Subject: **Forebay Conceptual Design Criteria (Final Draft)**

Project feature: Southern Forebay

Prepared for: California Department of Water Resources (DWR) / Delta Conveyance Office (DCO)

Prepared by: Delta Conveyance Design and Construction Authority (DCA)

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1. Introduction

1.1 Purpose and Scope of Memorandum

The Delta Conveyance Project (Project) would include intakes along the Sacramento River between the confluences with American River and Sutter Slough and a tunnel between the intakes and a forebay at the downstream terminus of the main tunnel referred to as the Southern Forebay. Water would either flow by gravity or be lifted by the Pumping Plant from the tunnel into the Southern Forebay. Discharge from the Southern Forebay would occur through the Southern Forebay Outlet Structure, at the south end of the reservoir, into the South Delta Conveyance Facilities for connection to the existing State Water Project (SWP) Harvey O. Banks (Banks) Pumping Plant and Central Valley Project (CVP) C.W. Bill Jones (Jones) Pumping Plant.

1.2 Southern Forebay

This Conceptual Design Criteria Technical Memorandum (TM) provides the conceptual design framework for forebay facilities. The purpose of this TM is to support conceptual development of the Southern Forebay and associated appurtenant structures for the purposes of the Engineering Project Report and supporting environmental documentation. The criteria and guidance presented in this TM should be thoroughly reviewed and updated to support preliminary and final design.

This TM documents known relevant constraints as well as geotechnical, civil, structural, electrical, and mechanical standards to be used in the conceptual analyses and design of the Southern Forebay and associated appurtenant structures. In addition, this TM is intended to guide development of designs for the elements associated with the Southern Forebay that are consistent with permit and code requirements, industry design standards, DCA design criteria requirements and preferences, and general design criteria and engineering work products. Design criteria for other Delta Conveyance project components are captured in complementary TMs and other project memoranda under separate covers.

The information contained in this TM is based on limited geotechnical information, engineering evaluations, and preliminary hydraulic analyses that have been completed for the Project. The criteria and guidance in this document will be updated or superseded and additional criteria may be developed, as appropriate, as the design of the Southern Forebay facilities are further advanced in future design phases.

While the material presented in this TM has been prepared in accordance with recognized engineering principles, these design criteria should not be used by the design engineer without first exercising competent engineering judgment with respect to its suitability for the complexity and importance of the facilities being designed. As previously stated, this document is intended for conceptual design and is not intended for use in preliminary or final design, procurement, or construction.

2. Regulatory Authority and Standards

There are numerous regulatory agencies that require consultation and permit issuance for design, construction, and operation of the forebay and associated facilities. The California Department of Water Resources, Division of Safety of Dams (DSOD) regulatory criteria are the most critical in describing the overall requirements for design. This section includes a list of other regulatory agencies and general codes and standards that pertain to forebay design.

2.1 Division of Safety of Dams

The DSOD is the lead state agency with jurisdiction over the design, construction, and operation of the planned Southern Forebay, including the associated appurtenant structures.

Per DSOD (DSOD, 2020a):

> *"Jurisdictional dams are dams that are under the regulatory powers of the State of California. A "dam" is any artificial barrier, together with appurtenant works as described in Sections 6002 and 6003 of the California Water Code. A dam owner is a person or non-federal entity with legal responsibility for the dam.*
>
> *"If the dam height is more than 6 feet and it impounds 50 acre-feet or more of water, or if the dam is 25 feet or higher and impounds more than 15 acre-feet of water, it will be under our jurisdictional oversight, unless it is exempted. The DSOD Jurisdictional Size Chart (image right [image not shown]) summarizes the above criteria.*
>
> *"Jurisdictional height of a dam, as determined by DSOD, is the vertical distance measured from the lowest point at the downstream toe of the dam to its maximum storage elevation, which is typically the spillway crest. This same approach is also used for calculating the dam height for determining the annual fee."*

Based on the likely storage volume and operational height, the embankment for the forebay is anticipated to be classified as a dam within DSOD's jurisdiction. Therefore, the forebay embankment and appurtenant facilities would need to conform to applicable DWR and DSOD statutes and regulations pertaining to dams and reservoirs, with the design of the forebay facilities subject to design review and approval by DSOD prior to construction. Construction would be subject to DSOD oversight and approval prior to acceptance of the forebay for use.

The Southern Forebay would be considered an off-stream reservoir. The California Water Code was amended in 1965 (following the 1963 Baldwin Hills Reservoir failure) by legislation to put off-stream storage reservoirs under DSOD jurisdiction.

DSOD requirements for analysis and design of dams is related to the consequences of failure of that dam. DSOD guidelines quantify the hazard potential of a dam using the Total Class Weight (TCW) parameter. The TCW is determined using four factors: height of the dam, reservoir storage, estimated downstream evacuation, and downstream damage potential (DSOD, 2018). The DSOD TCW parameters for the Southern Forebay would be based on dam breach and flood routing studies to be prepared during future design phases.

