SECTION 01 81 16 - LOCK STRUCTURES

1.01 SUMMARY:

A. This Section covers the Employer's Requirements for Lock Structures that shall be safe, structurally sound, economical, practical, and durable, with minimum maintenance costs and fit for a design life of 100 years. The following structures for the Atlantic and Pacific locks are included in this Section.

1. **Approach Structures**: The approach structures are required to help pilots align or pre-position vessels to reduce entrance time. They will also be used for tying up vessels when necessary.

2. [A16]**Lock Walls**: The lock walls shall form the lateral boundaries of the lock chambers, and shall include the requirements of the filling and emptying (F-E) ports and culverts, as well as provisions for the installation of other embedded items such as fenders, bollards, ladders, and utilities. [A16]

3. [A16]**Lock Heads**: The lock heads shall house the lock gates. [A16]

4. **Water-Saving Basins (WSBs)**: These structures shall consist of the water impoundment basins and surrounding retaining walls or dikes, the conduits connecting the basins to the main culverts, and housings for the valves regulating the passage of water between the culverts and basins.

5. **Crossunders**: These tunnels are located below the lock floor and serve as the means for passing utility lines from one side of the lock to the other.

6. **Lock Floors**: The lock floors shall form the lower boundary of the lock chambers.

[A7]7. **Valve Chambers**: These structures shall house the valves and bulkheads for the main culverts and Water-Saving Basin conduits described in Section 01 81 23 (*Culvert and Conduit Valves*). [A7]

8. [A10]**Maintenance Closure Structures**: These structures shall house the maintenance closure systems described in Section 01 81 19 *(Lock Gates*). [A10]

B. [A17]Part 1 of Volume VI, Reference Documents, contains conceptual drawings of the locks which are provided for information only and subject to the provisions of Sub-Clause 5.1 of the Conditions of Contract. [A17]

1.02. [A16]REFERENCES: [A16]

A. **Centre d'Etudes Techniques Maritimes et Fluviales (CETMEF)**:

ROSA-2000 — Recommandations pour le calcul aux états-limites des ouvrages en site aquatique (recommendations for

calculating the stated limits of water openings for aquatic infrastructure), also available from Presses de l'Ecole Nationale des Ponts et Chaussées.

B. **Permanent International Association of Navigation Congresses (PIANC)**:

Final Report of the International Commission for the Study of Locks (1986).

Seismic Design Guides for Port Structures (2001).

C. **Comité Européen de Normalisation (CEN)**:

EN 1990	Eurocode 0. Basis of Structural Design.
EN 1991	Eurocode 1. Actions on Structures.
EN 1992	Eurocode 2. Design of Concrete Structures.
EN 1993	Eurocode 3. Design of Steel Structures.
EN 1994	Eurocode 4. Design of Composite Steel and Concrete Structures.
EN 1997	Eurocode 7. Geotechnical Design.
EN 1998	Eurocode 8. Design Provisions for Earthquake Resistance of Structures.

D. **British Standards Institution (BSI)**:

BS 6349-0-03	Maritime Structures.
BS 6349-1-03	Maritime Structures. Code of Practice for General Criteria.

E. **U.S. Army Corps of Engineers (USACE), Engineering Manuals and Other Documents**:

[A7]EM-1110-1-1804	Geotechnical Investigations.
EM-1110-2-2000	Standard Practice for Concrete for Civil Works.
EM-1110-2-2100	Stability Analysis of Concrete Structures.
EM-1112-2-2104	Strength Design for Reinforced Concrete Hydraulic Structures.
EM-1110-2-2200	Gravity Dam Design.
EM-1110-2-2502	Retaining and Flood Walls.

EM-1110-2-2602	Planning and Design of Navigation Locks.
EM-1110-2-2906	Design of Pile Foundations.
ER-1110-2-1150	Engineering and Design for Civil Works Projects.
ETL-1110-2-355	Structural Analysis and Design of U-Frame Lock Monoliths.[A7]

F. **Maritime Handbook**:

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1.03 REQUIREMENTS:

A. **Approach Structures**:

1. **Pacific Lock Complex**:

a. The southwest approach structure at the Pacific entrance and the northwest approach structure at the Gatun Lake entrance shall have a minimum length of 500 m, measured from the respective Knuckle. The structures shall be parallel to the lock-chamber axis and in line with and extending from the western lock walls and be suitable for tying up the range of vessels that will utilize the waterway. The Contractor shall design the Pacific lock southwest approach structure and the Pacific lock northwest approach structure as part of the Works. The work to execute and complete the Pacific lock southwest approach structure and the Pacific lock northwest approach structure [A17]is the subject of the agreed Provisional Sums stated in the Schedule of Project Elements and Prices, which may be instructed by the Employer's Representative pursuant to Sub-Clause 13.5 of the Conditions of Contract. [A17]

b. [A16]The design for the Pacific lock shall include, at the north and south ends of the eastern and western lock walls, a wing wall structure that starts from the Knuckle with a minimum length of 70 m and at an angle of 30 degrees with respect to the lock-chamber axis. [A16]

