B.F. Sisk Dam Raise and Reservoir Expansion Project Feasibility Report

Appendices







SAN LUIS & DELTA-MENDOTA WATER AUTHORITY

BUREAU OF RECLAMATION

FINAL

December 2020

B.F. Sisk Dam Raise and Reservoir Expansion Project

Final Feasibility Report

Appendix A1: Modeling Technical Report



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RECLAMATION



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Attachment

Attachment A. CalSim II Assumptions for No Action Alternative Conditions
Attachment B. Comparison of No Action Alternative Conditions and Project Alternatives

Chapter 1 Background and Project Description

The purpose of the B.F. Sisk Dam Raise and Reservoir Expansion Project (Project) is to provide a suite of available alternatives for the Dam Raise Alternative being considered for the B.F. Sisk Safety of Dams Modification Project. The Crest Raise Action under the B.F. Sisk Safety of Dams Modification Project includes increasing the dam crest by 12 feet to reduce safety concerns for the downstream public by reducing the likelihood of overtopping if slumping were to occur during a seismic event (Reclamation, 2019). The Dam Raise Alternative would further increase the crest of the dam above the Safety of Dams project, which would allow for additional water supply storage in San Luis Reservoir above existing reservoir capacity. The increase in water supply storage (up to 130,000 acre-feet) would provide additional water supply reliability and greater operational flexibility for the project investors. The analysis investigated a number of alternatives to determine the water supply and operational effects of the project.

This technical appendix to the Feasibility Report and environmental documentation describes the modeling tools and assumptions used in analysis of the Project alternatives. The Feasibility Report evaluates several alternatives for the ability to satisfy project objectives/purpose and need. Each alternative was simulated in a model of the Central Valley Project (CVP) and State Water Project (SWP) to determine effects on water supply and project operations for the project investors and the project's effects to other areas of the CVP/SWP system. For each of the alternatives, model results from the CVP/SWP system model, CalSim II, were used as input to a spreadsheet post-processor model which simulated the storage, delivery, and accounting of rescheduled and/or carryover water supplies by CVP South-of-Delta contractors in San Luis Reservoir. Model results for each alternative were compared to results of a No Action Alternative (NAA) to quantify changes in water deliveries, reservoir storage levels, river flows, and CVP/SWP operations in the Sacramento-San Joaquin River Delta (Delta). Simulated incremental water deliveries were used in the economic analysis of each alternative, conducted as part of the Feasibility Report. Simulated reservoir storage, river flows, Delta outflow and Delta exports were used to evaluate relative environmental effects during preparation of the Environmental Impact Report/ Supplemental Environmental Impact Statement (EIR/SEIS). Key model results are summarized and presented in this report for each alternative.

In the EIR/SEIS, the Investor-Directed subalternative is presented with four operational configurations: Configuration A, Configuration B, Configuration C, and Configuration D. For this modeling analysis, Configurations A and B are presented in this modeling technical report under Investor-Directed Storage Alternative- Configuration A and B, with the upper target quantity of carried-over water in San Luis Reservoir of 180,000 acre-feet. Configurations C and D are presented in this modeling technical report under Investor-Directed Storage Alternative- Configuration C and D, with the upper target quantity of carried-over water in San Luis Reservoir of 310,000 acre-feet.

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Chapter 2 Water Operations Modeling

Water operations modeling is a key step in the analysis of the Project alternatives. Water operations model results frequently serve as the basis of subsequent economic and environmental analyses. This section provides brief descriptions of the models used to analyze the alternatives. Descriptions include model assumptions and modifications made to baseline model files provided by Reclamation. Model limitations for the analysis of the Project alternatives are also described.

2.1 Operations Models

Two models were used to analyze effects of the Project alternatives. CalSim II was used to simulate CVP/SWP operations, including San Luis Reservoir. Subsequent analyses tiered off the CalSim II results to simulate and analyze the operations of rescheduled and/or carryover water in San Luis Reservoir.

2.1.1 CalSim II

Water operations modeling of the CVP/SWP system was performed using CalSim II. CalSim II is a planning model designed to simulate operations of CVP and SWP reservoirs and water delivery systems. CalSim II simulates flood control operating criteria, water delivery policies, and in-stream flow and Delta outflow requirements. CalSim II is the best available tool for modeling CVP and SWP operations and is the primary system-wide hydrologic model used by California Department of Water Resources (DWR) and Reclamation to conduct planning and impact analyses of potential projects.