2.2 Additional Regulatory Agencies

DSOD would be the lead regulatory agency with respect to the design, construction, and operation of the Southern Forebay embankment and appurtenant structures. These facilities would also be affected by the requirements and oversight of additional federal, State, and local regulatory agencies. These agencies may include, but are not limited to:

- U.S. Army Corps of Engineers (USACE)
- U.S. Bureau of Reclamation (Reclamation)
- U.S. Fish and Wildlife Service (USFW)
- State of California State Water Resources Control Board (Water Board)
- State of California Central Valley Flood Protection Board (CVFPB)
- California Department of Fish and Wildlife (CDFW)
- California Department of Transportation (Caltrans)
- Various regional and local agencies (e.g., reclamation districts)

2.3 General Codes and Standards

Additional general codes and standards would also apply to the design of the Southern Forebay facilities. The following general codes and standards are not typically cited in conceptual design but would be incorporated into the criteria used for preliminary and final design of specific facilities, as applicable. These general codes and standards may include, but are not limited to:

- American Concrete Institute (ACI)
- American Institute of Steel Construction (AISC)
- American National Standards Institute (ANSI)
- American Society of Civil Engineers (ASCE)
- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
- American Society of Mechanical Engineers (ASME)
- ASTM International (ASTM)
- American Welding Society (AWS)
- American Water Works Association (AWWA)
- California State Water Code
- California Building Code (CBC)
- California Energy Code (CEC)
- California Division of Occupational Safety and Health (Cal/OSHA)
- International Building Code (IBC)
- International Electrical and Electronics Engineers (IEEE)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- Steel Structures Painting Council (SSPC)
- Underwriters Laboratory (UL)

3. Overview of Forebay Facilities

3.1 Vertical Datum and Survey Control

Existing project-related documentation includes references to both the National Geodetic Vertical Datum of 1929 (NGVD29) and the North American Vertical Datum of 1988 (NAVD88). For conceptual design purposes, all design elevations in this TM are specified in NAVD88 elevations. Project horizontal datum in this TM is the North American Datum of 1983 (NAD 83) with coordinates based on the California State Plan Coordinate System Zone 2 or 3 (as appropriate).

3.2 Southern Forebay Description

Water diverted from the intakes would be conveyed through a tunnel to the Southern Forebay. Water could flow by gravity or be lifted by the pumping plant that would be located at the northern boundary of the Southern Forebay. Water would then be conveyed to the approach channels for the Banks and Jones pumping plants. The difference in daily supply and demand flow timing and magnitude would result in the potential need for balancing storage in the Southern Forebay. The temporary storage of diverted water would also enable the SWP and the CVP facilities to maximize operational flexibility of the existing pumping plants regardless of the timing of upstream diversions into the system at the North Delta intakes.

Pertinent project characteristics for the Southern Forebay will be refined as project planning and conceptual engineering efforts are advanced.

The following specific characteristics have been identified for the Southern Forebay:

- The Southern Forebay would be located at the downstream end of the tunnel with the new pumping plant located on the northern embankment of the forebay.
- The Southern Forebay would be an at-grade storage reservoir formed using a perimeter earthen embankment (from about 24 to 36 feet tall, depending on site topography). Natural ground elevations in the vicinity of the likely Southern Forebay location vary between about elevation -8 to 4 feet (NAVD88), and the site would be graded to create the necessary interior storage range and promote gravity flow across the forebay to the outlet structure.
- The Southern Forebay would be adjacent to the existing SWP Clifton Court Forebay. The target storage would be approximately 9,000 acre-feet with a range of operating water levels between elevation 5.5 to 17.5 feet (NAVD88) to meet the minimum water surface elevation requirement at the SWP and CVP facilities.
- At the south end of the Southern Forebay, outlet shafts would discharge water into the South Delta Conveyance facilities to convey water into the approach channels of the existing SWP and CVP pumping plants.
- In general, it is assumed the Southern Forebay would include the following:
  - Embankment slopes would range from 3 horizontal (H) to 1 vertical (V) (3H:1V) to 6H:1V depending on foundation conditions and related slope stability requirements.
  - Embankment foundation improvements would be implemented where needed (i.e., cutoff walls for seepage, or ground improvement for embankment stability) due to potentially poorly consolidated or weak foundations and seismic conditions.
  - Excavation and grading of the interior floor of the forebay would occur to maximize storage.
  - Seepage collectors and drainage layers would be installed within the embankment.
  - Along the perimeter of the outboard toe of the embankment (exterior slope), a minimum 15-foot-wide access and monitoring corridor would be installed.

The Southern Forebay Conceptual Site Plan and Conceptual Cross-Section are shown in Figures 3-1 and 3-2, respectively. Although not shown on the figures below, the conceptual design of the Southern

Forebay would also include an emergency spillway and an emergency outlet works to meet DSOD requirements that are described in separate TMs.