2. **Atlantic Lock Complex**:

a. The northeast approach structure at the Atlantic entrance shall have a minimum length of 500 m measured from the Knuckle, and shall be parallel to the lock-chamber axis and in line with and extending from the eastern lock wall and be suitable for tying up the range of vessels that will utilize the waterway. The Contractor shall design the Atlantic lock northeast approach structure as part of the Works. The work to execute and complete the Atlantic lock northeast approach structure [A17]is the subject of the agreed Provisional Sums stated in the Schedule of Project Elements and Prices, which may be instructed by the Employer's

Representative pursuant to Sub-Clause 13.5 of the Conditions of Contract. [A17]

b. [A16]The design for the Atlantic lock shall include, at the north and south ends of the eastern and western lock walls, a wing wall structure that starts from the Knuckle with a minimum length of 70 m and at an angle of 30 degrees with respect to the lock-chamber axis. [A16]

3. **General**:

a. The Contractor's design for the [A7]lock[A7] approaches shall allow safe entrance and exit maneuvers.

b. At sea entrances, the approach structures shall not divert density currents that could adversely affect vessels maneuvering in the area.

c. Numerical and physical models shall be used to help ascertain the impact of the lock approach configuration and approach structures on currents and vessels.

d. The approach structures shall be of the type that is best suited for satisfying the navigational requirements given the existing geotechnical conditions.

e. [A16]The approach structures shall be designed to fitted with fenders and accommodate utilities and other quay-side equipment, including bollards, ladders, and lighting recesses. [A16]

f. Except where dolphins are utilized or the approach structure is not directly connected to land, the surface shall be designed so that surface water drains into the drainage system and not into Canal waters.

g. Where dolphins are provided, walkways shall be provided between dolphins to permit access for line handlers. The walkways shall be located towards the [A7]landside[A7] of the dolphin to avoid damage by vessels. The design shall include provisions for the walkway to absorb differential movement of dolphins without damage. The walkways shall be equipped with handrails on both sides that meet the requirements of Section 01 81 16.16 (*Lock Appurtenances*).

[A7]h.[A7] [A16]The design of the bottom of the channel in the approach area shall include the protection required to avoid erosion or scouring due to turbulence caused by the movement of vessels [A7]and water spilling from the lower chamber.[A7] The geotechnical conditions at each Site shall be evaluated and the protection provided accordingly. [A16]

B. **Lock Walls and Lock Floors**:

1. **General**:

a. Wall systems that would require maintenance or replacement of components for continued integrity of the system within the [A7]design[A7] life (100 years) shall not be considered.

b. The [A11]Contractor's[A11] design for the lock floors shall account for a realistic upward water pressure below the floors. Systems for the prevention or the load transfer of this water pressure that would require maintenance or replacement of components for continued integrity of the system within the [A7]design[A7] life (100 years) shall not be considered.

c. Wall design shall include the requirements for the culverts and conduit specified in Section 01 81 13 (*Filling and Emptying Systems*).

d. The lock-wall design shall include provisions for the installation of embedded items including, but not limited to, fenders, bollards, capstans, ladders, and utilities (lighting, potable water lines, wastewater lines, air lines, and control and communications cables). Refer to Section 01 81 16.16 (*Lock Appurtenances*) for requirements for fenders, bollards, and other operational fixtures. Refer to the specific utility Sections for their requirements.

e. [A16]The design of the lock walls shall consider the shafts that provide access to the Crossunders beneath the chamber floors.[A16]

1) The shafts shall be designed for the elevators specified in Section 01 86 13 (*Plant – Mechanical Systems and Equipment*), fixed ladders that meet OSHA requirements, and the utility lines that are passed through the Crossunders.

2) There shall be a physical barrier in the shaft between the Crossunder elevators and the utilities. The physical barrier shall be resistant to water and shall have a fire resistance rating of no less than one hour.

3) The shaft dimensions shall permit the installation and removal of the utilities for which the Crossunders are designed, together with adequate room for maintenance, as well as provisions for ventilation and lighting of the shafts and Crossunders. Refer to Section [A7]01 81 36.13 *(O & M[A7] Buildings and Facilities – Space Programming)* for additional requirements.

f. The lock walls shall [A7]be designed to fulfill the requirements of the [A10]maintenance closure[A10] system as defined in [A10]Subparagraph 1.03 H.[A10] of this Section and in Section 01 81 19 (*Lock Gates*).[A7]

g. Markings shall be provided along the lock walls to allow pilots and tugboat masters to visually determine the distance traveled and the distance remaining for adequate positioning of vessels in each lock chamber. Refer to Section 01 81 16.16 (*Lock Appurtenances*) for requirements.

h. A well shall be provided in one wall of each lock chamber for the hydro-meteorological sensors described in Section 40 91 00 (*Primary Process Measurement Devices*).

i. The surface of the lock walls shall be designed so that surface water drains into the drainage system and not into Canal waters.