CalSim II is a simulation by optimization model. The model simulates operations by solving a mixed-integer linear program to maximize an objective function for each month of the simulation. CalSim II was developed by Reclamation and DWR to simulate operation of the CVP and SWP for defined physical conditions and a set of regulatory requirements. The model simulates these conditions using 82 years of hydrology from water year 1922 through 2003.

CalSim II modeling conducted for the B.F. Sisk Dam Raise and Reservoir Expansion Project was developed from a baseline model provided by Reclamation to the project team. The model provided is based on Alternative 1 developed by Reclamation for the Reinitiation of Consultation on the Long-Term Operation (ROConLTO) of the Central Valley Project and State Water Project (Reclamation, 2019). The model's input hydrology incudes historical hydrology projected to Year 2030 with climate change and with projected 2020 modifications for operations upstream of the rim reservoirs. Land use projections for this model are based on Year 2020 estimates for the Sacramento Valley, and draft Year 2030 estimates for the San Joaquin valley. Regulatory requirements imposed under Alternative 1 included all existing regulatory requirements, as well as actions detailed in the 2019 USFWS and the 2019 NOAA Fisheries Biological Opinions (BO) for delta smelt and listed salmonid species, respectively (USFWS 2019, NOAA Fisheries 2019). The baseline model also includes the changes to operating criteria and requirements put in place under the 2018

Coordination Operations Agreement (COA) Addendum. Additional key assumptions governing CVP/SWP operations in CalSim II are described in Attachment A.

2.1.2 Modifications to Reclamation CalSim II Baselines

The baseline model provided by Reclamation required modifications for use in evaluating operations under the Project alternatives. The follow sections describe key changes.

2.1.2.1 San Luis Reservoir Expansion

The most significant modification to the baseline model provided by Reclamation was to increase the maximum storage allowed in San Luis Reservoir by 130,000 acre-feet. This modification was made for the CVP-Only and CVP/SWP Shared Storage alternatives. For the Shared Storage alternative, the 130,000 acre-feet increase was split between CVP/SWP storage using the existing storage split of approximately 48% CVP and 52% SWP. For the Shared Expansion, this resulted in an increase to the maximum storage in CVP San Luis of 62,000 acre-feet and an increase to the maximum storage in SWP San Luis of 68,000 acre-feet.

Although changes were not explicitly made to San Luis operations or to the "rulecurve" in CalSim II, the increase to the maximum allowed storage does result in operational changes to San Luis Reservoir and throughout the CVP/SWP system.

2.1.2.2 Fixed CVP North of Delta Allocations and Trinity Imports

For the CVP-Only and Shared Storage alternatives, CalSim II was modified to fix water supply allocations for North-of-Delta CVP Ag Service and M&I contractors to the allocations developed in the NAA. Initial model simulations with the expanded San Luis Reservoir resulted in impacts to North-of-Delta reservoir operations and deliveries that would oscillate from year-to-year and that were larger volumetrically than the incremental increase in San Luis Reservoir storage available from the B.F. Sisk Dam Raise and Reservoir Expansion Project. Given the small volume of the B.F. Sisk Dam Raise and Reservoir Expansion Project (130,000 acre-feet) relative to the rest of the CVP/SWP system, it would be expected that the effects to North-of-Delta operations and deliveries would be small to nonexistent. As such, CVP North-of-Delta Ag Service and M&I allocations, as well as Trinity imports, were fixed to the model output from the NAA baseline for the CVP-Only and Shared Storage alternatives.

2.1.2.3 CVP South-of-Delta Ag and M&I Allocations

Despite fixing the CVP North-of-Delta allocations and Trinity imports to the NAA baseline output, there was still an unacceptable level of sensitivity to both North-of-Delta and South-of-Delta CVP operations and deliveries. It was determined that the allocation logic in the model was not adequately sensitive enough to balance the relatively small increase in supply (130,000 acre-feet) available from the B.F. Sisk Dam Raise and Reservoir Expansion Project. Accordingly, additional logic was added to the model that set CVP South-of-Delta allocations for Ag Service and M&I contractors to be a minimum of the allocations output from the NAA baseline, and could only be increased by the proportional change in the Water Supply Index (WSI) relative to the South-of-Delta CVP Ag Service and M&I demands. Despite these changes to the model code, deliveries to CVP South-of-Delta Ag Service and M&I were still unrealistically low in several years. As such, allocations were manually adjusted in 7 years for CVP South-of-Delta Ag Service and in 2 years for CVP South-of-Delta M&I.

