

SECTION 35 73 00 - BORINQUEN DAMS 2E, 1W, AND 2W

1.01 SUMMARY:

A. General:

1. ^{A16}This Section covers the Employer's Requirements for the design and construction of Borinquen Dams 2E, 1W, and 2W and ancillary facilities required for access to, maintenance of, and performance monitoring of the dams.
^{A16}
2. The dams shall be safe, structurally sound, economical, practical, and durable, with minimum maintenance costs and suitable for a design life of 100 years.
3. The Contractor ^{A17}shall produce design documents and construction specifications for ^{A17}the dams. The design documents and specifications shall specifically address the design standards and codes, loading conditions, design assumptions, methods of analysis, analysis results, design concepts, procedures, formulas, references, construction specifications, method statements, and drawings as required to convey the concept, detailed design, and construction methodology.
- ^{A16}4. Volume VI, Part 14 ^{A17}includes preliminary designs (drawings and specifications) that the Contractor may, if he so chooses, use as a reference for the design of the dams. See Sub-Clause 5.1 of the Conditions of Contract. ^{A17}

B. Reference Documents: ^{A17}Volume VI, Part 1 of the Contract contains the conceptual drawings of the Third Set of Locks Project. These drawings are provided for information only. See Sub-Clause 5.1 of the Conditions of Contract. ^{A17}

C. Construction Scope: The scope of the construction work for Dams 2E, 1W, and 2W and ancillary facilities includes the following items. ^{A16}

1. **Clearing and Grubbing:** Clear and grub the work area of trees, shrubs, stumps, roots, brush, and other vegetation; debris; existing foundations; pavements; utility lines; structures; fences; and other items that would interfere with construction operations.
2. **Cofferdam Construction:** Construct cofferdam ^{A9}or similar^{A9} structure across the previous Cocoli River outlet into Miraflores Lake at the northeast end of Dam 2E.
3. **Foundation Dewatering:** Install and operate dewatering system to allow for excavation and embankment construction in the dry.
4. **Foundation and Abutment Excavation:** Remove all soils ^{A9}— including fill, alluvium, and residual soils — down to bedrock for Dam 2E. Soils may be left in place under the outboard portion of dams^{A9} 1W and 2W provided that it can be

demonstrated that static and seismic stability can be maintained. Weathered rock shall be removed from the core foundations as required in Subparagraph ^{A9}1.03.A.3^{A9}.

5. ^{A9}**Rock-Foundation Treatment:** Perform rock-foundation treatment work including initial cleaning of the rock foundation surfaces for inspection and mapping; dental excavation; placing dental and backfill concrete; placing slush grout; shotcreting; and final cleaning of the rock-foundation surfaces prior to embankment-fill placement.^{A9}
6. **Foundation Seepage Control:** Construct ^{A9}seepage-control^{A9} system in rock to minimize seepage through the rock foundation.
7. **Dam Construction:** Construct zoned embankments for dams ^{A9}2E, 1W,^{A9} and 2W.
8. **Instrumentation:** ^{A9}Design, install, and test instrumentation required for dam-performance monitoring.
9. **Crest Access Roads:** Construct access roads on the dam crests and connect the roads to existing facilities.

1.02 ^{A16}REFERENCES: ^{A16}

A. American Society for Testing and Materials (ASTM) International Standards:

^{A10} C 33-07	Standard Specification for concrete aggregates.
^{A10} C 117-04 ^{A10}	Standard Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
^{A10} C 127-07	Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate ^{A10}
^{A10} C 131-06 ^{A10}	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and ^{A9} Impact in Los Angeles Machine. ^{A9}
^{A10} C 136-06 ^{A10}	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
^{A10} C 535-03 ^{A10}	Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and ^{A9} Impact in Los Angeles Machine. ^{A9}
^{A10} D 698-07	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 Ft-Lbf/Ft ³ (600 Kn-M/M ³)) ^{A10}
^{A10} D 1556-07 ^{A10}	Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method

