FINAL INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT / ENVIRONMENTAL IMPACT REPORT (EIS/EIR)

APPENDIX C: GEOTECHNICAL ENGINEERING

PORT OF LONG BEACH
DEEP DRAFT NAVIGATION STUDY
Los Angeles County, California

October 2021

US Army Corps of Engineers ®

Port of LONG BEACH
THE PORT OF CHOICE

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LIST OF ACRONYMS/ABBREVIATIONS

ACRONYMS/ABBREVIATIONS	MEANING
ANSS	Advanced National Seismic System
CCC	Criterion Continuous Concentration (chronic)
CISN	California Integrated Seismic Network
CLE	Contingency Level Earthquake
CMC	Criterion Maximum Concentration (acute)
4,4"-DDT	Dichlorodiphenyltrichloroethane DDT (pesticide)
DE	Code-Level Design Earthquake
ERL	Effect Range Low
ERM	Effects Range Medium
EMI	Earth Mechanics, Inc.
H:V	horizontal on vertical
MLLW	mean lower low water
NOAA	National Oceanic and Atmospheric Administration
OLE	Operational Level Earthquake
PED	Pre-Construction Engineering Design
PGA	peak ground acceleration
POLB	Port of Long Beach
S_1	1-second spectral acceleration
SAP	Sampling and Analysis Plan
SAPR	Sampling and Analysis Plan Report
SC-DMMT	Southern California Dredge Material Mgmt Team
USACE	United States Army Corps of Engineers
USEPA	United Sates Environmental Protection Agency
USGS	United States Geological Survey

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1 INTRODUCTION

Presented herein is the Geotechnical Study Report prepared in support of the Port of Long Beach (POLB) Deep Draft Navigation Feasibility Study. The overall objective of this report is to summarize existing geotechnical conditions, considerations, and constraints, as well as present recommendations and conclusions for the proposed dredging activities within the POLB and associated federal waterway channels.

1.1 Study Area

The Study Area is located on the coast of southern California in San Pedro Bay at the POLB, which is approximately 20 miles south of downtown Los Angeles, California. To the west and northwest of San Pedro Bay are the communities of San Pedro and Wilmington, respectively, to the north is the City of Long Beach, and to the east is the community of Seal Beach. The study area includes the waters in the immediate vicinity (and shoreward) of the breakwaters in the POLB including the main channel, west basin, southeast basin, and other areas. The federal channel includes the entrance at Queens Gate (the gap between the Long Beach Breakwater and the Middle Breakwater) extending northward along the west of Pier J and east of Pier F, the Navy Mole, and Pier T. This study does not include any land areas within the harbor. The study area is shown as Plate C1 in Attachment 1.

1.2 Port Operations

The POLB handles domestic and international shipping trade that utilizes the San Pedro Bay water ways for berthing of shipping containers and liquid bulk vessels. The port handles 2,000 vessel calls and 82.3 million metric tons of cargo annually. Presently, access to the main channel, Pier J, West Basin, and the Southeast Basin is limited by depth. The proposed improvements will provide increased transportation efficiency and safety for port navigation. The design vessels for this project are cargo ships with 52-foot draft and oil tankers with 70-foot draft.

1.3 Proposed Improvements

The scope of this feasibility study is dredging to widen portions of the Main Channel (bend easing) to a depth of -76 feet MLLW, deepen the Approach Channel from -76 feet MLLW to depths ranging from -78 feet to -83 feet MLLW, deepen portions of the West Basin with depths ranging from -53 feet to -57 feet MLLW, create a Pier J approach channel and basin, and a standby area.

1.4 Geotechnical Scope of Work

The objective of this geotechnical report is to evaluate the proposed dredging elevations and lateral limits based on available data and provide conclusions and recommendations to meet the safety, cost, and navigational requirements of the project. There are two geotechnical aspects of the project:

A. The effects of dredging on the stability of adjacent structures
B. Dredgeability of the sediments and the suitability of the dredged materials for disposal

The USACE portion of the geotechnical evaluation for this feasibility study was:

A. The stability effects of dredging within the federal channel at the Queens Gate entry through the Long Beach Breakwater.
B. The dredgeability of the sediments and compatibility of the dredged material with proposed beach disposal sites. This will be addressed under a separate cover.

Within the POLB harbor, stability analysis of the proposed dredge locations was performed by POLB's consultant, AECOM, and geotechnical sub consultant Earth Mechanics Inc. (EMI). The results of POLB's geotechnical analysis are included in this report as Attachment 2.

USACE geotechnical tasks for this report included:

A. Review and summarize existing geotechnical data.
B. Peer review the geotechnical analyses completed by POLB's consultants and evaluate how they impact the federal channel.
C. Conduct slope stability analyses of the Long Beach Breakwater and Middle Breakwater with the proposed dredge cuts.

2 AVAILABLE INFORMATION

Characterization of baseline geotechnical and geologic conditions for the study area included acquisition, compilation, and review of existing, available data sources. The present conditions and design parameters are based primarily on the existing data the POLB provided, which includes previous geotechnical studies and investigations dating back to 1942. As-built plans and design manuals available in United States Army Corps of Engineers (USACE) Los Angeles District files were also reviewed. Available information is listed in Section 2.1.1 of this report and cited in Section 8.

2.1 Summary of Existing Reports and Studies

This section presents existing reports and studies prepared for previous projects at the POLB, design guidance, and criteria. These documents assisted in providing an understanding of the site-geotechnical conditions that existed prior to port development and the configuration of port channels, slopes and other facilities as a consequence of development. References for the reports and studies are provided in Section 8.

2.1.1 Existing Reports and Studies

- Report of Foundation Investigation Proposed Wharf, Berths 245, 246, and 247 Pier J (Dames and Moore 1967)
- Report – Foundation Investigation Berths 243 and 244, Pier J (Dames and Moore 1970)
- Report of Soil and Foundation Investigation: Proposed Sea-Land Container Terminal Pier G expansion, Berths 226 – 230 (Dames and Moore 1972)
- Comprehensive Condition Survey Los Angeles – Long Beach Breakwaters: Geotechnical Appendix, (USACE 1987)
- Queens Gate Dredging – Geotechnical and Chemical Investigation (Sea Surveyor 1994)
- USACE Memoranda regarding rock encountered during dredging (USACE 1999a-d, USACE 2001).
- Final Report of Geotechnical Investigation Volume 1 – Soil Data Report: Pier G Terminal Development Project (Kleinfelder 2000)
- Final Report of Geotechnical Investigation: Proposed New Container Wharf Pier J, Berths 235 and 236 (Kleinfelder 1996)
- Comprehensive Condition Assessment of the Middle Breakwaters (USACE 2014)
- Port Wide Ground Motion Study: Final Addendum No. 3 (Earth Mechanics 2015)
- Wharf Design Criteria, Version 4.0 (POLB 2015)
- Port-Wide Dredge Plan and Federal Channel Expansion Study (AECOM 2016)
- Geotechnical Input for Berth and Channel Deepening (Earth Mechanics 2017)

2.2 Summary of Existing Drawings and As-built Plans

From the design and record drawings database, POLB provided available drawings and details of various port structures along the channels and waterways. These drawings included critical data such as the design water depths of existing port structures, current water depths and distances to the proposed/existing channels and waterways from the toe of the existing port structures. POLB's consultants (AECOM and EMI) used the data and drawings to develop potential wharf improvement solutions and to assess setback distances; the results of this analysis are presented in Attachment 2.

2.2.1 Existing Drawings and As-built Plans

The POLB supplied the design team with cross-sections and as-built plans that were the basis of evaluation for the constructed conditions used in the analysis. Plans are itemized below and referenced in Section 8.

- General Plan of Breakwater & Dredging, West Arm
- Pier A Berth 201, Quay Wall
- Pier E Berths 122-124, Wharf
- Pier F and Pier G, Diking, Dredging and Filling
- Pier E Berths 125-127, Cast-In-Place Wharf
- Pier F Berths 204-205, Wharf
- Pier J and Pier F Extension, Rock Dike – Hydraulic Fill
- Pier E Berth 121, Tanker Terminal Offshore facilities
- Pier J Expansion, Rock Dike and Hydraulic Fill
- Pier J Berths 245-247, Wharf Modification
- Pier J Breakwater
- Pier J Expansion, Berths 266-270, Wharf
- Pier T Marine Terminal, Dredging and Wharf Construction
- Pier T Marine Terminal, Berths 134-136, Dredging and Wharf Extension
- Pier S Berths 102-110, Dike Realignment
- Pier T Marine Terminal, Berths 132-134, Dredging and Wharf Extension, Volume 2
- Pier G Berths 232-236, Terminal Redevelopment, Berth 236 Wharf, Landfill and Back Area
- Pier G Berths 232-236, Terminal Redevelopment, Berth 232 Wharf and Backlands

3 BACKGROUND AND EXISTING CONDITIONS

The development of the San Pedro Bay began at the end of the 19th century with the initial construction of the breakwater. After approximately 12 years of construction and dredging the POLB was officially dedicated on June 24, 1911. Over the past 100 years the POLB has undergone several expansion and redevelopment projects since the original development. Construction and composition of the port structures presented below are based upon design cross-sections and as-built plans referenced in Section 2.

While the geology of the port remains relatively unchanged, the POLB has had an impact on surficial sedimentation due to port activities and dredging operations. Present conditions of the basin floor are based upon bathymetry data recently collected in the port as well as the National Oceanic and Atmospheric Administration (NOAA) Nautical Chart of the Los Angeles and Long Beach Harbors (Chart No. 18751) which provide sounding depths from the MLLW datum. The bathymetry map and Chart No. 18751 are included in Attachment 3, Plates C6 and C7.

The following sections provide a summary of the project's basins' sedimentation and existing conditions of the adjacent piers and wharfs.

3.1 West Basin

The West Basin is located within the north-central region of the port and is bounded on the north by Pier T, to the west and south by the Navy Base Mole, and the Middle Harbor/Long Beach Channel to the east. Basin elevations are generally around -50 feet MLLW with shallower regions within the prohibited anchorage region of the Navy Base Mole. Dredging in winter 2016 was performed along the majority of Pier T and widening of the channel at the east end of the mole. Based on previous explorations in the West Basin, soils there generally consist of soft or loose sediments grading to medium stiff and medium dense sands to stiff silts in the surficial 20 feet before transitioning into dense to very dense sands and silty sands.

3.1.1 Pier T (Pier Echo/ US Naval Shipyard)

Located at the north end of the West Basin, at Pier T (formerly part of the U.S. Naval Shipyard) the depth immediately adjacent to the wharf structures varies from -36 to -54 feet MLLW, with an average depth of -50 feet MLLW in the vicinity of Berths 130 to 140, and an average depth of -40 feet MLLW for Berths 122 to 126. In winter 2016 this area was dredged to a depth of -55 feet MLLW to facilitate docking of larger vessels at Pier T. The wharf is supported by timber piles, sheet piles, and tiebacks with deadman anchors (POLB 1956; POLB 2002_A; POLB 2002_B).

3.1.2 Navy Base Mole (Pier W/ US Naval Shipyard)

Bordering the south perimeter of the West Basin is the 17-acre Navy Base Mole which was constructed in the 1940's as part of a new naval station and included 100 acres of Terminal Island. The design cross sections indicate the mole is comprised of hydraulic fill with quarry rock dikes and rock armoring (Naval Operating Base 1944).

3.2 Southeast Basin

Subsurface soils in the Southeast Basin are similar in composition to those in the West Basin. The basin ranges in depth from -35 to -64 feet MLLW with an original design depth of -55 MLLW. Previous explorations indicate soils in the Southeast Basin, including the foundation of the structures referenced below, generally consist of soft clay grading to stiff clay around a depth of 10 feet below bottom of basin before transitioning into the underlying dense to very dense sands and silty sands.

3.2.1 Pier F (Pier A)

The westward expansion of the Southeast Basin included the construction of Pier F, designated Pier A prior to 1993. In the 1960s, wharfs were expanded to accommodate Berths 203 through 208 with repairs to the rock dike being performed in the 1970s. The pier consists of typical hydraulic fill, rock dikes and 18-inch diameter precast concrete piles. The region adjacent to Pier F has the greatest depths to the mudline with elevations in the Southeast Basin averaging at approximately -65 feet MLLW (POLB 1952; POLB 1961; POLB 1966; POLB 1967).

3.2.2 Pier G

Providing berthing access to the north central region of the Southeast Basin, Pier G was originally constructed with hydraulic fill and a series of rock dikes with stone armoring. Recent redevelopment of the region included the installation of 18- and 24-inch-diameter prestressed concrete piles in the 1990s, creating Berths 227 through 230. The depth immediately adjacent to the wharf structures at Pier G varies from -45 to -59 feet MLLW, with an average depth of -54 feet MLLW (POLB 1966; POLB 1967).

3.2.3 Pier J

The southernmost expansion of the Port of Long Beach, Pier J, provides access to the northeastern, east, and southern regions of the Southeast Basin. Similar to the construction sequence at Pier G, Pier J construction and development of the wharfs and pier included hydraulic fill and a series of rock dikes with stone armoring as well as 18- and 24-inch-diameter concrete piles. The east portion of Pier J has a shallow mudline elevation of nearly -55 feet MLLW that transitions to -65 feet MLLW at the west end near the entrance to the Southeast Basin (POLB 1967; POLB 1991; POLB 1994; POLB 1995).

3.3 Pier J East Approach and Pier J Breakwaters

For cargo and shipping vessels that will berth along the eastern region of Pier J, ships are conveyed through the Middle and Long Beach Breakwater at the Queens Gate Entry before entering the Pier J east approach. Several expansion projects were completed during the last three decades of the 20th century. The southernmost expansion created an inlet for Berths 260 through 270 which are now protected by two breakwaters comprised of quarry run cores with armoring focused upon the seaward side. The southernmost sections of the breakwaters are constructed at 1.75 horizontal on 1 vertical (1.75H:1V) along the seaward side with an armored reinforced toe and 1.5H:1V along the landward side. The top of the breakwaters was designed with a top elevation of 12 to 18 feet MLLW that extends to the harbor seabed at -35 to -48 feet MLLW (POLB 1991; POLB 1994; POLB 1995).

3.4 Queens Gate Entrance and Main Breakwaters

The Queens Gate is the main entrance through the Middle and Long Beach Breakwaters into the Long Beach Outer Harbor of San Pedro Bay. The approach and main channel are, on average, at an elevation of -78 to -80 MLLW as indicated by bathymetry data and sounding depths (see Attachment 3, Plates C6 and C7). In 2001, the channel through Queens Gate was dredged to a maximum over-depth elevation of -78 feet MLLW with dredged side slopes in soil constructed at 3H:1V (Sea Surveyor 1994).

As shown in Figure 3-1, the composition of both the Middle and Long Beach Breakwaters is comparable in the design cross-section (Coastal 1986). At the crest of the breakwaters, the stone class is significantly larger, Class A, than the underlying course, Class B, with clay cores and sand cores chiefly constructed from locally dredged sediments in San Pedro Bay. Based on condition surveys of the Middle and Long Beach Breakwaters, the thickness of the layers may vary by a few feet (USACE 1987, 2014).

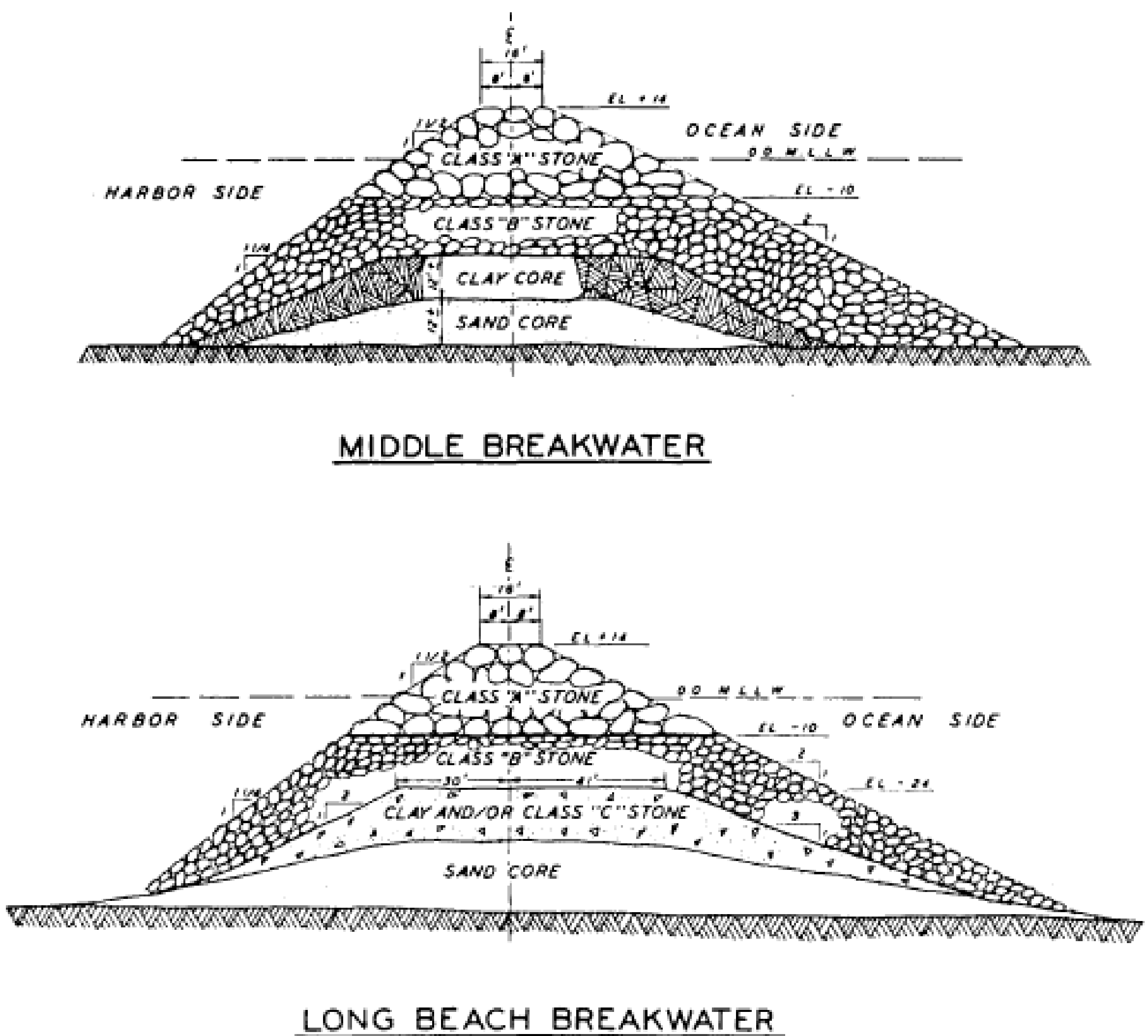

Figure 3-1 Middle and Long Beach Breakwater Cross Sections

3.5 Approach Channel

The approach channel is the deepened area on the ocean side of the breakwaters south of Queens Gate. The channel is approximately 1,200-1,300 feet wide and currently is dredged to an elevation of approximately -76 to -80 feet MLLW according to a 2015 bathymetric survey. The approach channel was deepened from -60 MLLW to -76 MLLW from November 1998 to December 2000. Rock and debris were unexpectedly encountered during late 1998 to about March 1999 dredging operation, with the largest size stone recorded during that period approximately 3 feet in largest dimension; while the rock excavated in each load made up less than 1% of the volume, the amount of rock not picked up by the dredge and left scattered at the bottom was not possible to estimate. This rock would cause the suction heads to be raised and lose suction power, affecting the hopper dredge's performance. The debris consisted predominantly of metal bars and was encountered with less frequency than the rock. All the stone encountered was located seaward of Queen's Gate and there is no record of any stone being encountered landward of Queen's gate. The assessment provided by the USACE project Geologist at that time indicated that stone or rock will be encountered throughout the Long Beach Entrance Channel in sparse quantities, since most of this rock has been transported to the project area via natural processes (e.g. stream or storm deposited). Only a minor fraction was apparently accidentally spilled from the barges carrying quarry rock for other projects in the area or knocked off the nearby breakwaters by storms. Detailed subsurface explorations are recommended during PED phase to better characterize the materials, estimate the size and amount of rock and debris and to better determine the dredging methods for this channel.