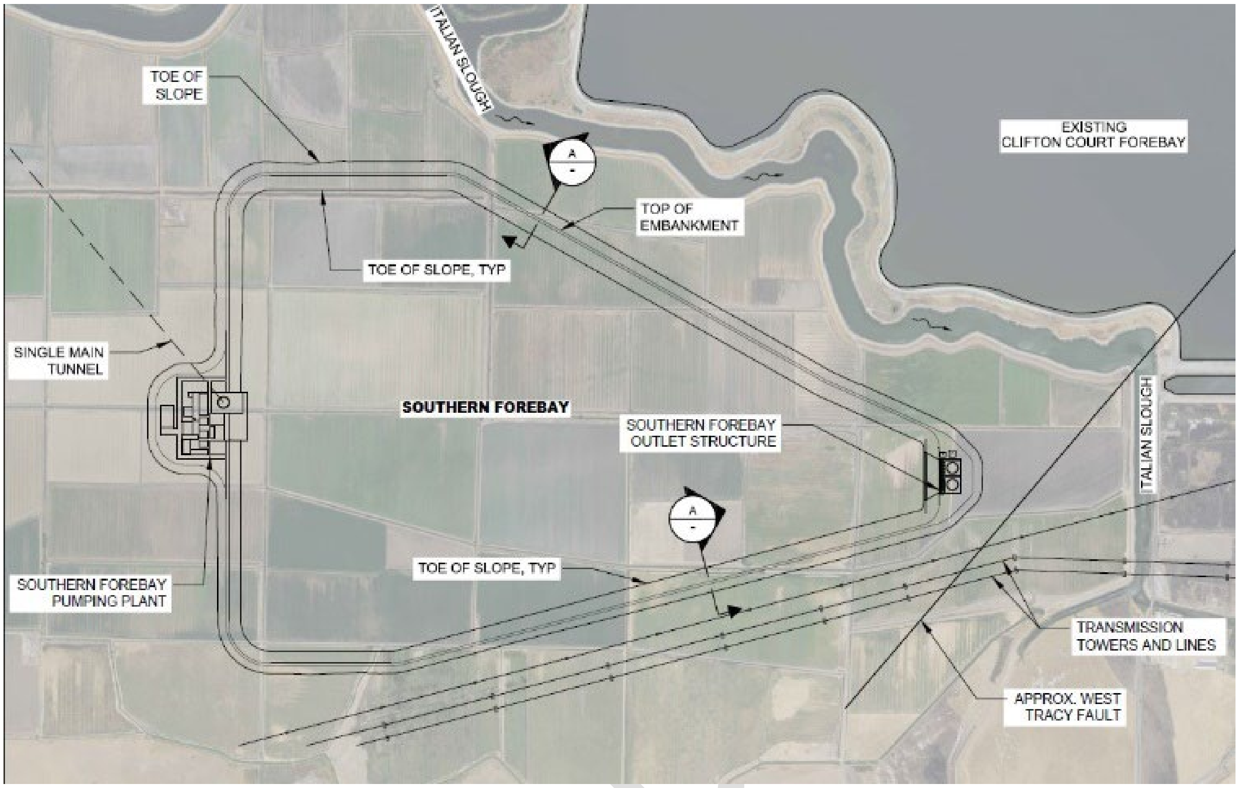

Figure 3-1. Southern Forebay Conceptual Site Plan

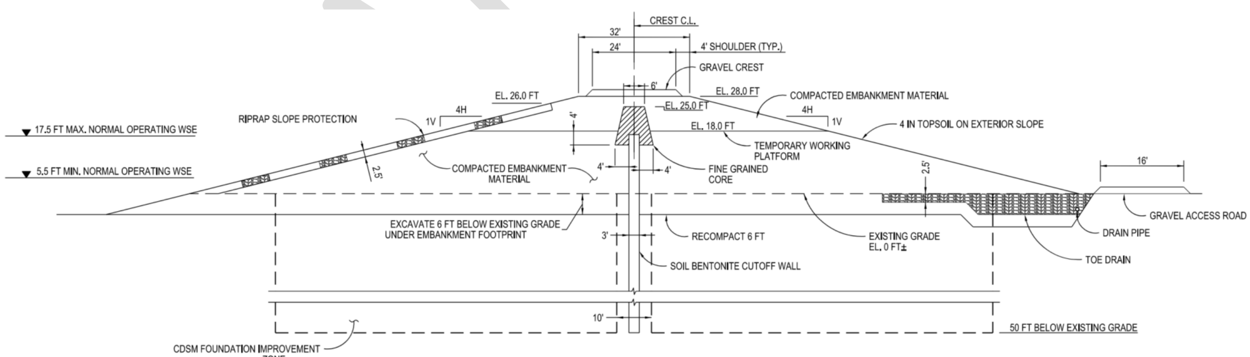

Figure 3-2. Southern Forebay Conceptual Cross-Section

4. Seismic Design Criteria

4.1 Seismic Design Parameters

Seismic Design Criteria will be provided in a separate TM.

4.1.1 MCE and Seismic Ground Motion Parameters

Design earthquake ground motions for the Maximum Credible Earthquake (MCE) would be developed for the Southern Forebay facilities and would be further refined based on the final forebay location. MCE and ground motion parameters would be developed as follows:

- Ground motions would be developed using a deterministic ground motion analysis in accordance with the requirements of DSOD.
- The DSOD Hazard Matrix (DSOD, September 2017) would provide guidance on the statistical level (e.g., median, 84th percentile) of ground motions to be used based on the slip rate of the controlling seismic source and hazard class of the planned embankment.
- Acceleration time histories (at least three sets) would be selected to represent the design ground motions for each MCE scenario. It is possible that multiple scenarios will be considered.

4.1.2 Earthquake During Construction

During the construction of the Southern Forebay, temporary construction and excavation slopes and other features must remain stable during an earthquake. The potential for earthquake loading of incomplete facilities during construction has a relatively low probability of occurrence. For analyzing stability during construction, the design earthquake would be based on a 100-year return period event. The associated seismic performance requirement is that the temporary construction and excavation slopes and other facilities under construction should suffer little or no damage and no interruption of function.

4.1.3 Fault Displacement

Fault-related deformation near the embankments could occur with movement on specific faults or proximate active fault zones. The potential for fault rupture and related surface displacements would be further assessed based on the final locations of the forebay facilities and subsequent geotechnical and seismic studies to be completed for the project.

5. Hydraulic and Hydrologic Design Criteria

5.1 Hydraulic Design Parameters

The storage and functional requirements of the forebay are described in Section 3, Overview of Forebay Facilities.

5.2 General Freeboard Requirements

The Southern Forebay would be designed to meet DSOD minimum total freeboard requirements for off-stream reservoirs. Based on preliminary conceptual design, it is anticipated that minimum total freeboard for the forebay embankment would be a minimum of 3 feet (total freeboard is the vertical distance between the normal operating reservoir level and the emergency spillway weir crest).

The residual freeboard for the Southern Forebay would not be less than 1.5 feet, per DSOD guidelines. Residual freeboard is the unused vertical difference between the maximum reservoir water surface level under extreme conditions, including:

- During the Probable Maximum Flood (PMF), including wind setup and wave run-up.
- Considering peak inflow from the upstream portion of the Delta Conveyance project.

