	GEI_002B_S03A_6-7.5	SPT	6-7.5	31	17	14									
	S06A_014_015S	GEI_002B_S06A_13.5-15	SPT	13.5-15	55	26	29			74.7						
	S09A_021_023S	GEI_002B_S09A_21-22.5	SPT	21-22.5	46	27	19			77.7			45.6			
	S10A_024_026T	GEI_002B_S10A_024_026T	Shelby Tube	24-26	51	25	26									CU
	S13A_031_032S	GEI_002B_S13A_31-32.5	SPT	31-32.5	97	36	61						75.9			
	S17A_041_043S	GEI_002B_S17A_41-42.5	SPT	41-42.5	25	13	12			40.9			17.2			
GEI_003B	S02A_004_005S	GEI_003B_S02A_3.5-5	SPT	3.5-5	46	27	19									
	S03A_006_008S	GEI_003B_S03A_6-7	SPT	6-7				30.6	52.2	17.2	10.7	6.5				
	S05A_012_013S	GEI_003B_S05A_11.5-13	SPT	11.5-13	41	22	19			45.0						
	S06A_014_016T	GEI_003B_S06A_14-16.25	Shelby Tube	14-16.25						18.1						
	S08A_020_021S	GEI_003B_S08A_19.5-21	SPT	19.5-21	55	26	29			81.2			41.0			
	S09A_022_024T	GEI_003B_S09A_22-24.25	Shelby Tube	22-24.25	48	13	35			68.4						CU, CN
	S11A_028_029S	GEI_003B_S11A_27.5-29	SPT	27.5-29	66	30	36						71.0			
	S14A_035_037S	GEI_003B_S14A_35-36.5	SPT	35-36.5	92	40	52			96.6			75.8			
GEI_004B	S01A_001_003S	GEI_004B_S01A_1-2.5	SPT	1-2.5	68	35	33									
	S04A_011_013T	GEI_004B_S04A_11-13.25	Shelby Tube	11-13.25	81	36	45									CU, CN
	S06A_017_018S	GEI_004B_S06A_16.5-18	SPT	16.5-18	98	35	63						67.7			
	S08A_023_024S	GEI_004B_S08A_22.5-24	SPT	22.5-24	129	55	74						100.8		8.8	
	S10A_028_029S	GEI_004B_S10A_27.5-28.75	SPT	27.5-28.75						48.7						
	S12A_033_034S	GEI_004B_S12A_33-34	SPT	33-34				10.3	59.1	30.6	16.7	13.9				
GEI_005B	S03A_006_008S	GEI_005B_S03A_6-7.5	SPT	6-7.5	81	42	39			97.9						
	S04A_008_010T	GEI_005B_S04A-8-10.25	Shelby Tube	8-10.25	70	32	38						47.3	71.0		
	S05A_010_012S	GEI_005B_S05A_11-11.75	SPT	11-11.75											5.1	
	S05B_010_012S	GEI_005B_S05B_10.25-11	SPT	10.25-11	89	34	55						60.7		4.7	
	S07A_016_018T	GEI_005B_S07A_16-18.25	Shelby Tube	16-18.25	103	40	63									CU, CN
	S08A_019_021S	GEI_005B_S08A_19-20.5	SPT	19-20.5	114	38	76			96.1			99.2			
	S11A_027_028S	GEI_005B_S11A_26.5-28	SPT	26.5-28	110	41	69			98.7			86.9			
	S13A_032_033S	GEI_005B_S13A_31.5-33	SPT	31.5-33	137	49	88						117.4			
	S16A_039_041S	GEI_005B_S16A_39-40.5	SPT	39-40.5						42.0						
GEI_006B	S01A_002_003B	GEI_006B_S01A_2-3	Bag/Grab	2-3	68	35	33			98.7						
	S03A_008_011T	GEI_006B_S03A_8-10.5	Shelby Tube	8-10.5	69	31	38						46.8	73.6		
	S04A_011_012S	GEI_006B_S04A_10.5-12	SPT	10.5-12	96	37	59									
	S06A_015_016S	GEI_006B_S06A_14.5-16	SPT	14.5-16	93	36	57			93.5			74.9			
	S08A_019_021S	GEI_006B_S08A_19-20.5	SPT	19-20.5	94	34	60						77.6			
	S10A_024_026S	GEI_006B_S10A_24.3-27.5	SPT	24.3-27.5	117	42	75						91.0			
	S11B_027_028S	GEI_006B_S11B_26.5-27.5	SPT	26.5-27.5						52.5						
	S12A_029_031S	GEI_006B_S12A_29.5-30.5	SPT	29.5-30.5	19	16	3			49.8			19.8			

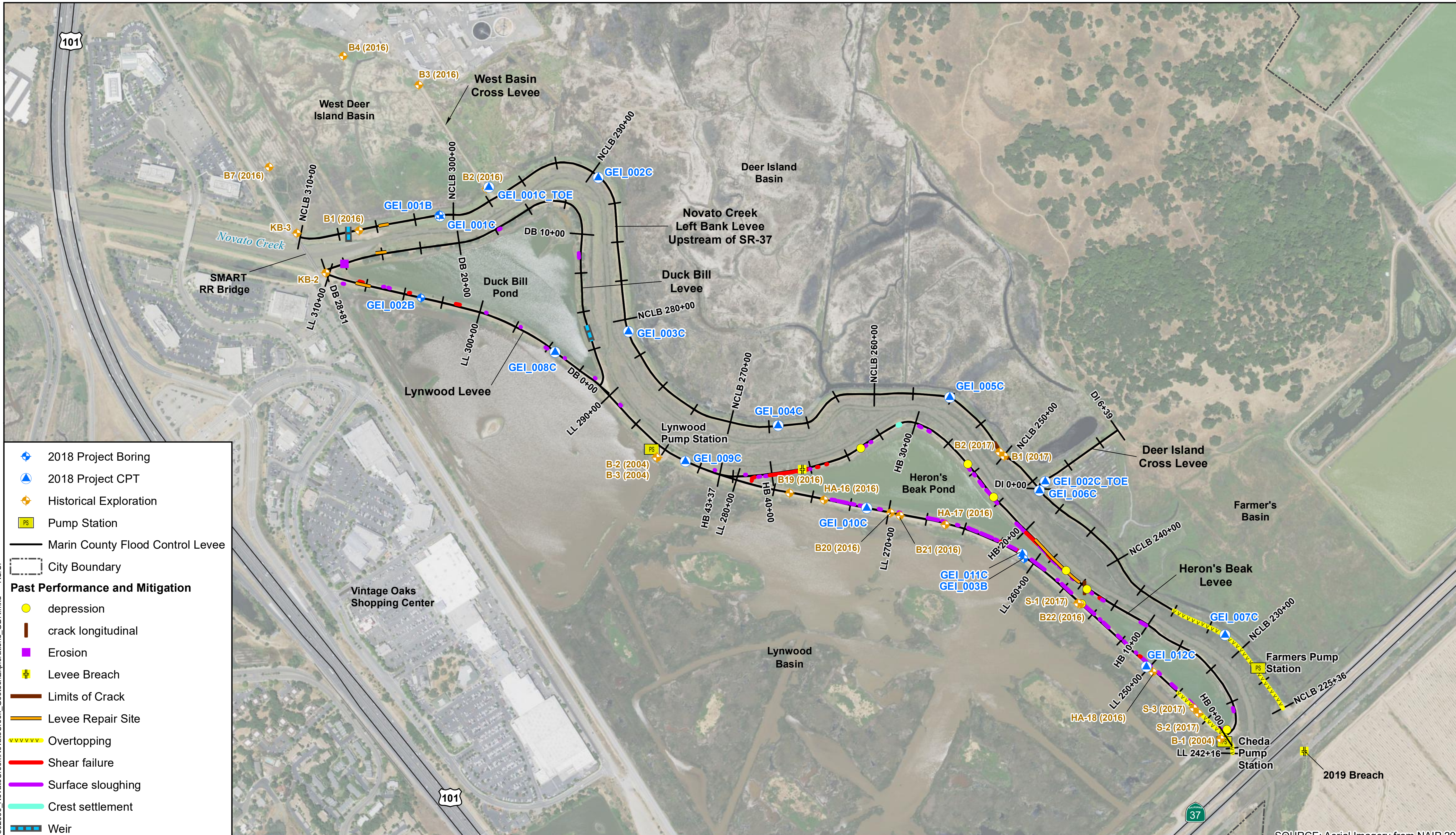
Notes:
1. pcf = pounds per cubic foot
2. CU = Consolidation Undrained Triaxial Compression
3. CN = Incrementally Loaded Consolidation

Figures



Z:\Projects\1802696_NovatoCreek\NovatoCreek_ProjectLocation.mxd RS
28Mar2019

Novato Creek	GEI Consultants	Project Location
Marin County		OCTOBER 2019 FIGURE 1