3.6 Local Marine Geology

The POLB study area is located entirely within the San Pedro Shelf, which is a relatively flat, isolated and narrow projection of the continental shelf. The bathymetry of the ocean surface at the shelf mimics this flat surface and slopes to the south at a rate of 10 feet per mile. The natural water depth of the Bay ranges from 20 to 50 feet. These depths have been increased from 50 to 70 feet locally due to dredging along the man-made channels and harbors and basins, as part of the creation of the marine infrastructure in the study area.

Based on previous USACE (and other entities) studies in the Port of Long Beach, referenced in section 2.1.1, it was found that the uppermost 20 to 100 feet of material beneath the bay is unconsolidated Quaternary-aged marine sediments. These sediments consist primarily of alternating layers of sand and silt, with very minor amounts of clay, gravel and seashells. However, as discussed above, cobble and boulder sized stone present seaward of the breakwaters was encountered during previous dredging of the approach channel. The shelf sediment is consistently found across the study area and all the man-made features in the study area are founded upon it. The thickness of the sand and silt layer vary between 5 and 50 feet and increases in density with depth. Clay, gravel and seashells are relegated to the uppermost 50 feet of the sediment and are found as thin localized lenses mixed within the thicker layers of sand and silt. The very top of the sea floor sediment, primarily landward of the breakwaters, consists of a suspended, light layer of mud (suspended clay and silt) atop a very loose layer of sand to silt. The thickness of the floating layer is approximately 2 to 6 inches.

The Long Beach harbor and marina infrastructure in the Bay is composed of Anthropogenic (man-made) fill (map symbol af). The fill consists of loose sand, silty sand and silt that was placed as a result of sediments dredged from the Bay since the 1930s. The marine sediment geology is shown on the Attachment 1, Plate C5 Local Marine Geology.

3.6.1 Liquefaction

Soil liquefaction is the partial loss of strength in sandy soils beneath the water table that occurs due to temporary increases in pore water pressure during intense earthquake shaking. As previously mentioned, much of the unconsolidated natural marine sediments in the study area are composed of coarse sand to silt that become denser with depth. Because of the increasing density with depth, the liquefaction potential of such sediments is low, except for shallower deposits of small natural isolated lenses of loose coarse sand and silty sand sediment. The liquefaction potential is higher for loose to medium dense sand and silty sand sediments that have been recently disturbed by anthropogenic activity (man-made fill). Sediments with high potential for liquefaction are found in the various man-made fill marina infrastructure in the study area that are composed of loose, dredged fill. Examples of such structures are Long Beach harbors and its ancillary jetties, slips and wharfs, and Long Beach and San Pedro breakwaters.

Past geotechnical engineering investigations in the Ports of Long Beach and Los Angeles indicate varying degrees of potential for soil liquefaction in the project area. An investigation at Pier J (Kleinfelder, 1996) indicated potential for liquefaction in soils as deep as elevation -57 ft MLLW with earthquake-related ground settlement of 8 to 12 inches. Additional geotechnical reports for Pier J (Geofon 1986) and for Pier T (Diaz-Yourman 2002) suggested that liquefaction of artificial fill is likely but liquefaction of the underlying native marine sediments is not likely.

The leftover deepening footprint after dredging is composed of the same sandy native sediment before dredging. Therefore, liquefaction potential of native sediments after dredging activities remains unchanged as not very likely.

3.7 Faulting and Seismicity

All of southern California including the study area is seismically active. The project study is in the San Pedro Bay shelf, whose seismicity is characteristic of recurring small earthquakes with moment magnitudes less than 4.5. The Bay is located within the inner margin of the southern California Continental Borderland, and north of the Newport submarine canyon and south of the Palos Verdes peninsula. This margin trends from southeast to northwest with a system of marine basins and ridges which are bound by several active faults.

Three major active faults in the vicinity of the study area are the San Andreas, Palos Verdes and Newport-Inglewood. They are all capable of producing a moment magnitude 7 earthquake. The San Andreas is the largest principal active fault in Southern California and is located approximately 65 miles north-northeast of the study area. The Newport-Inglewood and Palos Verdes are located approximately 2 miles northeast and 2 miles southeast of the study area, respectively. Historically, the study area has been subjected to seismic events with a Magnitude 6 (1933 Long Beach earthquake – Magnitude 6.3). A study by EMI (2015), presents the geography, source, and probabilistic seismic hazard parameters for the local faults.

Of the local faults discussed in EMI (2015), the THUMS-Huntington Beach fault and the Compton blind-thrust fault are considered the most significant tectonic features from the San Pedro margin because they both pass directly through the port of Long Beach. Both faults are potentially active and capable of producing a moment magnitude 7 earthquake (BSSA 2019); these two faults, and the Palos Verdes fault, are shown in Attachment 1, Plate C5, Local Marine Geology.

3.7.1 Historic Earthquakes

The Advanced National Seismic System (ANSS) provides a national network comprised of 15 regional seismic networks which are operated by the United States Geological Survey (USGS), among which include the California Integrated Seismic Network (CISN). This network is capable of providing detection and data of seismic events which are available for public records as the ANSS Comprehensive Earthquake Catalog. Table 3-1 provides a summary of the seismic history within a given radius from the study area.

Table 3-1 Seismic History

Magnitude	Number of Events within Radius			
Richter Scale	1 mile	10 miles	25 miles	100 miles
<4	10	1429	8439	208473
4<M<6	1	35	101	669
>6	0	0	1	9

Recorded or documented events extend from 1933 to the present. Within 100 miles, the greatest earthquake event was a magnitude of 7.5 on July 21, 1952 in Grapevine, California approximately 95 miles north of the POLB. Closer to the study area, 15 miles southeast at Newport Beach, on March 11, 1933 a magnitude 6.4 event was recorded; this event likely led to an aftershock earthquake the same day in Signal Hill, less than 1 mile away, with a magnitude of 4.4. The region is well characterized by earthquake events Magnitude 4 and less.

3.7.2 Design Earthquake Levels

The POLB's Wharf Design Criteria (POLB 2015) refers to an Operational Level Earthquake (OLE), Contingency Level Earthquake (CLE) and Code-Level Design Earthquake (DE) as the three levels to be modeled as the earthquake shaking motion for the various harbor improvements. The OLE corresponds to a 72-year return period ground motion having a 50 percent probability of being exceeded in 50 years; the CLE has 475-year return period with 10 percent chance of exceedance in 50 years. During an OLE, a structure is anticipated to experience minimal non-structural damage such that operations may resume promptly after the event. The CLE, however, considers an event where public safety is not impacted though there may be significant structural damage including total loss or failure of the structure. The design earthquake is determined in accordance with the California Building Code and ASCE 7-10 with 2 percent chance of exceedance in 50 years for a return period of 2,475 years.

For stability analysis of the breakwaters, the USGS online design maps tool was used to obtain the necessary seismic shaking information at the Queens Gate location. Based on site class D: the peak ground acceleration (PGA) modified for site class (PGA_M) is 0.627g; the short period design spectral acceleration (SDS) is 1.055g; and the design 1-second spectral acceleration (SD1) is 0.6g.

3.8 Physical Character of Sediment

Sediments in the study area comprise sand, silt, and clay of varying proportions. The physical character of the native (undisturbed) sediments is described in section 3.6 of this appendix. Based on the USCS soil classifications, the sediments are predominantly composed of thick alternating beds of silty sand (SM) and sand with silt (SP-SM). The sediments also contain some occasional thin layers of clay (CH). Sandy portions of the sediment are predominantly fine grained, rounded and composed of quartz and mica minerals.

Minor thin layers and localized lenses of gravel and clays are present within the sandy sediment and are found mostly within the upper 50 feet. As discussed above, cobble and boulder sized stone is also present seaward of the breakwaters and was encountered during previous dredging of the approach channel. The marine sediments are generally unconsolidated and increase in density with increasing depth.

A thin layer of suspended silt and clay (mud) is present atop the sea floor surface in areas of less disturbance or where recent man-made activities (e.g., dredging and harbor modifications) have not altered the surrounding natural subsurface conditions. This mud layer is approximately 2 to 6 inches thick and overlies a very loose unconsolidated layer of sand or silt. Underlying this shallow surface sediment are the thicker alternating layers of silty sand to sand, as mentioned above.

Gravel, cobble, and debris may be encountered in limited quantities, within project depths. As discussed above (Section 3.5), significant quantities of rock and debris, including particles up to three feet, were encountered in the Approach Channel during a 1998-2000 dredging contract.

3.9 Chemistry and Biotoxicity Character of Sediment

Bulk sediment chemistry and bio toxicity (bio-assay) testing has been performed on the sediments in the project site limits as part of past dredge investigations. The testing was done to evaluate the suitability of dredged sediments for disposal and/or placement in the vicinity of the project area and at the USEPA offshore disposal area of LA-2. The testing areas are shown on Inventory Map of Environmental Testing Events (Attachment 1, Plate C3). Four testing events are described as follows:

1994 Queens Gate Approach Channel - Bulk sediment chemistry tests were run on sediment collected by the Los Angeles District Corps of Engineers via vibracores for the Approach Channel. Chemistry results showed low detections of phthalate compounds and tributyltin and metals that were all below Effects Range Low criteria. Test conclusions indicated that all sediments were acceptable for placement at nearby beach nourishment areas and as fill at North Energy Island ocean borrow pit.

2012 Pier J Entrance Channel and Pier T - Bulk sediment chemistry tests were run by POLB on sediment collected from vibracores from areas on east entrance area of Pier J and at the Pier T and its West Basin entrance channel. Chemistry results indicated that all sediments were below ERL, except for Copper and Nickel that were above ERL for Pier J DU-COMP sample; and 4.4”-DDE and Total DDT above ERL for Pier T DU1-COMP and Pier T DU2-COMP. Pier T and J sediments were considered suitable for placement at Long Beach Middle Harbor fill site.

2013 Pier J Turning Basin, Pier J Berths 245-247, Pier T Berths 132-134 - Bulk sediment chemistry and effluent elutriate tests were run by POLB on sediment collected from these areas by vibracores and surface grab samples. Chemistry results for Pier J Turning Basin showed 4,4’-DDE and Total DDT above ERL but below ERM and elutriate results were below criterion continuous concentration (acute). All Pier J elutriate chemical results were below all criterion continuous concentration (CCC and CMC). Pier T chemical elutriate results were all below criterion continuous concentration, except for Copper which was above criterion maximum concentration (CMC). Pier J and T sediments were considered suitable for placement at Long Beach Middle Harbor fill site.

2014 Pier T and Pier Echo - Bulk sediment chemistry, bio-toxicity and effluent elutriate tests were run on sediment collected by POLB via vibracores and ponar samplers from Pier T and Pier Echo. Biotoxicity results indicated that samples Pier T-DU08, 10 and 11 did not meet limiting permissible concentration requirements for ocean disposal due to amphipod toxicity. Marine organism tissue samples were analyzed further for mercury, dichlorodiphenyltrichloroethanes (DDT) and polychlorinated biphenyls (PCB). Tissue results indicated low bioaccumulation potential, with concentrations less than Food and Drug Administration (FDA) action levels and those shown to have toxic effects. Elutriate test results were below Criterion Continuous Concentrations and Criterion Maximum Concentrations criteria. Chemistry results were all below ERL except for detections of silver and 4,4'-DDT above ERM for Pier T-DU06-COMP surface sample. Suspended particulate phase testing results indicated that sediments did not pose a toxicity risk to water column organisms during placement activities. Sediment from Pier Echo showed elutriate test results less than CMC and CCC criteria and indicated that placement activities would also not result in water quality impacts. Pier T and Echo sediments were considered suitable for placement at Long Beach Middle Harbor fill site.

<u>2018 Queens Gate Approach Channel</u> - Bulk sediment chemistry tests were run by Los Angeles District Corps of Engineers on sediment collected from vibracores from a small shoaled area near the entrance to the Long Middle Breakwater at the Approach Channel. Chemistry results indicated that all sediments were below ERM except for DDT and 4.4'-DDE, which were elevated above ERL. Biotoxicity tests were run on clams and worms mixed with the Approach Channel sediment. Chemistry and biotoxicity results indicated no adverse ecological effects were predicted based on these results. The sediment was considered suitable for placement at the offshore USEPA LA-2 open ocean disposal site.

3.10 Dredgeability of Sediment

All sediment at the project site is considered to be dredgeable by either hydraulic (cutterhead or hopper dredge) or mechanical (clamshell) dredging methods. Sediment to be dredged near marine terminals, piers and revetments is not expected to be difficult to dredge but should be removed by mechanical dredging methods to reduce potential sloughing or slope failures near those structures. Dredging near Queens Gate and in the Approach Channel will be harder due to greater density and presence of rock and debris. Dredging in that area may be better accomplished by clamshell methods rather than hydraulic methods because of harder dredging and to mitigate the risk of slope failure. The deeper, oceanward portions of the Queens Gate and Approach Channel alternative dredge footprints may need to consider more robust hydraulic cutterhead or mechanical clamshell dredge methods, because the sediment there is denser and contains more rock, up to 39 inches in size, than sediment to be dredged from all of the alternative footprints that lie inside (harborside) of Queens Gate. The rest of the proposed areas to be deepened could likely be dredged by hydraulic methods.

3.11 Physical and Chemical Compatibility of Sediment for Placement

The sediment chemistry and biotoxicity testing areas between the years 1994 and 2014, and the sampling locations for geotechnical and environmental purposes for the period between 1961 and 2014 are shown in Attachment 1, Plates C3 and C4 respectively.

Test results from gradation testing between 1994 and 2014 show that much of the sediment previously dredged from the project study final alternative footprints is composed of approximately 30 to 60% silty sediment. This sediment was too fine, therefore not compatible for use as nourishment material for nearshore and/or onshore beach placement areas. Chemical and biotoxicity testing results of the same timeframe show that much of the sediment previously dredged was also too contaminated to be placed as beach material. Because of this, the Southern California Dredge Material Management Team (SC-DMMT) and the U.S. Environmental Protection Agency approved of its use as disposal material at the

USEPA offshore LA-2 disposal site and for use as artificial fill (engineered fill) at POLB middle harbor slip (confined disposal site).

3.12 Geotechnical and Environmental Sampling and Analysis

Additional physical, chemistry and biotoxicity sampling and testing and sediment suitability analysis will be required as part of pre-dredge investigations prior to deepening any one of the project study final alternative array footprints. The physical testing and sampling should involve offshore cone penetrometer testing (CPT) to evaluate density and dredgeability. Vibracore or other off-shore sampling methods should be conducted after the CPT evaluation to evaluate grain-size distribution, presence of rock and foreign material, and to collect samples for chemical/environmental testing.

A sampling and analysis plan (SAP) and sampling and analysis report (SAPR) will also need to be prepared prior to dredging and dredge disposal activities according to the latest SC-DMMT guidelines. The SC-DMMT and USEPA will need to review and approve the SAP and SAPR and will also need to approve the suitability for final placement of dredged sediment. All of these activities will need to occur as part of the Pre-Construction Engineering Design (PED) phase.

3.13 Instability Due to Dredging

Sediment to be dredged for Federal Channel deepening near marine terminals, piers and revetments should be removed carefully to reduce potential sloughing or slope failures near those structures. Dredging in “box cut” configurations should not be permitted and increased, real time monitoring of the area between the structure and the dredging should be implemented in those areas. The deepening of the channel near Queens Gate within the east portion of the Federal Channel Limits at the east side Long Beach breakwater and its junction with the Pier J Approach Basin could be subject to slope failures. These locations have been identified because the bottom toe of the east breakwater is less than 100 feet from the Federal Channel and increases the risk for slope failure there.

During the dredging of Pier 400, east of Terminal Island, the contractor experienced slope stability issues due to running sands likely caused by east-sloping bedding planes. It is recommended to assess the bedding orientations in the Project area during the PED phase to ensure slope stability is maintained.

4 SLOPE STABILITY OF PROPOSED DREDGING

As part of the feasibility study, slope stability for the basins, wharfs and piers in the study area of the POLB was evaluated by POLB's consultant (See Attachment 2, Earth Mechanics 2017 memo). Stability was expressed as allowable standoff distances from structures. Within the federal waters of the approach channel at the Queens Gate Entry through the Long Beach Breakwater, USACE performed an evaluation of the slope stability based upon the parameters and configurations of previously performed investigations, studies, and as-built plans.

As stated in section 3.13 above, bedding orientations in the Project area need to be assessed during PED to determine if standoff distances recommended by EMI need to be reevaluated, or other mitigation measures need to be implemented.

4.1 Queens Gate Entry

Cross-sections of the main breakwaters, shown in Plate C2 of Attachment 1, were obtained from historical design documents as well as repairs associated with the Middle Breakwater to the west of Queens Gate Entry and the Long Beach Breakwater to the east. These documents also provide subsurface data collected from two borings, M2 in the Middle Breakwater, and L1 in the Long Beach Breakwater (USACE 1987). USACE analysis for the current feasibility study is based upon the information presented in those documents in conjunction with the NOAA Nautical Chart of the Los Angeles and Long Beach Harbors (Chart No. 18751) which provides sounding depths based upon the MLLW (see Attachment 3, Plates C6 and C7).

4.1.1 Design Parameters and Assumptions

The unit weights and strength parameters for stability analysis of the soil and breakwater materials were based partly on the limited data available near the Queens Gate Entry and partly on assumptions and engineering judgment. Values used for the analysis are provided in Attachment 4, Slope Stability Modeling.

Middle and Long Beach Breakwater

Construction and parameters for the breakwater are typical of the material types as described by the previous comprehensive condition assessments performed for the Long Beach and Middle Breakwaters (USACE 1987, 2014). The breakwater cross-sections were modeled as their idealized construction formation as shown in Figure 3-1 absent any deformations or significant void space.

Foundation Soils

The soil deposition and strength parameters are based on the data collected from 1986-1987 and presented in the Comprehensive Condition Survey of the Los Angeles-Long Beach Breakwaters (USACE 1987) from borings M2 (Middle Breakwater) and L1 explorations (Long Beach Breakwater). The soil (sediments) underlying the breakwaters and within the Queens Gate Entry vary from sands and silty sands to sandy silts and silts, and although there were minor amounts of clay, a "simplified" single layer of silty sand was assumed for modeling purposes. Soft sediments, such as loose surface mud or compressible clays, were not included as part of the stability model, since there has been no appreciable decrease in channel depth to indicate accumulating sediments since dredging activities in the late 1990s (USACE

1998). As indicated by the chart and map in Attachment 3, the channel depth is actually deeper than the plans from 2001; the current channel depth is at the same depth or deeper than the depth dredged indicated in the chart and plans (see Attachment 2, EMI 2017 memo for further details).

