FINAL INTEGRATED GENERAL REEVALUATION REPORT AND ENVIRONMENTAL IMPACT STATEMENT

SAN FRANCISCO BAY TO STOCKTON, CALIFORNIA NAVIGATION STUDY

APPENDIX E: Geotechnical

JANUARY 2020

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LIST OF ABBREVIATION AND ACRONYMS

g	gravitational acceleration
H:V	horizontal to vertical
MLLW	mean lower low water
O&M	operation and maintenance
PED	pre-construction, engineering, and design
PGA	peak ground acceleration
USACE	US Army Corps of Engineers
USGS	US Geologic Survey

1.0 INTRODUCTION

This **GEOTECHNICAL APPENDIX** provides a summary of geologic conditions for the San Francisco Bay to Stockton, California Navigation Improvement Project. Chemical and biological characteristics of sediments along San Francisco Bay to Stockton are presented elsewhere. Elevations in this **GEOTECHNICAL APPENDIX** reference mean lower low water (MLLW) for the 1983 to 2001 epoch.

1.1 Project Description

The Recommended Plan for the San Francisco Bay to Stockton, California Navigation Improvement Project would deepen the existing maintained channel depth of the Pinole Shoal Channel and the Bulls Head Reach portion of the Suisun Bay Channel from -35 feet MLLW to -38 feet MLLW, with approximately 13.2 miles of new regulatory depths (See Figure 1.1 and Figure 1.2). Approximately 10.3 miles of the Pinole Shoal Channel (stations 0+00 to 548+00) and all 2.9 miles of the Bulls Head Reach to Avon (stations 0+00 to 62+00, and 88+00 to 159+00) would be dredged. A 2,600 foot-long sediment trap (width of 300 feet) would be constructed at Bulls Head Reach (located between stations 62+00 and 88+00 of the Bulls Head Reach), with a depth of -42 feet MLLW, plus 2 feet of overdepth. The sediment trap would be maintained at -42 feet MLLW during future maintenance dredging to reduce rapid shoaling in the channel and emergency maintenance.

If the entire overdepth prism were dredged, the Recommended Plan would result in approximately 1.6 million cubic yards of dredged material from an approximate 318-acre footprint. The breakout of volumes for each feature is shown as follows:

- Pinole Shoal deepening = 1,443,900 cy
- Bulls Head Reach deepening = 159,300 cy
- Bulls Sediment Trap & Overdepth 2 feet = 120,600 cy
- Rocky Obstruction (Suisun Bay Channel)) = 40 cy of rock (950 sq. ft).

All construction is expected to occur during the existing environmental work windows developed by the San Francisco Bay Long Term Management Strategy for the Placement of Dredged Material unless other work windows are developed during consultation with the resource agencies. The environmental work window for the Pinole Shoal Channel is from June 1 through November 20 and the work window for the Bulls Head Reach portion of the Suisun Bay Channel is from August 1 through November 30.

It is assumed that the timing of the channel deepening will occur immediately after completion or concurrent with the operation and maintenance (O&M) dredge cycle within each reach. Although feasible, dredging contract acquisition approach and timing is tight for accomplishment of both O&M dredging and channel deepening in one environmental work window therefore, this avoidance measure does carry some risk. Should dredging extend past the environmental work window, additional coordination would immediately be initiated with the appropriate agencies. O&M material would be placed at in-bay sites SF-10 and SF-16, according to the Federal standard. New construction material from Pinole Shoal would be placed at Cullinan Ranch; new construction material from Bulls Head Reach would be beneficially used at a suitable and permitted site, currently assumed to be Montezuma Wetlands. The beneficial use placement at and Cullinan Ranch and Montezuma Wetlands is currently assumed to offset benthic foraging habitat and residual impacts.

The Recommended Plan has estimated average annual net benefits of $10.5 Million (fiscal year 2020 price levels, 2.75% discount rate).