[A7]j. The lock walls shall include slots for the installation of a closure system or the relocation of the upstream or downstream gates when dewatering is required for maintenance. The slots shall be located between the upstream gates and the lake culvert intakes and between the downstream gates and the sea discharge outlets. Refer to Section 01 81 19 (*Lock Gates*) for the requirements.[A7]

k. The Contractor may incorporate a system for lowering the water level behind the walls by gravity in order to reduce the hydrostatic loading. The system shall be maintainable and guarantee a constant reduction in water level behind the walls. When the Contractor incorporates a system for lowering the water level, the Contractor shall:

1) Install a system for monitoring the water level throughout the life of the structure.

2) Demonstrate that the proposed system shall be reliable in maintaining the design water level without requiring frequent maintenance or affecting lock operations. Frequent maintenance is assumed to be more than once a year.

C. **Lock Heads**:

1. **General**:

a. The lock heads shall be designed to permit the installation, operation, and removal of the gates.

b. The [A11]Contractor's[A11] design shall account for the limitation of longitudinal groundwater seepage next to and below the locks. This limitation will result from critical ground water velocities with respect to prevention of transport of material and through the loss of stability in the fill next to the locks and the soil and rock below the locks.

The level of the groundwater next to and below the locks shall be [A7]included in the analysis and design for seismic events.[A7]

c. The lock head design shall include Recesses in the lock floor and the lock wall that are able to resist the forces from the lock gates[A7], including forces generated by the seismic loadings. [A7]

d. The lock head design shall include the requirements for the culverts [A7]for the F-E system described in Section 01 81 13 (*Filling and Emptying Systems*), if required.[A7]

e. A structure for the lock heads that would require maintenance or replacement of components for continued integrity of the structure within the [A7]design[A7] life time (100 years) shall not be considered.

f. The lock head design shall also include provisions for the installation of appurtenances such as: bollards, ladders, and utilities (lighting, potable water lines, wastewater lines, air lines, and control and communication cables and devices).

g. The Contractor's design shall prevent the accumulation of debris that would obstruct the operation of the gates (through the provision of sumps, scuppers, or other suitable features in the civil work) or include a preventive system on the gates to ensure their proper operation.

h. The gate Recesses shall include provisions for the installation of the Recess closure to be designed under Section 01 81 19 (*Lock Gates*). This bulkhead will permit the use of the gate Recesses for performing maintenance on gates. The gate Recesses shall also provide:

1) Adequate space to permit the movement of personnel and materials around the gates when they are in the Recess for maintenance.

2) Access to and from the Recesses for personnel and materials. Space shall also be provided for the installation of the personnel hoist described in Section 01 86 13 (*Plant – Mechanical Systems and Equipment*).

3) Adequate light and ventilation to ensure good working conditions.

4) For electrical and mechanical services. Electrical connections shall be provided according to Section 01 81 29 (*Electrical and Lighting System*). Water and compressed air connections shall be provided according to Section 01 86 13 (*Plant – Mechanical Systems and Equipment*).

5) For the installation of the pumping system required for dewatering the Recess, as described in [A7]Section 01 92 00.13 (*Dry Outages*).

i. (Reserved)

j. (Reserved)

k. (Reserved)

l. (Reserved)[A7]

m. [A5]If required, a fixed-path track way that meets the requirements for the rolling gate upper wagon described in Section 01 81 19 (*Lock Gates*) shall be provided at the top of each lock head Recess.[A5]

1) The trackway shall be located above the maximum water level and be accessible to personnel for routine maintenance.

2) The trackway shall be designed to require minimum maintenance. [A16]The design shall provide for ease of both maintenance and replacement when required.[A16] If the replacement cycle does not coincide with the gate-maintenance cycle, replacement shall be accomplished with minimum downtime of the lock.

3) The trackway shall be designed for all of the loads imposed by gates on the trackway.

4) The design, fabrication, and construction of the trackway shall be based on the tolerances necessary to ensure the proper operation of the gate.

n. A fixed path trackway that meets the requirements for the rolling gate lower wagon described in Section 01 81 19 (*Lock Gates*) shall be provided at the bottom of each lock head Recess.

1) The trackway shall be designed to require no maintenance between replacements of its components.

2) The design shall permit the removal or installation of the entire trackway [A7]at the Recess in a maximum time of 24[A7] hours utilizing the Employer's crane Titan [A7]and without the need to dewater[A7], when replacement is required. [A7]Track replacement at the Recess must be performed without the use of the track-maintenance limpet. Trackway sections within the gate Recess must be removed or installed in the dry by using the gate-Recess closures described in 01 81 19 *(Lock Gates).*[A7] Refer to Annex – 1 of Section 01 81 19 (*Lock Gates*) for characteristics of Employer's floating cranes.

3) The trackway shall be designed for all of the loads imposed by the gate.

4) The design, specification, fabrication, and construction of the trackway shall be based on the tolerances necessary to ensure the proper operation of the gate.

o. Above-water surfaces shall be designed so that surface water drains into the drainage system and discharges at the lower end of the lock and not into the lock chambers.

p. The top surface of the lock head shall be at the same level as the lock wall to permit the movement of personnel, vehicles, and equipment without the need for ramps or stairs when practical.

q. The Contractor may incorporate a system for lowering the water level behind the walls by gravity in order to reduce the hydrostatic loading. The system shall be maintainable and guarantee a constant reduction in water level behind the walls. When the Contractor incorporates a system for lowering the water level, the Contractor shall:

1) Install a system for monitoring the water level throughout the life of the structure.