Stability Modeling

The analyses address global stability concerns presented by the proposed dredging and do not address the internal stability of the breakwaters. Slope stability analysis was performed using Geostudio software with the 2016 Slope/W extension and may be considered conservative as it only evaluated the condition in two dimensions. Pseudostatic modeling for seismic conditions considered the DE for the study area. A reduction was applied to the PGA to arrive at a seismic coefficient for psuedostatic analysis consistent with the method presented by FHWA/NCHRP 12-70. The seismic coefficient for limit-equilibrium pseudostatic slope stability analysis was estimated to be 0.23 for the design earthquake, using a slope height of 97 feet, site class D, PGA_M = 0.627, S_1 = 0.6, F_{pga} = 1.0. and F_v = 1.5.

4.1.2 Results

In accordance with USACE standards, the minimum required factor of safety is 1.5 for slope stability. By increasing the standoff distance to 100 feet, the factor of safety increases by 5 to 10 percent for the Middle and Long Beach Breakwater; there were no appreciable changes in the factor of safety by increasing beyond 100 feet as the stand-off distance for dredging activities.

For seismic conditions, USACE minimum required factor of safety is 1.1. Increasing the standoff distance, beyond the toe of the breakwater, yielded no appreciable change in the factor of safety for a series of seismic conditions.

Table 4-1 presents the factors of safety computed based upon particular static and seismic conditions.

Table 4-1 Queens Gate Entry – Factor of Safety

Middle Breakwater				**Long Beach Breakwater**			
No Standoff	50'	100'	200'	No Standoff	50’	100’	200'
Static Conditions							
1.80	1.93	1.97	1.97	1.67	1.74	1.74	1.76
Seismic Conditions (DE)							
0.74	0.74	0.74	0.74	0.67	0.68	0.68	0.68

Standoff distances are measured from the toe of slopes and were determined utilizing the parameters and assumptions presented above in USACE analysis of the federal channel located at the Queens Gate Entry.

Based on this analysis, any dredging activities that remain contained to within the limits of the main channel to a depth of -81 ft MLLW, with 2 feet of over-dredge, will not further impact the stability of the breakwaters. All dredging should be performed in accordance with port practices of slopes being maintained no steeper than 3H:1V. Setback distances to structures should be measured from the base of the slope at the toe. The models for stability analysis of the federal channel are included in Attachment 4.

Since the seismic (pseudostatic) slope stability analyses computed safety factors are less than 1.0, those slopes are expected to fail during the design earthquake. A slope displacement calculation was conducted to evaluate whether such earthquake-related failures of the breakwater slopes would involve significant loss of material from the breakwaters or minor displacements of stones. Using the method presented in FHWA/NCHRP 12-70, the yield acceleration (expressed in terms of gravity) for Middle Breakwater ranged between 0.14 and 0.15 with a computed lateral displacement of 3 to 4 inches. Long Beach Breakwater had a marginally lower yield acceleration of 0.12 to 0.13 and displacement of 5 to 6 inches.

See Table 4-2 for the calculated yield accelerations and lateral displacements for corresponding standoff distances.

Table 4-2 Queens Gate Entry – Computed Lateral Displacement

Middle Breakwater				Long Beach Breakwater			
No Standoff	50'	100'	200'	No Standoff	50’	100’	200'
Estimated Yield Acceleration (g)							
0.145	0.148	0.149	0.149	0.125	0.125	0.126	0.128
Estimated Lateral Displacement (inches) at Design Earthquake							
3.8	3.6	3.5	3.5	5.2	5.2	5.1	5.0

4.2 Port of Long Beach Harbor Slope Stability Analyses

POLB’s consultant, AECOM, tasked their sub-consultant, EMI, to perform a Berth and Channel Deepening study within the POLB harbor. The study considered three different dredging elevations of -53 ft, -55 ft, and -57 ft MLLW within the basins and as deep as -81 ft MLLW within the main channel. Those elevations include 2 feet of over dredging as well as standoff boundaries from the existing port structures to prevent potential damage or undermining due to the proposed dredging activities within the waterways of the port harbor. The study also included recommendations for wharf improvements where necessary to facilitate the scope of dredging.

Five loading conditions were analyzed:

- Static
- Static and Operational Level Earthquake
- Static and Modified Operational Level Earthquake
- Static and Contingency Level Earthquake
- Static and Design Level Earthquake

Wharf improvements include a few scenarios: a continuous Z-section bulkhead, combination of soldier piles and Z-sheets, and double soldier piles with Z-sheets. The methodology for ground improvement is assumed to be various configurations of jet grouting. A summary of the proposed improvements for dredging configurations is presented in Table 4-3.

Table 4-3 Improvements

Pier	Depth*	Static	Static + Modified OLE	Static + OLE	Static + CLE	Static + DE
F	-53	WI	WI	WI & GI	WI & GI	WI & GI
	-55	WI	WI	WI & GI	WI & GI	WI & GI
	-57	WI	WI	WI & GI	WI & GI	WI & GI
G	-53	None	None	None	None	WI
	-55	None	None	None	None	WI
	-57	WI	WI	WI	WI	WI
J	-53	WI	WI	WI & GI	WI & GI	WI & GI
	-55	WI	WI	WI & GI	WI & GI	WI & GI
	-57	WI	WI	WI & GI	WI & GI	WI & GI
T	-53	None	None	None	None	WI
	-55	None	None	None	None	WI
	-57	None	None	None	WI	WI

WI Wharf Improvement *OLE Operating Level Earthquake*
GI Ground Improvement *CLE Contingency Level Earthquake*
**feet below MLLW, includes 2 feet of over-dredge* *DE Design Earthquake*

AECOM provides a discussion and summary of the improvements and associated costs in the document Wharf Structure Improvements and Berth Dredging Evaluation. A memo summarizing the geotechnical analysis within the POLB is included as Attachment 2**.** The recommended standoff distances are provided in Section 5.0.

5 CONCLUSIONS AND RECOMMENDATIONS

Geotechnical conclusions are presented herein regarding the proposed dredging for the POLB Deep Draft Navigation Project. This Feasibility-Level geotechnical study includes a summary of the geotechnical constraints and recommendations for dredging based on the existing conditions as presented by the previous studies, reports and existing design cross-sections and As-built plans.

The geotechnical evaluation of conditions within the port and recommendations for harbor structures were performed by the POLB's consultants and sub consultants. Those studies are summarized within this report as Attachment 2; further assessment of the bedding orientations is recommended during PED to anticipate for potential impact of running sands on slope stability.

In order to maintain the USACE minimum factors of safety, "stand-off" distances have been proposed based upon stability analysis performed by the USACE and POLB, as shown in Table 5-1:

Table 5-1 Port of Long Beach Dredging Standoff (Feet)

Pier T	Pier F	Southeast Basin	Pier J	Pier J Breakwater	Queens Gate Entry
150	100	100	100	50	100

Although the slope stability analysis of Queens Gate Entry satisfies USACE static factors of safety with no standoff, the distance was recommended for constructability to reduce potential for undermining slopes of the breakwaters. The standoff distance would allow for dredging to extend outside of the main channel's current boundaries and allow space for future ground improvement if desired for the project.

Seismic stability analysis of the Middle and Long Beach Breakwaters at Queens Gate Entry indicate ground improvement may be required to meet the USACE standards for factors of safety. Engineering Manual 1110-2-2904: Design of Breakwaters and Jetties states,

> *Since failure of most breakwater and jetty projects that are a result of an earthquake will not result in catastrophic consequences, these structures are generally not designed with seismic considerations. For projects located in high seismic risk zones, however, the geotechnical evaluation for these projects should at least consider the potential impact of seismic damage. If the cost to repair the seismic damage is considerable, as compared with the replacement cost, a detailed seismic evaluation may be warranted. The decision to design for seismic considerations should be made on a case-by-case basis.*

A cost analysis should be performed to assess the level of impact if Queens Gate Entry was no longer accessible due to slope failure of either of the main breakwaters and if structural or seismic upgrades are prudent/desirable. It should be noted that since the construction of the breakwaters, there have been several seismic events ranging up to a magnitude of 6 and any sustained damage did not impede port activities.

Although the majority of the sediment at the project site is considered to be dredgeable by either hydraulic (cutterhead or hopper) or mechanical (clamshell) methods, it is recommended that for dredging near the port structures (marine terminals, piers, revetments, breakwaters, wharfs), a clamshell dredge be used to reduce potential for sloughing or failure of the slopes.

At the Queens Gate and Approach Channel, a clamshell dredge is recommended due to the potential presence of oversize rock and debris, as well as to mitigate the risk of slope failure of nearby breakwaters; if a hopper dredge is chosen for this area, contractor would need to assess the impact that large rocks and debris can have on the dredge’s performance. A hopper dredge can be used for the rest of the proposed areas to be dredged.

6 RECOMMENDED ADDITIONAL STUDIES

If the project progresses beyond the feasibility level, the following geotechnical studies should be conducted during PED:

- Exploration and laboratory testing of foundation soils within the Queens Gate Entry Channel and Long Beach Breakwater (nearer to the project area). This should include a phase of off-shore Cone Penetrometer Testing (CPT) first to evaluate material density and consistency. The CPT investigation should be followed by a phase of vibracore drilling to collect samples for laboratory testing and evaluate grain-size distributions for beach placement or disposal, as well as chemical constituents and potential contamination. To estimate rock quantities, "potholing" with a clam shell large enough for a 3-foot rock is suggested.
- A detailed geotechnical investigation of the subsurface conditions in the project study area, including drilling, sampling, and testing, would be necessary to draw firm conclusions regarding the potential for soil liquefaction in the study area and its impact on the proposed project features.
- Assess bedding orientations in the Project area; running sand issues likely due to east-sloping bedding planes have been observed in previous projects in the area.
- Perform 3D stability analysis at breakwaters for further refinement of slope stability if lesser standoff distances are needed.
- Conduct cost analysis for seismic stability of the main breakwaters.
- Conduct chemical/environmental testing of sediment samples and evaluate suitability for placement in the designated disposal sites; prepare a SAP and a SAPR for SC-DMMT and USEPA approval.

7 LIMITATIONS AND RISK

This report is intended only for use by USACE, the POLB, and its designers for the proposed Berth and Channel Dredging Study. The recommendations contained in this report are based on available drawings, assumptions made due to incomplete information, and engineering judgement.

Specific to the federal channel at Queens Gate Entry, the current design assumptions and analysis indicate there are underlying stability issues that may pose issues in the future; these have been previously studied and documented elsewhere in the port. Lacking more detailed explorations and testing immediately within the channel and breakwaters, design assumptions may not appropriately characterize the subsurface conditions which could lead to construction or design challenges leading to costly changes in the future as the project progresses.

Discussion of the limitations and risk within the Port of Long Beach can be found in the analysis memorandum, Attachment 2.

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APPENDIX C: GEOTECHNICAL ENGINEERING - ATTACHMENT 1

PLATES

Plate C1 – Study Area

Plate C2 – Cross Section A-A' Through Queens Gate

Plate C3 – Inventory Map of Environmental Testing Events for Sediment

Plate C4 – Borehole Sediment Sample Locations for Geotechnical and Environmental Sampling Purposes (1961 to 2014)

Plate C5 – Local Marine Geology

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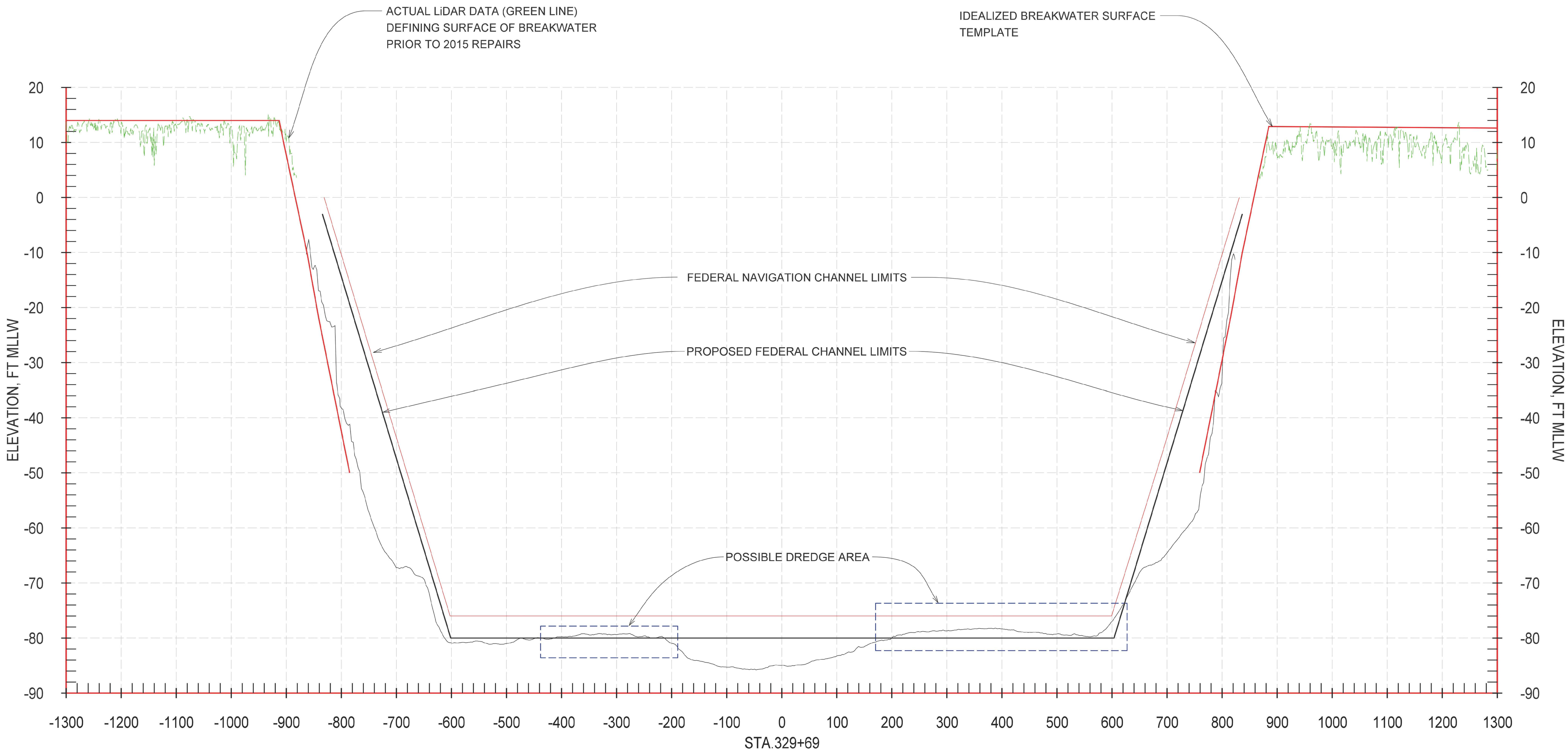
POLB
NAVIGATION IMPROVEMENTS

STUDY AREA

DATE: NOVEMBER 2017

PLATE
C1

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PORT OF LONG BEACH ENTRANCE CHANNEL

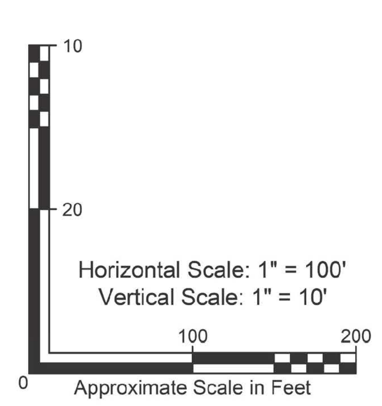
AT

QUEENS GATE

CROSS SECTION LOOKING NORTH

SURVEY DATA FROM USACE SURVEY

NOVEMBER, 2015



ALL LOCATIONS ARE APPROXIMATE

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
PORT OF LONGBEACH ENTRANCE CHANNEL
AT QUEENS GATE

US Army Corps of Engineers Los Angeles District	CKD BY: JY/MLR	PLATE
	DWN BY: jbd / **eh**	C-2
	DATE: February 2021	

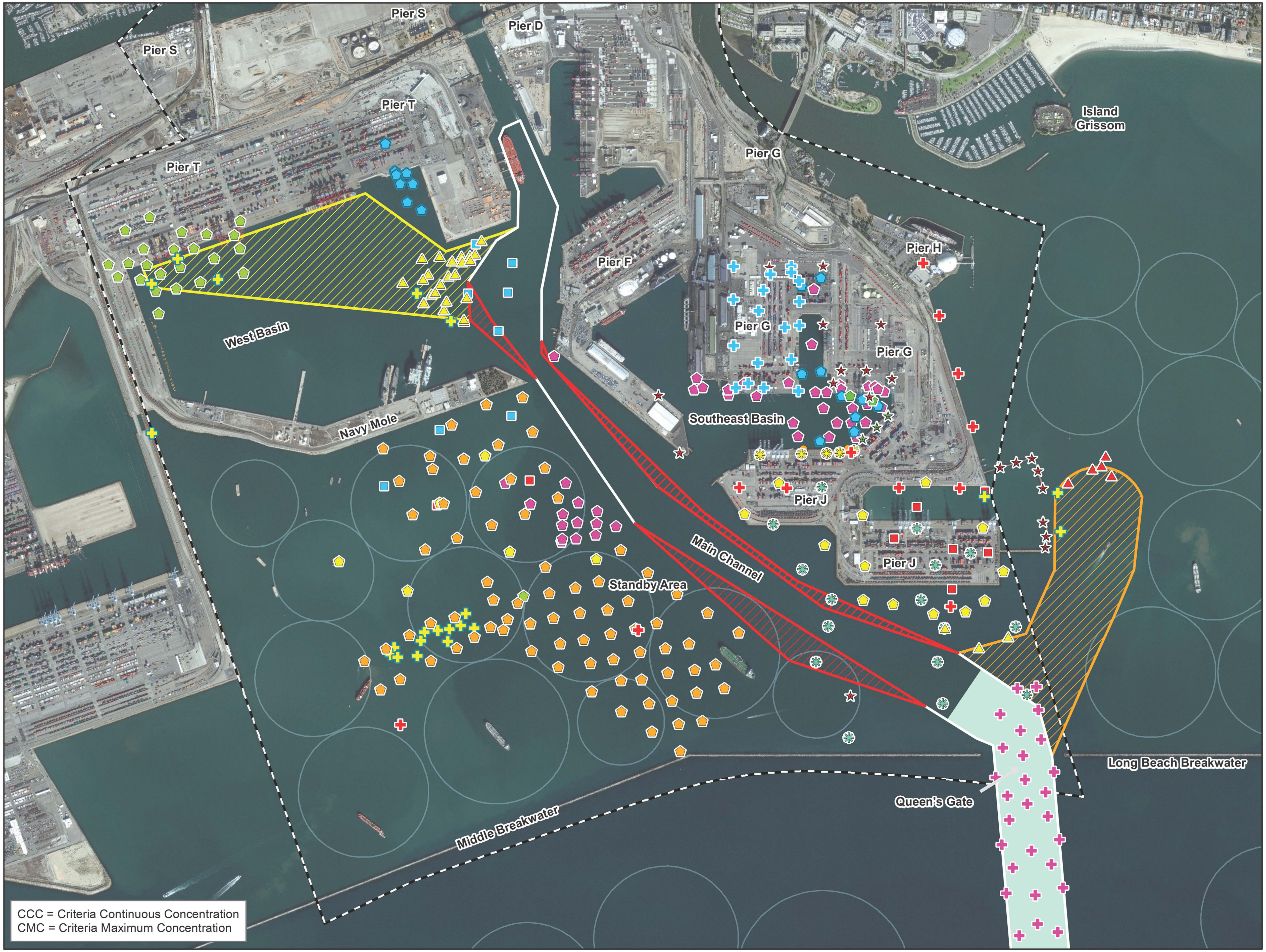
POLB NAVIGATION IMPROVEMENTS

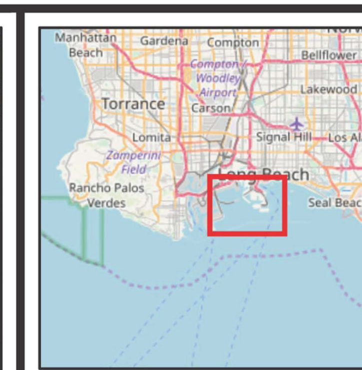
INVENTORY MAP OF ENVIRONMENTAL TESTING EVENTS FOR SEDIMENT

PLATE C3

Map Date: 9/3/2019

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT





Legend

(Year Collected)