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| ^{A10} D 1557-07 ^{A10} | Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort [56,000 ft-lbf/ft ³ (2,700 kN-m/m ³)] |
| ^{A10} D 2216-05 ^{A10} | Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock |
| ^{A10} D 4318-05 ^{A10} | Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils |
| ^{A10} D 5030-04 ^{A10} | Standard Test Method for Density of Soil and Rock in Place by the Water Replacement Method in a Test Pit |
| ^{A10} D 5080-08 ^{A10} | Standard Test Method for Rapid Determination of Percent Compaction |
- B. U.S. Army Corps of Engineers (USACE) Engineering Manuals:**
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|----------------|-----------------------------|
| EM-1110-1-1804 | Geotechnical Investigations |
| EM-1110-2-1902 | Slope Stability |
| EM-1110-2-1100 | Coastal Engineering Manual |
- C. U.S. Army Corps of Engineers (USACE) Handbook for Concrete and Cement:**
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| CRD-C-119 | Flat and Elongated Particles in Coarse Aggregate |
| CRD-C-120 | Flat and Elongated Particles in Fine Aggregate |
- D. U.S. Bureau of Reclamation (USBR):**
- Design Standards No. 13, Embankment Dams, Chapter 5, Protective Filters.
- Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams
- Earth Manual
- E. References for Analysis Models:**
- Geo-Slope International. SEEP/W for ^{A9}Finite Element Seepage Analysis; SLOPE/W for Slope Stability Analysis, ^{A9} Version 3. Calgary, Alberta, Canada.
- Itasca. FLAC. Fast Lagrangian Analysis of Continua, Version 5.0, user's guide, Itasca Consulting Group, Inc., Mill Place, 111 Third Street, Suite 450, Minneapolis, Minnesota.
- Wright, S.G. UTEXAS4, A Computer Program for Slope Stability Calculations, Shinoak Software.

Plaxis BV. Finite Element Code for Soil and Rock Analyses, Plaxis V8, Netherlands.

F. ACP Documents:

^{A17}Volume VI, Part 2 includes the overall Geotechnical Data Report and, within the folder for consultants' reports, the two geotechnical interpretive reports for dams 2E, 1W, and 2W, covering the foundation and in-situ construction materials, respectively. The aforementioned geotechnical interpretive reports — both dated May 12, 2008 — are not to be construed to reflect the Employer's acceptance of the interpretation of the foundation and construction materials that the Contractor is likely to encounter during construction of dams 2E, 1W, and 2W. Such interpretations were arrived at by the consultant retained by the Employer to perform the geotechnical work involved and are included merely as another reference that the Contractor can use to assess and decide on the geotechnical conditions he is likely to encounter. See Sub-Clause 5.1 of the Conditions of Contract.^{A17}

I.C.P. Memo 55, Design of Drainage Facilities.

1.03 REQUIREMENTS:

A. Design:

1. **Alignment and Layout Requirements:** Alignment of ^{A9}dams 2E, 1W,^{A9} and 2W shall be controlled by the Pacific Approach Channel (PAC) alignment; the dams can be parallel to the PAC centerline. Dam 2E will be located on the east side of the ^{A9}PAC, and dams^{A9} 1W and 2W will be located on the west side of the PAC.
 - a. The nominal PAC invert elevation shall be at 9.14 m PLD north of Station 6+064 and 6.42 m PLD south of Station 6+200 (with 2 percent slope between these stations). The crest elevations of the dams shall not be less than 32.00 m PLD. ^{A10}The dam crest elevation shall be confirmed by analyses for wave run-up combined with the locks design flood level [Refer to Section 01 10 00 (*General Project Requirements*), Subparagraph 1.02 L.].^{A10} The dam crest widths shall be based on the results of ^{A9}seismic-stability and ship-grounding^{A9} analyses; but shall not be less than 30.00 m. Furthermore, the crest widths shall be subject to approval by the Employer¹.
 - b. A nominal width ("dredging buffer zone") at the toe of the slope on the PAC side of the embankments shall be set at 5 m at the PAC invert

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elevation and shall be outside the theoretical PAC excavation limits.

- c. The slopes of the dams shall be based on the results of analyses as described in Subparagraph 1.03 A.8., but shall not be steeper than the slopes indicated below.

- 1) ^{A9}**Inboard Slopes of Dams 2E, 1W,^{A9} and 2W:** 3 horizontal:1 vertical (3H:1V).
- 2) **Outboard Slope of Dam 2E:** 3H:1V above elevation 16.00 m and 2H:1V below this elevation.
- 3) ^{A9}**Outboard Slopes^{A9} of Dams 1W and 2W:** 2.5H:1V.

2. **Geotechnical Parameters:** ^{A17}The Contractor shall be solely responsible for the interpretation of the information provided by the Employer. The Contractor should conduct any additional investigations he deems necessary to supplement the currently available information to properly characterize the Site for the design and construction of dams 2E, 1W, and 2W and ancillary facilities. ^{A17}

The Contractor shall:

- a. Assess the geological and geotechnical stratification and the engineering properties of all soil and rock ^{A9}types, including ^{A9} classification, average and range of strength and deformation properties, permeability, etc.
- b. Construct test fills for embankment core, filter, drain, ^{A9}earth-fill shell, and rock-fill shell zones using in-situ materials and the ^{A9} Contractor's proposed methods and procedures to demonstrate compliance with the ^{A17}relevant Employer's Requirements. ^{A17}
- c. Provide a geotechnical report including at least the recommended design parameters for all soil and rock types, recommended excavation methods, dewatering methodology during construction, and sources and utilization of soils and rock materials for embankment-dam construction.