The changes made to CVP South-of-Delta allocations resulted in minor effects on the CVP/SWP system as a whole, but resulted in a more efficient and realistic operation of San Luis Reservoir and CVP South-of-Delta Ag Service and M&I contractor deliveries.

2.1.3 Level of Development

CalSim II simulations at a Year 2030 Level of Development (LOD) are used to depict how the modeled water system might operate with an assumed physical and institutional configuration imposed on a long-term hydrologic sequence (Reclamation, 2019). A future LOD study is needed to explore how the system may perform under an assumed future set of physical and institutional conditions. This future setting is developed by assuming year 2030 land use, facilities, and operational objectives and is used for the No Action Alternative (NAA) Condition for the National Environmental Policy Act (NEPA) analysis.

A NAA CalSim II simulation depicts how the Delta, its major tributaries, and the CVP/SWP may operate in the future without the Project. Areas tributary to the Delta have experienced numerous physical and institutional changes over the decades, and are continuing to experience change. Projecting the availability of facilities, institutional, and regulatory requirements, and the practices that will affect the management of future water supplies and demands is a daunting task. Nevertheless, reasonable assumptions must be made regarding these items to estimate future conditions. These assumptions include actions from the 2019 USFWS and the 2019 NOAA Fisheries Biological Opinions (BO) for delta smelt and listed salmonid species, respectively and the 2018 COA Addendum.

2.1.4 CalSim II Limitations

There are limitations to the use of CalSim II for most projects. A key limitation for the B.F. Sisk Dam Raise and Reservoir Expansion Project analysis is the ability to adequately simulate San Luis Reservoir operations. CalSim II is the only available model that adequately simulates the integrated operations of the CVP and SWP both north and south of the Delta; therefore, it is relied upon as the foundation of most studies that affect CVP/SWP operations. However, CalSim II was developed primarily to simulate reservoir operations upstream of the Delta, Delta conditions and exports. CalSim II does not consider several variables that affect San Luis Reservoir storage. An understanding of the limitations of CalSim II for the analysis of the Project alternatives is necessary to properly characterize results.

One method for evaluating model adequacy is to compare model results with observed data. Unfortunately, this method is no longer appropriate for CalSim II and San Luis Reservoir storage. CalSim II assumptions for the No Action Alternative include actions in the 2019 USFWS and the 2019 NOAA Fisheries BOs, as well as actions resulting from the 2018 COA addendum. Both the BOs and the COA Addendum affect the coordinated operations of the CVP/SWP, and requirements contained in each can result in significant operational changes, including changes in upstream reservoir release, the ability to move water through the Delta, and the operation of both the CVP and SWP portions of San Luis Reservoir. CVP operators have been operating to the requirements under the BOs since February 2020 and the requirements under the COA Addendum since December 2018. The CalSim II simulation period does not include the historical hydrology for this period, nor do we have sufficient observed data to make any type of comparison. Therefore, there is no common period between the model and observed data under a similar regulatory condition. Furthermore, a comparison of historical San Luis Reservoir storage and simulated

storage under the BOs and COA Addendum would illustrate the change in regulatory requirements but would not be useful for understanding model limitations.

2.2 Rescheduled Water Operations Post-Processor

CalSim II does not currently include logic to simulate the storage, delivery, and accounting of rescheduled water in San Luis Reservoir by CVP South-of-Delta Ag Service and M&I contractors. In actual operations, CVP San Luis storage often includes rescheduled or other non-Project stored water, which can reduce the frequency of CVP San Luis Reservoir reaching deadpool, as well as provide an important water supply in dry and critical years for many CVP South-of-Delta contractors. As these operations can affect and be an important component of San Luis Reservoir operations, particularly in drier years, it was determined to be necessary to model rescheduled water in San Luis Reservoir for the Project alternatives.