- 1961
- 1967
- 1970
- 1971
- 1975
- 1976
- 1977
- 1989
- 1992
- 1994
- 1995
- 1996
- 2000
- 2001
- 2002
- 2011
- 2012
- 2013
- 2014

Project Areas

- Main Channel Widening
- Main Channel Widening
- Pier T West Basin
- Pier J Approach/Basin
- Main Channel
- Approach Channel
- Standby Area (Anchorage)
- POLB Boundary

SOURCES:
Imagery Background: Image Copyright 2015 DigitalGlobe Inc

Reference Map: © OpenStreetMap (and) contributors, CC-BY-SA

Coordinate System: NAD 1983 StatePlane California V FIPS 0405 Feet
Datum: NAD 1983

N

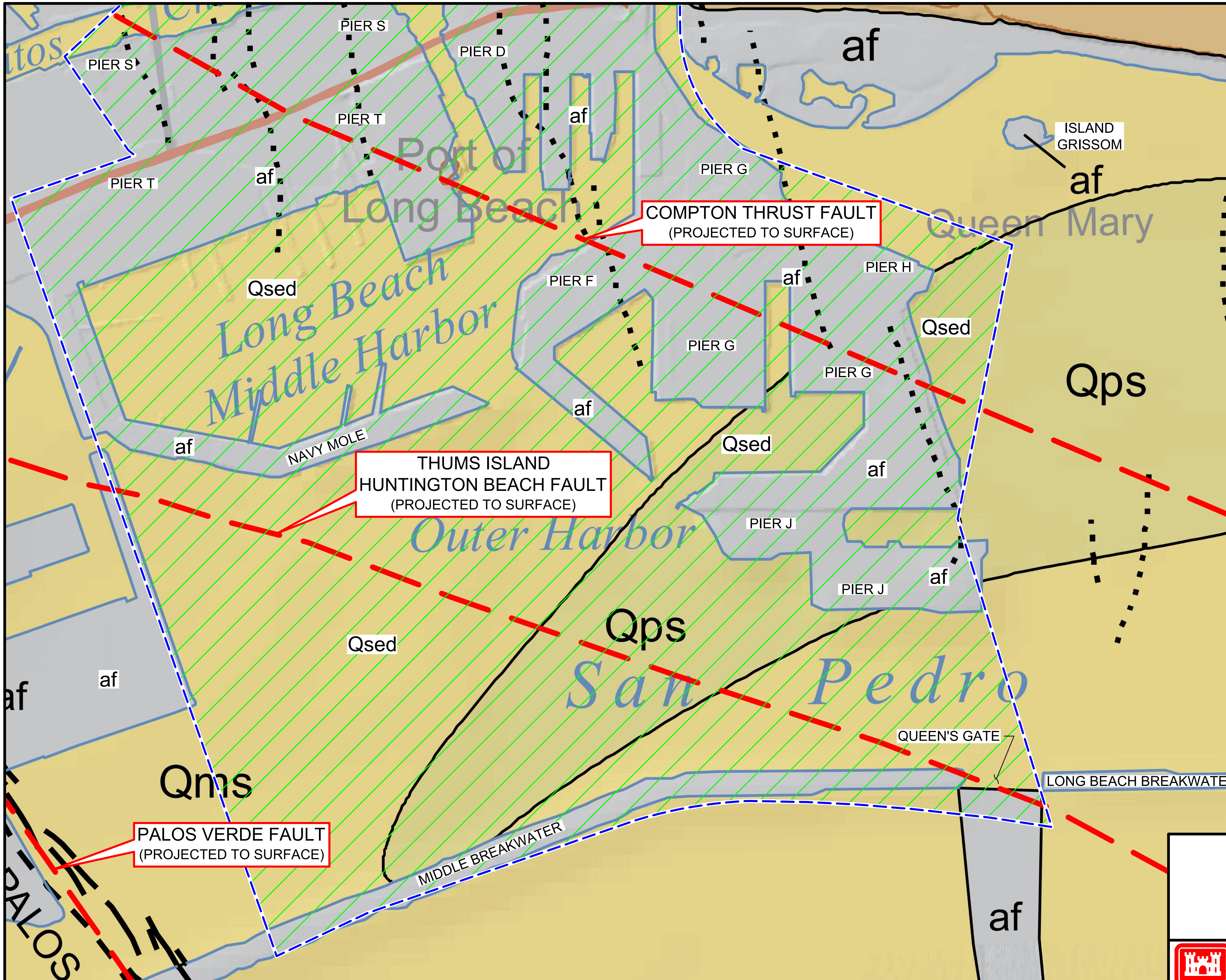
0 1,000 2,000 Feet

1 inch = 2,000 feet

POLB NAVIGATION IMPROVEMENTS

Borehole Sediment Sample Locations for Geotechnical and Environmental Sampling Purposes (1961 to 2014)
PLATE C4
Map Date: 9/3/2019

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



EXPLANATION

SYMBOLS

POLB BOUNDARY

Qsed BOUNDARY

POTENTIALLY ACTIVE EARTHQUAKE FAULTS (USGS, U.S. Quaternary Faults website accessed on 2/12/2021, https://usgs.maps.arcgis.com

UNITS

af	ARTIFICIAL FILL - ALL LAND AREAS WITHIN POLB BOUNDARY ARE ARTIFICIAL FILL
Qsed	QUATERNARY SEDIMENT: LOOSE TO SUSPENDED 4 INCH LAYER OF MUD AND SILT UNDERLAIN BY ALTERNATING LAYERS OF SEDIMENT COMPOSED OF SAND, SILTY SAND AND SILT
Qms	UNCONSOLIDATED SHELF SEDIMENT
Qps	PLEISTOCENE SEDIMENTARY DEPOSITS, UNDIVIDED

Sources: Excerpt of "GEOLOGIC MAP OF THE LONG BEACH 30' x 60' QUADRANGLE, CALIFORNIA", Version 2.0, BY California Geologic Survey. Dated: 2016

ALL LOCATIONS ARE APPROXIMATE

N

0 2000' 4000'
Approximate Scale in Feet

PORT OF LONG BEACH
NAVIGATION IMPROVEMENTS
LOS ANGELES COUNTY, CALIFORNIA
STUDY AREA
LOCAL MARINE GEOLOGY

US Army Corps of Engineers
Los Angeles District

CKD BY: LS/JPY	PLATE
DWN BY: jbd	C5
DATE: March 2021	

Plot Date: 3/03/2021 10:33:09 AM, Plotted by: l1ed9jbd, File Name: POLB_B01-PLATE C5_MARINE GEOLOGY.DWG, Plate C5_Project Features Map

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APPENDIX C: GEOTECHNICAL ENGINEERING - ATTACHMENT 2

FEDERAL CHANNEL EXPANSION STUDY GEOTECHNICAL INPUT FOR BERTH AND CHANNEL DEEPENING

(Earth Mechanics, Inc. 1-19-2017)

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DATE: January 19, 2017 **EMI PROJECT NO:** 15-152

TO: Jeff Khouri, P.E. / AECOM
Richard Mast, P.E. / AECOM

FROM: Pratheep K. Pratheepan, P.E. / Earth Mechanics, Inc. (EMI)
Arul K. Arulmoli, G.E. / EMI

SUBJECT: ***Geotechnical Input for Berth and Channel Deepening***
Port-Wide Dredge Plan and Federal Channel Expansion Study
Port of Long Beach, California

Introduction

Port of Long Beach (POLB) retained AECOM team to provide engineering consultancy services for the Port-Wide Dredge Plan and Federal Channel Expansion Study Project. As a part of this project, a Berth and Channel Deepening study (Sub-Task 1.8) was performed in support of the Federal Expansion Study. The objective of this study is to provide cost input to the US Army Corps of Engineers for the work associated with deepening the berths, as well as provide input on required “stand-off” distances for the deepened channel from critical infrastructure. Three potential dredge depths (-53 ft MLLW, -55 ft MLLW and -57 ft MLLW) with a 2-ft over dredge allowance were considered for the dredging in this study. This study also includes widening of the main channel at some locations (to -76 ft MLLW). Attachment 1 shows the proposed Navigation Improvements. To facilitate this study, potential wharf improvement solutions and associated costs for each berth dredge depth were developed by the AECOM team. In addition to the wharf improvement solutions, Earth Mechanics, Inc (EMI) also provided “stand-off” distances from the existing port structures (dikes, bulkhead walls, breakwaters, etc.) to protect the port structures from any potential undermining/damage due to the dredging and operations within the Federal Channels and waterways.

This memorandum provides the summary of preliminary geotechnical input provided by EMI for the Berth and Channel Deepening study. EMI provided the geotechnical input as a subconsultant to AECOM.

Review of Available Drawings

From the design/record drawings database, POLB provided available drawings and details of various port structures along the channels and waterways. These drawings included critical data such as, the design water depths of existing port structures, current water depths and distances to the proposed/existing channels and waterways from the toe of the existing port structures. The list of reports provided by POLB and reviewed by EMI are included in the References section.

The information from these drawings was used to develop potential wharf improvement solutions and to determine the “stand-off” distances.

Proposed "Stand-Off" Distances

Portions of the proposed channel dredging are within the vicinity of existing port structures such as bulkhead walls, breakwaters and rock dikes. "Stand-off" distances from the toe of these structures are recommended to minimize any potential damages/undermining of these existing structures. Recommended "stand-off" distances are summarized in Table 1 and a schematic diagram shown in Figure 1. Assumptions involved in developing these "stand-off" distances are listed below.

1. No dredging will be performed within the standoff distance.
2. The dredge slopes beyond the standoff distances will be designed to be stable during dredging and long term operational conditions.

Proposed Wharf Improvements

The proposed berth dredging depths, are deeper than the design/existing water depths at many of the berths. Therefore, wharf improvement solutions need to be implemented before dredging near the existing wharves to avoid any damages to the existing wharf structures due to failure of the existing slopes during dredging. Based on past experience with similar projects, an underwater bulkhead wall at the toe of the existing slope is considered to be an effective and practical wharf improvement solution.

However, since the underwater bulkhead walls are cantilever type structures, under high loading conditions, such as very tall dredge cuts or seismic loadings, additional backland or mid slope ground improvements may be required. Due the rock protections on slopes and buried utilities in the backland, jet grouting is considered to be most suitable ground improvement option.

The below listed assumptions were used to develop the wharf improvement solutions.

1. Bulkhead and other improvements are based on engineering judgement and limited high level evaluations. Further geotechnical and structural analyses are needed to finalize these configurations.
2. Under Static and all seismic conditions [i.e., Operating Level Earthquake (OLE), Contingency Level Earthquake (CLE) and Design Earthquake (DE)], bulkheads should generally not reduce stability of the existing slope. Maximum lateral displacements at the top of the bulkhead: 3", 12", and 36", under OLE, CLE and DE, respectively, to meet the POLB Wharf Design Criteria (WDC) screening criteria for 24" octagonal precast, prestressed concrete piles. Moment demand on the bulkhead section under OLE was kept within the elastic moment capacity of the bulkhead section ($F_y = 50$ ksi).
3. Maximum lateral displacement at the top of the bulkhead under Modified OLE was assumed to be about 12 inches. Moment demand on the bulkhead section was kept below approximately 1.5 times the elastic moment capacity of the bulkhead section ($F_y = 50$ ksi).
4. "Berth Pocket" in front of the proposed bulkhead (i.e. waterside filled with rock) was assumed for scour protection.
5. An over dredge allowance of 2 feet was assumed.

Based on past experience with similar berth deepening projects and engineering judgement, potential wharf improvement solutions were developed for each berth area. Recommended wharf improvement solutions are summarized in Tables 2, 3 and 4, respectively for dredge depths, -53 ft, -55 ft and -57 ft MLLW water depths.

Limitations

This memorandum is intended only for the use of AECOM, its designers, and the Port of Long Beach for proposed Berth and Channel Dredging Study. This memorandum is based on the project as described and the information provided by AECOM and obtained from available drawings. The recommendations contained in this memorandum are based on available drawings, assumptions made due to incomplete information, and engineering judgement. EMI has no responsibility for errors and incompleteness of available design drawings and assumptions made by EMI due to these errors and incomplete information.

EMI should be notified of any pertinent changes or new information in the as-built and proposed plans. Such changes or variations may require a re-evaluation of the recommendations contained in this report.

The data, opinions, and recommendations contained in this study memorandum are applicable to the specific project element(s) and location(s) which is (are) the subject of this memorandum. They are not intended for design and have no applicability to any other design elements or to any other locations and any and all subsequent users accept any and all liability resulting from any use or reuse of the data, opinions, and recommendations without the prior written consent of EMI.

Services performed by EMI have been conducted in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions. No other representation, expressed or implied, and no warranty or guarantee is included or intended.

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Port of Long Beach, 1952, “Pier A Berth 201, Quay Wall,” Drawing No. HD-10496, Specification No. 347, May 28.

Port of Long Beach, 1956, “As-Built Drawing, Pier E Berths 122-124 Wharf,” Drawing No. HD-10734, Specification No. 448, September 14.

Port of Long Beach, 1961, “Pier F & Pier G, Diking, Dredging & Filling,” Drawing No. HD-10866, Specification No. 526, February 8.

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Port of Long Beach, 2006, "Pier G Berths 232-236, Terminal Redevelopment, Berth 232 Wharf and Backlands," Drawing No. HD-10-1937, Specification No. HD-S20170A, June 20.

Port of Long Beach, 2015, "Wharf Design Criteria, Version 4.0," May 20.

Table 1: Recommended "Stand-Off" Distances from Port Structures

Existing Structures		Recommended "Stand-Off" Distance[1] (ft)
Structure Type	**Structure Location**	
Bulkhead Wall	Berths D32 and D33	150
Steel Cells	Berths T122, T124 and T126	
Rock Dike	Future potential Pier J South triangular fill	100
	West face of Pier F from the tip of the Pier F Mole to the Pilot Station and around the corner to F202.	
	Berths F202 and F203	
	Berths G230	
	Berths J260, J262, J264 and J265	
	Tip of the Navy Mole	
Breakwater	Pier J South Breakwaters	50

1) Please note the "stand-off" distances are measured from the toe of the existing dikes or bulkhead walls (See Figure 1).

Table 2: Berth Deepening to EL. -53 ft MLLW plus 2 FT Over Dredge (i.e. Lowest El. -55 ft MLLW)

Pier / Berth	Mudline Elevation at Pierhead Line[1] (ft, MLLW)		Bulkhead and Additional Improvements				
	Designed	Existing	Static Only[2]	Static + Modified OLE[3]	Static + OLE	Static + CLE	Static + DE
Pier F/ F204 & F205	-36	-38.2 to -39.5	Solution 12 HZ1180MA & AZ36-700N Combination HZ1180MA from -32' to -100' AZ36-700N from -32' to -65'	Solution 24 Double HZ1080MD & AZ36-700N Combination HZ1080MD from -32' to -125' AZ36-700N from -32' to -65'	Solution 12 HZ1180MD & AZ36-700N Combination HZ1180MD from -32' to -110' AZ36-700N from -32' to -65' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 15 ft Wide From -20 to -65	Solution 24 Double HZ1080MD & AZ36-700N Combination HZ1080MD from -32' to -115' AZ36-700N from -32' to -65' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -20 to -65	Solution C23 Continuous HZ880MA HZ880MA from -32' to -120' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -20 to -65
Pier G/ G232 & G236	-55	-52 to -53	No improvements needed	No improvements needed	No improvements needed	No improvements needed	AZ36-700N Sheet Pile From -51 to -70
Pier J North/ J245 Thru J247	-48	48.6 to -49.6	AZ36-700N Sheet Pile From -44' to -80'	Solution 12 HZ1180MA & AZ36-700N Combination HZ1180MA from -44' to -100' AZ36-700N from -44' to -65'	Solution 12 HZ1080MA & AZ36-700N Combination HZ1080MA from -44' to -85' AZ36-700N from -44' to -65' + Top GI 30 ft Wide From +10' to -60'	Solution 12 HZ880MC & AZ36-700N Combination HZ880MC from -44' to -85' AZ36-700N from -44' to -65' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -35 to -65	Solution 12 HZ1080MD & AZ36-700N Combination HZ1080MD from -44' to -90' AZ36-700N from -44' to -65' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -35 to -65
Pier J South/ J266 Thru J270	-55	-47.5 to -47.9	No improvements needed	AZ50 Sheet Pile From -51 to -90	AZ36-700N Sheet Pile From -51 to -70 + Top GI 30 ft Wide From +10' to -60'	AZ36-700N Sheet Pile From -51 to -75 + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -30 to -65	AZ50 Sheet Pile From -51 to -80 + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -30 to -65
Pier T/ T132 Thru T140	-55	-48 to -51	No improvements needed	No improvements needed	No improvements needed	No improvements needed	AZ40-700N Sheet Pile From -51 to -70

NOTES:
[1] Information provided by POLB
[2] Static condition is expected to accommodate PGA of approximately 0.1g
[3] Maximum lateral displacement at the top of the bulkhead under Modified OLE is assumed to be about 12 inches. Moment demand on the bulkhead section was kept below approximately 1.5 times the elastic moment capacity of the bulkhead section (Fy = 50 ksi).

PGA – Horizontal Peak Ground Acceleration
OLE – Operational Level Earthquake; PGA = 0.21g (WDC, 2015 & EMI, 2006); CLE – Contingency Level Earthquake; PGA = 0.51g (WDC, 2015 & EMI, 2006); DE – Design Earthquake; PGE = 0.54g (WDC, 2015 & EMI, 2015)
WDC – POLB Wharf Design Criteria
Sheet piles and King piles used are by Skyline Steel (NUCOR Company). Equivalent sections by other manufacturers are also acceptable.

See Assumptions and References listed respectively, in Page 2 and 3 of the memorandum.