3. ^{A9}**Embankment-Foundation^{A9} Objectives:** The Contractor shall demonstrate that the dam foundation:

- a. Has sufficient strength for static and seismic stability loading conditions and eliminates liquefaction potential. Accordingly, soils ^{A9}(including fill, alluvium, and residual soils)^{A9} shall be removed to expose bedrock where they may affect static or seismic stability of the dam slopes.
- b. Will minimize settlement and deformation of the embankments to avoid impairing the structural and seepage-control integrity of the dams under all design loading conditions.
- c. Can be treated to control seepage and prevent piping of embankment materials into discontinuities in the dam foundations. Accordingly,

highly or more weathered rock shall be removed from the core foundations to expose ^{A9}only ^{A9} slightly to moderately weathered rock.

4. ^{A16}**Foundation Seepage Control:** The foundation seepage cutoff shall be a grout curtain or cutoff wall and shall be based on geotechnical conditions (e.g., hydraulic conductivity data) and performance reliability. ^{A16} Foundation seepage control shall, in combination with filters and drains, prevent piping of foundation materials. Furthermore, the Contractor shall demonstrate that seepage losses through the dams and their foundations will not impair the operation of ^{A9}the Canal or the safety of dams and will not exceed a total discharge of 500 gallons per minute for ^{A9}all three dams.
 - a. The minimum depth of the cutoff shall be 15 m below the core foundation. The cutoff shall be deepened to intercept localized fracture and shear zones that have high hydraulic conductivities at greater depths.
 - b. If a grout curtain is used, the performance goal of the grouting program is to achieve a residual Lugeon value ^{A9}of 7 or ^{A9}less. Verification holes shall be water tested to confirm the residual Lugeon values.
 - c. If a cutoff wall is used, the hydraulic conductivity of the cutoff walls shall be at least 10^{-7} cm/sec as measured in accordance with acceptable laboratory testing procedures.
 - d. Where shear zones are encountered in the foundation, stitch grouting shall be performed or ^{A9}another ^{A9} form of cutoff constructed.
5. **Dam Interface with Locks:** The south ends of ^{A9}Dams ^{A9}2E and 2W will connect with the north end of the new locks. The Contractor shall design watertight connections that prevent the potential for piping and uncontrolled leakage under both operating and design seismic conditions.
6. **Availability and Use of Excavation Materials for Dam Construction:** The Contractor may utilize materials ^{A9}he has excavated, materials stockpiled from previous PAC excavations for embankment construction, or materials procured from other sources. In all cases, only uncontaminated natural soils shall be used, with no ^{A9}wastes of any type. Organic matter will not be allowed in embankment fills.
7. **Abutment Stability:** The Contractor shall demonstrate that the abutments of the dams are stable for long-term and seismic conditions. Seismic criteria are specified in Subparagraph ^{A9}1.04 C. ^{A9}
8. **Analysis Requirements:**
 - a. Embankment slope stability analyses shall be performed using computer programs such as UTEXAS4 or SLOPE/W for the loading conditions indicated in Subparagraph ^{A9}1.04 B.1. ^{A9} to demonstrate that the embankment slopes meet specified design criteria.

- b. The phreatic surface within the embankment dams for the various lake levels indicated in ^{A9}Subparagraph ^{A9} 1.04 B.1. shall be calculated from seepage analyses using finite-element models (FEMs) such as SEEP/W.
 - c. Assessments of seismic deformations in the dam shall be substantiated by theory from literature and be analyzed by specific numerical models using FLAC, ^{A9}Plaxis, ^{A9} or equivalent software.
 - d. ^{A9}Ship-grounding analyses shall be performed to demonstrate that damage to the embankment dams will not extend to the core, filter, and drain zones. Calculations shall be made for vessel impact, ^{A9} which shall include appropriate analytical methods to approximate the maximum impact forces. Full documentation of the analysis methods and results shall be provided.
9. **Instrumentation for Dam Performance Monitoring:** Instrumentation is required for dam performance monitoring. The types of instruments and instrument locations shall be selected based on the results of seepage analyses and geologic and other design considerations. Parameters to be monitored shall include water pressures, horizontal and vertical surface ^{A9}movements, ^{A9} and earthquake accelerations. [The Contractor shall consider additional instrumentation to demonstrate the performance and operational requirements stated in paragraph 1.04.E.6.](#)
- a. ^{A9}The piezometer instrumentation sections in dams 2E, 1W, ^{A9} and 2W shall be located at maximum embankment sections, geologic contacts, active fault crossings, major shear zones, and at other points along the dam axes.
 - b. The number of instrumentation sections shall be at least as follows.
 - ^{A9}1) **Dam 2E:** 6 sections.
 - 2) **Dam 1W:** 2 sections.
 - 3) **Dam 2W:** 3 sections. ^{A9}
 - c. Installation of instrumentation shall minimize disruption of ^{A9}construction, ^{A9} and the instrumentation system shall be reliable and include appropriate redundancies. The installation of the piezometers (vibrating wire type) and accelerographs shall be compatible with an automated data acquisition system (ADAS) to be installed by the Employer as part of Dam 1E construction.
 - d. The design and installation details of the [ADAS](#) will be provided to the Contractor by the Employer.
10. **Erosion Protection at South End of Dams 2E and 2W:** The Contractor shall provide for erosion protection against overtopping flood flows at the south ends of ^{A9}dams 2E and 2W, where they abut the north end of the Water-Saving Basin/Lock Structure ^{A9}.