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0 300 600 1,200

Feet

N W E S

Novato Creek Levee Evaluation Project
Novato, California

Marin County Flood Control
and Water Conservation District

GEI Consultants

GEOTECHNICAL EXPLORATIONS
NOVATO CREEK AND LYNWOOD BASIN LEVEES

JANUARY 2020

FIGURE 2

0 250 500 1,000

Feet

Novato Creek Levee Evaluation Project
Novato, California

Marin County Flood Control
and Water Conservation District

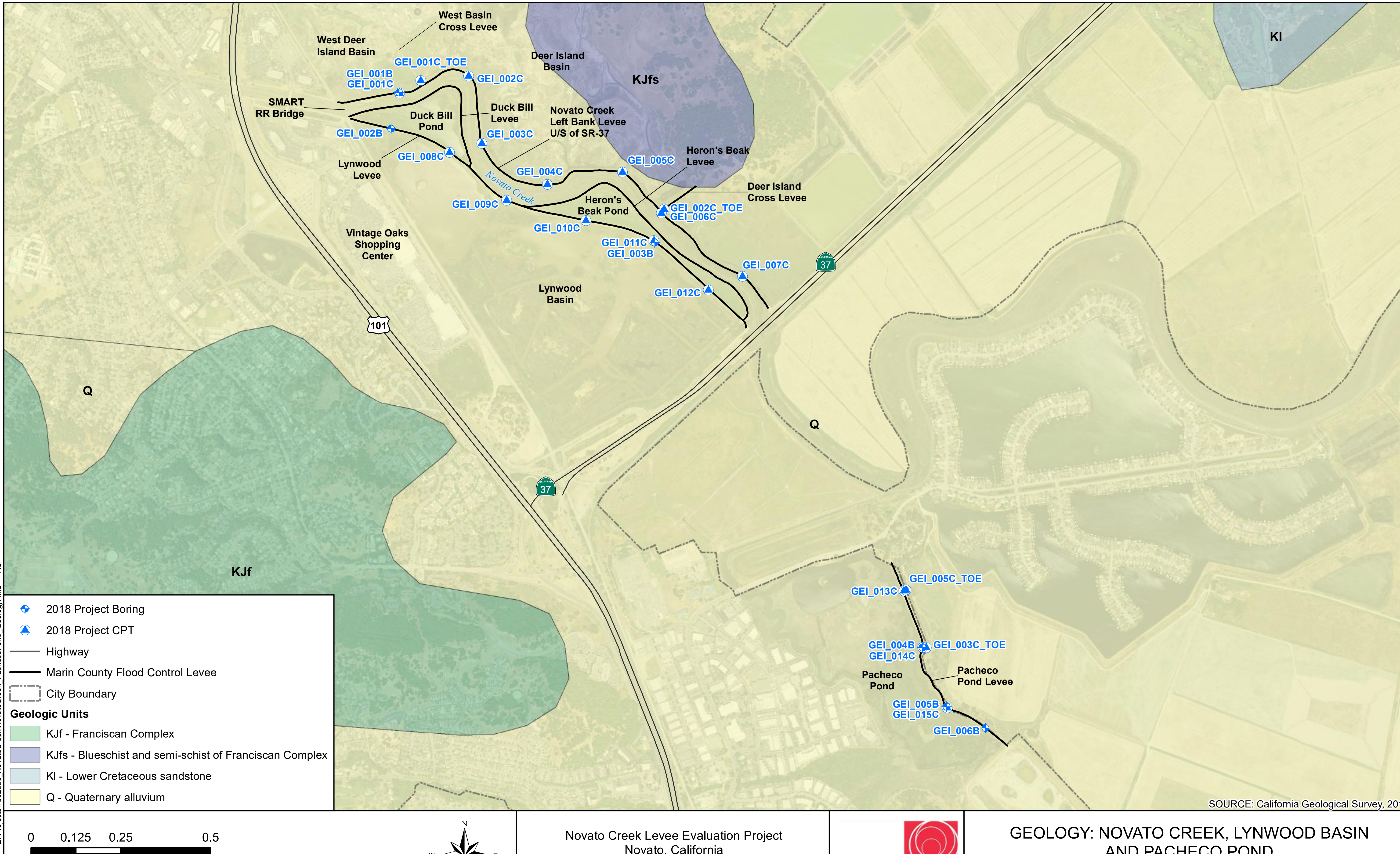
GEI Consultants

GEOTECHNICAL EXPLORATIONS
PACHECO POND LEVEE

OCTOBER 2019

FIGURE 3

07-Jan-2020 Z:\Projects\1802696_NovatoCreek\PachecoPond_GeotechExplorations_GDR.mxd RS/SI



Novato Creek Levee Evaluation Project
Novato, California

Marin County Flood Control
and Water Conservation District

GEI Consultants

GEOLOGY: NOVATO CREEK, LYNWOOD BASIN
AND PACHECO POND

OCTOBER 2019

FIGURE 4

08-Jan-2020 Z:\Projects\1802696_NovatoCreek\NovatoCreek_PachecoPond_Geology.mxd RS

Appendix A

Historical Document Review

Appendix A - Historical Document Review Summary

Date	File Name	Document Name	Location	Document Type	Description
6/1/1972	1972-Novato Creek Study_Royston Hanamoto_June 1972	Novato Creek Study	General	Report	Report collected and correlated exsiting data relating the existing creek system in Novato Creek Watershed; explore potential means of flood control.
3/1/1983	1983_CDM_NCFCProject	Novato Creek Flood Control Project	General	Report	Maps showing Novato Creek Basin, 100-yr flood zone, and 1982 flooded area (including our project area) List of 5 USACE alternatives for channel improvements that were not viable projects. Flood analysis info also presented in report
3/1/1984	1984_EMI_NovatoCkFC_EIR	EIR for Novato Flod Control Project	General	Comments and Responses	Comments and responses of the Draft EIR, but EIR is not included in this file.
9/30/1988	1988_FEMA_FloodInsuranceStudy	Flood Insurance Study	General	Report	This study investigates the existence and severity of flood hazards in the City of Novato, developed floord risk data for various areas of the community, and H&H analyses. Stream discharges for 10, 50, 100 and 500-yr alsolisted.
7/27/1990	1990_Mark_Group_Geotechnical_Vintage_Oaks	Geotechnical Investigations for Vintage Oaks	Vintage Oaks Shopping Center	Report	Investigation report covers Vintage Oaks shopping center at Novato, which is the area between Hwy 101 and the Lynwood Basin. The report includes boring logs and test data. Geotech info was used for the foundation design of retail stores and parking lots.
4/26/1990	1990_PCI_DeerIslandWetlandEnh	Wetland Enhancement of Deer Island	Deer Island	Memo and hand sketches	Wetland enhancement for Deer Island, which includes deepening the slough/channel depth. Deer Island is just outside of our project area but may affect our project if permanent ponds are created.
3/25/2006	1996_NovatoGeneralPlan			General Plan	Original plan developed in March 1996. General plan covers land use, transporation, housing, environment, safety& noise, public facilities, etc.

Appendix A - Historical Document Review Summary

Date	File Name	Document Name	Location	Document Type	Description
3/14/2002	2002_NHC_Memo_H&H_BMK5	H&H Modeling Assessment at Bel Marin Keys V	Bel Marin Keys Novato Creek d/s of SR 37	Memorandum	H&H assessment and basin description of Pacheco Creek, Arroyo San Jose, Pacheco Pond, Novato Creek, and San Pablo Bay Tides. Suumary of proposed alternatives also included.
5/7/2002	2002_PWA_FloodandSedimentStudy	Lower Novato Creek Flood and Sediment Study	Novato Creek d/s of SR 37	Report	Study reviewed the hydraulics of the Novato Creek system and characterize the effects of sedimentation.
4/1/2003	2003_BMKV Expansion Hamilton Wetlands Restoration Project_FSEIR	Final EIR/EIS Bel Marin Keys V Expansion of Hamilton Wetland Restoration Project	Bel Marin Expansion Site/ Pacheco Pond	Report	Final supplemental EIR/EIS for the Bel Marin Keys area and Pacheco Pond.
10/20/2003	2003_Novato2028StrategicPlan	Community Strategic Plan - Vision for Novato 2028	General	Report	Novato's town history, community's issues (affordable housing, budget crisis, removations, taxes, etc.), demographics, health, education, and infrastructure.
5/19/2004	2004_Geotech Report MC Pump Stations_Kleinfelder_19May04	Prelim Geotech Report Marin County Pump Stations	Lynwood Levees	Report	**Key Document:** 3 borings (B-1 through B-3) 65-96 feet deep located at pumps stations along Lynwood levee. Boring logs and lab data included.
1/1/2004	2004_RestorationOpps_Ignacio_Creek_LC	Prelim Assessment of Opportunities for Restoration and Fish Barrier Removal	Lower Ignacio Creek	Report	Prelim assessment of fish habitat and passage for Ignacio Creek and Novato Creek.
6/1/2005	2005_DraftHydrologic and Hydraulic StudyVol1	H&H Study Phase II Vol I Baseline Conditions and Hist Morphology of Novato Creek	Bel Marin Keys and Pacheco Pond	Report	Study consists of field data collection and H&H numeric modeling. Field work includes: bathymetric survey, meas of tidal elev and velocity, meas of suspended sediments, etc. Geomorph description, historical timeline of events, and creek profiles
3/31/2005	2005_Habitat Assmnt Lynwood Basin_Kleinfelder_31Mar05	Prelim Habitat Assessment and Wetland Survey for Lynwood Basin Pump Station Replacement Project	Lynwood Pump Station	Report	Report collected habitat and wetland survey information. The intent of the report is to provide the District with necessary biological info to obtain permits for the pump station replacement project.

Appendix A - Historical Document Review Summary

Date	File Name	Document Name	Location	Document Type	Description
1/1/2006	2006_HH_Draft_Report_Vol2	H&H Study Phase II Vol 2 H&H and Sedimentation in Novato Creek	Novato Creek, Ble Marin Keys, and Pacheco Pond	Report	Report covers field sampling and water levels, bathemetric surveying, and modeling (H&H and sedimentation).
9/1/2007	2007_NovatoHH_PhaseIISupplemental_Noble_NHC	H&H Supplemental Study Phase II - H&H and Sedimentation in Novato Creek	General	Report	H&H modeling of flood potential scenarios/parameters and results, navigability impact and flood dynamics impact.
6/1/2014	2014_NovatoCr_EC_FINAL_140630_sm	Hydraulic Assessment of Existing Conditions Novato Creek Watershed	General	Report	Report contains hydraulic analysis and quantifies and predicts the route of the channels and overbank flows from Novato Creek to other creeks. Watershed and geomorphic assessment of our project is also included. Project area is called Upper Baylands in this report.
8/19/2015	2015 Levee Repair Plans	Novato Creek Levee Repair Project	General	Drawings	**Key Document:** Design drawings for three repair sites along the Novato Creek levees between the SMART rail and Hwy 37.
8/1/2015	2015 Levee Repair Specs	Specs for Novato Creek Levee Repair	General	Specifications	Specs for the Novato Creek levee repair.
6/1/2016	2016_NWP_AlternativesAnalysis_Report_FINAL_000	Novato Creek Hydraulic Study Analysis of Alternatives	General	Report	Hydraulic study of the Novato Creek basin.
2/1/2017	2017 Emergency Repair	Herons Beak Detenion Pond Berm Breach Repair	Herons Beak Pond	Report	Photos, invoices, and 1 detail drawing of repair. Map showing the location of breach is not clear.
1/28/2017	2017 HTE GADR draft	Draft Geotechnical Analysis and Design Report	North Deer Island	Report	**Key document:** Report is for north deer island which is north of Novato Creek and east of the SMRT rail. There are 2 borings that will be helpful. Geologic map showing our area (pdf pg 41/102) shown. Generalized subsurface profile, lab data, and seep/stab analysis also included.
5/21/2012	052112 Miller Pacific Soil Analysis Report_2012 Novato Creek Drege	Results of Novato Creek Sediment Sampling and Testing	Novato Creek	Report and Lab Results	Index testing results for the sediment removed from Novato Creek. Only location NC 3-4 covers our project area.