Table 3: Berth Deepening to EL. -55 ft MLLW plus 2 FT Over Dredge (i.e. Lowest El. -57 ft MLLW)

Pier / Berth	Mudline Elevation at Pierhead Line[1] (ft, MLLW)		Bulkhead and Additional Improvements				
	Designed	Existing	Static Only[2]	Static + Modified OLE[3]	Static + OLE	Static + CLE	Static + DE
Pier F/ F204 & F205	-36	-38.2 to -39.5	Solution 12 HZ1180MD & AZ36-700N Combination HZ1180MD from -32' to -105' AZ36-700N from -32' to -67'	Solution 24 Double HZ1180MD & AZ36-700N Combination HZ1180MD from -32' to -130' AZ36-700N from -32' to -67'	Solution 12 Double HZ1080MD & AZ36-700N Combination HZ1080MD from -32' to -115' AZ36-700N from -32' to -67' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 15 ft Wide From -20 to -65	Solution C23 Continuous HZ880MC HZ880MC from -32' to -120' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -20 to -65	Solution C23 Continuous HZ1080MD HZ1080MD from -32' to -125' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -20 to -65
Pier G/ G232 & G236	-55	-52 to -53	No improvements needed	No improvements needed	No improvements needed	No improvements needed	AZ40-700N Sheet Pile From -51 to -80
Pier J North/ J245 Thru J247	-48	48.6 to -49.6	AZ40-700N Sheet Pile From -44' to -85'	Solution 24 Double HZ1080MA & AZ36-700N Combination HZ1080MA from -44' to -105' AZ36-700N from -44' to -67'	Solution 12 HZ1180MA & AZ36-700N Combination HZ1180MA from -44' to -90' AZ36-700N from -44' to -67' + Top GI 30 ft Wide From +10' to -60'	Solution 12 HZ1080MA & AZ36-700N Combination HZ1080MA from -44' to -90' AZ36-700N from -44' to -67' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -35 to -65	Solution 12 HZ1180MD & AZ36-700N Combination HZ1180MD from -44' to -95' AZ36-700N from -44' to -67' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -35 to -65
Pier J South/ J266 Thru J270	-55	-47.5 to -47.9	No improvements needed	Solution 12 HZ880MC & AZ36-700N Combination HZ880MC from -51' to -95' AZ36-700N from -51' to -67'	AZ50 Sheet Pile From -51 to -75 + Top GI 30 ft Wide From +10' to -60'	AZ46-700N Sheet Pile From -51 to -80 + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -30 to -65	Solution 12 HZ880MC & AZ36-700N Combination HZ880MC from -51' to -85' AZ36-700N from -51' to -67' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -30 to -65
Pier T/ T132 Thru T140	-55	-48 to -51	No improvements needed	No improvements needed	No improvements needed	No improvements needed	AZ50 Sheet Pile From -51 to -80

NOTES:
[1] Information provided by POLB
[2] Static condition is expected to accommodate PGA of approximately 0.1g
[3] Maximum lateral displacement at the top of the bulkhead under Modified OLE is assumed to be about 12 inches. Moment demand on the bulkhead section was kept below approximately 1.5 times the elastic moment capacity of the bulkhead section (Fy = 50 ksi).
PGA – Horizontal Peak Ground Acceleration
OLE – Operational Level Earthquake; PGA = 0.21g (WDC, 2015 & EMI, 2006); CLE – Contingency Level Earthquake; PGA = 0.51g (WDC, 2015 & EMI, 2006); DE – Design Earthquake; PGE = 0.54g (WDC, 2015 & EMI, 2015)
WDC – POLB Wharf Design Criteria
Sheet piles and King piles used are by Skyline Steel (NUCOR Company). Equivalent sections by other manufacturers are also acceptable.

See Assumptions and References listed respectively, in Page 2 and 3 of the memorandum.

Table 4: Berth Deepening to EL. -57 ft MLLW plus 2 FT Over Dredge (i.e. Lowest El. -59 ft MLLW)

Pier / Berth	Mudline Elevation at Pierhead Line[1] (ft, MLLW)		Bulkhead and Additional Improvements				
	Designed	Existing	Static Only[2]	Static + Modified OLE[3]	Static + OLE	Static + CLE	Static + DE
Pier F/ F204 & F205	-36	-38.2 to -39.5	Solution 24 Double HZ1080MD & AZ36-700N Combination HZ1080MD from -32' to -110' AZ36-700N from -32' to -69'	Solution C23 Continuous HZ1080MA HZ1080MA from -32' to -135'	Solution 12 Double HZ1180MD & AZ36-700N Combination HZ1080MD from -32' to -120' AZ36-700N from -32' to -69' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 15 ft Wide From -20 to -65	Solution C23 Continuous HZ1080MD HZ1080MA from -32' to -125' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -20 to -65	Solution C23 Continuous HZ1180MD HZ1180MD from -32' to -130' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -20 to -65
Pier G/ G232 & G236	-55	-52 to -53	AZ36-700N Sheet Pile From -51' to -80'	AZ36-700N Sheet Pile From -51' to -80'	AZ36-700N Sheet Pile From -51' to -80'	AZ40-700N Sheet Pile From -51 to -80	Solution 12 HZ880MC & AZ36-700N Combination HZ880MC from -51' to -85' AZ36-700N from -51' to -69'
Pier J North/ J245 Thru J247	-48	48.6 to -49.6	AZ48-700N Sheet Pile From -44' to -90'	Solution 24 Double HZ1180MD & AZ36-700N Combination HZ1180MD from -44' to -110' AZ36-700N from -44' to -69'	Solution 24 Double HZ1080MA & AZ36-700N Combination HZ1080MA from -44' to -95' AZ36-700N from -44' to -69' + Top GI 30 ft Wide From +10' to -60'	Solution 12 HZ1180MD & AZ36-700N Combination HZ1180MD from -44' to -95' AZ36-700N from -44' to -69' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -35 to -65	Solution 24 Double HZ1080MD & AZ36-700N Combination HZ1080MD from -44' to -100' AZ36-700N from -44' to -69' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -35 to -65
Pier J South/ J266 Thru J270	-55	-47.5 to -47.9	AZ36-700N Sheet Pile From -51' to -80'	Solution 12 HZ1080MD & AZ36-700N Combination HZ1080MD from -51' to -100' AZ36-700N from -51 to -69'	Solution 12 HZ880MC & AZ36-700N Combination HZ880MC from -51' to -85' AZ36-700N from -44' to -69' + Top GI 30 ft Wide From +10' to -60'	AZ50 Sheet Pile From -51 to -90 + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -30 to -65	Solution 12 HZ1080MA & AZ36-700N Combination HZ1080MA from -51' to -95' AZ36-700N from -51' to -69' + Top GI - 30 ft Wide From +10' to -60' + Mid Slope GI - 30 ft Wide From -30 to -65
Pier T/ T132 Thru T140	-55	-48 to -51	No improvements needed	No improvements needed	No improvements needed	AZ50 Sheet Pile From -51 to -80	Solution 12 HZ1180MA & AZ36-700N Combination HZ1180MA from -51' to -85' AZ36-700N from -51' to -69'

NOTES:
[1] Information provided by POLB
[2] Static condition is expected to accommodate PGA of approximately 0.1g
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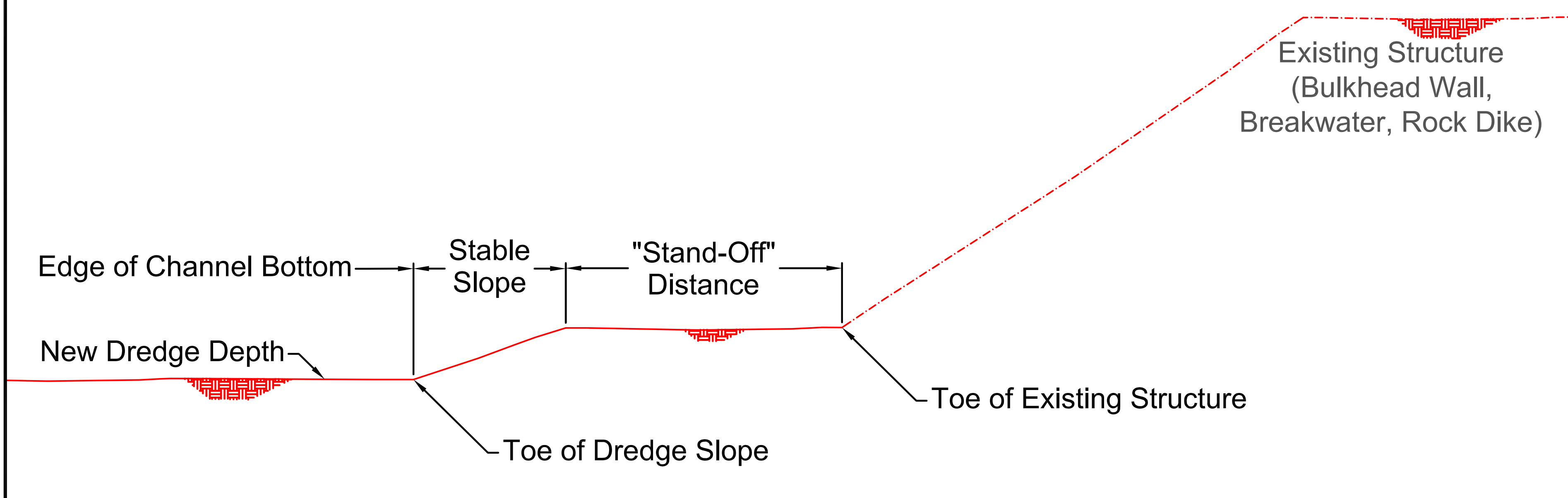
WDC – POLB Wharf Design Criteria
Sheet piles and King piles used are by Skyline Steel (NUCOR Company). Equivalent sections by other manufacturers are also acceptable.

See Assumptions and References listed respectively, in Page 2 and 3 of the memorandum.



NOT TO SCALE

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BERTH AND CHANNEL DEEPENING
PORT WIDE DREDGE PLAN AND FEDERAL CHANNEL EXPANSION STUDY
PORT OF LONG BEACH, CALIFORNIA

Project No: 15-152 | Date: 01-19-2017

Schematic Diagram of
"Stand-Off" Distance

Figure 1

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ATTACHMENT 1: POLB NAVIGATION IMPROVEMENT PLAN

POLB NAVIGATION IMPROVEMENTS

MAIN POLB MAP

Date: 10/25/2016

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

APPENDIX C: GEOTECHNICAL ENGINEERING - ATTACHMENT 3

Plate C6 – BATHYMETRY MAP
&
Plate C7 – NOAA CHART NO 18751

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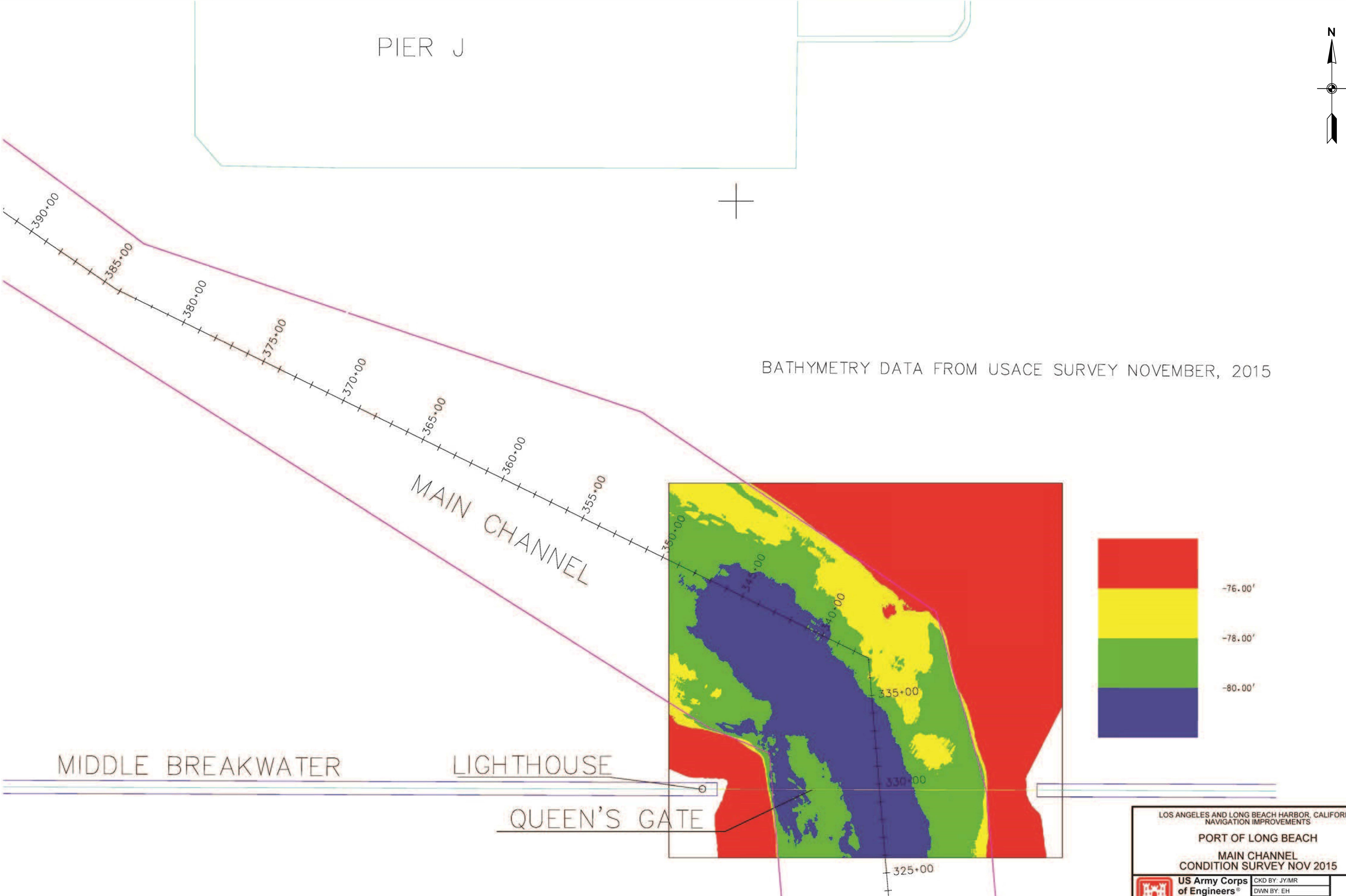

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS

PORT OF LONG BEACH

MAIN CHANNEL
CONDITION SURVEY NOV 2015

US Army Corps of Engineers®
Los Angeles District

CKD BY: JY/MR
DWN BY: EH
DATE: NOVEMBER 2017

PLATE
C6

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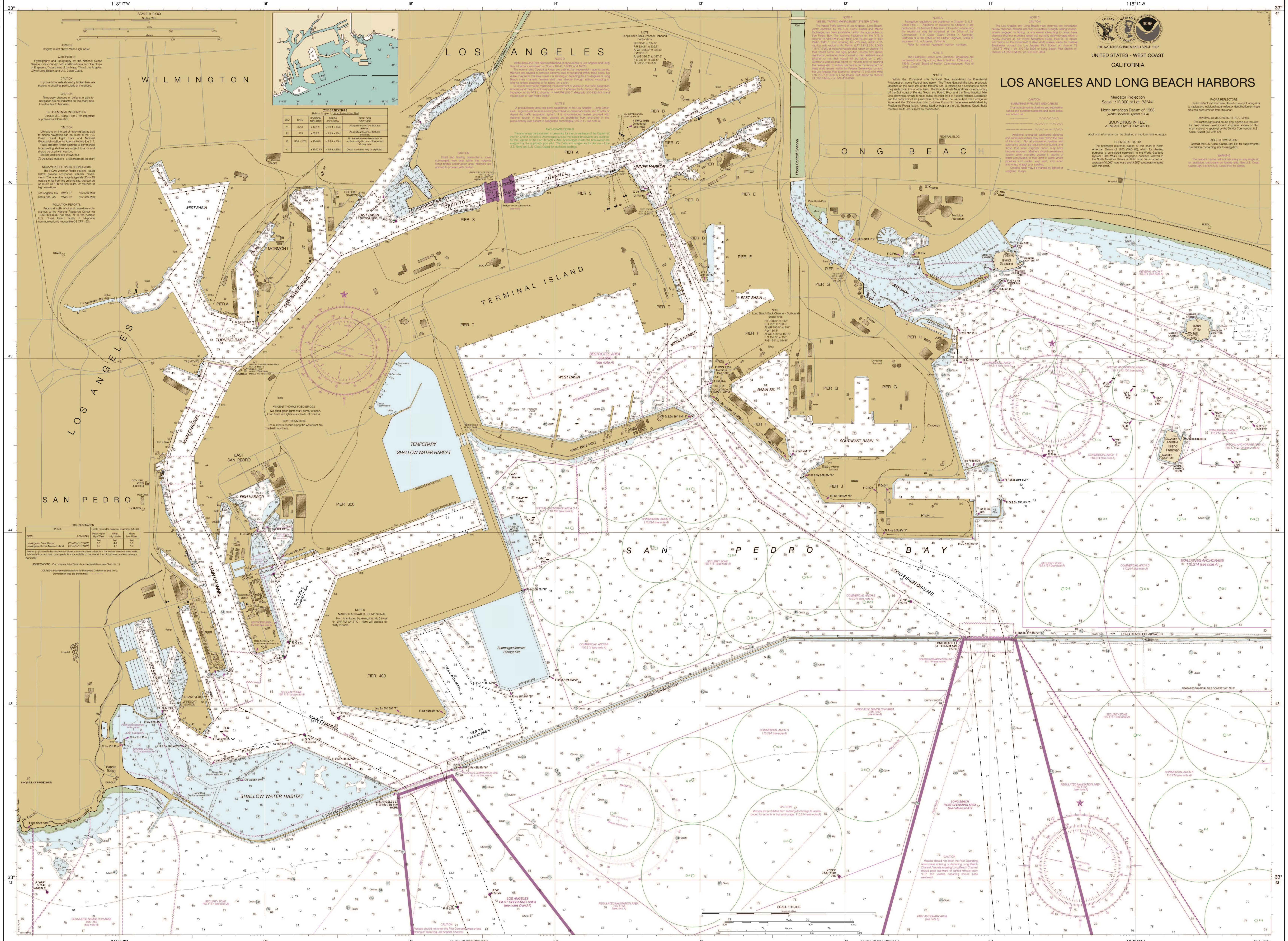
18751



CAUTION
This chart has been corrected from the Notice to Mariners (NM) published weekly by the National Geospatial-Intelligence Agency and the Local Notice to Mariners (LNM) issued periodically by each U.S. Coast Guard district to the dates shown in the lower left hand corner. Chart updates corrected from Notice to Mariners published after the dates shown in the lower left hand corner are available at nauticalcharts.noaa.gov.

NOAA encourages users to submit inquiries, discrepancies or comments about this chart at http://www.nauticalcharts.noaa.gov/staff/contact.htm.

SOUNDINGS IN FEET

Published at Washington, D.C.
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE
COAST SURVEY

FATHOMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FEET	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102

Los Angeles and Long Beach Harbors
SOUNDINGS IN FEET - SCALE 1:12,000

18751

48th Ed., Jul. 2016. Last Correction: 2/28/2017. Cleared through:
LNM: 0817 (2/21/2017), NM: 0917 (3/4/2017)

To ensure that this chart was printed at the proper scale, the line below should measure six inches (152 millimeters).