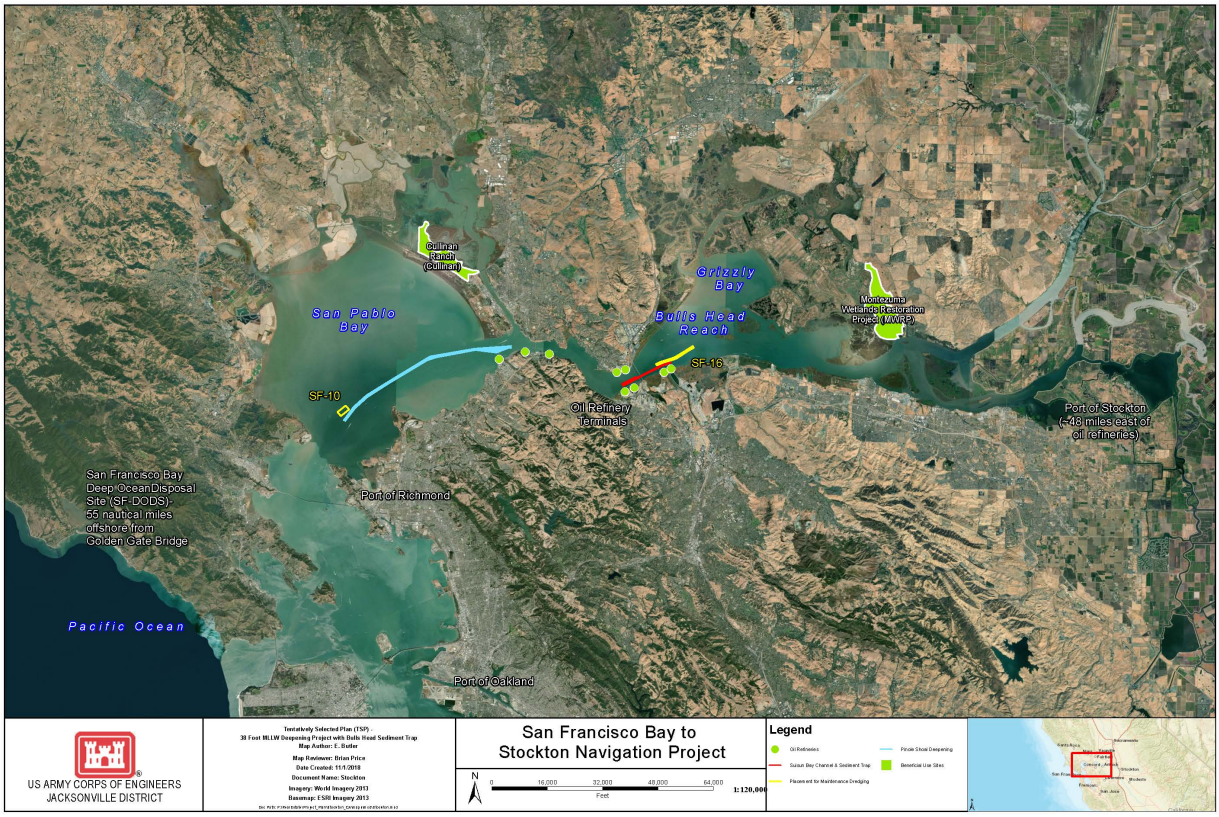

Figure 1.1: Project Area

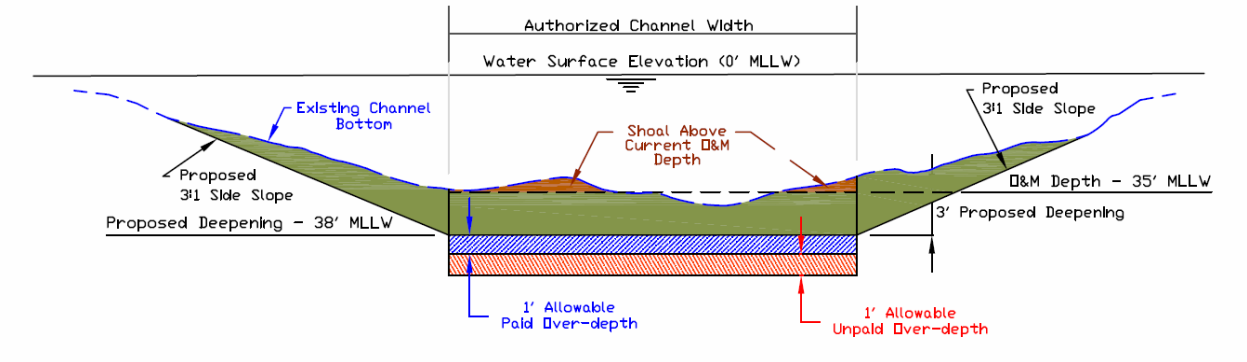

Figure 1.2. Recommended Plan for San Francisco Bay to Stockton

2.0 AVAILABLE INFORMATION

This **GEOTECHNICAL APPENDIX** uses information from a subsurface exploration program (USACE, 1990, 1993, 1994) and a sampling and analysis program (USACE, 2014a, 2014b) to characterize sediments along San Francisco Bay to Stockton. A description of these separate efforts is provided below.

2.1 Subsurface Exploration Program (1989 to 1994)

A subsurface exploration program was completed under four separate investigations from 1989 to 1994. The purpose of the subsurface exploration program was to determine physical, chemical, and biological characteristics of sediments for San Francisco Bay to Stockton. Relevant information from these investigations are captured in the following reports.