B. Construction:

1. **Construction Area Constraints:** In addition to other requirements specified in the RFP, the constraints on utilization of the ^{A17}Site follow. ^{A17}
 - a. Construction equipment shall be kept outside of the Miraflores Lake ship channel prism.
 - b. Material disposal and hauling shall be done via land routes; the existing Pedro Miguel and Miraflores locks shall be used as little as possible.
 - c. Staging areas shall be located on the west bank of Miraflores Lake.
2. **Dewatering and Surface Water Control for Excavations:** In addition to the other requirements specified in the Employer's Requirements, the Contractor shall comply with the requirements of Section 31 23 00 (*Excavation and Fill*), paragraph 1.03.A.3.
 - a. The Contractor shall dewater the existing excavations, ponds, and ^{A9}lagoons and ^{A9} shall maintain foundation excavations free of water to provide for dry working conditions. ^{A9}Waste-disposal^{A9} procedures for liquids and sediments that might require special handling shall be implemented by the Contractor.
 - b. The Contractor shall design, install, and maintain a groundwater-monitoring system for each excavation. The system shall include, but not be limited to, a network of piezometers and observation wells to be installed by the Contractor. Plans shall establish the method and frequency of observations, ^{A9}as well as^{A9} the method for recording data, analyzing data, and interpreting results. Records shall be available ^{A9}to the ^{A9} Employer's Representative.
 - c. The Contractor shall design diversion ditches, dikes, and grading and shall provide an appropriate ^{A9}surface-drainage system to control storm-water runoff in order^{A9} to maintain dry working conditions.
3. **Disposal of Excess Waste Materials:** Materials in the disposal site west of dams 1W and 2W (Cocoli disposal site) shall be placed against the west side of the dams, to an elevation not exceeding 30.00 m PLD, and extending for a minimum distance of 100 m west of the dams. The surfaces of the disposal sites shall be graded to drain and seeded for erosion protection.
4. ^{A9}**Foundation-Surface^{A9} Treatment:** The foundation surface shall be treated to prevent embankment materials from piping into rock discontinuities.
5. **Cofferdam Construction:** A cofferdam or other means shall be constructed across the Cocoli River outlet into Miraflores Lake at the northeast end of Dam 2E to provide for dry working conditions in the dam sites. The cofferdam shall be an independent structure from Dam 2E. ^{A9}The bank between Miraflores Lake and a lagoon at the northeast end of Dam 2E shall be made sufficiently watertight

to maintain dry conditions for foundation excavations, and this watertightness shall be confirmed prior to any such excavation.^{A9}

6. **Blasting Constraints:** Blasting shall be conducted so as to avoid damage to the embankments and adjacent structures. The Contractor shall control dust generation and minimize noise resulting from blasting operations. Refer to Section 31 23 16.26 (*Drilling and Blasting*) for additional blasting requirements.
7. **Embankment Fill:** Embankment fill shall be placed and compacted utilizing methods and equipment suitable for the particular material and conditions. Compaction in the vicinity of structures shall be done in a manner that will attain the required degree of compaction without causing damage to the structures. Compaction shall result in an earthwork body that is not susceptible to excessive post-construction settlement (not more than 1 percent of the embankment height above the foundation) under normal loads and that attains the required strengths.
8. ^{A9}**Wet-Weather Construction Requirements:** The Contractor shall consider precipitation data (see Subparagraph 1.04 D.1.)^{A9} to minimize construction disruptions and avoid schedule delays. The Contractor shall conduct his operations so that wet weather construction ^{A9}does^{A9} not impair construction quality.
9. **Erosion and Sediment Control:** The Contractor shall provide for ^{A9}erosion- and sediment-control^{A9} devices to prevent sediment from entering streams, Miraflores Lake, the foundation excavation, any adjacent excavations being performed by others, or the embankment fill during construction.
10. **Environmental Management:** All work shall comply with the Section 01 57 19.13 (*Environmental Management System*).