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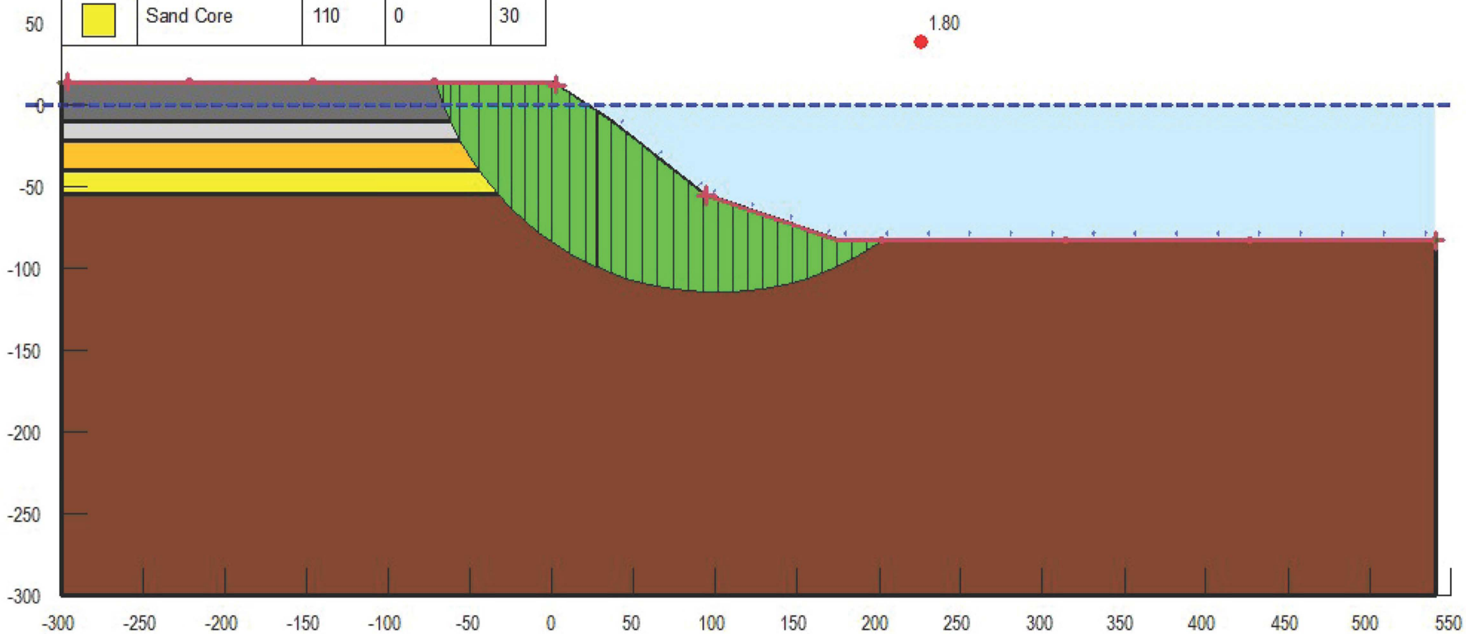
US Army Corps of Engineers® Los Angeles District	CHECKED BY: JY/MR	PLATE
	DRAWN BY: eh	C7
	DATE: NOVEMBER 2017	

APPENDIX C: GEOTECHNICAL ENGINEERING - ATTACHMENT 4

USACE SLOPE STABILITY MODELS

Blank page to facilitate duplex printing

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30

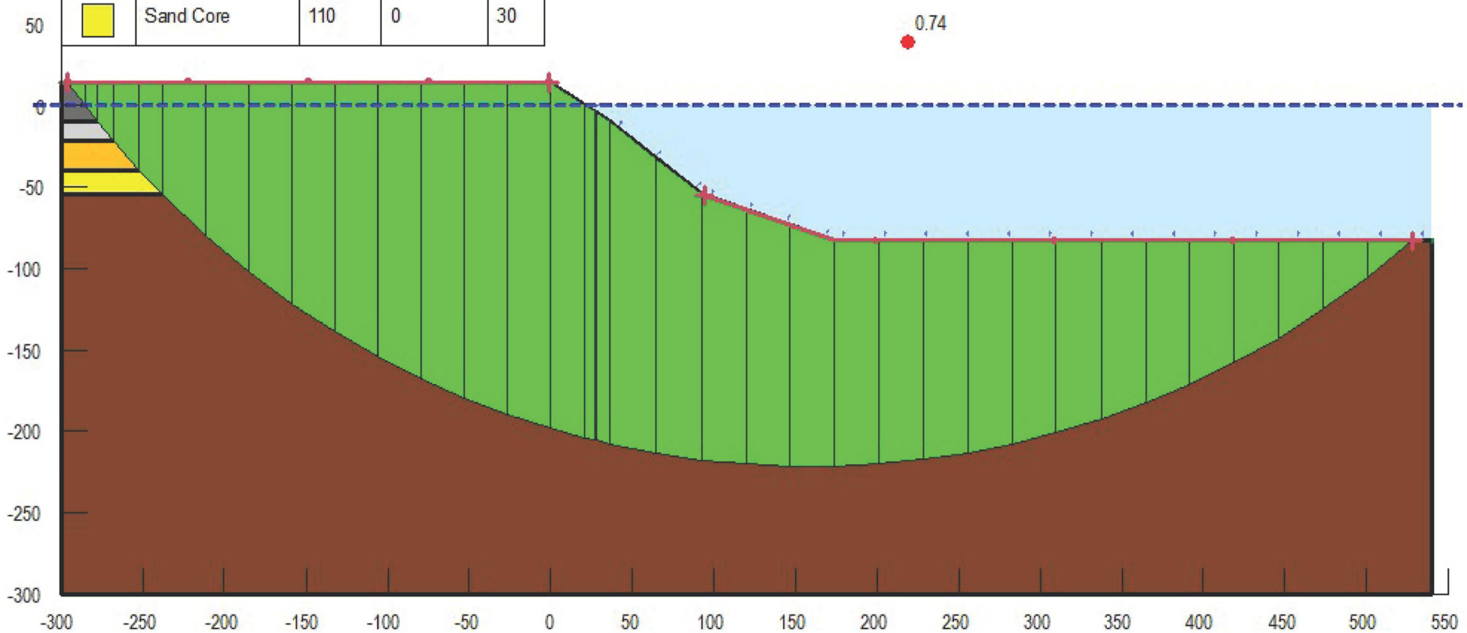


MIDDLE BREAKWATER - NO STANDOFF
STATIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
NO STANDOFF STATIC

US Army Corps of Engineers ® Los Angeles District	CKD BY: JY/MR	PLATE
	DWN BY: EH	D1
	DATE: JANUARY 2021	

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30



MIDDLE BREAKWATER - NO STANDOFF

SEISMIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS

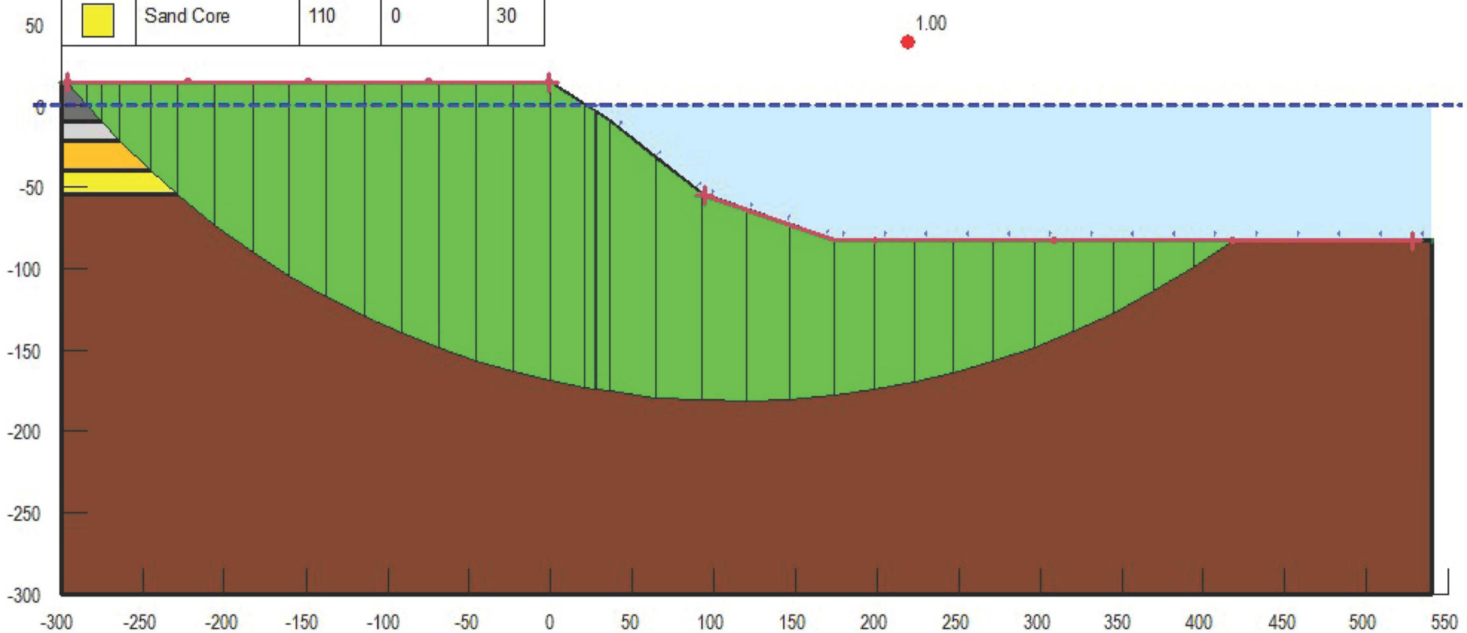
PORT OF LONG BEACH

DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
NO STANDOFF SEISMIC

US Army Corps of Engineers ® Los Angeles District	CKD BY: JY/MR	PLATE
	DWN BY: EH	D2
	DATE: JANUARY 2021	

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D02.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30



MIDDLE BREAKWATER - NO STANDOFF

YIELD ACCELERATION

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS

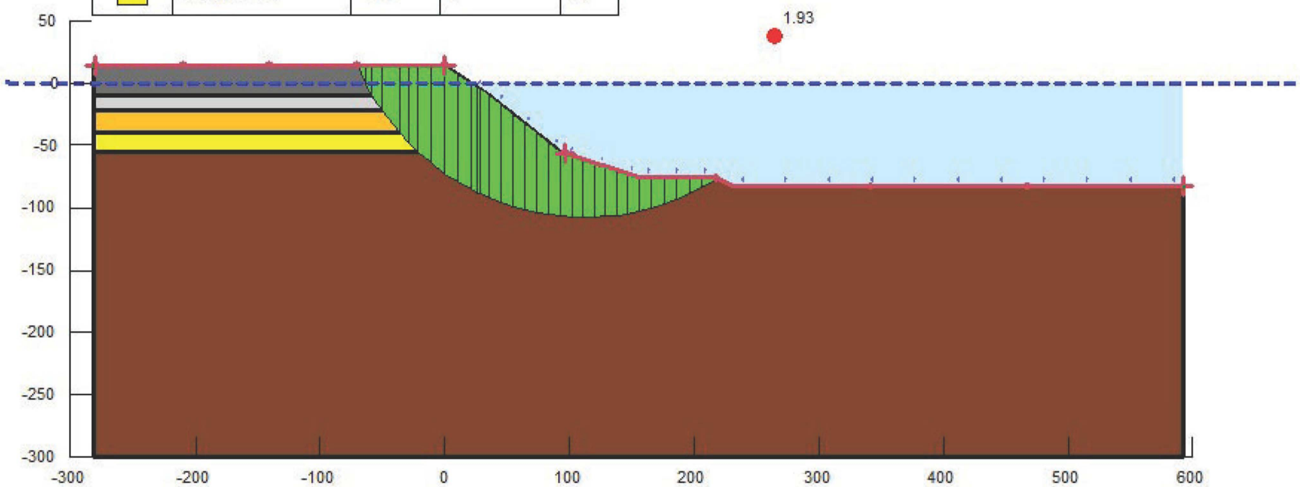
PORT OF LONG BEACH

DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
NO STANDOFF YIELD ACCELERATION

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR	PLATE
DWN BY: EH	D3
DATE: JANUARY 2021	

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30



MIDDLE BREAKWATER - STANDOFF 50 FEET
STATIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
STANDOFF 50FT STATIC

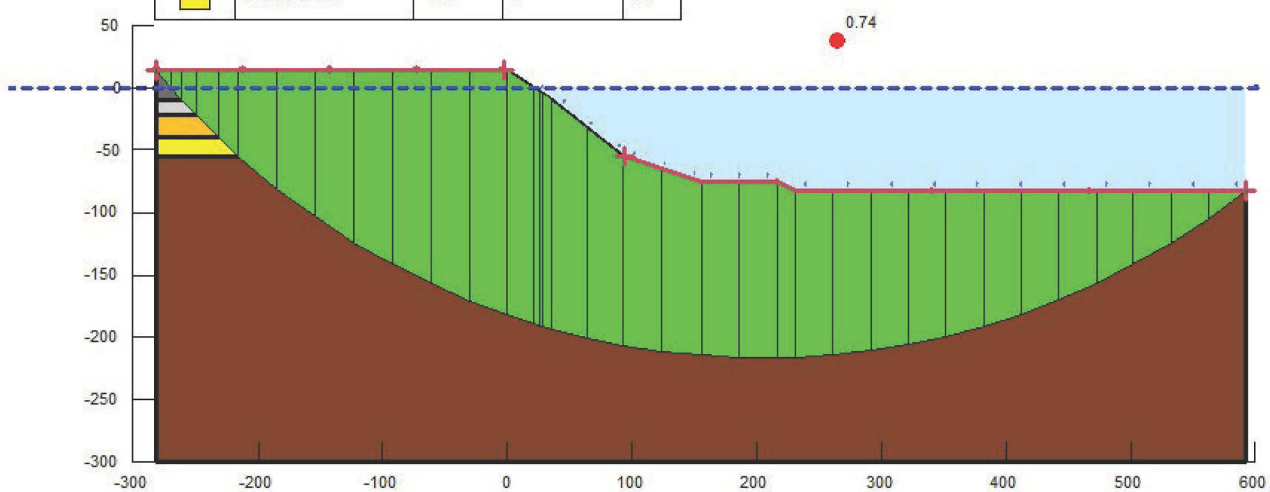
US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR
DWN BY: EH
DATE: JANUARY 2021

PLATE
D4

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D04.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30



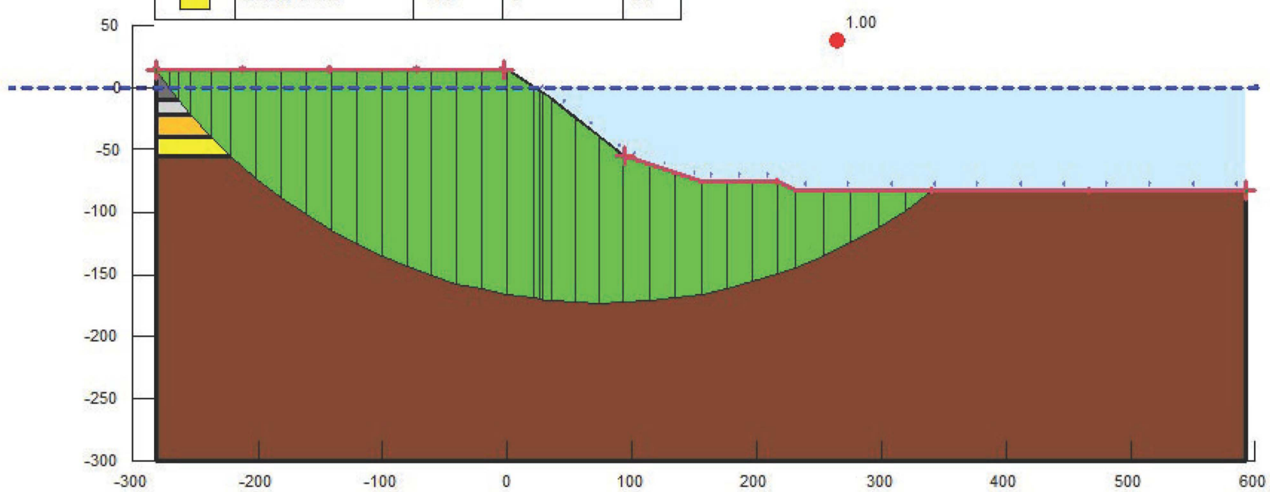
MIDDLE BREAKWATER - STANDOFF 50 FEET
SEISMIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
STANDOFF 50FT SEISMIC

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR	PLATE
DWN BY: EH	D5
DATE: JANUARY 2021	

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30



MIDDLE BREAKWATER - STANDOFF 50 FEET
YIELD ACCELERATION

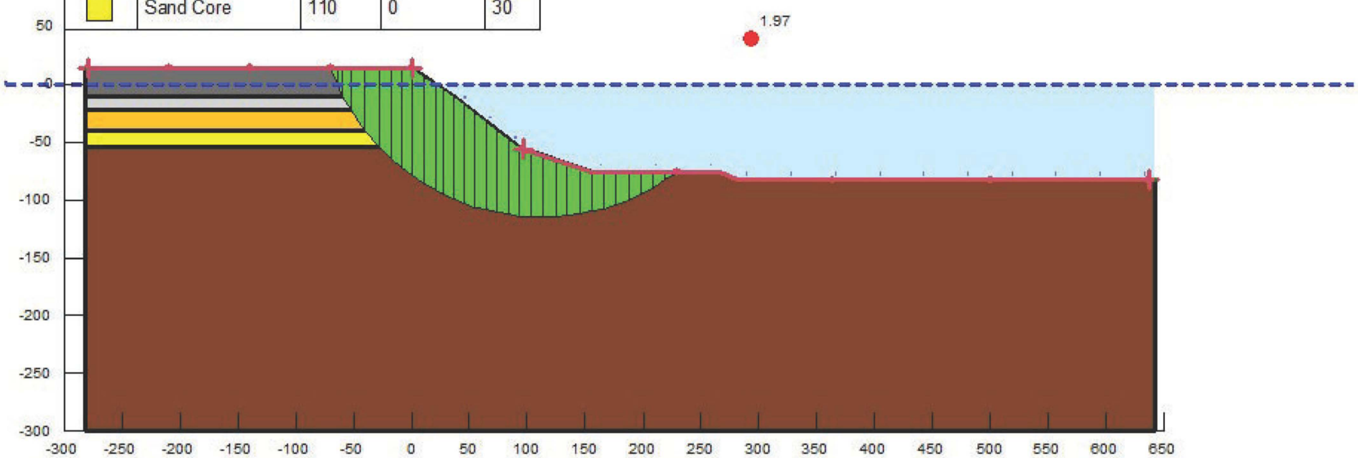
LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
STANDOFF 50FT YIELD ACCELERATION

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR
DWN BY: EH
DATE: JANUARY 2021

PLATE
D6

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D06.DGN



Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30

MIDDLE BREAKWATER - STANDOFF 100 FEET
STATIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS

PORT OF LONG BEACH

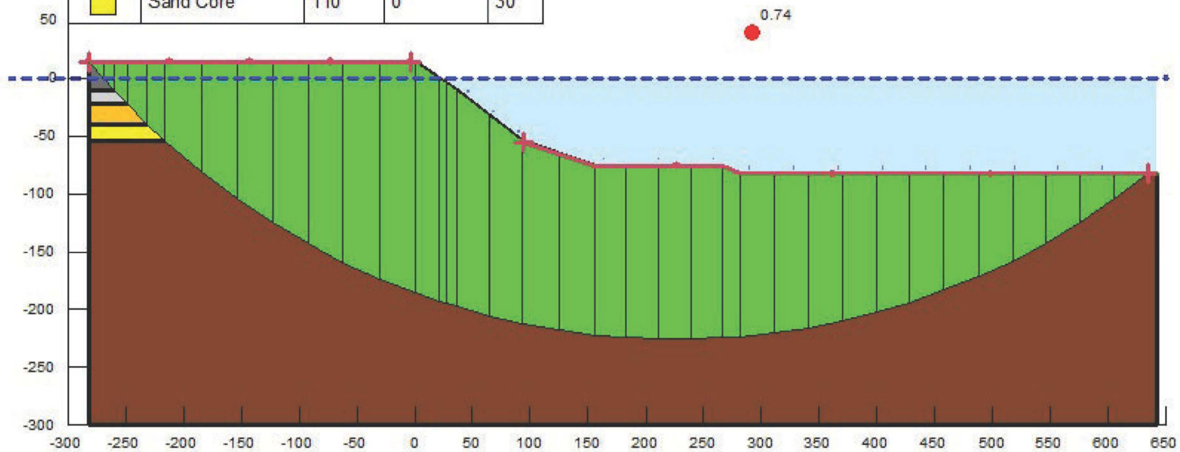
DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
STANDOFF 100FT STATIC