2) Demonstrate that the proposed system shall be reliable in maintaining the design water level without requiring frequent maintenance or affecting lock operations. Frequent maintenance is assumed to be more than once a year.

D. **WSBs**:

1. **Pacific Lock Complex**:

a. [A8] (Reserved) [A8]

b. The dimensions of the basins shall be such as to comply with the requirements of Section 01 81 13 (*Filling and Emptying Systems*).

c. [A7]The Contractor's design for the basins and conduits, if supported on fill,[A7] shall include provisions to control differential settlement.

2. **Atlantic Lock Complex**:

a. [A8] (Reserved) [A8]

b. The dimensions of the basins shall be such as to comply with the requirements of Section 01 81 13 (*Filling and Emptying Systems*).

3. **General**:

a. The basins shall be separated by a structure that is watertight and of the height required to avoid overflow from one basin to another under normal operating conditions.

b. The structure separating the basins between any given levels shall include provisions for safe pedestrian access from one end to the other.

c. Upstream and downstream structures shall include a roadway permitting two-way vehicular and heavy equipment traffic, as well as a walkway for pedestrians.

d. Ladders or a means of access/egress shall be provided every 100 m in each basin.

e. [A7](Reserved)[A7]

f. [A7] (Reserved)[A7]

g. [A7] (Reserved)[A7]

h. [A7](Reserved)[A7]

i. The WSB design shall also include provisions for channeling overflow [A7]water toward the lock sea entrance in[A7] the event of accidental flooding during operations.

j. Provisions shall be included in each WSB for the installation of the hydro-meteorological sensors described in Section 40 91 00 (*Primary Process Measurement Devices*).

k. Above-water surfaces shall be designed so that surface water drains into the drainage system.

E. **Crossunders**:

1. **General**:

a. There shall be two Crossunders at the upper level and one at the lower level of each lock complex.

b. The Crossunders shall be located below the lock floors, and access shall be by means of the elevators located in shafts in or behind the lock walls.

c. The design shall include provisions for proper drainage.

d. Sumps shall be provided at each end to permit the installation of pumps as described in Section 01 86 13 (*Plant – Mechanical Systems and Equipment*) for the removal of water. Pumps shall discharge into the drainage system and not into the lock chambers.

e. The dimensions of the Crossunders shall include an aisle that shall permit two workers to walk side by side with sufficient clearance from the utilities. The minimum clear height in the crossing shall be 2.5 m. The minimum width shall be 3.0 m. [A16]Alternative cross sections with

the same functionality can be proposed to the Employer's Representative. [A16]

f. All Crossunders shall be of the same size. The size shall be determined by the Crossunder requiring the largest dimensions.

g. In addition to the elevators, permanent ladders shall be provided in the access shafts as required by Section [A7]01 81 36.13 (*O&M Buildings and Facilities –Space Programming*).[A7]

h. All Crossunders shall be provided with communication pathways as specified in Section 27 05 28 (*Communications Pathways for Inside Plant*) and Section 33 81 26 (*Outside Plant Pathways for Underground Communications*), ventilation as specified in Section 01 86 13 (*Plant – Mechanical Systems and Equipment*), and lighting and power supplies and power receptacles as specified in Section 26 50 00 (*Lighting Systems*) and Section 26 20 00 (*Electrical Low Voltage Distribution Work*).

2. **Pacific Lock Complex**:

a. One of the Crossunders in the upper level shall be for the IDAAN 24 inch water line, the Employer's 18 inch water line, and any other water or air lines required crossing from one wall to the other. The design shall include the space and support locations for the installation of one additional 24 inch water line and one additional 18 inch water line.

b. One of the Crossunders in the upper level and the Crossunder in the lower level shall be for electrical lines as specified in Section 01 81 29 (*Electrical and Lighting System*) and Section 26 05 43 (*Underground Ducts and Raceways for Electrical Systems*) and for telecommunication lines as specified in Section 01 81 26 (*Communications, Control, Safety, and Security Systems*).

3. **Atlantic Lock Complex**:

a. One of the Crossunders in the upper level shall be for the Employer's 16 inch water line. The design shall include sufficient space and support locations for the installation of one additional 16 inch water line.

b. One of the Crossunders in the upper level and the Crossunder in the lower level shall be for electrical lines as specified in Section 01 81 29 (*Electrical and Lighting System*) and Section 26 05 43 (*Underground Ducts and Raceways for Electrical Systems*) and for telecommunication lines as specified in Section 01 81 26 (*Communications, Control, Safety, and Security Systems*). The upper-level Crossunder shall also be utilized for the crossing of Trans-Isthmian fiber optic cable.