USACE. (1990). Chemical Evaluations of John F. Baldwin Ship Channel Sediment. Prepared by Battelle/Marine Sciences Laboratory.

USACE. (1993). Ecological Evaluation of Proposed Dredged Material from the John F. Baldwin Ship Channel (Phase III-Biological Testing). Prepared by Battelle/Marine Sciences Laboratory.

USACE. (1994). Ecological Evaluation of Proposed Dredged Material from Bulls Head Channel (Lower Suisun Bay). Prepared by Battelle/Marine Sciences Laboratory.

Sediments were collected using a four-inch diameter vibracore sampler deployed from a barge to a depth of -47 feet MLLW. Soil classification of sediments was performed in accordance with ASTM D 2488. Grain size of sediments was determined for composite samples, in accordance with Puget Sound Estuary Program Protocol. Composite samples were prepared from "homogenized" sediments from a segment of core sample, a core sample in its entirety, an area of dredging, or a particular sediment unit. The Puget Sound Estuary Program Protocol is consistent with ASTM D 421 and ASTM D 422. The number of core samples collected and composite samples prepared are summarized in Table 2.1.

Table 2.1. Summary of the Subsurface Exploration Program (1989 to 1994)

Date of Investigation		1989	1992	1994
Pinole Shoal Channel	Vibracore Samples	30	26	-
	Composite Samples	48	30	
Suisun Bay Channel (Bulls Head Reach)	Vibracore Samples	9	3	9 [1]
	Composite Samples	11	4	18 [1]

[1] *Only core samples and composite samples within limits of San Francisco Bay to Stockton are listed*

2.2 Maintenance Dredging Sampling and Analysis (2014)

Sediment samples were collected in 2014, ahead of O&M dredging along the Pinole Channel and the Suisun Bay Channel. The purpose of the sampling and analysis was to determine the suitability for placement of O&M material at in-Bay disposal sites or upland beneficial reuse sites. Findings from the sampling and analysis are captured in the following reports.

USACE. (2014a). Sampling and Analysis Results for Sediment Samples Collected from the Pinole Shoal Channel. Final Report. Prepared by Atkins North America.

USACE. (2014b). Suisun Bay Channel and New York Slough 2014 Maintenance Dredging Sampling and Analysis Report. Prepared by Environmental Cost Management.

Sediments were collected using a vibracore sampler deployed from a barge to a depth of -37 feet MLLW and -39 feet MLLW. Soil classification of sediments are believed to have been performed in accordance with ASTM D 2488. Grain size of sediments was determined for composite samples, in accordance with ASTM D 4464 and Puget Sound Estuary Program Protocol for sediments along the Pinole Shoal Channel and the Suisun Bay Channel, respectively. Composite samples were prepared from "homogenized" sediments from an area of O&M dredging. The Puget Sound Estuary Program Protocol is consistent with ASTM D 421 and ASTM D 422. The number of core samples collected and composite samples prepared are summarized in Table 2.2.

Table 2.2. Summary of Sampling and Analysis (2014)

Date of Investigation		2014
Pinole Shoal Channel	Vibracore Samples	12
	Composite Samples	3
Suisun Bay Channel (Bulls Head Reach)	Vibracore Samples	5 [1]
	Composite Samples	1 [1]

[1] *Only core samples and composite samples within limits of San Francisco Bay to Stockton are listed*

3.0 SEISMICITY

The San Andreas Fault, Hayward Fault, Rodgers Creek Fault, and Green Valley Fault are the principle sources of seismic hazards along San Francisco Bay to Stockton (USGS, 2008). The Hayward Fault and the Franklin Fault transects the Pinole Shoal Channel, and the Concord Fault transects the Suisun Bay Channel (Jennings and Bryant, 2011). Peak ground acceleration (PGA) with a two-percent probability of exceedance in 50 years (i.e., a return period of 2,475 years) is estimated to be on the order of 0.64g to 0.77g (USGS, 2008). These values are based on the upper 30 meters of subsurface having an average shear velocity of 180 meter per second.

4.0 SUBSURFACE CONDITION

Sediments and rock will be encountered along San Francisco Bay to Stockton. However, rock encountered will be limited to a rocky obstruction west of the western limits of the Pinole Shoal Channel. Sediments include O&M material and new construction material. Rock will be of Franciscan Complex.

4.1 Pinole Shoal Channel

O&M material along the Pinole Shoal Channel is anticipated to classify as sand with varying amounts of silt and clay. Shells will also be encountered. Based on three composite samples, fines content is anticipated to range from six to 12 percent and clay fraction is anticipated to range from two to five percent.