1.04 DESIGN CRITERIA:

- A. **General:** ^{A9}The following subparagraphs describe the design criteria for dams 2E, 1W, and 2W, including the geotechnical, seismic hazard, hydrological, and operational criteria.^{A9}
- B. **Geotechnical Criteria:**
 1. **Loading Conditions and ^{A9}Slope-Stability^{A9} Criteria:** The Contractor^{A17} shall perform any Site^{A17} investigations he deems necessary to determine the potential planes of weakness beneath the dams, the strength of the materials, internal (pore) and external water pressures, and other parameters necessary to perform stability analyses of the dams.
 - a. Foundation strengths shall be established with explorations and testing procedures conforming to current international practice ^{A9}and standards for dam engineering^{A9}.

- b. Foundation strengths shall be established through detailed geotechnical investigation and testing to ensure ^{A9}that strength^{A9} parameters are not assumed only as predictive averages.
- c. The minimum acceptable factors of safety are as ^{A9}follows^{A9}.

Stability Criteria				
Load Condition	Slopes¹	^{A9}Water-Surface^{A9} Elevation²		Minimum Acceptable Factor of Safety
		Inboard Side	Outboard Side	
End of and ^{A9} during construction ^{A9}	Inboard & outboard	Empty	Maximum operating level	1.3
Long- ^{A9} term steady ^{A9} seepage	Outboard	Maximum operating level	Minimum operating level	1.5
Maximum ^{A9} flood surcharge pool ^{A9}	Outboard	New ^{A9} locks design flood level ^{A9}	Minimum operating level	1.4
Rapid ^{A9} drawdown ^{A9}	Inboard	Maximum operating level	Minimum operating level	1.3

Notes.

1 Inboard side = PAC side; outboard side = Miraflores Lake side for Dam 2E and west side for Dams 1W and 2W. For dams 1W and 2W, stability analyses shall be performed for the outboard slopes without the disposal fill in place.

2 See Subparagraphs ^{A9}1.04 D. and 1.04 E.^{A9}, for flood and operating levels, respectively.

2. **Dam Seismic Deformation Criteria:** The Contractor shall demonstrate ^{A9}that seismic dam deformations will not compromise the ability of the structure to retain Gatun Lake, lead to any overtopping, or require emergency response that impedes the^{A9} Operation of the Canal. The embankment zones shall remain functional and not be disrupted by the seismic deformations. Accommodation of fault displacements is covered in Subparagraph ^{A9}1.04 C.3.^{A9}
3. **Filter and Drain Criteria:** The Contractor shall design embankment dam filters, drains and transitions to accommodate the ^{A9}following^{A9}.
 - a. Gradations shall be designed using internationally accepted filter and drainage criteria to prevent piping, promote drainage, and prevent segregation of the materials during placement operations [e.g., refer to U.S. Bureau of Reclamation (1994), Design Standards No. 13, Embankment Dams, Chapter 5, Protective Filters, September]. Such gradations shall apply to the materials ^{A9}in place in the embankments after hauling, placing,^{A9} and compaction operations have been completed.

- b. Durability of the materials shall meet internationally accepted durability criteria [e.g., refer to ASTM C 33 or U.S. Bureau of Reclamation (1998), Earth Manual, 3rd edition].
- c. Maximum quantity of flat and elongated particles shall be limited to provide for a cohesionless material that will not support an open crack.
- d. Filter and drain zone dimensions shall:
 - 1) Accommodate foundation fault ^{A9}displacement^{A9}.
 - 2) Be sufficiently thick to convey seepage without building up phreatic surface in the downstream shell. ^{A9}The thicknesses shall be at least twice the fault displacement amount, in both horizontal and vertical directions (see Subparagraph 1.04 C.3.).^{A9}
- 4. **Crest Overbuild:** Crest overbuild shall accommodate post-construction settlement so that the long-term crest elevation will remain above the design crest elevation, but shall not be less ^{A10}than 1 percent ^{A10}of the structural height of the dam, where structural height is the height of the embankment above the foundation.

C. ^{A9}**Seismic-Hazard^{A9} Criteria:**

- 1. **Design Earthquakes and Peak Ground Accelerations:** The dams and abutments shall withstand the 2,500-year earthquake ground motions without release of Gatun Lake or any overtopping. The dams and abutments shall also withstand the ^{A9}1,000-year earthquake ground motions without damage that requires emergency response and repairs or that^{A9} impedes Operation of the Canal.
- 2. **Style and Amount of Fault Displacement:** The style and amount of fault displacement for dam design shall be as ^{A9}follows.^{A9}

Style and Amount of Fault Displacement		
Fault	Horizontal Component (m)	Vertical Component (m)
Pedro-Miguel	3.0 (strike-slip)	0.5 (thrust slip - west side up)
Miraflores	1.0 (strike-slip)	0.5 (thrust slip - west side up)
Unnamed	1.0 (strike-slip)	0.5 (normal slip - west side down)

- 3. **Fault Displacements for Dam Design:**
 - a. Dams 2E and 2W shall be designed to allow for up to 1.0 m of strike-slip fault offset and 0.5 m of thrust slip and normal slip fault offset anywhere within their foundations.
 - b. Dam 1W shall be designed to allow for up to 3.0 m of strike-slip fault offset and 0.5 m of thrust slip fault offset anywhere within its foundation.