F. **Geotechnical**:

1. [A16]The Contractor shall conduct geotechnical investigations, carry out analyses, designs and construction, and draft specifications in accordance with all applicable criteria and standards stipulated in the Employer's Requirements. [A16]

2. [A17]The Contractor shall conduct any additional investigations he deems necessary to properly characterize the Site for the design and construction of the Works. [A17]

3. The Contractor shall:

   a. Assess the geological and geotechnical stratification and the engineering properties of all soil and rock types including classification, average and range of strength and deformation properties, permeability etc.

   b. [A16]Provide a geotechnical report including the design parameters he will use for all soil and rock types, excavation methods, stability analyses of the building pit, dewatering during construction and the measures he will implement to limit the settlements in the surrounding areas, foundation design for all relevant parts, anticipated behavior of the structures during construction and the operation stage. [A16]

[A7]G. **Valve Chambers**:

1. Valve chambers shall include the requirements for the culverts and conduits for the F-E system described in Section 01 81 13 (*Filling and Emptying Systems*) and 01 81 23 (*Culvert and Conduit Valves*).

2. There shall be a bulkhead shaft upstream and downstream of the valves to permit work in the valve area without putting the entire culvert or conduit out of service as outlined in Section 01 92 00.13 (*Dry Outages*).

3. A shaft shall be provided in the valve area that will permit access for work on the valve supports. The access-shaft opening shall be at least 3.5 m long x 2 m wide and have a minimum clear height of 2.5 m at the bottom in order to permit the lowering of equipment with dimensions 3 m long x 1.5 m wide x 2 m high.

4. In addition to the requirements of Subparagraphs 1.03 G.1.b. and 1.03 G.1.c. of this Section, refer to Section 01 92 00.13 (*Dry Outages*) for the requirements of the pumping system.

5. The openings of all shafts that extend to the surface shall be covered by means of a removable grille with a minimum live-load capacity equivalent to an AASHTO HS-20 truck.

H. [A10]**Maintenance Closure Structure**: [A10]

1. The [A10]maintenance closure [A10] structure shall be located between the intake and the upstream gate.

2. Structures required for the [A10]maintenance closure[A10] systems shall be designed to facilitate their future installation at each lock facility as a retrofit if the fabrication option is not exercised.

   a. The Contractor shall perform all the civil works deemed necessary to allow future installation of his proposed [A10]maintenance system[A10] without the need to require a continuous interruption of lock operations.

   b. Lock outages required for future installation of the [A10]maintenance closure[A10] system shall not exceed 7 periods of no more than 12 hours each.

   c. Future installation of the systems shall not require demolition of completed structures, with the exception of parts specifically designed and detailed for future removal.

   d. The bearing surface required for the relocation of the upper rolling gates described in [A10]Subparagraph 1.03 B.1.j.[A10] may be integrated into the [A10]maintenance closure [A10] civil works. A separate rolling-gate bearing surface is not required after construction of the [A10]maintenance closure[A10] system.

3. The [A10]maintenance closure [A10] structure design shall resist the forces from the [A10]maintenance closure [A10] system for the maintenance condition and the seismic loadings as required by Section 01 81 16.13 (*Seismic Design Criteria*).

4. A structure that would require maintenance or replacement of components for continued integrity of the structure within the design life time (100 years) shall not be considered.

5. The [A10]maintenance closure [A10] structure design shall also include provisions for the installation of appurtenances such as: bollards, ladders, and utilities (lighting, potable water lines, wastewater lines, air lines, and control and communication cables and devices).

6. The Contractor's design shall prevent the accumulation of debris that would obstruct the operation of the [A10]maintenance closure [A10] system.

7. If the [A10]maintenance closure [A10] system is permanently installed, then the system shall be designed to permit maintenance at the Site. The requirements shall be as indicated in [A10]Subparagraph 1.03 C.1.h. [A10] of this Section.

8. The top surface of the [A10]maintenance closure [A10] structure shall be at the same level as the lock wall to permit the movement of personnel, vehicles, and equipment without the need for ramps or stairs when practical.

9. The design shall include any barriers or other safety features required to safeguard the personnel working in the area. [A7]

1.04 DESIGN CRITERIA:

A. **General**: This Paragraph establishes the design and specification criteria for the new Lock Structures at the Pacific and Atlantic Sites. The criteria include overall stability, strength, durability, serviceability, and foundation requirements for the structures. [A16]The Contractor shall develop comprehensive design and specification statements for each of the major structures.[A16] These shall specifically address the design standards and codes, loading conditions, design assumptions, methods of analysis, structural concepts, procedures, formula, references, construction specifications, and drawings as required to convey the concept, the detailed design, and the construction methodology. The following minimum conditions shall apply.

1. **Stability**:

a. The stability criteria shall be applicable to rock-founded locks and shall include safety requirements against sliding, flotation, overturning, bearing pressure, and deformation. For the purpose of establishing the safety factors for use in the stability analyses, all structures covered under this Section are to be designated as either [A11]essential or normal. The lock walls, lock heads, valves and gates at the upper level have been designated as essential structures; all other structures in this Section are to be designated as normal.[A11]

b. [A16]The Contractor shall develop his own interpretation of [A17]all geotechnical information and [A17] of any other information derived from additional investigations he deems necessary to perform in order to properly characterize the geotechnical conditions he will, or is likely to encounter during construction. On the basis of such interpretation and/or characterization the Contractor shall determine the potential planes of weakness beneath the structure, the strength of the materials, uplift forces, and other parameters necessary to perform stability analyses.[A16] Soil-structure interaction shall be substantiated by theory from literature and be analyzed by specific finite-element models (FEMs) using Plaxis or equivalent software.