Appendix A - Historical Document Review Summary

Date	File Name	Document Name	Location	Document Type	Description
6/7/2017	060717 Lynwood Levee Eval	Lynwood Levee Evaluation	Lynwood Levees	Report	Evaluation info/results based on walking Lynwood levee. No explorations were drilled or soil tested. Existing conditions summarized (crest elevation, width, slopes). Report not very useful.
6/14/2016	061416 Novato Creek Sed-Test Lab Results	Sediment Test Lab Results	Novato Creek	Lab Results	Sediments tested for sulfide, pH, organic carbon, oil, diesel, gasoline, mercury, etc.
7/27/2016	072716 dredge stockpiles	Geotechnical Evaluation for North Deer Island Detention Basin	North Deer Island	Report	**Key document:** Report includes boring and hand auger logs for borings along Heron's Beak Pond as well as lab data.
8/10/2016	081016 Geotech Memo to GLEI during construction	Clarification to the Selection and Placement of Earthen Material for Structural Core Levee	Lynwood Levee and Deer Island Basin	Memo	Memo clarifies specs for the core levee material to be used for Lynwood levee and Deer Island Basin.
8/16/2017	081617_Lynwood-Levee-Stockpile-report	Soil Sampling and Testing for Stockpiles for Lynwood Levee	Lynwood Levee	Report	**Key document(?):** Report includes hand augers in the stock piles along Lynwood levee as well as lab data.
9/26/2017	092617 Draft Geotechnical Investigation-longitudinal crack	Geotechnical Investigation for Novato Creek Levee Deer Island Basin.	Novato Creek	Report	**Key document:** Report includes two borings on Novato Creek left bank. Logs, lab data, and slope stability analysis included.
10/20/2015	102015 HTE Levee Repair	Novato Creek Levee Repair (Sites 2 and 3)	Novato Creek	Letter	Letter states that the areas tested were constructed in accordance with the recommendations. Location of repair sites, lab data, etc. were not provided in this document.
11/9/2016	110916 HTE_Erodible Weir Final Report	Erodible Weir Constrcution (Site 1)	Novato Creek	Letter	Letter states that the areas tested were constructed in accordance with the recommendations. Location of repair sites, lab data, etc. were not provided in this document.
NA	CFR-2002-title44-vol1-chapI-subchapB	Title 44 Subchaper B - Insurance and Hazard Mitigation	NA	Certified Document	Title 44

Appendix A - Historical Document Review Summary

Date	File Name	Document Name	Location	Document Type	Description
5/1/2015	Flood Control_NovatoCreek 073115_highres.pd	Novato Creek Baylands Historical Ecology Study	Novato Creek	Report	Historical information on Novato Creek and the tidal channels, habitat types, and transition zones.
3/15/2011	Geotech SMART	Prelim Geotech Report for SMART path North Segment	SMART Rail Alignment	Report and Drawings	**Key Document:** Report has drawings that have 4 explorations along the SMART line crossing over Novato Creek (KB-2/KB-3 and KCPT-2/KCPT-3). Boring/CPT logs and lab data included in report.
3/10/2016	lynwood_deer_island_survey_memo_12 mar16	Deer Island / Lynwood Basin Survey	Deer Island and Lynwood Basin	Memo	Memo summarizes and shows the locations where bathymetric and topographic survey were performed for the area.
9/9/2015	NORCAL Downhole GPR Report	Geophysics Survey for PG&E Transmission Tower 184	Novato Creek	Report	Geophysics survey of the transmission tower at the toe of Novato Creek left bank.
12/1/2012	Novato_EC2014_ Apendix_Survey	Novato Creek Survey Control	Novato Creek	Data	Survey control points, N/E, descritption, and datum
4/11/2018	S_W_HEC-RAS_ModelDocumentation_Update_April_2018	Existing Conditions Novato Creek HEC-RAS Model	Novato Creek	Memo	Existing conditions HEC-RAS - model development, organization, sea level rise, tidal boundary conditions, etc.
7/2/2019	2019 SCCPachecoLeveeBreachRepairMemo2019_Tillus	J:\Marin County FCD\Projects\1802696_Novato Creek LLAP\Task 2\Reference Docs	Pacheco Pond	Report	February 2019 storm past performane included levee breach, erosion, near overtopping. Three sites were repaired. Report includes photos, location map of past performance, and typical sections.

Appendix B

Geotechnical Exploration Work Plan

Geotechnical Exploration Work Plan

Novato Creek Levee Evaluation Project

Marin County, California

Submitted to: Marin County Flood Control and Water Conservation District

Date: September 2018
Project No. 1802696

Table of Contents

GEI Consultants

Tables

Figures

Appendices

Abbreviations and Acronyms

ASTM	American Society for Testing and Materials
CAL	Standard California Sampler
CPT	Cone Penetration Testing
DWR	California Department of Water Resources
FEMA	Federal Emergency Management Agency
GEI	GEI Consultants, Inc.
GPS	Global Positioning Satellite
HASP	Health and Safety Plan
District	Marin County Flood Control and Water Conservation District
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
QA/QC	Quality Assurance/Quality Control
SMART	Sonoma Marin Area Rail Transit
SPT	Standard Penetration Test
USA	Underground Service Alert
USACE	United States Army Corps of Engineers

1 Introduction and Background

1.1 Project Overview

1.1.1 Background

GEI Consultants, Inc. (GEI) is assisting the Marin County Flood Control and Water Conservation District (District) in the Novato Creek Levee Evaluation Project (Project) located in Novato, California. Exploratory borings and CPTs were previously performed along Novato Creek left bank near the Sonoma Marin Area Rail Transit (SMART) bridge and along Lynwood Levee adjacent to Heron's Beak Pond (see Appendix A). No historic explorations were identified for the Pacheco Pond levees. Geotechnical exploration and evaluations are needed to better understand and characterize the levee and foundation conditions.

This Project's goal is to meet the United State Army Corps of Engineers (USACE) criteria to become eligible for the PL 84-99 Levee Safety Program for non-federal levees and possible future FEMA accreditation. This project includes the geotechnical evaluation of the levees' existing condition, determination of feasibility and costs of modifications, and identifying improvements for these levees.

1.1.2 Purpose and Scope

The District and GEI are undertaking geotechnical explorations along the 8,500 ft of levee along upper Novato Creek left bank, the 6,800 ft of Lynwood levee borders the Lynwood Basin, and the 3,400 ft of levee along Pacheco Pond. The purpose of the explorations is to characterize geotechnical subsurface conditions, close data gaps, and provide key information to support feasibility level design going forward.

The field explorations will be performed using ConeTec, Inc. from San Leandro, CA, and Cascade Drilling (Cascade), from West Sacramento, CA. Explorations are expected to begin the week of September 24, 2018 and be completed by November 12, 2018.

This Geotechnical Exploration Work Plan (Plan) describes the relevant information associated with the current exploration program. This Plan includes the proposed exploration locations, depths, types of samples, exploration methods, and a general plan for laboratory testing of collected samples. A site-specific Health and Safety Plan (HASP) has been prepared for this exploration program.

This Plan's scope is limited to:

- Reviewing existing data and planning/layout of proposed subsurface explorations;
- Performing the following geotechnical explorations:
  - Combination of hollow-stem auger/mud-rotary boring at 1 location along the Novato Creek left bank levee;
  - Combination of hollow-stem auger/mud-rotary borings at 2 locations along the Lynwood Levee;
  - Combination of hollow-stem auger/mud-rotary borings at 2 locations along the Pacheco Pond Levee;
  - 7 CPTs along the Novato Creek left bank levee crown;
  - 2 CPTs along the landside levee toe of the Novato Creek left bank;
  - 5 CPTs along the Lynwood Levee crown;
  - 3 CPTs along the Pacheco Pond Levee crown;
  - 2 CPTs along the landside levee toe of the Pacheco Pond Levee;
- Documenting final boring and CPT locations and elevations;
- Geotechnical laboratory testing;
- Preparing finalized gINT boring logs and providing CPT logs.

Information collected during the subsurface exploration program will be documented in a Geotechnical Evaluation Report.

1.2 Site Description

The project area is in Marin County west of San Pablo Bay (Figure 1). The Novato Creek Levee System consists of the upper Novato Creek left bank, Lynwood Levee as shown on Figure 2, and Pacheco Pond Levee as shown on Figure 3. The upper Novato Creek left bank levee is located between the SMART Trestle and SR-37. The Lynwood levee is located to the southwest of the upper Novato Creek left bank and separates the Lynwood stormwater detention basin from two wildlife preserve ponds. The Pacheco Pond levee is located south of SR-37, to the east of Pacheco Pond and South of Bel Marin Keys Blvd.

1.3 Existing Data Summary

Several previous geotechnical reports were reviewed by GEI prior to development of this Plan. These documents provide discussion of surface and subsurface conditions encountered during subsurface exploration as well as boring log and geotechnical laboratory testing data. A brief summary of the relevant geotechnical reports reviewed is provided below.

Kleinfelder, 2004: Geotechnical investigation for Lynwood and Cheda pump stations. Three borings were completed along the Lynwood levee, within the current Project area. Preliminary geotechnical evaluations for seismic site characterization were performed and recommendations were made for the geotechnical aspects of the proposed improvements.

Kleinfelder, 2011: Geotechnical investigation for the preliminary engineering phase of the SMART Project. Borings and CPTs were performed as part of the investigation. Geotechnical recommendations were developed to support the engineering of various structures.

Hultgren-Tillis, 2016: Geotechnical evaluation of dredge stockpiles at the Gnoss Field and Lynwood Levee for use in constructing a new detention basin along Novato Creek. The report includes boring and hand auger logs for borings along Heron's Beak Pond.

Hultgren-Tillis, 2017: Geotechnical analysis and design for a planned detention basin levee for the North Deer Island Flood Protection Project. Tasks included borings and CPTs, geotechnical evaluations, and geotechnical recommendations for the construction of the basin levee and facilities. The report includes a geologic map of the current project area, a generalized subsurface profile, laboratory data, and seepage and stability analyses.