For this project and analysis, it was deemed most efficient to model the rescheduled water operations in a post-processor spreadsheet. The reasons for this are twofold: First, Reclamation policy indicates that rescheduled water operations should not impact or interfere with CVP operations or deliveries. As such, tracking rescheduled water is more of an accounting exercise since system conditions North-of-Delta and in the Delta should have minimal to no changes if rescheduled water is modeled or not. Secondly, the post-processor spreadsheet provided a quick and efficient platform to evaluate a number of alternatives and model assumptions.

The post-processor was developed to use CalSim II model output as input for North-of-Delta and Delta operations and available water supply. The post-processor simulates rescheduled water storage, delivery, and accounting. The post-processor uses several input parameters and assumptions to determine the annual volumes of water to reschedule by Ag Service and M&I contractors, and the patterns of rescheduled water accumulation (storage) and delivery. The input patterns and parameters were developed by reviewing the historical rescheduled water data, as well as any necessary adjustments to ensure compliance with Reclamation's existing rescheduled water guidelines and requirements.

2.2.1 Historical Rescheduled Water Operations

An understanding of historical CVP South-of-Delta rescheduled operations and accounting were reviewed to provide supplemental information to accompany the CalSim II modeling results, as well as to inform the development of the operations logic and parameters in the post-processor. Figure 2-1 shows historical CVP San Luis Reservoir storage conditions at the end of February for the years 2010 through 2019. As the figure shows, rescheduled water is present in CVP San Luis in almost all of these years, and in some cases can make up a large portion of total CVP San Luis storage. The figure also demonstrates the ability contractors have to reschedule additional, non-Project supplies, such as transfer water.

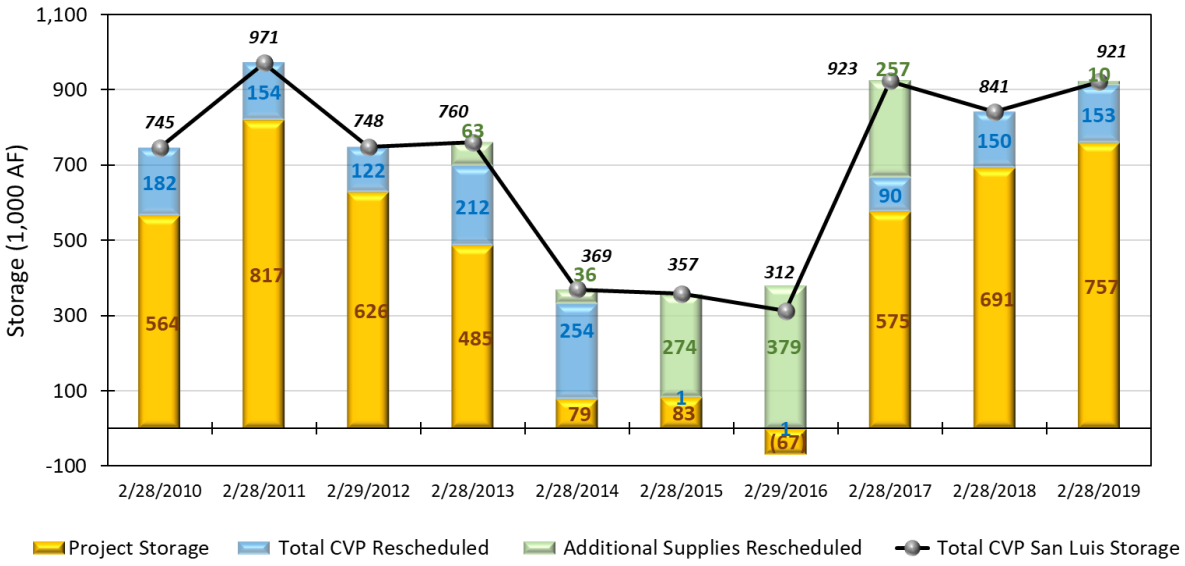


Figure 2-1. Historical CVP San Luis Reservoir End of February Storage

Reviewing February CVP San Luis storage provides the most useful insight into rescheduled water operations and accounting, as February is the last month of the contract year for most CVP contractors. Water in CVP San Luis is typically not considered rescheduled until the end of February, when contractors will unlikely be able to use their remaining project supplies for the current contract year. Additionally, looking at the rescheduled water volumes in February is useful to compare against the volumes of foregone pumping determined by Reclamation. Foregone pumping occurs when CVP exports are reduced as a result of the presence of rescheduled water in San Luis limiting the available CVP South-of-Delta capacity. When foregone pumping occurs, the corresponding volumes of rescheduled water are "spilled" and converted to CVP Project supply. Within the last 10 years, foregone pumping has occurred in 3 years (2011, 2017, and 2019), in volumes ranging from approximately 60,000 acre-feet to 160,000 acre-feet annually.