1) [A16] (Reserved) [A16]

2) [A16]Actual foundation strengths shall be established through detailed geotechnical investigation and testing procedures conforming to current construction standards to ensure that the strength parameters are not assumed only as predictive averages.[A16]

3) [A16]Actual seepage conditions and uplift pressures shall be determined to ensure a thorough knowledge of the loads to be applied beneath the structures. [A16]

2. **Strength**: All components of the structures covered under this Section shall be able to resist all applicable load conditions, including the reinforced-concrete

framing members, structural and miscellaneous steel, foundation piling (if any), and foundation materials.

3. **Serviceability**: The deformations shall be checked for usual, unusual, and extreme load combinations, as defined later in this Section.

4. **Seismic Stability**: For the seismic analysis of the structures covered under this Section, refer to Section 01 81 16.13 (*Seismic Design Criteria*).

B. **Loads**:

The following loads shall apply to the approach structures, lock walls, and lock heads. When not specified, the loads shall apply to all structures; where specified, the loads shall apply only to structures that are identified.

1. **Deadweight**: Load imposed due to the weight of the structure and equipment themselves. This load consists of concrete and steel items such as gates, valves, and other appurtenances on or embedded in the structures. The weight of the concrete structure shall be appropriately distributed so that its centroid coincides with the geometric centroid of the concrete item being analyzed.

2. **Earth Pressures**: For lock-structure design, four different earth loads shall be investigated.

   a. **Horizontal-Earth Pressures**: Values for these pressures for the following applicable conditions of the vertical cut slopes and backfill shall be determined through the soil-analysis methods recommended by the standards being utilized for the design, as follows:

      1) Drained.

      2) Saturated.

      3) Submerged.

      and taking into account the effect of horizontal wall movement due to temperature and varying water pressures causing an increase of the horizontal earth pressure on the wall. In the case of an earthquake, the cyclic character of the loads shall be taken into account for the unusual and extreme load conditions.

   b. **Vertical-Earth Pressure**: This load corresponds to the vertical weight of any soil acting on the structure.

   c. **Vertical-Shear (Down Drag)**: This refers to the shear force acting downward along a vertical plane adjacent to or near a structure-to-soil interface.

   d. **Silt**: This load corresponds to the horizontal and vertical silt pressures that could be deposited above the backfill.

3. **Water Pressures**: For the lock-structure design, the Contractor shall consider three different water loads.

a. **Horizontal Water Pressure - Operating Condition**: Since the water pressure acting against the face of the lock walls and base slab is variable and depends on the water levels that prevail at any particular time, the conditions at the following sites shall be verified.

1) **Approach Structures**: The requirement to consider this water load applies only if solid walls are used. Inside the navigational channel, the minimum water level shall be applied. At the back side of the wall, the maximum water level of the navigational channel shall be applied.

[A11]2) **Lock Walls**: Inside the lock, the minimum water level shall be applied. At the back side of the wall, the maximum water level of the lock chamber shall be applied for the usual load classification. If the design incorporates the means for lowering the water level, the lower level can be applied to the unusual and extreme load classifications.

3) **Lock Heads**: The areas of the lock head that are subject to variations due to changes in the level of the chamber, the minimum water level shall be applied. At the back side of the lock heads, the maximum water level of the lock chamber shall be applied for the usual load classification. If the design incorporates the means for lowering the water level, the lower level can be applied to the unusual and extreme load classifications. [A11]

4) **WSBs**: The structures between adjacent basins shall be designed for the extreme water variations (lower basin empty and higher basin full).

b. **Horizontal Water Pressure – Dry-Lock Condition**: The horizontal water pressure when the lock chambers or gate Recesses are empty shall be investigated.

1) **Lock Walls**: This would [A7]be[A7] identical to the load case in Subparagraph 1.04.B.3.a.2), except for the absence of water pressure at the front side (in the case of an empty chamber).

2) **Lock Heads**: For this situation, two cases shall be considered:

a) **Case 1**: One Recess in the dry condition and one Recess with water at the highest level.

b) **Case 2**: Both Recesses in the dry condition.

[A7]3) **Lock**: Complete dewatering of the lock between the seaside and lakeside lock heads. The emptying would begin at the higher level and progressively empty to the lower level.[A7]

c. **Vertical water pressure**: The uplift pressure of the water creates forces acting upward on the bottom of the lock wall base, lock floor, Water-Saving Basin floors, and any structures located below the lock floor. The analysis [A7]of[A7] the uplift pressure against the lock shall include the effect of this pressure [A7]on the structures, as well as[A7] all possible head values, including head loss due to drainage, permeability of the foundation, etc. The downward pressure at the inside of the structure corresponds with the level of horizontal water pressure.