Hultgren-Tillis, 2017: Geotechnical investigation for the Novato Creek Levee project located along the left bank of Novato Creek adjacent to the Deer Island Basin. This investigation was performed to evaluate a crack and slump that developed along the levee crest. Conclusions and recommendations for remediation were presented in the report.

The locations of the identified historic explorations by others are shown for reference in plan view on Figure 4, along with the proposed GEI explorations. Figures 2 and 3 also show a detailed site plan with proposed GEI explorations.

1.3.1 Foundation Conditions

Marin County is located in the Coast Ranges Geomorphic Province of Northern California (Figure 5). The region consists of bedrock materials of the Franciscan formation subjected to faulting and folding overlain by younger alluvial, fluvial, and Bay Mud deposits. The alluvial materials vary in depths to up to 60 feet below ground surface.

The Project site is generally underlain by Bay Mud, which consists of silt and clay with peat, organics, and fine sands. The Bay Mud varies in thickness and is estimated to be 5 to 60 feet thick. The Project levees were constructed with Bay Mud. Below the Bay Mud are alluvial soils consisting of interbedded silt, clay, sand, and gravel. Bedrock in the area varies between 35 to 75 feet below ground surface.

Previous explorations show the groundwater was generally encountered between elevation of 0.4 to -4.2 feet. Groundwater may vary depending on the season drilling occurred.

2 Health and Safety Plan, Permitting and Clearances

2.1 Site Specific and Drilling Contractor Health and Safety Plans (HASPs)

A site-specific Health and Safety Plan (Site HASP) was prepared by GEI prior to commencing field work to cover work performed by GEI field personnel. The drilling contractor will be required to prepare a Health and Safety Plan for their specific operations (Driller HASP). Copies of the Driller HASPs must be provided to GEI prior to the initiation of any Project field exploration activities. If GEI personnel observe the drilling crew not following the Driller's health and safety policies, we will remind the crew of the need to comply. If they fail to do so, we will contact and inform Driller's management of the situation. If GEI personnel observe an obvious and serious failure to comply with the Driller's HASP requirements, and if the drilling crew continues to be non-compliant, operations will be shut down until the safety issue is resolved.

The drilling contractor has the sole Health and Safety responsibility for their operation. However, GEI will be vigilant in our assessment of conditions related to our work and the driller's work with respect to maintain a safe work environment. GEI does not intend to complete an inspection checklist for Cascade's equipment.

2.2 Drilling Permits

At the direction of the District, an Environmental Health Services permit was obtained for the work included in this Plan.

Copies of these permits are included in Appendix B.

2.3 Utility Clearance

Before exploration activities begin, Underground Service Alert (USA) requires a visual inspection at each exploration location. GEI has completed the visual inspection, and outlined each location with stakes and white paint. USA was contacted prior to any subsurface exploration. A USA ticket number, as well as clearance date, expiration date and call-back-to-extend date, was obtained for each work area and documented for the project file. Table 1 includes the USA ticket number for each exploration.

Exploration locations may be hand cleared (hand augered) for the upper five feet as directed by the field engineer/geologist. Hand auger borings will be monitored and logged by the GEI representative on site.

Proximity to overhead utilities will be evaluated at each exploration location. In general, a clearance of at least 15 feet will be maintained between a drill rig mast and any overhead utilities (i.e., power lines).

2.4 Organization and Communication

The key point of contact for all communication related to the exploration activities is the GEI Project Manager. The GEI Project Manager will be a licensed Professional Geologist and Certified Engineering Geologist in the State of California. The GEI Project Manager will communicate with the District regarding progress updates or any issues that warrant input. Contact information is provided in Table 2.

During field activities, the GEI field engineers/geologists (point-of-contact on site) will prepare daily field reports summarizing work performed, footage drilled/explored, personnel and equipment on-site, and other related project information.

Geotechnical data, including boring and CPT logs and laboratory test results will be provided to the District in the Geotechnical Data Report.

Field exploration roles and responsibilities are as follows:

2.4.1 Field Engineer/Geologist

- Coordinates field logistics
- Supervises drilling and CPT activities
- Prepares descriptions of soil samples
- Prepares field logs
- Labels and stores all recovered samples
- Reports daily to the GEI Project Manager
- Facilitates daily safety meetings
- Communicates with utility locators, drilling or CPT crews, Project Manager, and site visitors

2.4.2 Project Manager

- Coordinates program with personnel responsible for clearances (county and city)

- Monitors and supervises ongoing field activities
- Monitors drilling progress
- Coordinates and reviews daily reports compiled by field personnel
- Reviews field staff labor costs and driller invoices
- Communicates with field engineers/geologists, Project Management team, and the District

3 Subsurface Exploration Plan

3.1 General

Prior to drilling, field personnel will review the field exploration program with the GEI Project Manager. Required permits and sub-consultants license and proof of insurance are included in Appendices B and C.

This review provides the basis for field work completion and offers field personnel the opportunity to raise any questions regarding project scope, procedures, schedule, or any issue that may not be clearly understood. Items discussed during this pre-drilling meeting include:

- Health and safety
- Goals, objectives, and scope of the field explorations
- Project schedule
- Sampling procedures and sample requirements for laboratory testing
- Criteria for the final depth of explorations
- Site access and client contacts
- Utility clearance
- Permits and security
- Potential of encountering hazardous materials
- Backfill requirements
- Disposal of cuttings and drill fluids
- Erosion control requirements, if necessary
- Site restoration requirements
- Applicable standards (ASTM, etc.) to be implemented

All fieldwork will be summarized daily using a Daily Field Report (Appendix D).

3.2 Objectives

The purpose of the explorations is to define (or refine) soil properties and geotechnical conditions of the underlying strata for engineering analyses required for the feasibility level analysis and evaluation. The focus of the geotechnical explorations will be on refining the thickness, extents, depth, and engineering properties of the fine-grained compressible layers underlying the study area. In addition, where appropriate, data will be obtained to either confirm or refine assumptions made in previous analyses.

3.3 Exploration Locations and Drilling Techniques

Geotechnical borings and CPTs will be conducted at locations shown on Figures 1 and 2. A total of 5 borings and 21 CPTs are planned along Novato Creek left bank crown and landside toe, the Lynwood Levee crown, and the Pacheco Pond Levee crown and landside toe. A summary of the exploration locations and types is below:

Planned Explorations:

- Novato Creek left bank levee – 1 boring, 9 CPTs
- Lynwood Levee – 2 borings, 5 CPTs
- Pacheco Pond Levee – 2 borings, 6 CPTs

Exploration locations, types, and targeted depths are summarized on Table 1.

3.3.1 Hollow Stem Auger/Mud-Rotary Borings

Borings will consist of a combination of hollow-stem auger and mud-rotary boring methods. Hollow-stem auger will be used to advance the boring until groundwater is encountered, then mud-rotary drilling will be used to help with sampling quality and borehole integrity.

The mud-rotary borings will be advanced using a 3.5-inch diameter side-discharge bit at the end of N-size rods. Disturbed samples will be obtained with 1.4-inch inside diameter (ID) standard penetration tests (SPTs). Relatively undisturbed samples will be obtained with 3-inch Shelby tubes.

The method of mud-rotary advancement usually consists of bentonite or EZ-Mud mixed into water, which is passed around the bit while drilling proceeds to flush cuttings from the borehole; this is also done to reduce friction and cool the bit and help retain an open hole without the use of casing wherever possible. The fluid is discharged from the collar into a tub to allow cuttings to settle and then recirculated down the boring. Cuttings will be monitored as they are discharged from the collar to assess changes in stratigraphy between sample intervals and to enable proper sampler choice.

3.3.2 CPT Explorations

Continuous CPT soundings will be performed to log foundation sediments using a truck-mounted or track-mounted 20- to 30-ton capacity cone apparatus in general accordance with ASTM D5778. The typical track-mounted CPT operation includes the track-mounted CPT rig, a 2-axle supply/water support truck with trailer, and a personal vehicle for the field personnel. The conventional instrumented cone assembly includes a cone tip with a 60-degree apex and a cross-sectional area of 15 square centimeters (cm^2), a sleeve segment with a surface area of 200 cm^2, and a pore pressure transducer near the base (shoulder) of the cone tip.

Prior to the start of testing, the rig is jacked up and leveled on four pads to provide a stable and level reaction for the cone thrust. During the test, the instrumented cone is hydraulically pushed into the ground at a rate of about 2 centimeters per second (cm/s), and readings of cone tip resistance, sleeve friction, and pore pressure are digitally recorded every second. As the cone tip advances, additional cone rods are added such that a "string" of rods continuously advances through the soil. As the test progresses, the CPT operator monitors the cone resistance and its deviation from vertical alignment.

Interpretation of the cone parameters are performed by on-board computers. Soils are classified based on the soil behavior type, which is an interpretation based on cone tip resistance and friction ratio. A continuous log of the soil is produced on a real-time basis.

Pore-pressure dissipation tests will be conducted in predominantly granular materials below the water table to determine approximate water levels and provide estimates of hydraulic conductivity. In a dissipation test, the CPT sounding is advanced to the test depth, or as directed by the field engineer/geologist, and then halted. In clays, pore pressure data is then recorded until approximately 50 to 75 percent of the induced excess pore pressure is dissipated, or to a maximum duration of approximately 30 minutes. In sands, pore pressure dissipation tests are generally conducted until 100 percent of the excess pore pressure is dissipated. All pore pressure data during the test are digitally recorded for subsequent analyses. After the dissipation test data are recorded, cone advancement is resumed. At the conclusion of each test, the electronic data are stored for further processing in the office.

3.3.3 Sampling Frequency and Types

Boring diameters will range from 4 to 6 inches, with soil sample diameters ranging from about 1.4 to 3 inches. Drilling techniques will be modified as appropriate based on encountered soil conditions. It is anticipated that four soil sampling techniques will be used during the geotechnical field exploration program:

- Standard Penetration Test (SPT)
- Mechanically Pushed Shelby thin walled tube

For mud-rotary and hollow-stem auger borings, soil samples will be collected on 2.5-foot intervals in the embankment and foundation using a combination of split spoon drive samplers (i.e., SPT or CAL samplers) and thin-walled Shelby tube or Piston tube samplers depending on consistency of soil.

The type of sampler used will be recorded by the field engineer/geologist. The sampling techniques are described in the following sections.