Additional analysis of the historical rescheduled water data indicated that on average approximately 98% of the water rescheduled in a given year is by CVP South-of-Delta Agricultural Service contractors, while approximately 2% is rescheduled by CVP South-of-Delta M&I contractors. Unless otherwise indicated (e.g. the Investor-Owned Alternatives), it was assumed for each of the alternatives in the SLE study that the volumes of water rescheduled in each year and subsequently delivered were comprised of 98% CVP South-of-Delta Ag Service project water and 2% CVP M&I project water.

2.2.2 Additional South-of-Delta Water Supplies

For this analysis the assumptions, patterns, and parameters used for the rescheduling operations were developed to include and account for a variety of water supplies that CVP South-of-Delta contractors use to complement their CVP project supplies. The availability of these additional water supplies can affect the annual volumes and the patterns of storage and use of rescheduled water by each contractor. These additional supplies may include transfer water from North-of-Delta or

South-of-Delta, groundwater pump-in supplies from the Mendota Pool, Delta-Mendota Canal exchanges, and several others.

However, actual operations and rescheduled use and storage patterns vary from year to year and from contractor to contractor. For this analysis, a generalized set of rules and parameters were used to simulate rescheduled water operations for CVP Ag Service and M&I contractors as a whole. As such, it was determined to not be necessary to include an explicit representation of the additional water supplies in the post-processor, but rather use the historical delivery volumes and patterns of these sources to help define the representation of rescheduled water operations in the post-processor.

2.2.3 Post-Processor Delivery Reduction Refinements

Additional refinements were included in the post-processor to limit delivery reductions under the Project alternatives to South-of-Delta SWP. The calculations developed assessed reductions in SWP exports and attempted to avoid those reductions (compared to the NAA) by reducing any corresponding increase in CVP exports. SWP exports were attempted to be adjusted to levels in the NAA, with any changes to SWP exports first used to supplement reductions to Table A deliveries, with any remaining changes used to supplement Article 21 deliveries and SWP San Luis storage, in that order. Any changes to CVP exports were assumed to make a one-to-one increase or decrease in South-of-Delta CVP Ag deliveries, with any remaining changes applied to CVP San Luis Storage. Overall reductions to SWP Table A and Article 21 deliveries were avoided but not completely eliminated. In actual operations under the Project, such an operation could be achieved by operating CVP exports using the existing operational criteria during times when the Project might allow for revised CVP exports that could result in a subsequent reduction in SWP South-of-Delta deliveries.

Chapter 3 No Action Alternative

The following section describes the No Action Alternative (NAA) and summarizes key model results for the alternative.

3.1 No Action Conditions

Results from the NAA simulation are used to depict operation of the CVP and SWP without Project alternatives at a future level of development. NAA results are used in a comparative sense with results from the Project alternatives to quantify changes in CVP/SWP operations. Operation of San Luis Reservoir and changes in deliveries to CVP South-of-Delta contractors and are key results for the NAA simulation. To provide an appropriate comparison for the alternatives, CalSim II output from the NAA was input to the post-processor to simulate rescheduled water operations. The results for the NAA with and without rescheduled water are summarized in the following figures and tables.

3.1.1 San Luis Reservoir

Figure 3-1 illustrates the probability of annual maximum and minimum total San Luis Reservoir storage for the NAA and NAA with rescheduled water simulations. The inclusion of rescheduled water results in higher annual maximum and minimum storages in almost all years, and a 2% increased probability of filling the reservoir.