The forebay would include an emergency spillway structure adequately sized to pass peak inflows with adequate freeboard. Freeboard requirements for spillway chutes and structures are not specifically defined by DSOD regulations. However, emergency spillway chute walls would be designed with sufficient height to accommodate super-critical flow depth plus cross-waves and bulking due to entrained air within the regime while maintaining a nominal amount of freeboard. Analysis required to determine emergency spillway wall heights should be performed as part of a later design phase.

Wind wave analysis should be performed to confirm upstream slope protection and freeboard requirements. Wave run-up is the vertical height above the still water level that an incident wave would run up the face of the embankment. Wind setup is a general tilting of the water surface due to the shear stress caused by winds. Wave run-up and setup would be calculated based on fetch length calculated in accordance with Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams (Reclamation, 2012). Design wind velocities will be obtained from the latest edition of the IBC (2018), generalized charts published by Reclamation (2012) and supplemented with National Weather Service data.

5.3 Hydrologic Design Parameters

5.3.1 Probable Maximum Flood

The Southern Forebay would receive inflows from two sources: 1) direct precipitation, and 2) flows from the tunnel. As an off-stream reservoir, the drainage area of the forebay would essentially be delineated by the perimeter of the reservoir rim.

The forebay would include an emergency spillway with sufficient capacity to safely convey reservoir inflows and mitigate the potential for the perimeter embankment to be overtopped. It is anticipated that the controlling inflow for the Southern Forebay would be the maximum discharge capacity of the new pumping plant, since the maximum diverted flows from the Project (i.e., from the upstream intake structures) under gravity flow conditions would be reduced by head losses.

As a conservative criterion, the conceptual design of the reservoir would include an estimate of the PMF for the watershed area delineated by the embankment perimeters. PMF inflows would be determined using the Probable Maximum Precipitation (PMP) estimates determined using Hydrometeorological Report No. 58/59 (HMR 58/59) methods. Alternatively, if a forebay embankment was designed to fully contain the maximum hydraulic head at the upstream-most intake with appropriate additional height for freeboard and wind/wave run-up then only discharge of direct precipitation would be required.

The critical PMP is the general storm PMP (all-storm) or the local storm PMP (thunderstorm), depending on which corresponding PMF produces the maximum reservoir water surface elevation for each facility. The general storm PMP would be calculated based on a 72-hour duration and a center-weighted distribution. The local storm PMP would be calculated based on a 6-hour duration and a front-weighted distribution. The critical PMP would be used to route the PMF through the forebay.

5.3.2 Construction Design Flood for Dam Safety

During construction of the Southern Forebay, cofferdams would be constructed at all forebay-associated inlet, outlet, and control facilities to protect the construction sites. Due to the expected presence of shallow groundwater at potential forebay locations, it is likely that construction of some foundation elements would require installation of dewatering systems. Cofferdams and dewatering systems would be designed to remain stable and operable during the construction-phase design flood. The emergency spillways and outlet at the Southern Forebay would not be operational until the end of the construction period. Therefore, cofferdams and dewatering systems would be sized to safely mitigate the effects of the pre-project, 50-year (2 percent annual chance of exceedance) flood event. The 50-year flood will be based on precipitation records available in NOAA Atlas 14.

5.3.3 External Flooding

The perimeter embankment of the forebay would be designed to withstand potential external flooding associated with the 200-year (0.5 percent annual chance of exceedance) flood event using climate change hydrology plus sea level rise in Year 2100 conditions. The embankment crest would be established at 4 to 6 feet above the 200-year external flood elevation to protect the embankment from overtopping due to wind-driven wave run-up consistent with California Code of Regulations, Title 23 Waters, Division 1, Minimum Dimensions of Standard Levee Sections, Freeboard for Bypasses (CCR, 2014). Freeboard is necessary for the embankment to prevent overtopping, which could lead to erosion downcutting through the embankment crest, leading to failure of the embankment. The spillway weir crest would be set at an elevation above the 200-year external flood elevation to limit backflow into the reservoir during extreme external hydraulic conditions. The spillway would be an erosion-resistant structure and therefore not susceptible to downcutting erosion.

6. Project Feature Performance Requirements and Design Criteria

This section presents the project feature performance requirements and conceptual design criteria for the forebay embankment, emergency spillways, emergency outlet works, and other appurtenant facilities.

6.1 General

The Southern Forebay would be designed to meet anticipated normal, flood, and seismic design loading conditions in accordance with applicable DSOD regulations as defined in *Statutes and Regulations Pertaining to Supervision of Dams and Reservoirs*, available on DSOD's website (DSOD, 2020b). This document addresses key definitions, application/review processes, and other practices. However, DSOD does not define specific guidelines or criteria.

Design standards published by other dam design agencies (such as USACE and Reclamation) would also be applicable to DSOD-regulated projects. Published DSOD guidelines, such as *Guidelines for the Design and Construction of Small Embankment Dams*, would generally apply but do not cover all design requirement aspects of the Southern Forebay.

General project performance requirements for the Southern Forebay are summarized below:

- The embankment, emergency outlet works, emergency spillway, and their appurtenances would be designed to prevent uncontrolled releases.
- The embankment, emergency outlet works, emergency spillway, and their appurtenances would be designed to have a useful service life of at least 100 years without requiring major repairs, other than maintenance.
- The embankment, emergency outlet works, emergency spillway, and their appurtenances would be operable following the MCE or PMF for the facility.