Relatively undisturbed samples will be sealed with wax, and with a cap and tape. Samples will be temporarily stored within the temperature controlled GEI Rancho Cordova office before being transported to the laboratory.

3.3.3.1 Standard Penetration Test (SPT) Sampler

Obtain samples in accordance with the procedure for Standard Penetration Test (SPT) as outlined in ASTM D1586. The SPT sampler, connected to an N rod only, will be driven into the ground using a 140-pound hammer falling 30 inches. The driller will provide the sampling spoon to the field engineer/geologist immediately after it is removed from the ground.

The driller will use a 1.375-inch-inside-diameter split barrel sampler without liners, as described in Figure 2 of ASTM D1586. The split-barrel portion of the sampler shall be at least 30 inches long to allow for recovery of 24 inches of material, or 24 inches long to allow for recovery of 18 inches of material. The field engineer/geologist will inspect and approve the sampler before any sampling is undertaken.

Use the following procedures in taking driven split spoon samples:

1. Clean out the boring to the sampling elevation using equipment that ensures that the material to be sampled is not disturbed by the operation. Withdraw the drill bit very slowly to prevent loosening of the soil around the hole.

2. After cleaning out the boring, compute the depth of the surface of the soil in the boring, to the nearest 0.1 foot, by measuring the length of drill rods and tools and the stickup of the drill rods. Compare the computed depth with the actual depth when the sampler rests on the bottom of the boring. If more than 6 inches of slough is observed, require the driller to clear the hole before driving the sampler.

3. Carefully lower the sampler and drill rods into the boring and measure the depth of the sampler when it rests on the soil at the bottom of the borehole. Measure

penetration of the sampler under the weight of the rods as accurately as possible when it occurs. With the sampler resting on the bottom of the hole, drive the sampler with blows from the 140-pound hammer falling 30 inches until either 18 inches (or 24 inches) have been penetrated or refusal conditions are encountered. Refusal is defined as 50 blows for six inches or less of penetration, a total of 100 blows have been applied, or there is no observed advance of the sampler during the application of 10 successive blows of the hammer.

4. For each sample, record the number of blows required to affect each six inches of penetration or fraction thereof. The first six inches is considered to be the seating drive. The sum of the number of blows required for the second and third six inches of penetration is termed the “standard penetration resistance.” The fourth interval (if applicable) will allow for additional recovery of the material being sampled.

5. Withdraw the sampler very slowly and smoothly so that no excess head of drilling fluid will exist inside the rods and so that there will be no appreciable suction created at the bottom of the sampler that will tend to cause loss of sample.

6. If a sample is not recovered or is found unsatisfactory as to size or condition, make a second attempt to obtain a satisfactory sample before advancing the casing to a lower depth. Over-driving the sampler to ensure sample recovery will be permitted only upon approval by the field engineer/geologist in each case.

7. Photograph the location of the boring and soil samples. Preserve each sample in 1-gallon sealed zip lock freezer bags. Subdivide samples if a material change is observed within the sample run. Label these samples from bottom to top using an A, B, C suffix. Store samples in 5-gallon plastic buckets with lids. Label buckets with boring identification, drilling depths, and date ranges for collected samples.

3.3.3.2 Shelby Tube Sampler

If fine-grained soils are encountered, relatively undisturbed samples will be taken by pushing a thin-walled tube sampler (“Shelby tube”) through the hollow-stem augers. Shelby tubes are generally 2 or 2.5 feet long, nominal 3 inches in diameter, and are hydraulically pushed into the soil. The rig pull-down pressure is monitored and recorded.

Take relatively undisturbed thin-walled tube samples in general accordance with ASTM D1587 using the following procedures:

1. Thoroughly clean the borehole as described above for split spoon sampling, lower the sampler and tube into the hole. Place the sampler in as close contact as

possible with the bottom of the hole; however, take care not to compress the soil beneath the sampler before pressing the tube.

2. Force the tube into the soil by a continuous and rapid motion without impact or twisting, under steady pressure at a rate of 4 to 8 inches per second, unless otherwise directed by the field engineer/geologist. Do not push the tube further than the length provided for the soil sample. Do not use pressure high enough to damage the thin-walled tube.

3. Leave the sample at rest for a few minutes. Increase the rest period to a minimum of fifteen (15) minutes if sample recovery is less than desired. Turn the tube two revolutions by hand prior to pulling the tube.

4. Add water or mud to the boring to ensure that the fluid level is at the top of the casing during withdrawal of the rods and sampler (for rotary wash borings only).

5. Withdraw the tube from the bottom of the hole in a smooth constant motion using hydraulic pressure to pull the tube at a rate of 1 inch per second or less. After the sample has been pulled free from the bottom of the hole, a distance of about 6 inches to 2 feet, remove the tube at a slow uniform withdrawal rate not to exceed 1 foot per second.

6. Carefully break the drill rod joints during withdrawal in as large sections as can be practically handled so as not to disturb the samples. Exercise extreme care while the sampler is being removed from the hole, and while the thin-wall tube is being removed from the sampler to prevent vibration of the rods or sampler by accidentally hitting the rods with a wrench or similar device. Immediately cap the bottom of the thin-walled tube after it is removed from the casing.

7. Seal the top of the tube with wax or plug and cap the top and bottom of the tube with a cap and tape.

8. An acceptable, relatively undisturbed sample for laboratory tests shall show no observable distortions in its stratifications and/or shear planes that can be reasonably attributed to the sampling and handling operations. Relatively undisturbed samples may be X-rayed to determine if the sample is acceptable.

If needed, a stationary (fixed) piston sampler operated by a separate piston rod (actuating rod) and a sampler head with an appropriate spring and piston rod cone check may be employed to improve sample recovery in soft soils.

Collected samples will be protected and packaged to avoid disturbance during delivery to the selected soil laboratory. The thin-walled tube samples will be stored and transported in the vertical "up-right" position. During transport, the samples will be secured vertically and surrounded with padding to prevent disturbance to the samples.

3.3.3.3 No Recovery

Occasionally, sampling is attempted but no sample is recovered. In all such cases, the letters "NR" should be written just below the sample number in the "Sample Number" column. Sampling equipment should be checked, and every attempt made to understand why no sample is recovered.

3.4 Exploration Depths

The anticipated boring depths are included in Table 1. All proposed explorations are planned to reach a minimum of 40 feet or four times the levee height below ground surface to obtain a better understanding of the extents of the fine-grained layers encountered in previous explorations and determine the extents of these materials throughout the study area.

3.5 Hours of Operation

Normal exploration activities will be between about 7 AM and 5 PM. Drill rig maintenance activities will be performed during normal working hours.

3.6 Description and Classification of Soils

Soils will be described in general accordance with ASTM D2487 and D2488 procedures, following guidance outlined in the "*Soil and Rock Logging, Classification, Description, and Presentation Manual*" (DWR, 2009). A soil description will include, as a minimum:

- Consistency (for cohesive soils) or relative density (for granular soils)
- Moisture condition
- Color
- Type of soil
- The Unified Soil Classification Symbol appropriate for the soil type
- Grain size

The various elements of the soil description should always be stated in the order given above. For example:

- soft, wet, gray - Fat CLAY (CH)
- dense, moist, brown SILTY SAND (SM), fine-grained to medium

Consistency or Relative Density of Soils

In the field, a semi-quantitative assessment of the relative density of sandy soils and the consistency of cohesive soils can be made using blow counts from SPTs, pocket penetrometer measurements, or torvane measurements. On the boring logs, the degree of relative density of granular soils is generally correlated to blow counts as shown below. The degree of consistency of cohesive soils is generally correlated to blow counts, pocket penetration measurements, and torvane measurements as shown below.

<table>
<tr><th rowspan="7">Fine Grained Soils</th><th>N Value (Blows/ft)*</th><th>Pocket Penetrometer (tsf)**</th><th>Torvane (tsf)**</th><th>Unconfined Compressive Strength (tsf)*</th><th>Consistency</th><th rowspan="7">Coarse Grained Soils</th><th>N Value (Blows/ft)*</th><th>Relative Density</th></tr>
<tr><td>0 - 2</td><td>< 0.25</td><td>< 0.12</td><td>< 0.25</td><td>Very Soft</td><td>0 – 4</td><td>Very Loose</td></tr>
<tr><td>2 – 4</td><td>0.25 – 0.50</td><td>0.12 – 0.25</td><td>0.25 – 0.50</td><td>Soft</td><td>5 – 10</td><td>Loose</td></tr>
<tr><td>4 – 8</td><td>0.50 – 1.0</td><td>0.25 – 0.50</td><td>0.5 – 1.00</td><td>Medium Stiff</td><td>11 – 30</td><td>Medium Dense</td></tr>
<tr><td>8 – 15</td><td>1.0 – 2.0</td><td>0.50 – 1.0</td><td>1.00 – 2.00</td><td>Stiff</td><td>31 – 50</td><td>Dense</td></tr>
<tr><td>15 – 30</td><td>2.0 – 4.0</td><td>1.0 – 2.0</td><td>2.00 – 4.00</td><td>Very Stiff</td><td rowspan="2">> 50</td><td rowspan="2">Very Dense</td></tr>
<tr><td>> 30</td><td>> 4.0</td><td>> 2.0</td><td>> 4.00</td><td>Hard</td></tr>
</table>

*Criteria presented in Terzaghi and Peck (1967). N value based on ASTM D1586; number of blows of 140-pound hammer falling 30 inches to drive a 2-inch – O.D., 1.4-inch-I.D. sampler one foot.

**Criteria as presented in AASHTO (1988)

The relative density and consistency descriptions may deviate from the published correlations for several reasons, including reliance on other test results or the field engineer/geologist's judgment based on observations of and/or manual manipulation of the sample. Manual tests for the consistency of fine-grained soils are shown below. In the case where the sampler passes from one soil type into another of markedly different properties, for example, from dense sand into soft clay, it should be recognized that the sampler performance may begin to reflect the presence of the lower layer before it reaches it. Therefore, care is required in the assessment of blow counts obtained from strata interfaces.