- c. Within 50 m of active fault locations, the thickness of the core and chimney filter/drain/transition zones shall be at least 1.5 times the ^{A9}horizontal-fault^{A9} displacement component. Likewise, the thickness of the blanket filter/drain/transition zones shall be at least 1.5 times the ^{A9}vertical-fault^{A9} displacement component.
 - d. The Contractor shall demonstrate that the core of the dam can accommodate ^{A9}the fault displacements indicated above without^{A9} piping.
4. ^{A9}**Design-Response Spectra:** Design-response^{A9} spectra shall be as presented in ^{A17}Volume VII, Part 3 of the Contract. ^{A17}
5. **Acceleration Time Histories:** Acceleration time histories shall be as presented in ^{A17}Volume VII, Part 3 of the Contract. ^{A17}
6. **Overtopping Hazards:** Dam design shall accommodate seiche and ^{A9}seismically induced^{A9} landslide with a wave height of 1.5 m (above the still water elevation) and a wavelength of about 160 m.

D. **Hydrological Criteria:**

1. **Hydrological Parameters:** The hydrological parameters for lake floods stages, ^{A9}precipitation, and wind speed shall be based on the Contractor's interpretation of the information provided in Volume VI, Part 7 (*Hydrometeorological Report*)^{A9} ^{A17}of the Contract and any other information which the Contractor chooses to use. A design wind speed of 115 km per hour shall be used. ^{A17}
2. **Freeboard:** The Contractor shall demonstrate that the crest of the dams will not be overtopped under ^{A9}new locks design flood level with concurrent wave run-up due to wind waves and wind setup^{A9}.
3. **Construction Flood:** ^{A10}The construction flood shall not be less than required for flood protection per Section 01 10 00 (*General Project Requirements*), Subparagraph 1.02 L. ^{A10}
4. **Drainage Facilities:** Drainage facilities and their design capacities shall be in accordance with Volume II, Part 2, Section 01 86 36 (*Drainage Systems*).

E. **Operational Criteria:**

1. **Lake Operating Levels:**
 - a. Gatun Lake operating levels shall be in accordance with Section 01 81 13 (*Filling and Emptying Systems*).
 - ^{A10}b. Miraflores Lake levels are as follows:
 - 1) Minimum level: 16.40m (53.8 feet)

- 2) Maximum level: 16.76m (55.0 feet)
- 3) Operating level: 16.60m (54.5 feet)^{A10}
- 2. **Gatun Lake^{A9} Drawdown:** This shall be as follows.^{A9}
 - a. 0.3 m from maximum operating level, in 5 to 6 hours.
 - b. 0.5 m from lockage wave surge (^{A9}see Subparagraph 1.04 E.4.d.^{A9})
- 3. **Dam Performance Under Ship Grounding:**
 - a. Damaged areas shall be readily repairable and be limited to damage of near-surface material (riprap erosion protection or rockfill shells). The ^{A9}rock-fill shells shall be sufficiently thick to prevent damage to the filter, drain,^{A9} and core zones.
 - b. ^{A17}Dams shall be designed and constructed to withstand ship-grounding forces of magnitudes corresponding to the loaded Design Vessel, including the hydrodynamic added mass of the vessel, its approach velocity and approach angle, its moment of inertia, and any other factor that affects the application of the impact load. The physical characteristics of the Design Vessel were based on hull geometry dimensions for bulk carriers and container ships. The Design Vessel is defined in Section 01 42 16 (*Definitions*) and further explained in Section 01 10 00 (*General Project Requirements*). The impact conditions (angle of incidence and approach velocity) shall be 30° at 8 knots and 45° at 4 knots.^{A17}
- 4. **Riprap Sizing:** Riprap shall be designed to resist wave erosion ^{A9}in order^{A9} to withstand the effects of the following, whichever controls:
 - a. Wind velocity (see Subparagraph ^{A9}1.04.D.^{A9}) and fetch considerations;
 - b. Ship-wake-induced waves of 1.5 m amplitude (from peak to trough), which ^{A9}is equivalent to that from a tugboat^{A9} at full speed (15 to 20 knots);
 - c. ^{A9}Tugboat propeller wash adjacent to and perpendicular to the riprap slope; or^{A9};
 - d. Lockage wave surge of 0.5 m amplitude.
- 5. **Crest Access Requirements:** Crest access roads are required on ^{A9}dams 2E, 1W, and 2W and shall be designed for low-volume maintenance traffic to the following general criteria.^{A9}
 - a. **Type of Road:** Standard two lane road (^{A9}7.3 m-wide^{A9} pavement plus stabilized shoulders) in center of dam crest.