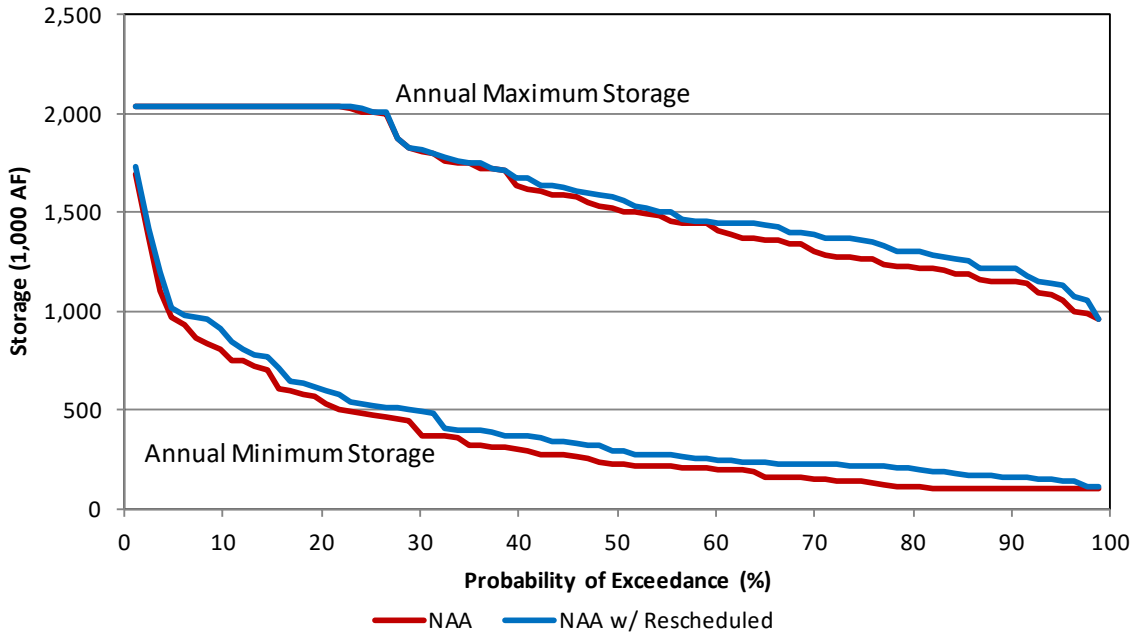


Figure 3-1. Probability of Annual Maximum and Minimum Total San Luis Reservoir Storage

Figure 3-2 illustrates the probability of annual maximum and minimum CVP San Luis Reservoir storage for the NAA and NAA with rescheduled water simulations. Results demonstrate that the presence of rescheduled water results in higher maximum and minimum storage in nearly all years, a 16% increase in the probability of filling CVP San Luis, and a 24% decrease in the probability of CVP San Luis reaching deadpool.