<table>
<tr><th rowspan="6">Fine Grained Soils</th><th>Manual Criteria*</th><th>Consistency</th></tr>
<tr><td>Thumb will penetrate soil more than 1 inch</td><td>Very Soft</td></tr>
<tr><td>Thumb will penetrate soil about 1 inch</td><td>Soft</td></tr>
<tr><td>Thumb will indent soil about ¼ inch</td><td>Firm</td></tr>
<tr><td>Thumb will not indent soil, but thumbnail will readily indent</td><td>Hard</td></tr>
<tr><td>Thumbnail will not indent soil</td><td>Very Hard</td></tr>
</table>

*ASTM D2488-09a – Criteria for describing consistency

Moisture Condition

The amount of moisture present in the soil sample should be described as wet, moist or dry. Soils that have visible free water are described as "wet" and usually come from below the water table. The descriptor "dry" is used when the soil appears to be air-dry, dusty, or dry to the touch. Soil samples that are damp but do not contain visible free water should be described as "moist." The term "saturated" is not used because it is difficult to determine, even by laboratory tests, whether a sample is truly saturated.

Color

Soil color should be described when the sample is first retrieved, at the natural moisture content.

Soil Classification

The Unified Soil Classification System (USCS) is the nucleus of the ASTM soil description system. Refer to ASTM D2487 and D2488 for a complete description of the soil classification process.

Grain Size

The constituent parts of a given soil type are defined on the basis of texture in accordance with particle-size designators. The dominant particle size is used to describe the soil as coarse-grained, fine-grained, or highly organic. Soil with more than 50 percent of the particles larger than the (U.S. Standard) No. 200 sieve (0.074 mm) is designated as being coarse grained. Soil (inorganic and organic) with 50 percent or more of the particles finer than the No. 200 sieve is designated as being fine grained. The gravel and sand components of soils are further defined on the basis of particle size as follows:

Soil Component	Grain Size
Boulders*	12 inch +
Cobbles*	3 inch to 12 inch
Coarse gravel	3/4 inch to 3 inch
Fine gravel	No. 4 sieve to 3/4 inch
Coarse sand	No. 10 to No. 4 sieve
Medium sand	No. 40 to No. 10 sieve
Fine sand	No. 200 to No. 40 sieve

*Boulders and cobbles are not considered soil or part of the soil's classification or description, except under miscellaneous descriptions, i.e. with cobbles at about 5 percent (volume).

Boring Logs

A field boring log will be completed for every hole drilled using the Boring Log form provided in Appendix D. At the beginning of the boring, the field engineer/geologist should record the following information on the log:

- Project name
- Project number
- The boring number
- The dates on which the boring is started and finished
- Borehole diameter
- Weight of hammer used for drive samples as reported by drilling subcontractor
- Drilling company
- Type of drill rig
- Drilling method, drill bit type
- Rig supervisor's name
- Approximate surface elevation
- Approximate rig hammer efficiency

As the boring progresses and is completed, the field engineer/geologist should complete the following information on the log:

- The last measured water depth and the date of the measurement
- Method of backfilling borehole.

The subsurface conditions observed in the soil samples and drill cuttings or perceived through the performance of the drill rig (for example, rig chatter in gravel, or sampler rebounding on a cobble during driving) should be described in "comments" column on the log. Besides descriptions of individual soil samples, boring logs should indicate the tops and bottoms of soil layers. Descriptions should be included for each soil layer, with horizontal lines drawn to separate adjacent layers. It is important that a complete description of subsurface conditions be provided on the field logs at the time of drilling. Completing descriptions based on laboratory test results is not an acceptable practice.

3.7 Access, Traffic Control and Staging

Traffic control measures, including the placement of caution tape, cones, and signs around the drilling operation, will be used during drilling at some locations where pedestrian, bicycle, or vehicle traffic occurs or limited property access exists.

Levee toe areas are unpaved. Rainfall should not impact drilling and CPT operations unless the ground at a given boring location becomes too soft to mobilize a CPT truck or drill rig, high water impounds against the levee, or lightning is present. Drilling will be terminated if lightning appears likely or if, in the opinion of the project team, water against the riverbank is too high. The GEI HASP states that work can resume 30-minutes after the last clap of thunder or flash of lightning. Drilling and/or CPTs will be suspended if the river level is forecast to rise above the levee foundation.

3.8 Waste Disposal

Soil cuttings generated will be placed into drums to be transported off site and disposed. Bentonite slurry will not be discharged on the ground surface; it will be contained and transported offsite for disposal at an appropriate landfill facility. Drilling fluids and wet soil cuttings will be pumped or shoveled into either 55-gallon drums or mobile hopper. Cascade will transport the drums or hopper to the designated staging area on County property and be transported off-site at the end of the week.

3.9 Exploration Completion and Site Restoration

In accordance with county requirements, all boreholes will be backfilled with cement grout at the completion of drilling. The grout proportions and quantities will be recorded on the boring log.

Grout will be placed into the borehole by tremie method through a pipe placed at the bottom of the borehole. The end of the tremie pipe will be kept in the grout as it fills the borehole and rises. When the grout mixture appears at the surface, the tremie pipe will be withdrawn. As the tremie pipe is withdrawn, additional grout shall be added to make up for any lost volume. Borings will be backfilled the day that the hole is completed.

Drill sites will be cleaned and restored as closely as practicable to pre-drilling conditions. At the completion of drilling, all equipment and materials, tools and unused materials will be removed and trash will be disposed offsite.

3.10 Documentation of Exploration Locations

The locations of borings will be documented using hand-held GPS units. After completion of the exploration program, the exploration location will be confirmed or refined using physical features on the ground and aerial imagery. The elevations will be estimated from available topographic surveys using a horizontal datum of NAD83 and vertical datum in NAVD88.

4 Laboratory Testing

4.1 Material Sampling and Testing Protocols

Geotechnical laboratory tests will be performed on selected samples obtained from the borings to assist with characterization of the geotechnical engineering properties of the subsurface materials. The geotechnical laboratory testing will be performed by Geocon Consultants, Inc. (Geocon) in their Rancho Cordova, CA laboratory. This program is subject to modification based on actual conditions encountered, and on the judgments of the GEI Project Manager.

4.2 Testing Program

Soil sample laboratory testing will include index tests (in-situ moisture content and density on disturbed samples, Atterberg limits, and grain-size distribution), shear strength, and consolidation tests, as appropriate. The list below summarizes the proposed laboratory testing.

- Sieve Analysis, ASTM D422
- #200 Sieve Wash, ASTM D1140
- Moisture Content and Density of Soils, ASTM D2937
- Atterberg Limits, ASTM D4318
- Consolidated-Undrained Triaxial Compression Testing, ASTM D4767
- Unconsolidated-Undrained Triaxial Compression Testing ASTM D2850
- One-Dimensional Incremental Consolidation Testing of Soils, ASTM D2435
- Organic Content, ASTM D2974

Actual number and type of tests performed at each boring will be determined by the GEI Project Manager based on the stratigraphic units encountered.

5 Quality Assurance/Quality Control (QA/QC)

5.1 Hammer Calibration

Cascade performed a hammer calibration test on site and provided GEI with the report. Hammer calibrations are performed by a series of SPT energy measurements on SPT hammers to measure the amount of energy delivered to the top of the drill string when sampling. Hammer calibration will be conducted at least yearly in accordance with ASTM D4633. Calibrated hammer efficiency will be noted on the first page of each boring log in the remarks area.

5.2 Boring Log and Data QC

Field quality control measures will be provided through senior engineering geologist oversight of the field activities throughout the duration of the geotechnical investigations.

GEI personnel are responsible for collecting and transporting soil samples to the soil testing laboratory, processing laboratory test results, and adjusting field boring logs based on laboratory test data.

Creating boring logs for this project includes:

- Field sampling and descriptions of the boring logs.
- Quality check of field observations.
- Preparation of a draft gINT log.
- If laboratory tests are performed on samples recovered from borings, soil classifications and descriptions will be refined as appropriate based on test results.
- CPT data will be compared with boring logs and laboratory data from nearby explorations.
- Final draft boring logs will be prepared based on adjustments for laboratory tests and subsequent quality checks.
- Final draft logs in gINT format will be reviewed by the Project Manager and any necessary final adjustments will be made prior to delivery to the District.

6 Public Awareness

All field personnel will be trained and informed to not provide opinions when approached by members of the general public or press who are seeking information regarding the Novato Creek Levee Evaluation Project. Rather, field personnel will explain that Marin County consultants are inspecting and documenting the subsurface conditions along the Novato Creek and Lynwood Basin levees. Field personnel will log the date and time of contact with members of the public, name of the person making the inquiry, and subject of the inquiry.

7 References and Documentation of Previous Explorations

AASHTO (1988). *Manual on Subsurface Investigations, Revision 1*. American Association of State Highway and Transportation Officials (AASHTO).

ASTM D422. *Standard Test Method for Particle-Size Analysis of Soils.*

ASTM D1140. *Standard Test Method for Amount of Material in Soils Finer than No. 200 (75µm) Sieve.*

ASTM D1586. *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling*.

ASTM D1587. *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*.

ASTM D2435. *Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading.*

ASTM D2487. *Standard Practice for Classification of Soils for Engineering Purposes (United Soil Classification System)*.

ASTM D2488. *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*.

ASTM D2850. *Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils.*

ASTM D2937. *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method*.

ASTM D2974. *Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*.

ASTM D4318. *Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.*

ASTM D4633. *Standard Test Method for Energy Measurement for Dynamic Penetrometers.*

ASTM D4767. *Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils*.

ASTM D5778. *Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils.*

DWR, 2009. *Soil and Rock Logging, Classification, Description, and Presentation Manual*. California Department of Water Resources, Division of Flood Management. September.

Terzaghi and Peck (1967). *Soil Mechanics in Engineering Practice*. Karl Terzaghi and Ralph Peck, Wiley, 1967.