4. **Vertical Live Load**: On the horizontal surface, a vertical live load of p=10 kN/m² shall be applied and included as the normal earth pressure load. The concentrated load due to outriggers from cranes that can access the top of the walls shall also be applied. In seismic conditions, only half of the live load shall be taken into account (5 kN/m²) [A7](deleted text)[A7].

5. **Bollards**: At the maximum spacing interval of 15 m apart, the bollards shall be able to withstand pulls of at least 1,500 kN.

6. **Seismic Loads:** Refer to Section 01 81 16.13 (Seismic Design Criteria) for permanent structures. [A17]For temporary structures, subject to the provisions of Sub-Clause 5.1 of the Conditions of Contract, the [A17] Contractor shall develop his own interpretation of the information provided in Volume VI, Part 3, Seismic Data for Temporary Structures.

7. **Wagons**: The load transferred to the upper and lower wagons due to gate movement during lockage operations and in all possible maintenance conditions shall be considered.

8. **Gate Loads**: There are three such loads to consider.

   a. Loads corresponding to the force resulting from the deadweight of lock gates and culvert valves.

   b. Forces transferred from the gates and valves due to hydrostatic pressure acting on the gates under normal conditions and under dry lock conditions. For dry lock conditions the water level between the two doors can be chosen by the Contractor. A variation of this level with +/-0.5 m shall be included in the calculations.

   c. Loads corresponding to the force resulting from the deadweight of the lock gates when suspended from the Recess structure [A7]or supported on the Recess floor[A7] under maintenance conditions with the lock gate Recess dewatered.

d. Forces on the gates at earthquake conditions. The alternating character of the forces shall be taken into account.

9. **Vessel Impact**: [A7]This is the[A7] load imposed by the impact of a vessel on the lock wall, gates, and/or approach structures [A17]and the load transmitted to the gate Recess from the gate due to the vessel impact defined in Section 01 81 19 (*Lock Gates*).

a. Structures shall be designed and built to withstand the vessel-impact loads of 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. [A17] [A7]The Contractor may use an appropriate analytical method to approximate the maximum impact forces, provided that full documentation of the method is provided.[A7]

b. The loads shall be consistent with those used in the design of the fender system specified in Section 01 81 16.16 (*Lock Appurtenances*).

10. **Other Loads**: Loads not described in this specification shall be investigated to ensure that they do not produce any unfavorable load condition on the lock walls, lock heads, or approaches. These loads may include, but are not limited to, wave pressure, crane and machinery loads, temperature, monolith joint loads, cofferdam tie-in loads, sheet-pile cutoff loads, cyclic loads, etc.

C. **Load Conditions**:

1. **Load Condition Description**:

a. **Normal Operating Loads**: All loads applied to the structure (backfill loads, uplift, vessel impact, and other loads that are present under normal operating conditions).

b. **Unusual Operating Loads**: All loads applied to the structure (backfill loads, uplift, vessel impact, and other loads that are present under unusual operating conditions), as with drawdown (the extreme low-water stage for the lower pool) or with vessel impact that lead to possible damage but without losing the lake.

c. **Maintenance Condition Loads**: All loads applied to the structure (backfill loads, uplift, vessel impact, etc.) with the lock chamber drawn down to a predetermined level.

d. [A16]**Earthquake Load**: All additional loads applied to the structures due to a seismic event. [A16]

e. [A7](Reserved)[A7]

f. [A7](Reserved)

g. **Construction Condition**: Backfill loads applied without uplift, loads associated with the requirements of Section 01 81 16.13 (*Seismic Design Criteria*), and hydrostatic forces active in the area as a result of construction plans.[A7]

2. Due to the severity of the loads and their frequency of occurrence, the load conditions shall be categorized as follows.

   a. **Usual Load Condition**: A load condition that affects the structure for extended periods on a recurring basis. This load condition has a return period less than or equal to 10 years.

   b. **Unusual Load Condition**: A load condition that the structure is subjected to occasionally and/or for short periods. This load condition has a return period greater than 10 years, but less than or equal to [A7]500[A7] years.

   c. **Extreme Load Condition**: A load condition that might happen only once or twice during the service life of the structure. This load case has a return period greater than [A7]500[A7] years.

3. The loading conditions presented in the following table are intended to be used for both the stability evaluation and structural design. Although this table includes the minimum loading conditions required by the Employer, the Contractor shall investigate and apply any additional loading conditions that the particular structure and Site conditions might require:

Loading Condition Classification		
Load condition	*Loading Description*	*Classification*
1A	Normal Operating with Operating Low Water Level in Lock Chamber	Usual
1B	Normal Operating with Operating High Water Level in Lock Chamber	Usual
2A	Unusual Operating Same as 1A or 1B with Extreme Low Water	Unusual
2B	Maintenance Condition	Unusual
2C	1A and 1B with [A11]Level I Earthquake[A11]	Unusual
2D	1A and 1B with [A11]Level II Earthquake[A11]	Extreme
3	Construction Condition	Unusual

4. **Load Combinations**:

   a. Load combinations are combinations of the various loads described in [A10]Subparagraph 1.04 B. [A10] of this Section corresponding to the different load conditions. The forces in the load cases shall be factored or unfactored depending upon the analysis being performed. The load factors used will depend upon the type of load, certainty of magnitude of load, and frequency of load being applied.

b. Analysis of the combination of the loads shall be performed according to appropriate design codes and sensitivity studies.