- b. **Pavement:** Asphalt pavement section design based on AASHTO HS20 loading.
 - c. **Design Speed:** 45 km/h.
- 6. **Commissioning and Testing:** Post-construction monitoring of the dams shall include regular visual observations of the ^{A9}embankments, ^{A9} their abutments, and nearby areas for unusual signs that may indicate adverse performance. Visual observations from regular inspections of the ^{A9}dams and ^{A9} monitoring of survey monuments and data from the piezometers shall be used for overall assessment of dam safety.
 - a. The dams shall be closely inspected for seepage and general performance during the period prior to filling of the ^{A9}PAC, but after the ^{A9} raising of the water level in outboard areas from a dewatered condition to the level of Miraflores Lake. The embankment and abutments shall also be closely inspected ^{A9}— during first filling of the PAC and for a period of not less than 12 months afterward, during which the PAC shall be continuously full —^{A9} for seepage and other signs that may indicate adverse performance.
 - b. The instrumentation shall be monitored at frequent intervals during initial filling of the PAC and over a period of not less than 12 months ^{A9}afterward, during which the PAC shall be ^{A9} continuously full. The measured piezometric levels shall be compared with the results of seepage analyses to assess differences between actual and design conditions.
 - c. If observations and/or monitoring indicate conditions that are not consistent with those assumed during design, the Contractor shall evaluate the performance of the dam considering the observed conditions. The Contractor shall demonstrate that the performance of the dam is not compromised. If the observed conditions show that the performance did not meet the requirements set forth in these specifications, the Contractor shall expeditiously implement mitigation measures to correct the situation at his own cost and to the satisfaction of the Employer's Representative.

1.05 SUBMITTALS:

- A. All drawings and other submittals shall be submitted in accordance with the requirements of Section 01 33 00 (*Submittal Procedures*) and the requirements of this Section for the following phases.
- B. ^{A17}**Design:** ^{A17} The Contractor shall submit to the Employer's Representative the information indicated below.
 - 1. **Drawings:**
 - a. General arrangement

- b. Embankment dams and PAC layout.
 - c. Excavation plans and sections showing general dimensions.
 - d. Embankment plans and sections showing general dimensions.
 - 2. **Documentation:** Embankment stability analyses.
- C. ^{A17}**Intermediate Design:** ^{A17} ^{A16}When the design has advanced sufficiently to allow the Employer to review the design, the Contractor shall submit, to the Employer's Representative, the information indicated below. ^{A16}
 - 1. **Drawings:**
 - a. ^{A9}General arrangement (updated).
 - a. Embankments and PAC layout (updated).
 - b. Excavation plans and sections (updated).
 - c. Foundation surface-treatment details.
 - d. Layout of dewatering system.
 - e. Erosion- and sediment-control plan and details.
 - f. Cofferdam plan, sections, and details.
 - g. Foundation seepage-control system plan, sections, and details.
 - h. Embankment plans and sections (updated).
 - i. Embankment details (e.g., crest and drainage details).
 - j. Access road details.
 - k. Staging, stockpile, and disposal areas.
 - l. Contractor [Site](#) access and haul routes.
 - m. Instrumentation plan, sections, and details.
 - n. Material-balance diagrams for all material types, showing material sources and placement in the embankments. The diagrams shall show volumes of the sources and embankments and the corresponding shrink and swell factors. ^{A9}

2. **Documentation:**

- a. ^{A9}Embankment-stability (updated), abutment-stability, seepage, seismic-deformation, and settlement analyses, with accompanying documentation on methodology and input parameters and a discussion of results.
- b. Ship-grounding analyses to demonstrate that damage to the embankment dams will not extend to the core, filter, and drain zones.^{A9}
- c. Geotechnical report including at least the recommended design parameters for all soil and rock types, recommended excavation methods, dewatering during construction, and sources and utilization of soils and rock materials for ^{A9}embankment-dam^{A9} construction. **The report shall also include methods to address expected fault displacement and his proposed compaction specification.**
- d. All relevant specifications ^{A9}including, but not limited to, dewatering system, excavation, foundation-surface^{A9} treatment, embankment materials and construction, foundation seepage control, and instrumentation.

D. ^{A17}**Final Design:** ^{A17} When the design has reached a level that is ready for construction, the Contractor shall submit, to the Employer's Representative, updated versions of the information indicated below.

1. **Drawings:**

- a. ^{A9}General arrangement.
- b. Embankments and PAC layout.
- c. Excavation plans and sections.
- d. Foundation-surface treatment details.
- e. Layout of dewatering system.
- f. Erosion- and sediment-control plan and details.
- g. Cofferdam plan, sections, and details.
- h. Foundation seepage-control system plan, sections, and details.
- i. Embankment plans and sections.
- j. Embankment details (e.g., crest and drainage details).
- k. Access road details.
- l. Staging, stockpile, and disposal areas.