Tables

GEI Consultants

Table 1: Summary of Proposed Explorations
Novato Creek Levee Evaluation
Marin County, California

Exploration ID	Creek	Exploration Location	Approximate Coordinates		Target Depth[1] (ft)	USA Ticket # (Exp 10/16/18)
			Latitude	Longitude		
SB-1	Novato Creek Left Bank	Crown - Paired	38.096599	-122.553414	40	W826100572
CPT-1	Novato Creek Left Bank	Crown - Paired	38.096608	-122.553291	40	
CPT-Toe 1	Novato Creek Left Bank	Toe	38.097104	-122.552158	50	W826100583
CPT-2	Novato Creek Left Bank	Crown	38.097396	-122.549753	50	W826100572
CPT-3	Novato Creek Left Bank	Crown	38.094586	-122.548965	50	
CPT-4	Novato Creek Left Bank	Crown	38.093053	-122.545621	50	
CPT-5	Novato Creek Left Bank	Crown	38.093608	-122.541817	40	
CPT-6	Novato Creek Left Bank	Crown	38.092008	-122.539721	40	
CPT-Toe 2	Novato Creek Left Bank	Toe	38.092129	-122.539492	40	W826100581
CPT-7	Novato Creek Left Bank	Crown	38.089533	-122.535544	40	W826100572
SB-2	Lynwood Levee	Crown	38.095185	-122.553649	55	W826100554
CPT-8	Lynwood Levee	Crown	38.094280	-122.550668	55	
CPT-9	Lynwood Levee	Crown	38.092415	-122.547688	55	
CPT-10	Lynwood Levee	Crown	38.091655	-122.543668	50	
SB-3	Lynwood Levee	Crown - Paired	38.090839	-122.540061	45	
CPT-11	Lynwood Levee	Crown - Paired	38.090846	-122.540108	45	
CPT-12	Lynwood Levee	Crown	38.088992	-122.537300	40	
CPT-13	Pacheco Pond	Crown	38.077201	-122.527111	45	W826100596
CPT-Toe 5	Pacheco Pond	Toe	38.077227	-122.527013	45	
SB-4	Pacheco Pond	Crown - Paired	38.074761	-122.525901	40	
CPT-14	Pacheco Pond	Crown - Paired	38.074742	-122.525905	40	
CPT-Toe 3	Pacheco Pond	Toe/Ramp	38.074684	-122.525703	40	
SB-5	Pacheco Pond	Crown - Paired	38.072343	-122.524633	45	
CPT-15	Pacheco Pond	Crown - Paired	38.072330	-122.524616	45	
CPT-Toe 4	Pacheco Pond	Toe	38.070993	-122.521593	45	
CPT-16	Pacheco Pond	Crown	38.070952	-122.521699	45	

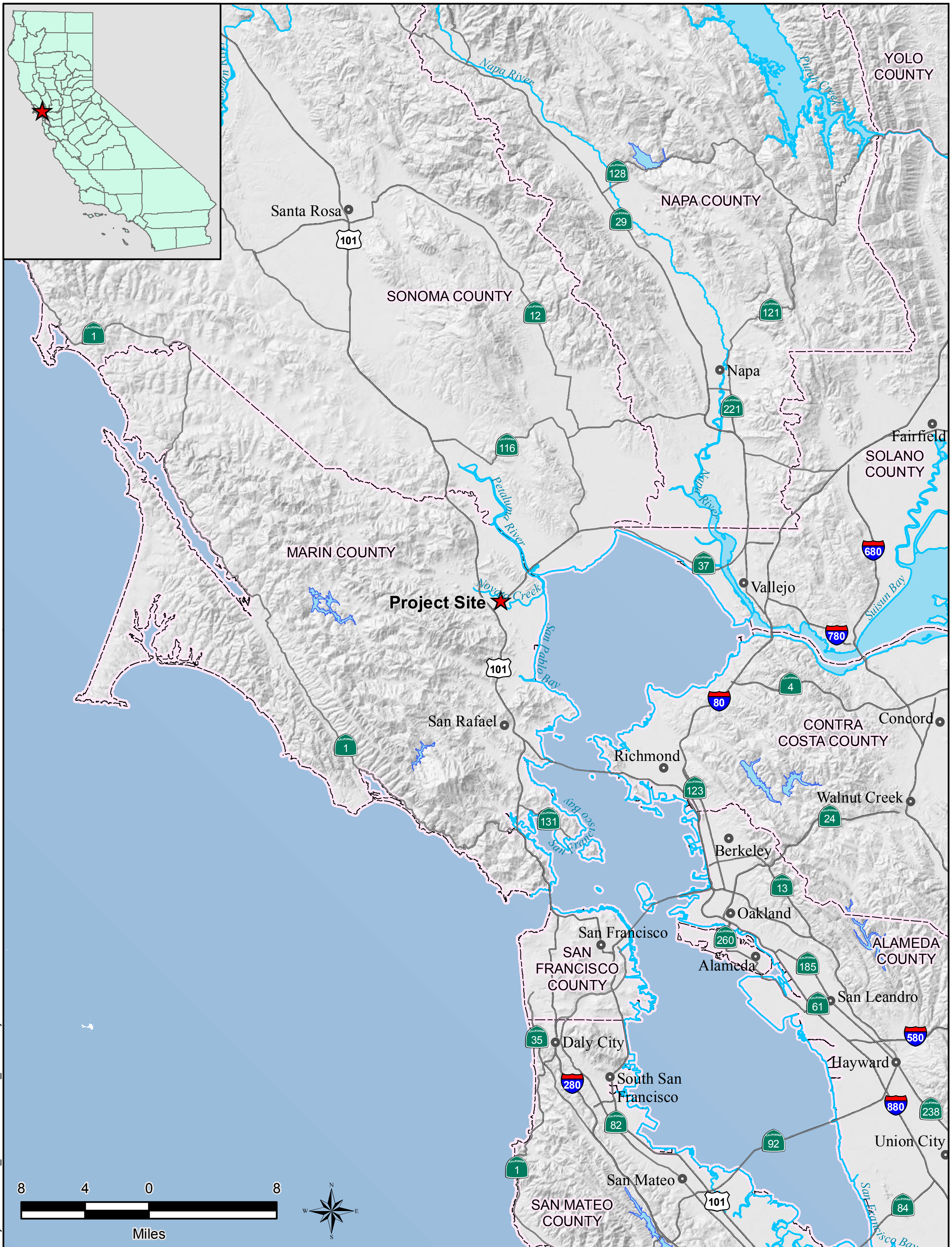
(1) Exploration depth will be minimum 40 feet deep or 4 times the levee height

Table 2. List of Contacts
Novato Creek Levee Evaluation
Marin County, California

Name	Role	Organization	Mailing Address	Telephone	Cellular Telephone
Steven Hawkins	Corporate Health & Safety Officer	GEI	455 Winding Brook Drive, Suite 201, Glastonbury, CT 06033	(860) 368-5348	(860) 916-4167
Autumn Eberhardt	Regional Health & Safety Officer	GEI	2868 Prospect Park Drive, Suite 400, Rancho Cordova, CA 95670	(916) 631-4525	(631) 481-5094
Graham Bradner	Project Manager	GEI	2868 Prospect Park Drive, Suite 310, Rancho Cordova, CA 95670	(916) 631-4577	(916) 709-3833
Robert Jaeger	Professional Engineer of Record	GEI	2868 Prospect Park Drive, Suite 310, Rancho Cordova, CA 95670	(916) 631-4531	
Nichole Tollefson	Project Engineer	GEI	2868 Prospect Park Drive, Suite 310, Rancho Cordova, CA 95670	(916) 631-4590	(916) 580-7030
Lisa Yabusaki	Field Inspector	GEI	2868 Prospect Park Drive, Suite 310, Rancho Cordova, CA 95670	(916) 631-4565	(808) 224-3553
Richard Keizer	Field Inspector	GEI	2868 Prospect Park Drive, Suite 310, Rancho Cordova, CA 95670	(916) 631-4593	(510) 673-8984
Eduardo Cerna-Alvarez	Field Inspector	GEI	2868 Prospect Park Drive, Suite 310, Rancho Cordova, CA 95670	(916) 631-4526	(831) 540-7620
Joanna Dixon	Client PM	Marin County	3501 Civic Center Drive Rm 304, San Rafel, CA 94903	(415) 473-7031	(415) 497-9773
Gwen Bart	Grout Inspector	Marin County	3501 Civic Center Drive Rm 304, San Rafel, CA 94903	(415) 473-6912	(707) 364-4287

Figures

GEI Consultants



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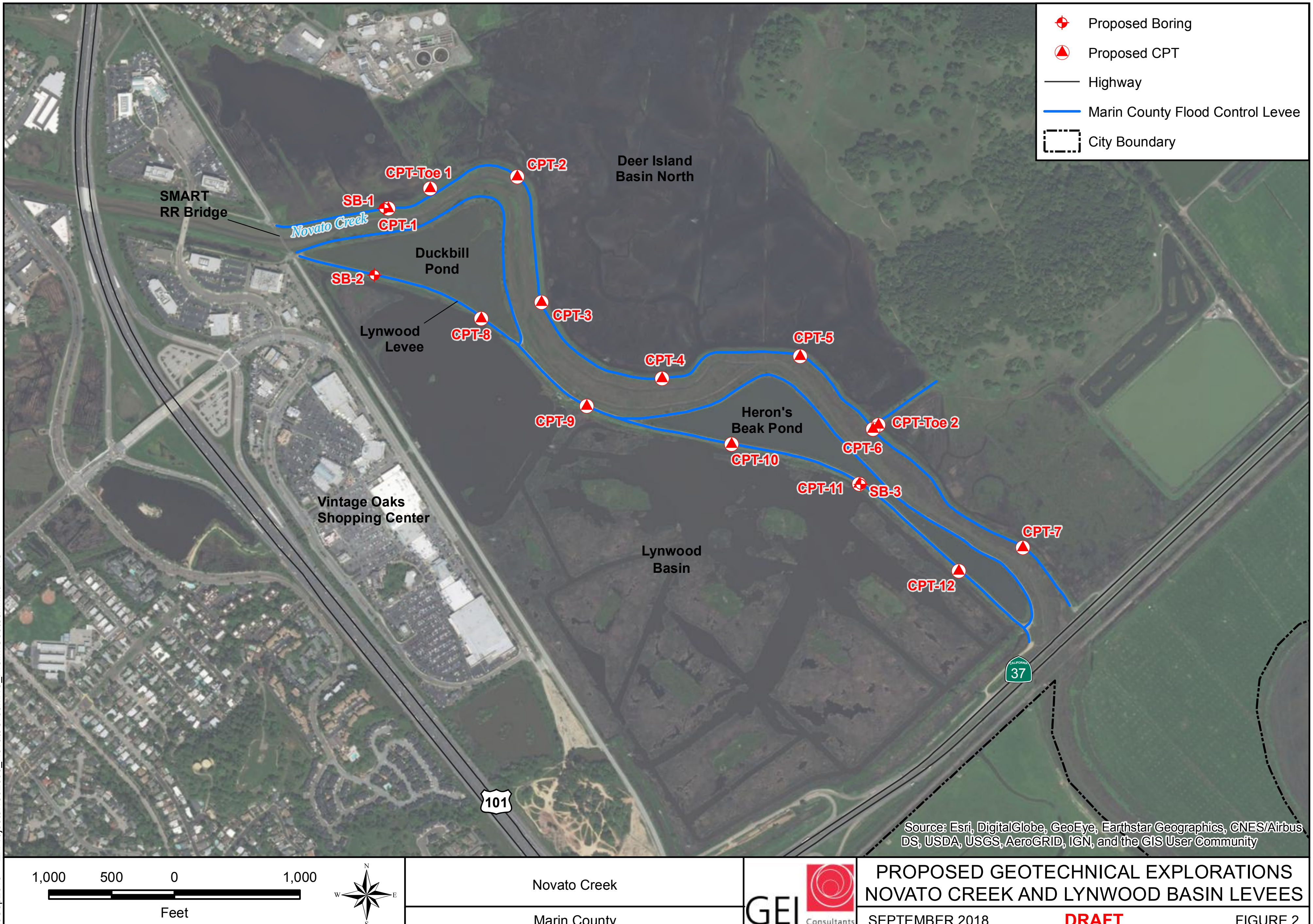
20Sep2018