- The embankment, emergency outlet works, emergency spillway, and their appurtenances would be designed to accommodate potential climate change, including sea level rise and ground subsidence.
- The external slopes of the embankment and associated facilities would be designed to protect diverted water against potential external flooding from the projected 200-year flood event, including sea level rise and climate change hydrology for Year 2100 conditions and wind fetch.

6.2 Forebay Embankments

The following considerations would be incorporated into the conceptual design criteria for the Southern Forebay embankment:

- The Southern Forebay would be designed as an earth embankment with a toe drain and possible internal drainage (to be further evaluated as part of future design phases). The earthfill would be designed so it can be constructed using materials from excavations and reusable tunnel material (RTM) to the maximum extent possible. The conceptual design shown in Figure 3-2 includes a low permeability embankment core, which should be further evaluated as part of future design phases.
- The height of the forebay embankments would be defined by the freeboard requirements above maximum internal storage levels and external flooding levels.
- The base elevations of the forebay would be driven by the hydraulics of the total Delta Conveyance system.
- The shape and grading within the forebay would need to promote gravity flow through the basin with a range of velocities and flow depths at the forebay inlets and outlets.
- Seepage through the embankments and foundations would be controlled by the design of the embankment fill materials, controlling the depth of foundation trenches (keyways), and vertical hydraulic barriers (e.g., cutoff walls), where deemed necessary. The conceptual designs would include considerations for internal seepage collectors, drainage layers, conveyance, and discharge. The need for and potential configuration of seepage management elements should be further considered during future design phases.
- Embankment deformations and cracking of the embankments under the MCE would be limited to safeguard the post-earthquake safety of the embankment and not inhibit the ability to maintain reservoir levels and operate the project in accordance with unrestricted conditions. This condition would apply to the deformations caused by earthquake shaking and to shearing and distortion due to offset of the foundation. Seismically-induced settlements caused by liquefaction of the foundation would also be limited. The final criteria would be based on the pattern of deformations and the location of the potential sliding mass within the embankment in relation to embankment design features, such as filter and transition thicknesses and embankment freeboard. The design performance would be considered acceptable if repairs following the MCE were limited to re-grading of the embankment and repairing of cracks. The remediated embankment would also be designed to resist the hazard of internal erosion (piping) caused by seismic deformation.
- Significant extents of foundation improvement would likely be required based on the likely presence of soft, compressible or weak foundation soils throughout the forebay area. The embankment would be constructed to limit and reduce the impacts of potential crest sagging or cracking due to poor foundation conditions. Embankment crests would be cambered as appropriate to address post-construction settlement. Camber is defined as additional height given to the crest in excess of the design crest elevation. Camber would vary with embankment height.

- Embankment slopes would be designed to resist runoff-induced erosion on the downstream face and wave-induced erosion on the upstream face (including waves resulting from hydraulic surge). The design of the downstream face of the embankment should be such that erosion due to external flooding would be limited and repairable through maintenance activities.

6.2.1 Embankment Stability Analyses

The stability of the temporary and permanent upstream and downstream embankment slopes during construction and post-construction would be evaluated as follows (evaluation of embankment foundations is integral to these analyses):

- The static stability cases to be evaluated include "End of Construction," long-term steady-state seepage conditions, and rapid drawdown (RDD) conditions.
- The stability analysis results would be used to confirm that the design of temporary and permanent embankment slopes meet acceptable safety factors.
- As the embankment may not be completed in one season, design water surface elevations and phreatic surface profiles would be developed to represent seasonal variations in groundwater, precipitation, and runoff conditions.
- Two-dimensional transverse cross-sections would be developed to represent the embankment and foundation conditions for slope stability analysis. Generally, analysis cross-sections will be spaced at 200- to 500-foot-intervals along the embankment dam alignments. The specific locations for analysis cross-sections would be selected based on the facility being evaluated and variability of the site subsurface conditions.
- For each of the analysis cross-sections, the phreatic conditions within the foundation and embankment corresponding to the analysis loading conditions would be developed based on the subsurface conditions encountered in site-specific geotechnical investigations.
- Static stability would be evaluated using limit equilibrium methods. RDD Analysis would use the three-stage limit equilibrium method (Duncan, Wright, and Wong, 1990).
- Pseudo-static analysis would use the two-stage limit analysis method. Post-earthquake stability analyses will be performed using reduced strengths for the liquefied materials. Other dynamic response and seismic deformation analyses would be performed using the methods described below.
- The foundation and embankment material characterization for the forebay would be updated, as appropriate, to incorporate additional geotechnical data that may become available (through research or additional geotechnical investigations).

Minimum acceptable factors of safety for the various loading conditions are listed in Table 6-1.

Table 6-1. Loading Conditions and Stability Criteria

Loading Condition	Slope	Minimum Recommended Factor of Safety
During and End of Construction	Upstream & Downstream	1.3
Long-Term, Steady State Seepage w/Maximum Storage Pool	Downstream	1.5
Long-Term with Maximum Surcharge Pool	Downstream	1.4

Table 6-1. Loading Conditions and Stability Criteria

Loading Condition	Slope	Minimum Recommended Factor of Safety
Rapid Reservoir Drawdown for Maximum Storage Pool	Upstream	1.3
Pseudo-static	Upstream & Downstream	1.0 (for determining k_y, yield accelerations only)
Post-Earthquake Stability (using post-earthquake strengths)	Upstream & Downstream	1.1 (for determining k_y yield accelerations, only)

Source: USACE, 2003b

6.2.2 Seismic Deformations

Dynamic response analyses would be performed along with analysis of seismic deformations and seismic settlements (e.g., those triggered by liquefaction) as follows:

- It is anticipated that dynamic analyses for conceptual design are likely to include multiple 2D sections at key areas of interest (i.e., near spillway, inlet/outlet structures).
- Analyses would be performed for the MCE events identified in Section 3.1.1 to demonstrate that embankment deformations and cracking would be within acceptable limits. Acceptability criteria would be based on the location of the sliding mass within the embankment (deformation pattern), the magnitude of total and relative deformations, and comparison to existing dam design features such as filter and transition materials thicknesses.
- Earthquake-shaking-induced shear deformations across filter and drain zones would be limited so that they do not exceed one-half the thicknesses of the filter and drain zones. Loss of freeboard from crest deformation would also be evaluated.
- Potential leakage through cracks in the core zones and the erodibility of the core and other embankment materials would be evaluated in order to design the zones to prevent piping and internal erosion.
- The material strength properties, MCE time histories, liquefied zones (if applicable), and post-earthquake residual strengths would be developed and provided to DSOD for approval.
- In addition to deformations caused by earthquake shaking, offset of the dam foundation by fault surface rupture could result in shearing and distortion of the embankment. If determined to be necessary to demonstrate dam safety, the potential impact of surface fault rupture on the dam would be assessed. The general methodology to estimate cracking potential would be evaluated as part of the design process.

6.2.3 Seepage Evaluations

Southern Forebay embankments would be designed to control seepage conditions within the embankment and foundation. Published guidance and criteria for acceptable seepage through water-retaining structures will be used as applicable (USACE, 1993, 2004, 2005a).

Minimum acceptable factors of safety for seepage conditions are listed in Table 6-2 below:

Table 6-2. Loading Conditions and Stability Criteria

Condition	Loading	Max. Allowable Exit Gradient[a]	Minimum Recommended Factor of Safety
Downstream Embankment Toe	Normal Max. Operating WSE	≤ 0.5	> 1.6[b]
Downstream Embankment Toe	Max. Reservoir WSE	≤ 0.6	> 1.3[b]
Ditch, Canal or Depression – At the Downstream Embankment Toe	Normal Max. Operating WSE	≤ 0.5	> 1.6[b]
Ditch, Canal or Depression – 150 feet from the Downstream Embankment Toe	Normal Max. Operating WSE	≤ 0.8	> 1.0[c]

[a] The saturated unit weights of the "in situ" landside blanket soils must be at or above 112 pounds per cubic foot (pcf) in order to use these exit gradient criteria. If soils weigh less than 112 pcf, the minimum Factor of Safety criteria shown shall be followed.

[b] Source: USACE EM 1110-2-1913

[c] Source: California Department of Water Resources Urban Levee Design Criteria

6.2.4 Southern Forebay Embankment Materials

The embankments would be constructed using materials from onsite excavations and reusable tunnel material (RTM) to the maximum extent possible. The Southern Forebay Embankments would be designed using geotechnical design methodology compatible with USACE Geotechnical Levee Practice and also in conformance with CCR Title 23. Comparison of criteria for embankment materials with preliminary geotechnical information is provided in Table 6-3:

Table 6-3. Embankment Material Criteria

Characteristic	USACE Geotechnical Levee Practice[a]	CCR Title 23[b]
Maximum particle size	2 inches	2 inches
Percentage Fines (passing No. 200 sieve, by weight)	≥ 20%	≥ 30%
Plasticity Index (PI)	8 ≤ PI ≤ 40	8 ≤ PI ≤ 40
Liquid Limit (LL)	45	45
Saturated Unit Weight	--	≥ 112 pcf
Other Criteria	Free of objectionable matter	Organics ≤ 2% by volume; No unsatisfactory materials[c]

[a] Geotechnical Levee Practice, USACE, Sacramento District, Engineering Division, GEEB, 04/11/2008.

[b] California Code of Regulations (CCR) Title 23-Proposed Technical Changes, Division 1. Central Valley Flood Protection Board, Article 8. Standards, Section 120. Levees. Updated May 21, 2011 (legal review pending).

[c] Unsatisfactory materials are described in the Title 23- Proposed Technical Changes as materials "such as trash, etc."

6.2.5 Filter and Drain Design

Durability requirements of filter and drain materials would satisfy ASTM C33, Standard Specification for Concrete Aggregates. Gradation requirements for granular filters and drains would be based on Reclamation filter compatibility requirements (Reclamation, 2011).

6.2.6 Embankment Erosion Protection

The requirements for upstream embankment (interior slopes) erosion protection would be based on wind fetch distance, wind velocity, and potential impacts from hydraulic surge. Material types and thicknesses of upstream embankment erosion protection would be evaluated using USACE recommendations (USACE, 1984, 2002; Reclamation, 1991). Rock durability requirements would be established based on Reclamation guidelines (Reclamation, 1998).

6.3 Southern Forebay Inlet and Outlet Facilities

The new pumping plant on the upstream (northern) embankment would discharge flow from the tunnels into the forebay. Under certain conditions, gravity flow of Delta Conveyance project diversions into the Southern Forebay would occur uncontrolled through the overflow features included at the pumping plant. At the south end of the forebay, outlet shafts would discharge water into the South Delta Conveyance Facilities to convey water into the existing SWP and CVP pumping plants. Bulkhead gates and trash racks would be provided at the outlet of the Southern Forebay for isolation and debris management. Design criteria for these facilities would be included under separate cover.

The inlet and outlet facilities and ancillary structures housing valves or other mechanical/electrical equipment would be designed to operate after the MCE event with the goal that resulting structural damage would not prohibit access for inspection and/or operation of mechanical and electrical systems. Systems would also be designed to accommodate potential long-term differential settlement across their foundations.

6.3.1 Integration with Other Project Features

The conveyance inlet and outlet facilities would be incorporated into the embankment conceptual design processes such that the connections of these facilities do not represent weak points for the respective structures (i.e., areas for potential seepage and/or differential settlement).