- m. Contractor site access and haul routes.
- n. Instrumentation plan, sections, and details.
- o. Material-balance diagrams for all material types, showing material sources and placement in the embankments. The diagrams shall show volumes of the sources and embankments and the corresponding shrink and swell factors.^{A9}

2. **Documentation:**

- a. Prior to beginning any construction work, results of tests demonstrating that the proposed fill materials meet the design requirements.
- b. Reports from an independent testing laboratory that compaction tests were conducted in accordance ^{A9}with ASTM standards and^{A9} that they demonstrate compliance with design requirements.
- c. The name and credentials of the independent testing laboratory, with sufficient additional information to enable the Employer to determine ^{A9}whether^{A9} the laboratory is acceptable. This information shall be furnished before ^{A17}the commencement of any excavation or placement of^{A17} compacted embankment fill.
- d. Prior to beginning any excavation work, the Contractor shall submit a ^{A9}stockpile-^{A9} and disposal-area plan consistent with the drawings. The plan shall show, in addition to the proposed location and size of stockpiles and waste piles, the Contractor's plan for excavation, describing the sequence and manner in which the material will be handled.
- e. Prior to beginning any excavation work, the Contractor shall submit an excavation plan consistent with the drawings. It shall describe the sequence and manner in which the excavation and plans for its support-system (if any) will be executed.
- f. Prior to beginning any embankment construction work, the Contractor shall submit a plan that details the sequencing and operations necessary for construction of each of the embankment zones, including a description of the methods to be used to place filter, ^{A9}drain, and transition materials in order to avoid contamination from materials in^{A9} adjacent zones or elsewhere and to ensure the specified compaction is achieved.
- g. Final versions of the design drawings and documentation specified ^{A17}as the intermediate design submittals^{A17} ^{A9}(Subparagraph 1.05 C.)^{A9}.
- h. ^{A9}Final embankment-stability, abutment-stability, seepage, and seismic-deformation analyses, with accompanying details on methodology and input parameters as well as a discussion of results.^{A9}

- i. ^{A9}Ship-grounding analyses demonstrating that damage to the embankment dams will not extend to the core, filter, and drain zones.^{A9}
 - j. All relevant specifications ^{A9}including, but not limited to, dewatering system, excavation, foundation-surface^{A9} treatment, embankment materials and construction, foundation seepage control, and instrumentation.
- E. **During and after Construction:** The Contractor shall submit, to the Employer's Representative, the information indicated below.
 - 1. **Drawings:** As-built drawings, which shall be kept ^{A9}up to^{A9} date during construction. As-built drawings shall include final foundation excavation and embankment surfaces, limits of embankment zones, and locations of instrumentation.
 - 2. **Documentation:** Updated design calculations, specifications, ^{A9}operation and maintenance (O&M) manuals, and information related to calibration, maintenance, and operation of instrumentation.^{A9}
 - 3. **Test Results:** Results of tests demonstrating that the constructed fill materials meet the design requirements. Such test results shall be submitted to the Employer on a weekly basis.
 - 4. **Decommissioning and Testing Plan:** ^{A9}Plan for inspections, testing, instrumentation-data acquisition, and evaluation prior to the first filling of the PAC, during the filling of the PAC, and for a minimum 12-month period during which the PAC is continuously full.^{A9}

1.06 QUALITY ASSURANCE:

- A. The Contractor, through his quality manager, shall verify conformance with the requirements of this Section. All requirements in Section 01 40 00 (*Quality Requirements*) shall apply to this Section.
- B. **General Testing and Procedures:**
 - 1. The Contractor shall submit ^{A10}a list^{A10} ^{A9}of and technical data about^{A9} instruments and equipment for inspection and testing.
 - 2. The Contractor shall submit a description of how ^{A9}quality-control^{A9} testing will be performed to comply with the specifications.
 - 3. The Contractor shall submit technical procedures and methods ^{A9}for performing quality-control^{A9} inspections for all features of the work.
- C. **Laboratory Testing:**
 - 1. **Control and Verification Testing:** Based on his method of construction, the Contractor shall submit the testing criteria, procedures, methods, and other

information upon which the ^{A9}various^{A9} number of control tests shall be made for each phase of the Works. When such routine control tests are performed, a duplicate sample of the first laboratory tests of each type shall be submitted to the Employer's Representative. The Employer's Representative, at his discretion, ^{A9}may^{A9} submit the sample for verification testing. Thereafter, duplicate samples shall be furnished for 10% of all other laboratory control tests performed.

2. **Capability Check:** The Employer's Representative reserves the right to check laboratory equipment for compliance with recognized standards and to check the laboratory technician's testing procedures, techniques, and qualifications.

END OF SECTION

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