Novato Creek	GEI Consultants	Site Vicinity		
Marin County		SEPTEMBER 2018	DRAFT	FIGURE 1



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Novato Creek

Marin County

GEI Consultants

PROPOSED GEOTECHNICAL EXPLORATIONS
NOVATO CREEK AND LYNWOOD BASIN LEVEES

SEPTEMBER 2018 **DRAFT** FIGURE 2

400 200 0 400

Feet

Novato Creek

Marin County

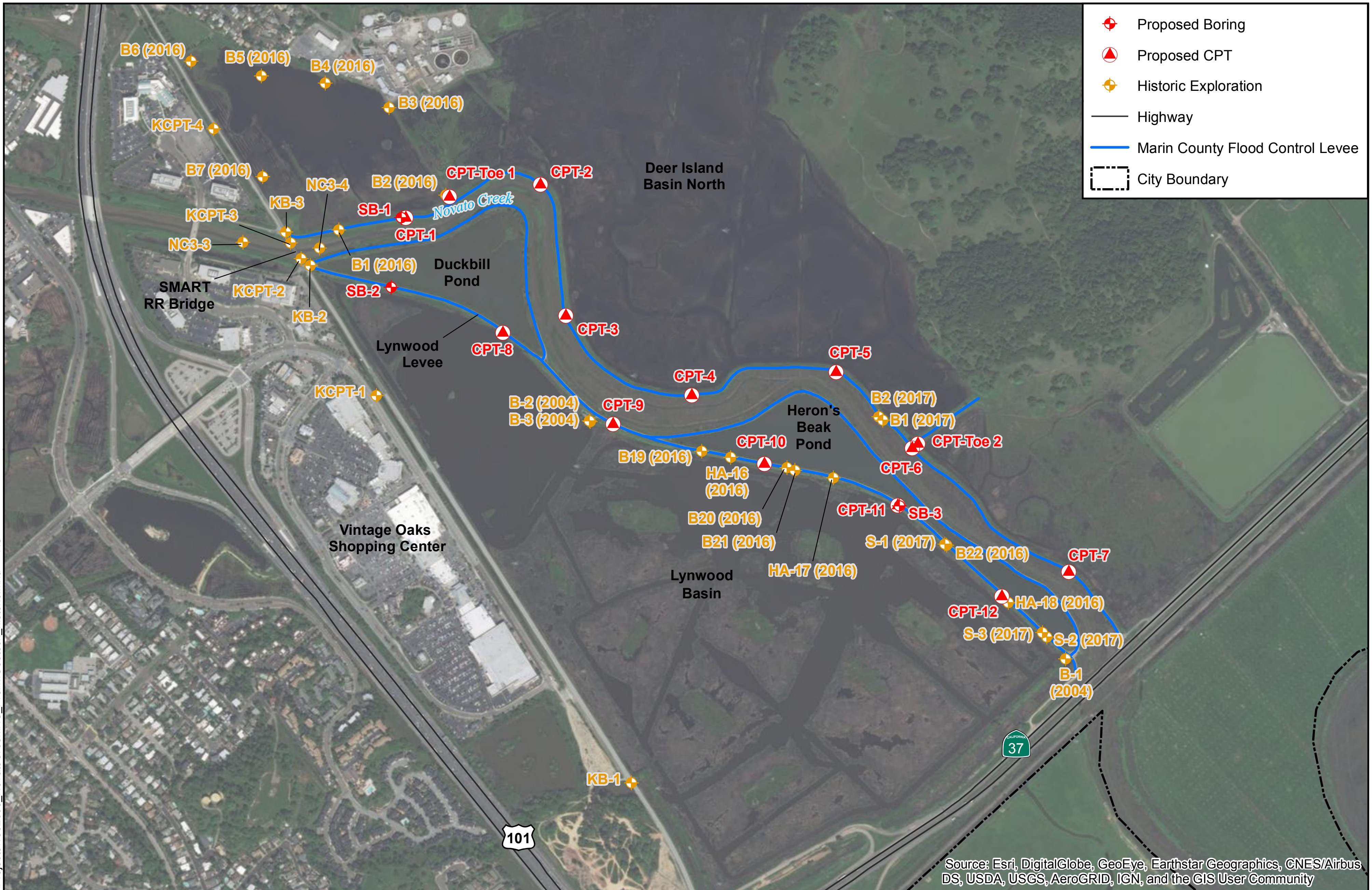
GEI Consultants

PROPOSED GEOTECHNICAL EXPLORATIONS
PACHECO POND LEVEE

SEPTEMBER 2018 | DRAFT | FIGURE 3

Z:\Projects\18026969_NovatoCreek\PachecoPond_PrelimGeotech.mxd RS

20Sep2018



1,000 500 0 1,000

Feet

Novato Creek

Marin County

GEI Consultants

PROPOSED AND HISTORIC GEOTECHNICAL EXPLORATIONS
NOVATO CREEK AND LYNWOOD BASIN LEVEES

SEPTEMBER 2018 **DRAFT** FIGURE 4

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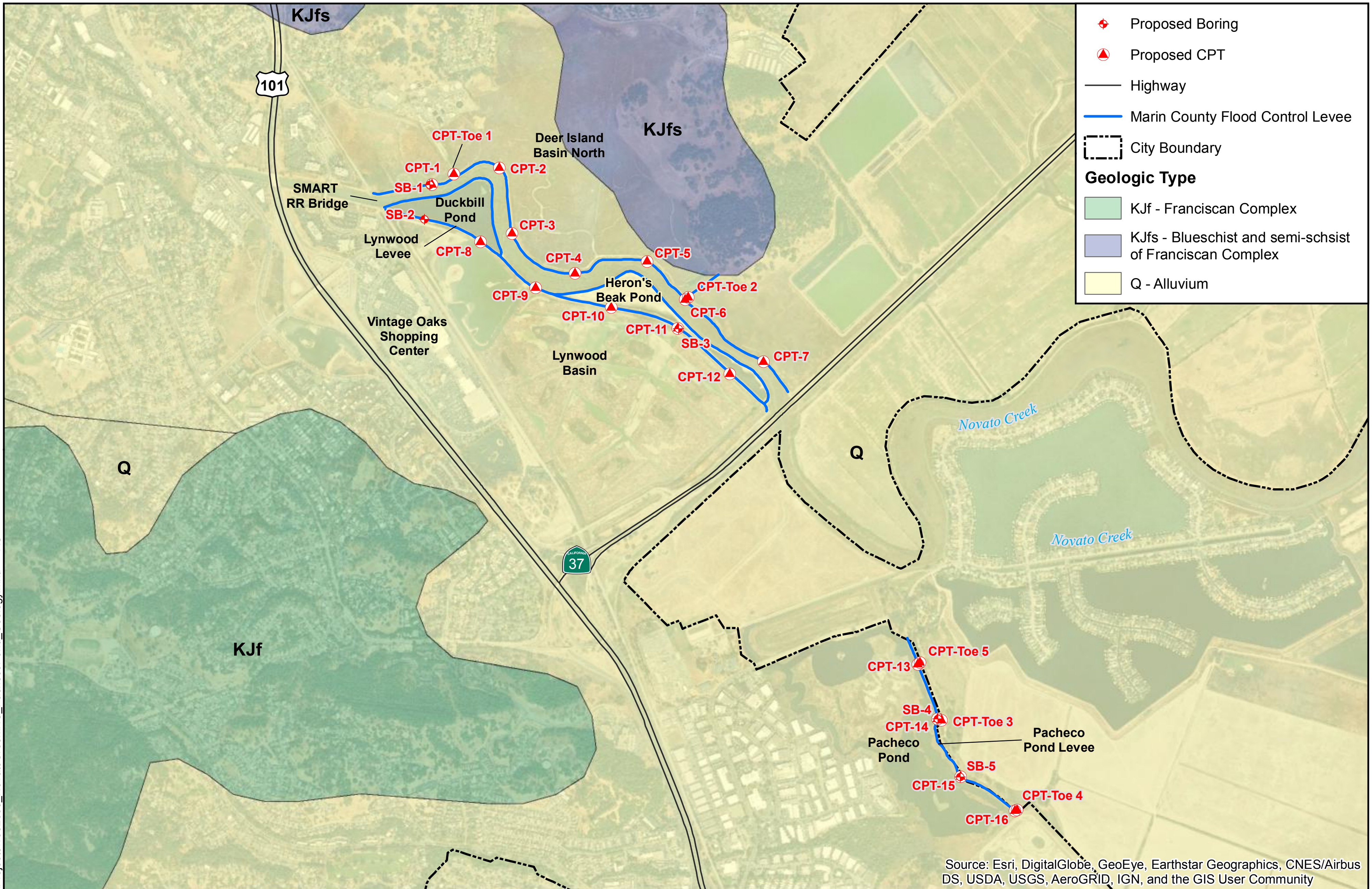
20Sep2018



1,000 500 0 1,000

Feet

Novato Creek

Marin County

GEI Consultants

GEOLOGY: NOVATO CREEK, LYNWOOD BASIN AND PACHECO POND

SEPTEMBER 2018 **DRAFT** FIGURE 5

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