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR
DWN BY: EH
DATE: JANUARY 2021

PLATE
D7

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D07.DGN



Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30

MIDDLE BREAKWATER - STANDOFF 100 FEET
SEISMIC

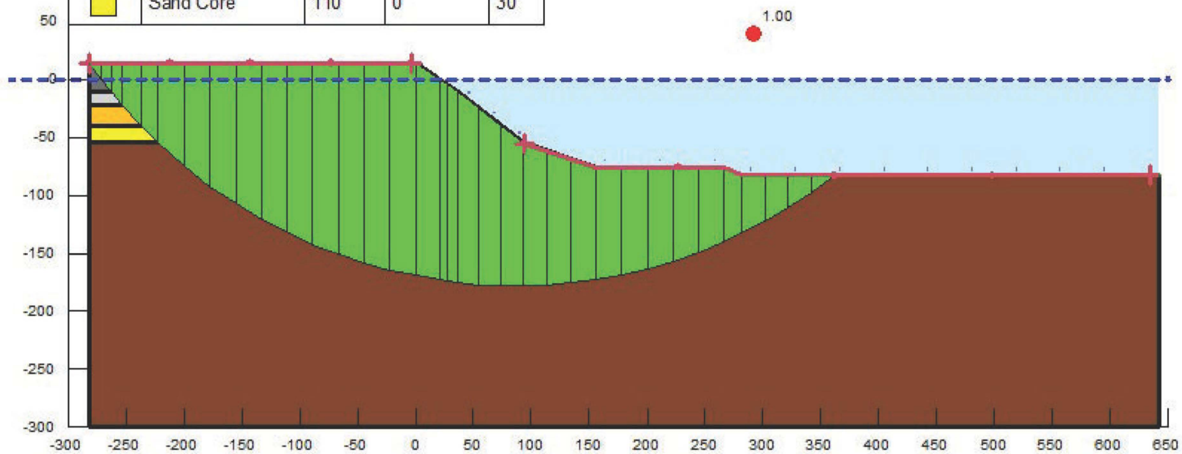
LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
STANDOFF 100FT SEISMIC

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR	PLATE
DWN BY: EH	D8
DATE: JANUARY 2021	

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D08.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30

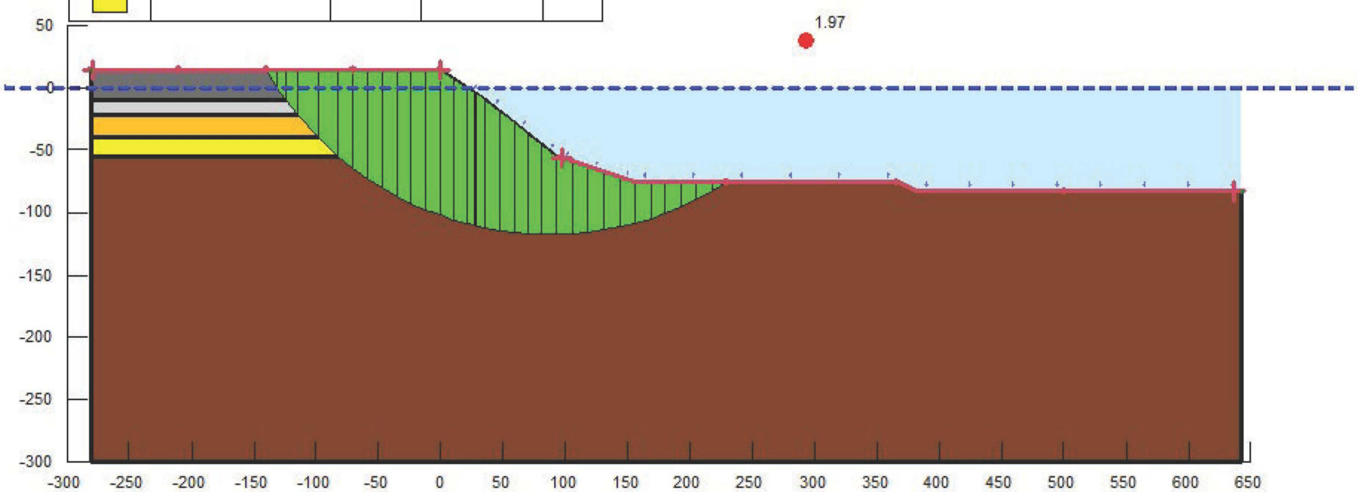


MIDDLE BREAKWATER - STANDOFF 100 FEET
YIELD ACCELERATION

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
STANDOFF 100FT YIELD ACCELERATION

US Army Corps of Engineers ® Los Angeles District	CKD BY: JY/MR	PLATE
	DWN BY: EH	D9
	DATE: JANUARY 2021	

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30

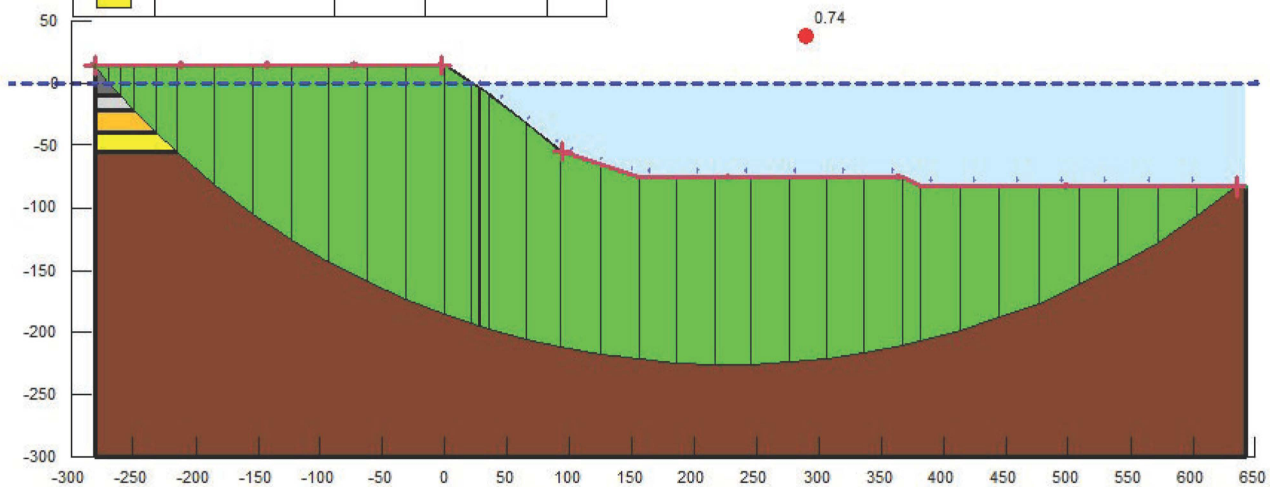


MIDDLE BREAKWATER - STANDOFF 200 FEET
STATIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
STANDOFF 200FT STATIC

US Army Corps of Engineers ® Los Angeles District	CKD BY: JY/MR	PLATE
	DWN BY: EH	
	DATE: JANUARY 2021	D10

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30



MIDDLE BREAKWATER - STANDOFF 200 FEET
SEISMIC

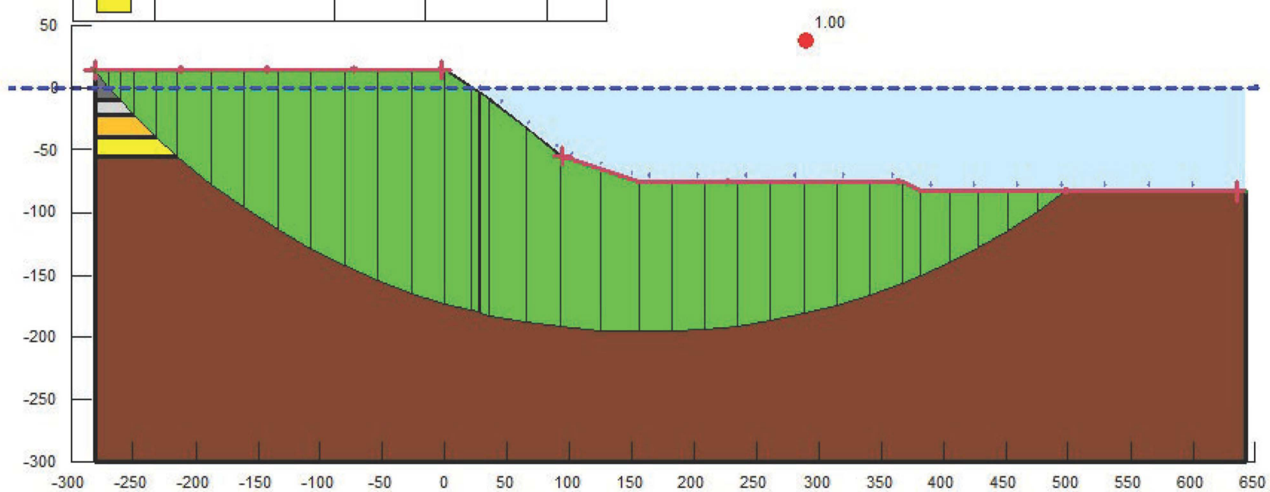
LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
STANDOFF 200FT SEISMIC

US Army Corps of Engineers ® Los Angeles District

CKD BY: JY/MR	PLATE
DWN BY: EH	D11
DATE: JANUARY 2021	

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D11.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	119	1,200	11
	Sand Core	110	0	30



MIDDLE BREAKWATER - STANDOFF 200 FEET
YIELD ACCELERATION

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
MIDDLE BREAKWATER
STANDOFF 200FT YIELD ACCELERATION

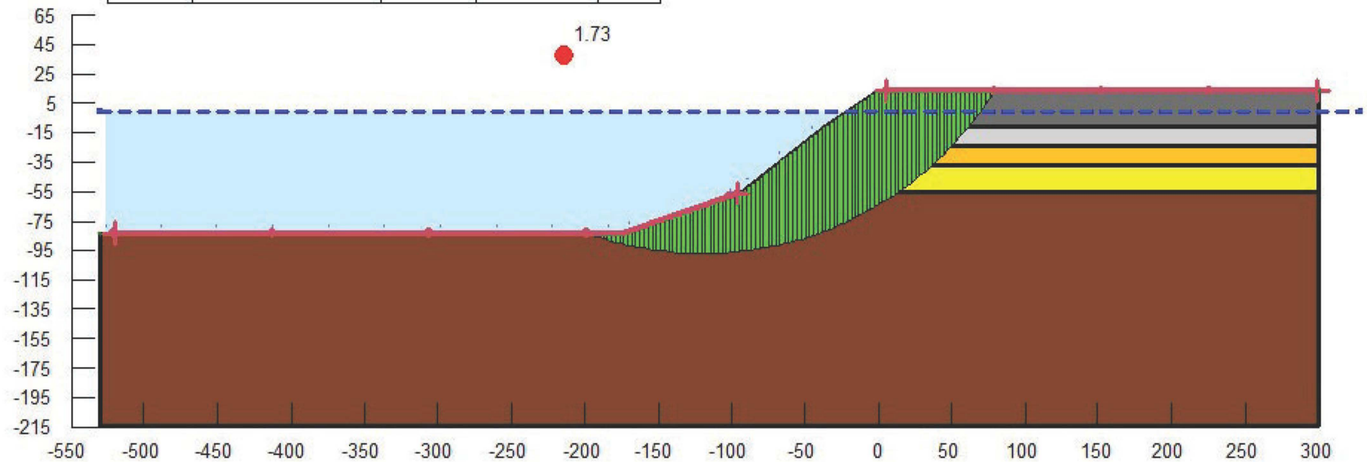
US Army Corps of Engineers®
Los Angeles District

CKD BY: JY/MR
DWN BY: EH
DATE: JANUARY 2021

PLATE
D12

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D12.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	136	1,200	9
	Sand Core	110	0	30



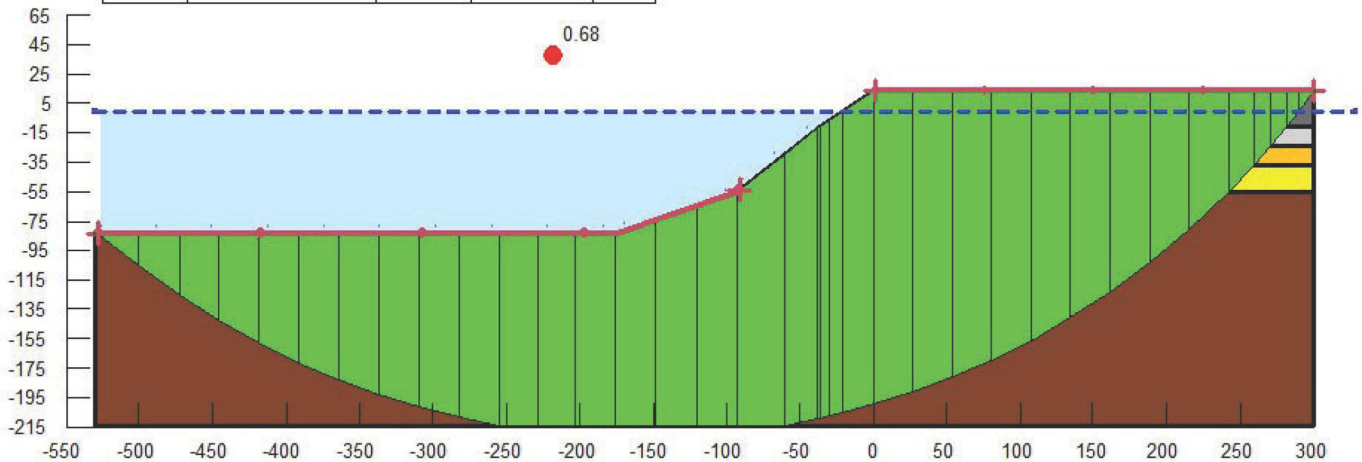
LONG BEACH BREAKWATER - NO STANDOFF STATIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
NO STANDOFF STATIC

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR	PLATE	
DWN BY: EH	D13	
DATE: JANUARY 2021		

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	136	1,200	9
	Sand Core	110	0	30



LONG BEACH BREAKWATER - NO STANDOFF SEISMIC

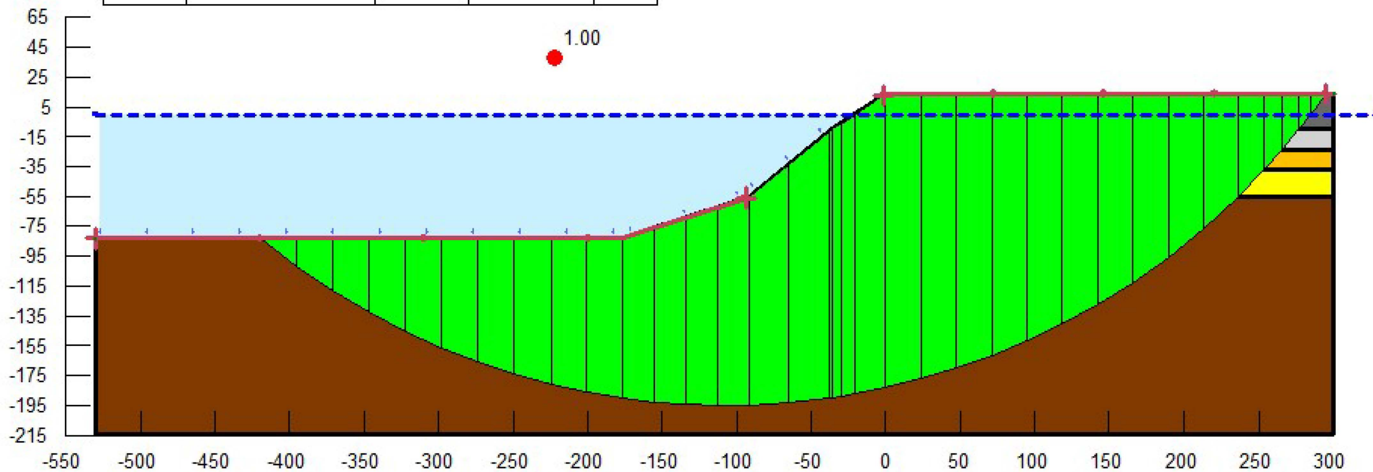
LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
NO STANDOFF SEISMIC

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR	PLATE
DWN BY: EH	D14
DATE: JANUARY 2021	

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D14.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
(dark grey)	Class A Stone	111	0	45
(light grey)	Class B Stone	120	0	45
(orange)	Clay Core	110	1,000	0
(brown)	Foundations Soils	136	1,200	9
(yellow)	Sand Core	110	0	30



LONG BEACH BREAKWATER - NO STANDOFF
YIELD ACCELERATION

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
NO STANDOFF YIELD ACCELERATION

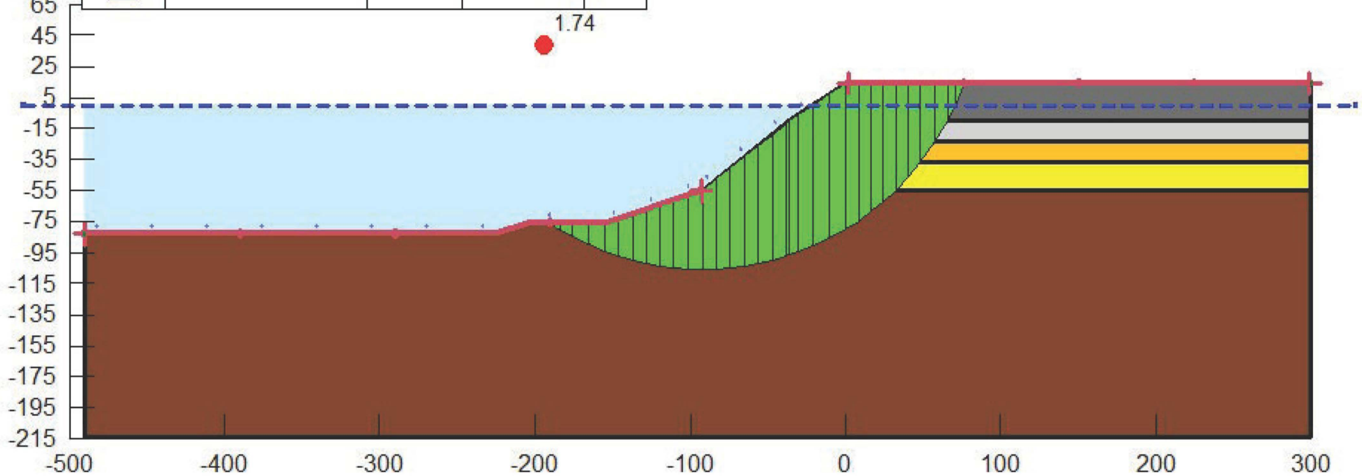
US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR
DWN BY: EH
DATE: JANUARY 2021

PLATE
D15

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D15.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	136	1,200	9
	Sand Core	110	0	30