6.4 Emergency Outlet Works

6.4.1 General

The Southern Forebay would have an emergency outlet system with sufficient capacity to allow for evacuation of the reservoir within the period of time mandated by DSOD as described below:

- For reservoirs that impound over 5,000 acre-feet of water, DSOD requires the outlet system be capable of lowering the maximum storage depth by 10 percent within 7 or 10 days and draining its full contents within 90 or 120 days, depending on factors such as downstream and seismic hazard, dam construction methods and age, known deficiencies, and type of dam (as determined by DSOD).

6.4.2 Emergency Outlet Conceptual Design

Conceptual design of the emergency outlet works systems would incorporate the following:

- The emergency outlet works would be appropriately sized per DSOD emergency drawdown requirements listed above.

- Emergency outlet conduits through the embankment would be concrete-encased and would be designed to allow for adequate compaction of earthen materials against the conduits to reduce the potential for seepage and piping.
- The emergency outlet works system would be subject to the same foundation objectives and requirements as the embankments.

The design of the emergency outlet control systems would also include the following:

- The ability to disconnect the power source and apply lock-out and tag-out to all gates.
- Flow measuring devices incorporated into the outlet works for the full range of flows.
- Telephone communication systems for communication with Delta Conveyance operations system and DSOD.
- Security alarms when local control of the valves is initiated.
- Flow-release alarms for use in warning the public of releases to natural water courses/drainages.

The location for the inlet of the emergency outlet works would be evaluated based on site-specific needs and constraints. Additional requirements would include:

- The inlet would be provided with either a guard gate or stoplogs at the upstream end so the gate can be operated and maintained without lowering the reservoir.
- The inlet would be equipped with trash racks for debris control (although debris loading is anticipated to be minimal).
- The Southern Forebay could include storage created by excavating below the surrounding natural ground elevation. Depending on the natural ground elevation corresponding to the inlet location, the emergency outlet may not achieve complete drawdown of the forebay (i.e., some “dead storage” may remain).

In general, structural design criteria for emergency outlet works would be based on the following:

- USACE Engineering Manual (EM) 1110-2-2100, Stability Analysis of Concrete Structures (USACE, 2005b).
- EM 1110-2-2104, Strength Design for Reinforced Concrete Hydraulic Structures (USACE, 2003a).
- Reclamation Spillway and Design Standards.
- American Concrete Institute (ACI) Standards.

6.4.3 Control of Emergency Outlet Flows

Requirements for control of the emergency outlet flows would include:

- An outlet works control structure would be provided to house operational control valves.
- The emergency outlet would include isolation and energy dissipation valves of various sizes to control releases over a range (to be determined) that would incorporate release rate required for emergency drawdown.
- An energy dissipation structure and lining or armoring of the discharge channel would be provided at the downstream of flow releases.

- Guard valves would be provided upstream of the main control valve to facilitate ease of maintenance and inspection of the outlet pipe(s).
- Flow control systems would be compatible and integrated with other planned project operations systems.

6.4.4 Gates, Valves, and Control Systems/SCADA

The emergency outlet works and ancillary structures housing valves or other mechanical/electrical equipment would be designed to operate after the MCE event with the goal that resulting structural damage would not prohibit access for inspection and/or operation of mechanical and electrical systems. Outlet works systems would also be designed to accommodate potential long-term differential settlement due to poor foundation conditions.

The emergency outlet works systems would contain gates and valves to provide releases from the reservoir for emergency drawdown, as required by DSOD guidelines. Design and operation of gates and valves would incorporate the following:

- Isolation gates and valves would be designed for operation in fully closed and fully open positions only.
- Regulating gates and valves would be able to regulate and control releases to within 20 percent of target flows.
- Regulating gates and valves would be able to be operated from closed to fully open or from fully open to closed in 15 to 30 minutes.
- All upstream gates and valves would be equipped with both local and remote supervisory control and data acquisition (SCADA) position indicators.
- Any large non-automatic gates or valves would incorporate means of attaching a portable electric motorized device for operation.
- Electrical actuators would be considered, where appropriate, as an option to hydraulic systems.
- All metallic equipment components of the emergency outlet would be designed with appropriate consideration of corrosion potential and resistance, as needed to achieve the required design life. Cathodic protection will be designed as required. Stainless steel would be used where possible and practical. Metallic continuity and dielectric isolation would be designed as key components of the pipeline corrosion control system.
- The main control valves and structure would be designed to facilitate access, inspection, and maintenance.
- To the extent practical, the inlet and outlet conduit required for emergency drawdown would allow visual inspection and maintenance by operations staff without lowering or dewatering the reservoirs.

SCADA controls required to operate the inlet, outlet works, spillway gates (if applicable), and other appurtenances would be designed to remain fully operable following the MCE. Vaults and structures would be designed to meet applicable health and safety codes, local city and county building codes, and OSHA requirements. If needed for mechanized valves, an independent sources of backup power (e.g., dedicated electrical standby generators) would be provided so that the emergency outlet system (including SCADA) could be operated for as much as 1 week in the event of a power failure.

6.5 Emergency Spillway

6.5.1 General

The Southern Forebay would include an emergency spillway with sufficient capacity to safely convey reservoir inflows and prevent the perimeter embankment from being overtopped. It is anticipated that the controlling inflow for the Southern Forebay would be the maximum discharge capacity of the new pumping plant, since the maximum diverted flows from the upstream intake structures under gravity flow conditions would be reduced by head losses. The crest of the emergency spillway would be set at an elevation at or greater than the internal maximum normal operating water surface plus operating freeboard, as well as, above the external 200-year flood elevation. Alternatively, if a forebay embankment was designed to fully contain the maximum hydraulic head at the upstream-most intake with appropriate additional height for freeboard and wind/wave run-up then only discharge of direct precipitation would be required.