New construction material along Pinole Shoal Channel is anticipated to classify as clay, silt, and sand. The alternating layers of silty clay, clayey silt, sandy silt, silty sand, sand, and inter-bedded clay and sand are discontinuous and of varying thickness. Sediments generally coarsen from west to east. Shells and wood debris (e.g., branches, twigs, and rootlets) will also be encountered. Organic soils grading to peat may also be encountered. Fines content is anticipated to range from nine to 94 percent and clay fraction is anticipated to range from five to 50 percent.

Recent bathymetric survey data, as discussed in the **CIVIL DESIGN APPENDIX**, suggests a rocky obstruction west of the western limits of the Pinole Shoal Channel will be encountered at elevation of -39.7 feet MLLW. The Recommended Plan will need to degrade the rocky obstruction to -43 feet MLLW to provide safe navigation. The rocky obstruction is believed to be of Franciscan Complex. Franciscan Complex is a subduction complex consisting of sandstone, shale, chert, limestone, volcanic rocks, metamorphic rocks, and minor plutonic rocks of Eocene and Late Jurassic to Late Cretaceous age (Wagner and Gutierrez, 2017).

4.2 Suisun Bay Channel

O&M material along the Suisun Bay Channel is anticipated to classify as sand with varying amounts of silt and clay. Shells, wood debris, and trace pyrite will also be encountered. Based on a single composite sample, fines content is anticipated to be on the order of 18 percent and clay fraction is anticipated to be on the order of 7 percent.

New construction material along the Suisun Bay Channel is anticipated to classify as clay, silt, and sand. The alternating layers of silty clay, clayey silt, sandy silt, silty sand, sand, and inter-bedded clay and sand are discontinuous and of varying thickness. Shells and wood debris (e.g., branches, twigs, and rootlets) will also be encountered. Fines content is anticipated to range from one to 97 percent and clay fraction is anticipated to range from one to 54 percent.

Rock is not anticipated to be encountered.

5.0 RECOMMENDATIONS

The Recommended Plan can be successfully pursued if consideration is given to the following.

- A subsurface exploration program was completed from 1989 to 1994 for San Francisco Bay to Stockton. However, a separate subsurface exploration program should be completed during Pre-Construction, Engineering, and Design (PED) to better characterize the sediment and rock to be encountered. The PED subsurface exploration program should include sediment and rock sampling and testing and may include a geophysical investigation. The geophysical investigation would help identify other rocky obstructions that may exist along San Francisco Bay to Stockton.

- Channels sloped 3H:1V are anticipated to perform satisfactorily under static loading based on past performance (i.e., no known slope failures along San Francisco Bay to Stockton since original project construction).

- Channels sloped 3H:1V may fail under dynamic loading (e.g., seismic events). In addition to slope failures, other seismic hazards include lateral spreading and fault ruptures along the Hayward Fault, Franklin Fault, and Concord Fault. However, risk from infrequent seismic events is characterized as low for San Francisco Bay to Stockton.

- O&M material will classify as sand with varying amounts of silt and clay. Fines content is anticipated to be less than 20 percent. Shells and wood debris will be encountered.

- New construction material will classify as clay, silt, and sand. The clay, silt, and sand will be inter-bedded and inter-mixed. Fines content is anticipated exceed 20 percent. Shells and wood debris will be encountered. Organic soils grading to peat may also be encountered.

- Rock will be encountered west of the western limits of the Pinole Shoal Channel. For cost estimation purposes, a barge-mounted long-reach excavator equipped with a hydraulic hammer should be assumed to be required to degrade the rocky obstruction. The barge-mounted long-reach excavator can also be equipped with a bucket to remove cuttings, if cuttings require removal. Alternatively, a grab dredger (e.g., clam shell bucket) can be used.

6.0 REFERENCES

Jennings, C.W., and Bryant, W.A. (2010). Fault activity map of California: California Geological Survey Geologic Data Map No. 6, map scale 1:750,000.

USACE. (1990). Chemical Evaluations of John F. Baldwin Ship Channel Sediment. Prepared by Battelle/Marine Sciences Laboratory.

USACE. (1993). Ecological Evaluation of Proposed Dredged Material from the John F. Baldwin Ship Channel (Phase III-Biological Testing). Prepared by Battelle/Marine Sciences Laboratory.

USACE. (1994). Ecological Evaluation of Proposed Dredged Material from Bulls Head Channel (Lower Suisun Bay). Prepared by Battelle/Marine Sciences Laboratory.

USACE. (2014a). Sampling and Analysis Results for Sediment Samples Collected from the Pinole Shoal Channel. Final Report. Prepared by Atkins North America.

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