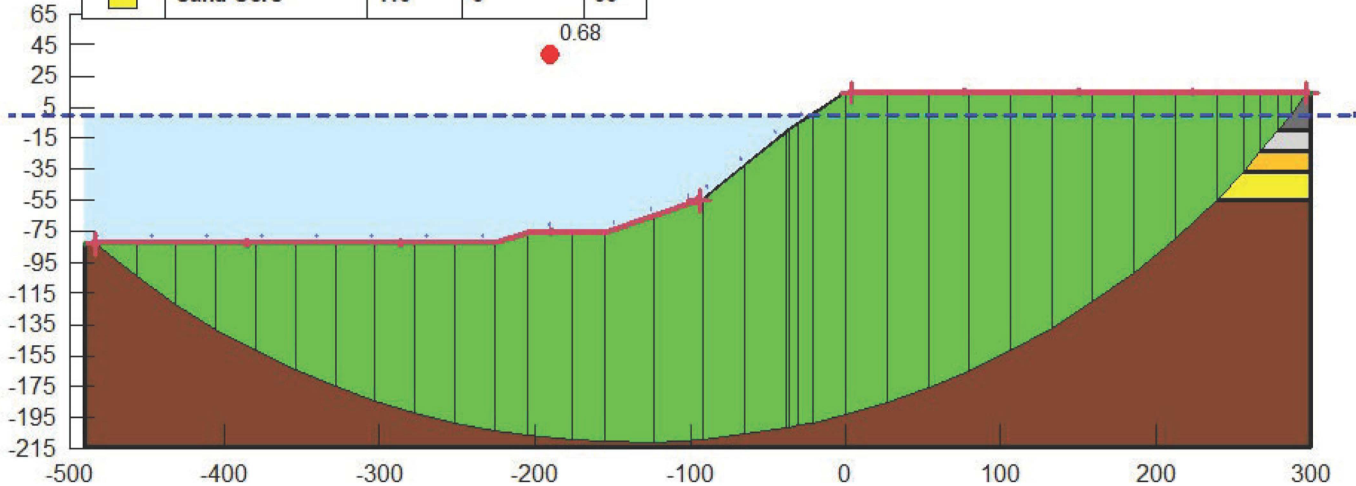
LONG BEACH BREAKWATER - 50 FEET STANDOFF STATIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
STANDOFF 50FT STATIC

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR	PLATE
DWN BY: EH	D16
DATE: JANUARY 2021	

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
(dark gray)	Class A Stone	111	0	45
(light gray)	Class B Stone	120	0	45
(orange)	Clay Core	110	1,000	0
(brown)	Foundations Soils	136	1,200	9
(yellow)	Sand Core	110	0	30



LONG BEACH BREAKWATER - 50 FEET STANDOFF SEISMIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS

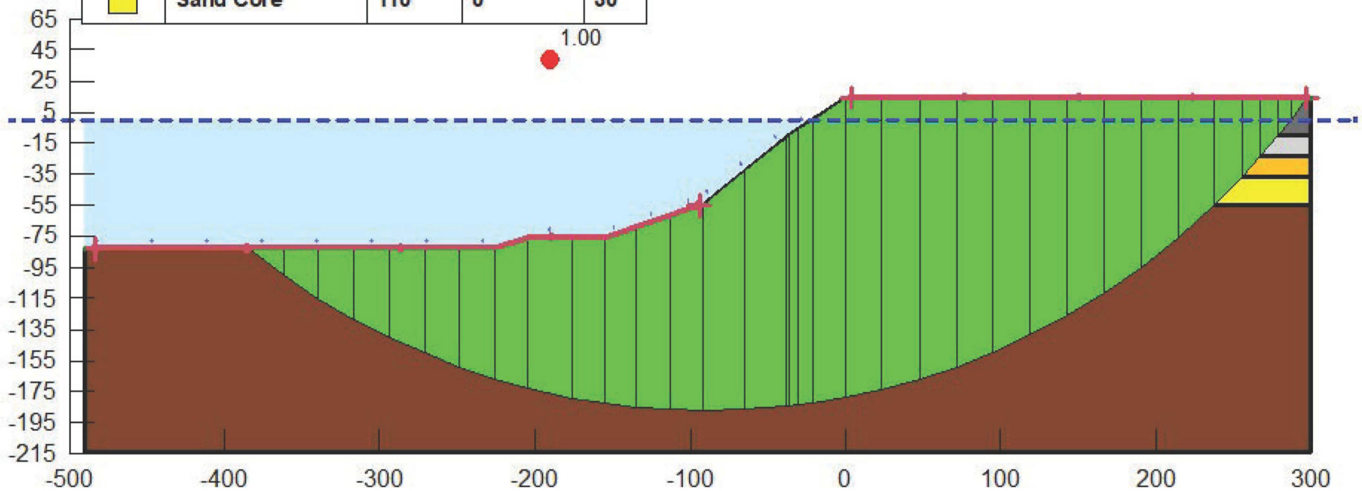
PORT OF LONG BEACH

DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
STANDOFF 50FT SEISMIC

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR	PLATE
DWN BY: EH	17
DATE: JANUARY 2021	

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	136	1,200	9
	Sand Core	110	0	30

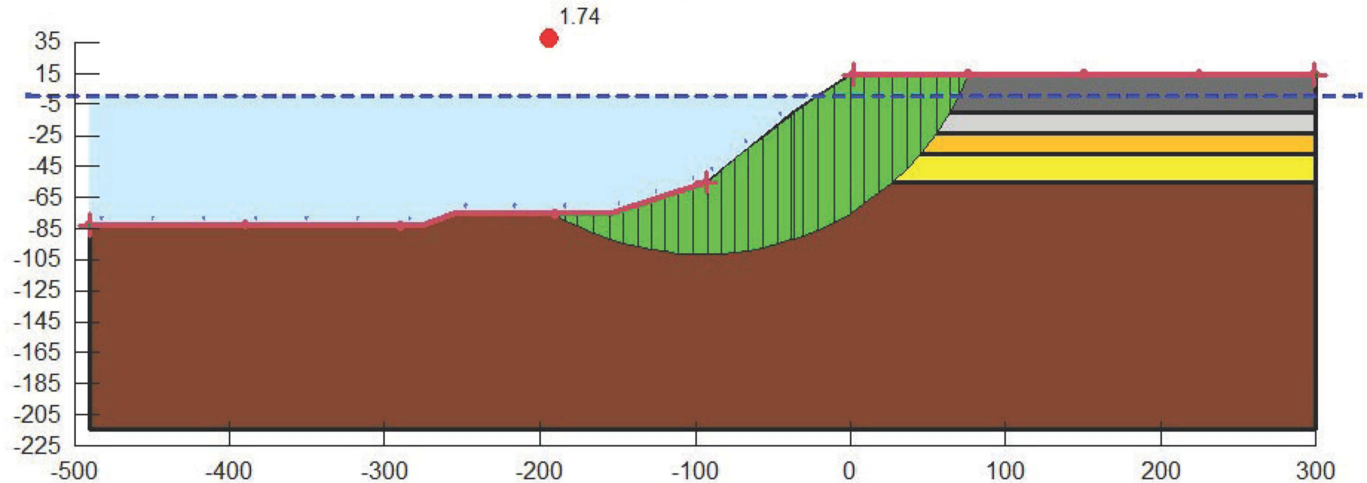


LONG BEACH BREAKWATER - 50 FEET STANDOFF
YIELD ACCELERATION

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA NAVIGATION IMPROVEMENTS PORT OF LONG BEACH DREDGING SLOPE STABILITY LONG BEACH BREAKWATER STANDOFF 50FT YIELD ACCELERATION		
US Army Corps of Engineers ® Los Angeles District	CKD BY: JY/MR DWN BY: EH DATE: JANUARY 2021	PLATE D18

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D18.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	136	1,200	9
	Sand Core	110	0	30



LONG BEACH BREAKWATER - 100 FEET STANDOFF STATIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS

PORT OF LONG BEACH

DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
STANDOFF 100FT STATIC

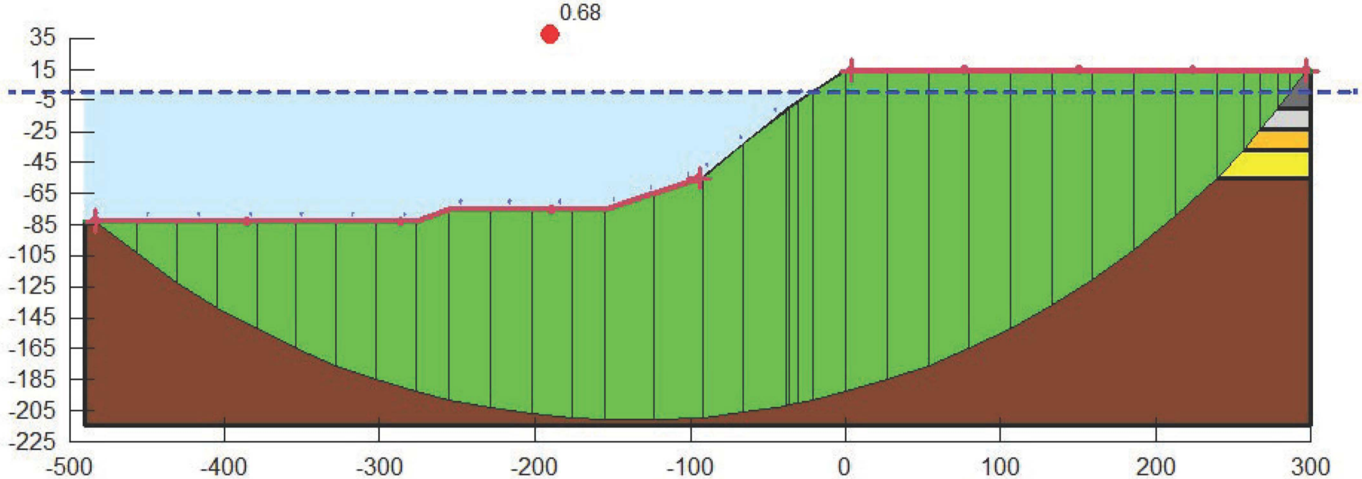
US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR
DWN BY: EH
DATE: JANUARY 2021

PLATE
D19

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D19.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	136	1,200	9
	Sand Core	110	0	30



LONG BEACH BREAKWATER - 100 FEET STANDOFF SEISMIC

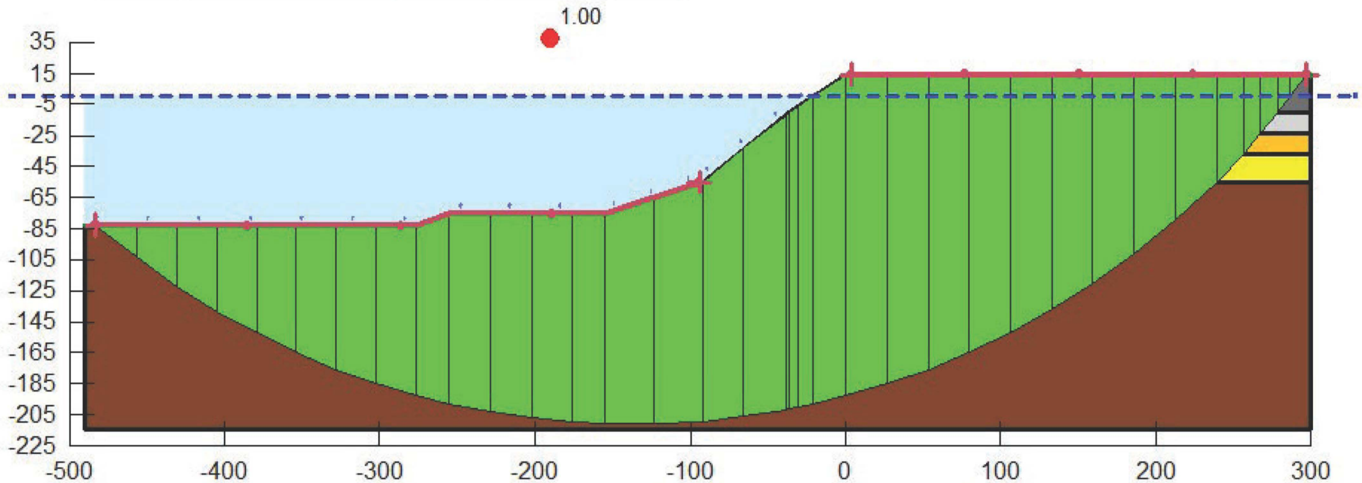
LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
STANDOFF 100FT SEISMIC

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR	PLATE
DWN BY: EH	20
DATE: JANUARY 2021	

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D20.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	136	1,200	9
	Sand Core	110	0	30



LONG BEACH BREAKWATER - 100 FEET STANDOFF
YIELD ACCELERATION

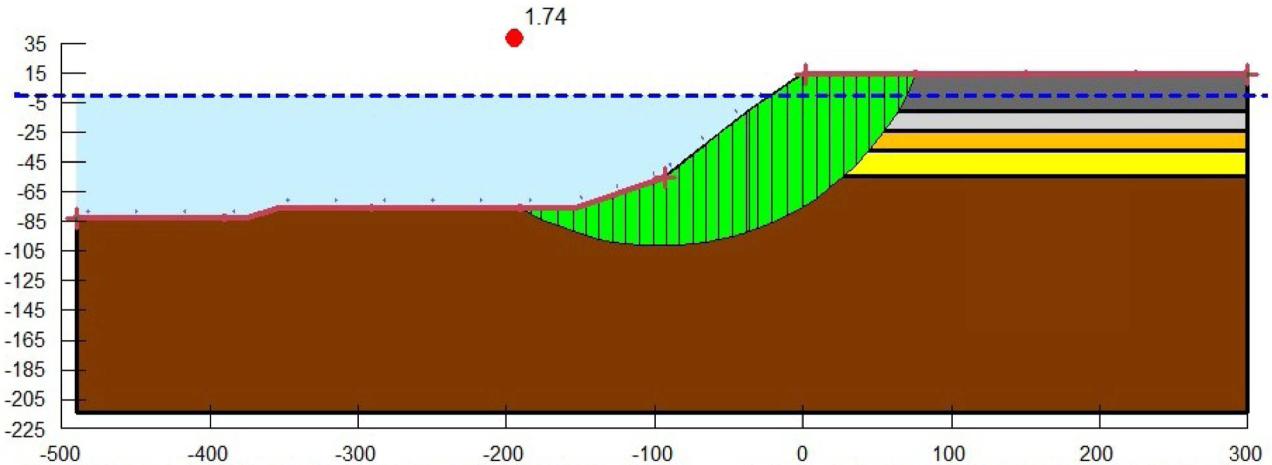
LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
STANDOFF 100FT YIELD ACCELERATION

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR	PLATE
DWN BY: EH	D21
DATE: JANUARY 2021	

HERNANDEZ F: \\SPL\DOCUMENTS\GEOTECH\YANG\PORT OF LB\REPORT\FIGURES_PLATES\C-4 GPOLC_D21.DGN

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	136	1,200	9
	Sand Core	110	0	30



LONG BEACH BREAKWATER - 200 FEET STANDOFF
STATIC

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS

PORT OF LONG BEACH

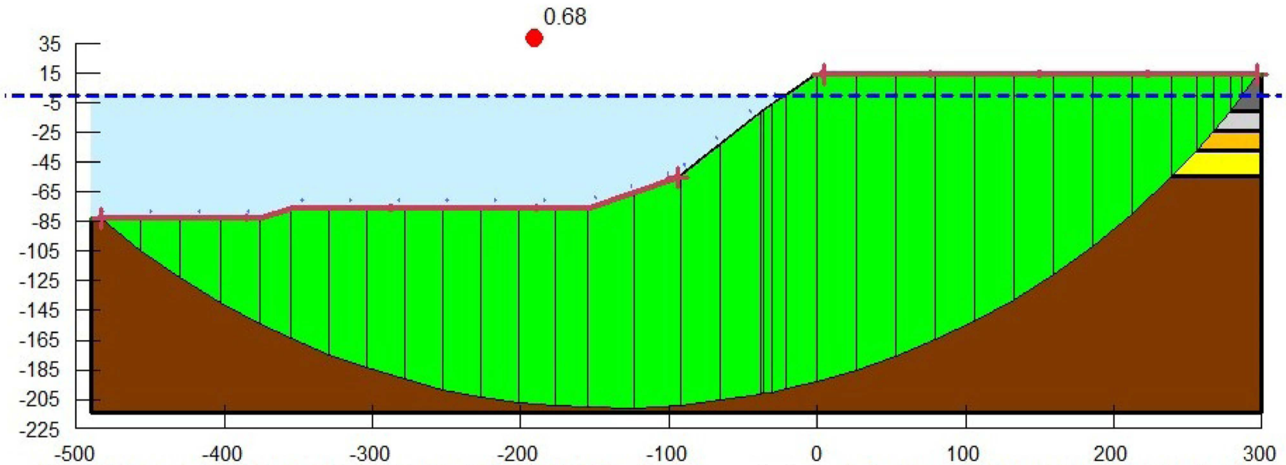
DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
STANDOFF 200FT STATIC

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR
DWN BY: EH
DATE: JANUARY 2021

PLATE
D22

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	136	1,200	9
	Sand Core	110	0	30



LONG BEACH BREAKWATER - 200 FEET STANDOFF
SEISMIC

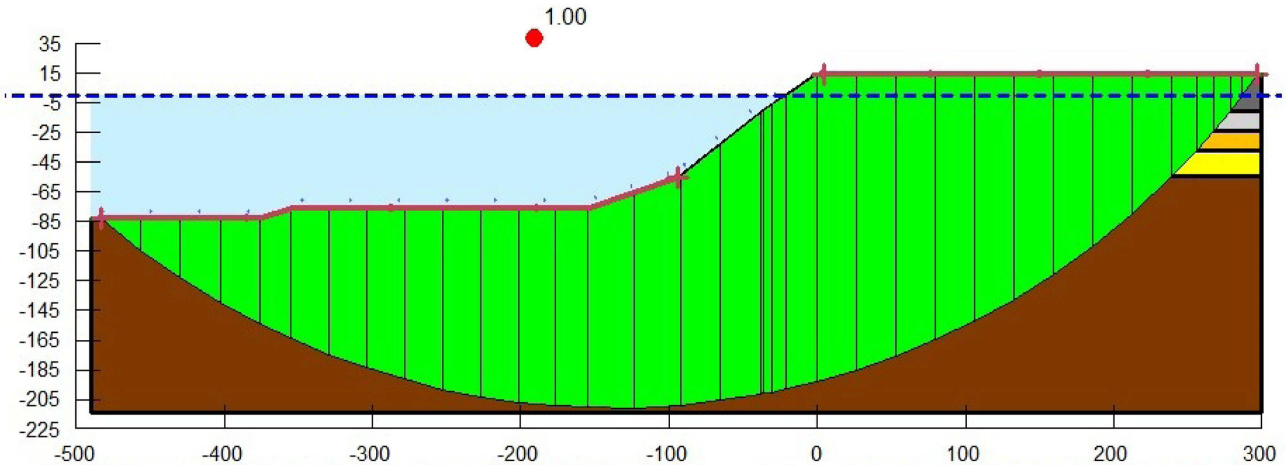
LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
STANDOFF 200FT SEISMIC

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR
DWN BY: EH
DATE: JANUARY 2021

PLATE
D23

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Class A Stone	111	0	45
	Class B Stone	120	0	45
	Clay Core	110	1,000	0
	Foundations Soils	136	1,200	9
	Sand Core	110	0	30



LONG BEACH BREAKWATER - 200 FEET STANDOFF
YIELD ACCELERATION

LOS ANGELES AND LONG BEACH HARBOR, CALIFORNIA
NAVIGATION IMPROVEMENTS
PORT OF LONG BEACH
DREDGING SLOPE STABILITY
LONG BEACH BREAKWATER
STANDOFF 200FT YIELD ACCELERATION

US Army Corps of Engineers ®
Los Angeles District

CKD BY: JY/MR	PLATE
DWN BY: EH	D24
DATE: JANUARY 2021	

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