6.5.2 Hydraulic Design

Criteria for design of the emergency spillway are presented in separate TMs. Hydraulic design of the emergency spillway would incorporate the following:

- The hydraulic design of the spillway would be governed by the greater of the maximum diverted operational inflow or hydrologic PMF.
- The spillway would be designed to accommodate the project design flow capacity, which could range from 3,000 to 7,500 cfs depending on the eventual project configuration. The allowable design head, selected to minimize the embankment height, would be 2.5 feet.
- Spillway discharge erosion would be controlled to prevent backcutting damage to the spillway structure or embankment.
- Flow velocities would be limited to the extent feasible to reduce the likelihood of potential cavitation damage and hydraulic jacking of spillway slabs. Energy dissipation would be incorporated into the spillway hydraulic design as appropriate.

Conceptual design of the emergency spillway structure would also incorporate the following:

- The emergency spillway design would provide safe conveyance of overflow releases, prevent erosion of the dam and foundation, and provide discharge to existing drainages/water courses.
- The emergency spillway would be constructed of non-erodible materials (e.g., reinforced concrete) and would be located on competent foundation material of suitable quality (foundation improvements would likely be required). The emergency spillway chute would also contain features (such as cut-offs) to reduce the likelihood of erosion and head-cutting downstream of the chute outlets endangering the integrity of the embankment. The need for a lined channel below the spillway would also be assessed.
- The emergency spillway would be designed to pass peak flows, while providing a residual freeboard that is not less than the specified minimum.
- Sufficient operating freeboard would be provided to minimize nuisance spills under foreseeable operating conditions. Operating freeboard is defined as the unused vertical difference between the maximum normal operating water surface level and the emergency spillway crest elevation.

- The emergency spillway control structure and chute (slabs and walls) would be designed for seismic loading consistent with the other appurtenant structures for the embankment. In a damaged condition, the spillway would be designed to safely pass a small flood (return period to be determined during future design phases) and/or minimum diverted inflow (percent of maximum flows also to be determined) following the MCE.
- The spillway would not be required to handle the PMF and/or maximum pumped inflows shortly after the MCE.

6.5.3 Structural Design

In general, structural design criteria for the emergency spillway would be based on the following:

- USACE Engineering Manual (EM) 1110-2-2100, Stability Analysis of Concrete Structures (USACE, 2005b).
- EM 1110-2-2104, Strength Design for Reinforced Concrete Hydraulic Structures (USACE, 2003a).
- Reclamation Spillway and Design Standards.
- American Concrete Institute (ACI) Standards.

6.6 Access and Support Facilities

6.6.1 Temporary Access and Support Facilities

During construction, temporary site access would be developed, including new or modified roads, and possibly stabilized levees.

6.6.2 Permanent Site Access and Support Facilities

Permanent site access, including roadways and parking areas, and permanent structures facilities would be included in the site plan.

- A road would be constructed along the entire length of the embankment crest. Surfacing would be a minimum of 15 feet wide.
- A bridge would be constructed to cross over the Southern Forebay Emergency Spillway. The deck of the bridge would be a minimum of 18 feet wide. Hinged approach slabs would be provided on each end of the bridge (to mitigate differential movement of the embankment and bridge).
- An access road would be constructed along the entire length of the downstream toe of the Southern Forebay embankment. The access road would be a minimum of 15 feet wide.
- Ramps would be constructed on the upstream face of the Southern Forebay embankments to provide access to key areas within the Southern Forebay from the embankment crest. At a minimum, ramps would be constructed adjacent to the Southern Forebay Inlet and Outlet structures. Ramps would be a minimum of 15 feet wide and would be graded no steeper than 20 percent with reinforced concrete paving.
- A ramp would be constructed on the downstream face of the Southern Forebay embankments for access from the downstream embankment toe to the embankment crest. The ramp would be a minimum of 15 feet wide and graded no steeper than 20 percent.

- Parking areas would be provided adjacent to structures (e.g., inlet and outlet structures, emergency spillway). The parking areas would be configured and sized to accommodate traffic anticipated for maintenance activities or a minimum of two service vehicles.
- All permanent project roadways, ramps, and parking areas would be provided with "all weather" surfaces. The specific surface type (e.g., gravel, asphalt, concrete) would be based on anticipated traffic volumes and vehicle loads (to be developed during future design phases).

6.6.3 Public Safety

Signage and public outreach related to construction as well as post-construction conditions following completion of the forebay facilities would be developed, including:

- Warning/notification signage along existing public access corridors during construction.
- Warning signage near the spillway.
- Exclusion fencing.
- Spillway log booms.

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8. Document History and Quality Assurance

Reviewers listed have completed an internal quality review check and approval process for deliverable documents that is consistent with procedures and directives identified by the Engineering Design Manager and the DCA.

Approval Names and Roles			
Prepared by	**Internal Quality Control Review by**	**Consistency review by**	**Approved for Submission by**
Joe de Larios / Project Engineer	Craig Hall / EDM Senior Geotechnical Engineer Graham Bradner / DCA Executive Director	Gwen Buchholz / DCA Environmental Consultant	Terry Krause / EDM Project Manager

This interim document is considered preliminary and was prepared under the responsible charge of Joseph de Larios, California Professional Engineering License GE2349.

Note to Reader

This is an early foundational technical document. Contents therefore reflect the timeframe associated with submission of the initial and final drafts. Only minor editorial and document date revisions have been made to the current Conformed Final Draft for Administrative Draft Engineering Project Report version.