5. **Requirements**: The table below gives the minimum requirements for the load-condition categories, based on unfactored load combinations.

[A11]**Essential Structures**[A11]			
Stability Analysis	**Load Condition Category**		
	Usual (U)*	Unusual (UN)*	Extreme (E)*
Global Safety Factor for Sliding	2.0	1.5	1.1
Global Safety for Flotation	1.3	1.2	1.1
Resultant Location	100% of base in compression	75% of base in compression	Resultant within base
Foundation Bearing Press	≤ allowable	≤ allowable	≤ 1.33 allowable
[A7]Deleted text[A7]			

* See Subparagraph 1.04 C.2.

Normal Structures			
Stability Analysis	**Load Condition Category**		
	Usual (U)*	Unusual (UN)*	Extreme (E)*
Sliding	1.5	1.3	1.1
Flotation	1.3	1.2	1.1
Resultant Location	100% of base in compression	75% of base in compression	Resultant within base
Foundation Bearing Press	≤ allowable	≤ allowable	≤ 1.33 allowable
[A7]Deleted text[A7]			

* See Subparagraph 1.04 C.2.

D. **Durability**: The design life of the structures shall be at least 100 years. The design and specifications shall address the durability of all elements of the structures, incorporating an assessment of potential deterioration of their exposure, particularly in the marine environment, throughout the design life including, but not limited to:

1. Durability of concrete.

2. Corrosion of metals.

3. Long-term performance of water stops and other components of the waterproofing systems.

4. Long-term performance of sealants, coatings, and other forms of protection.

5. Serviceability of embedded items.

6. Long-term performance of resilient rubber and synthetic bearing pads.

7. Maintenance and replacement of structural bearing pads.

E. **Structures**: Design and specifications shall adhere to the following general principles.

1. All slabs in the underground structures shall be of reinforced cast-in-place concrete.

2. The minimum thickness of all shaft walls including ventilation shafts shall be 300 mm.

3. [A7](Reserved)[A7]

4. [A7](Reserved)[A7]

5. [A7](Reserved)[A7]

6. [A16]The concrete shall be designed to meet the requirements regarding watertightness specified in Section 03 30 00 (*Concrete*). [A16]

1.05 SUBMITTALS: 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.

[A11]A. **After Letter of Acceptance – Design**: The Contractor shall submit to the Employer's Representative, for information, the following for the lock walls, approach structures, lock heads, lock floors, WSBs, Crossunders, and valve chambers. [A11]

1. **Drawings showing**:

a. General layout.

b. Plans and sections showing general dimensions.

2. **Documentation**: Analysis and design calculations.

B. [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 for the lock walls, approach structures, lock heads, lock floors, WSBs, Crossunders, and valve chambers. [A16]

1. **Drawings showing**:

a. Updated general layout.

b. Plans and sections.

c. Location-embedded items.

d. Plans and sections of upper and lower trackways for gates.

e. Location and dimensions of shafts and wells required for the installation of equipment specified in other Sections.

f. Reinforcement for typical sections.

2. **Documentation**:

a. Analysis and design calculations.

b. Tolerances that will govern the construction.

c. Means of ensuring watertightness.

d. Durability of structures.

e. All relevant specifications.

C. **Final** [A17]**Design**: [A17] When the design has reached a level that is apt for construction, the Contractor shall submit, to the Employer's Representative [A11]for review,[A11] the information indicated below for the lock walls, approach structures, lock heads, lock floors, WSBs, Crossunders, and valve chambers.

1. **Drawings showing**:

a. Plans, sections and details.

b. Location and installation details for embedded items.

c. Plans, sections and details of upper and lower trackways for gates [A7], including removal and installation procedures.[A7]

d. Location and dimensions of shafts and wells required for the installation of equipment specified in other Sections.

e. Reinforcement details

2. **Documentation**:

a. Analysis and design calculations.

b. Tolerances that will govern the construction.

c. Means of ensuring watertightness.

d. Durability of structure.

[A7]e. Methodology for installation and removal of upper and lower trackways, including sequence of activities and required equipment.

f. All relevant specifications and method statements.[A7]

D. [A16]**After Construction**: Prior to issuance of the Taking-Over Certificate the Contractor shall submit, to the Employer's Representative, the information indicated below for the lock walls, approach structures, lock heads, lock floors, WSBs, Crossunders, and valve chambers.[A16]

1. [A16]**Drawings**: As-Built Drawings.[A16]

2. **Documentation**: Updated design calculations and specifications.

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 a list and technical data of instruments and equipment for inspection and testing.

2. The Contractor shall submit a description of how quality-control testing will be performed to comply with the specifications and to verify the durability and watertightness of the structure.

3. The Contractor shall submit technical procedures and methods of performing quality-control inspections for all features of the work, including pre-cast and pre-cast/pre-stressed concrete elements, cast-in place concrete, and piling work (if any).

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 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, can 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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