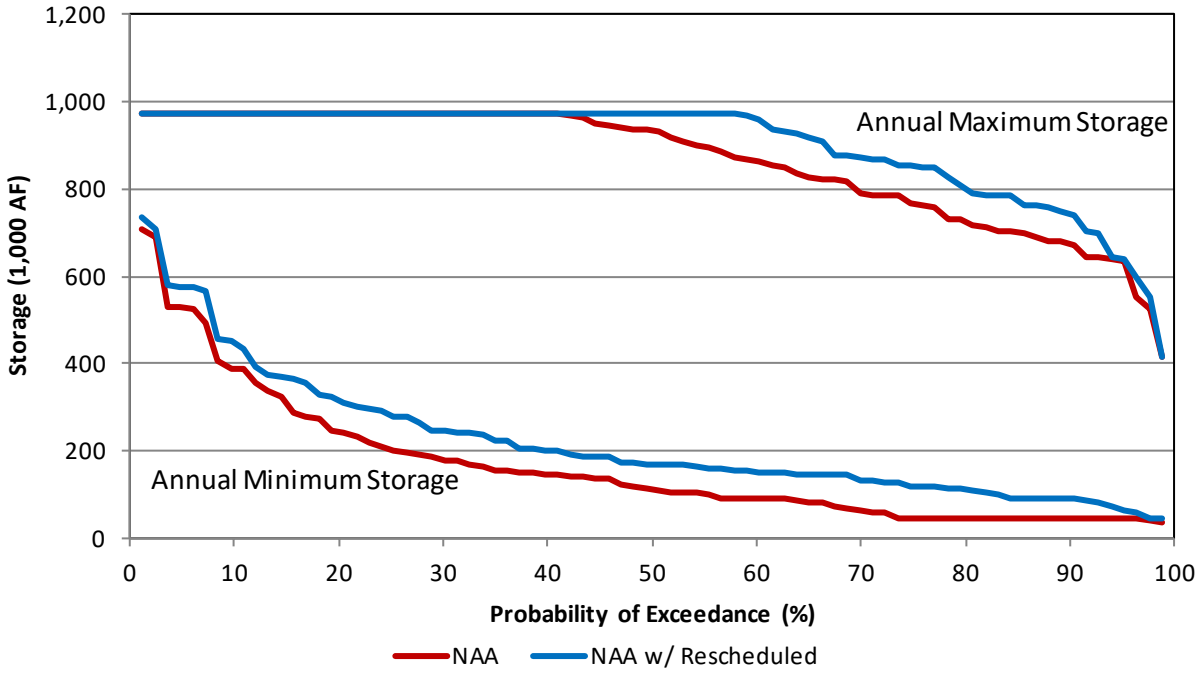


Figure 3-2. Probability of Annual Maximum and Minimum CVP San Luis Reservoir Storage

Figure 3-3 illustrates the probability of annual maximum and minimum SWP San Luis Reservoir storage for the NAA and NAA with rescheduled water simulations. Results demonstrate that the presence of rescheduled water results in no effect on SWP San Luis storage, and the probabilities of annual maximum (22% probability of filling) and minimum (50% probability of reaching deadpool) SWP San Luis are the same between the two simulations.

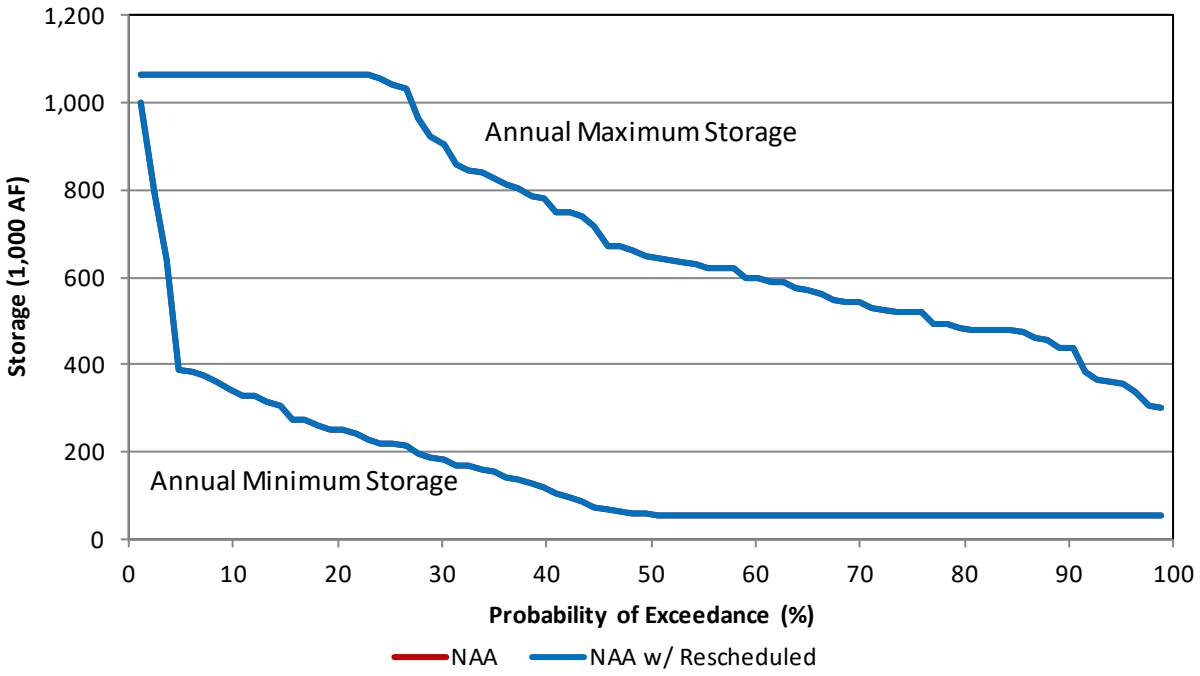


Figure 3-3. Probability of Annual Maximum and Minimum SWP San Luis Reservoir Storage

Storage and delivery of rescheduled water results in changes to average annual deliveries to CVP South-of-Delta Ag Service and M&I contractors, as some water supply is shifted from wetter years to drier years, and some supply is lost due to "foregone pumping".

3.1.2 CVP South-of-Delta Deliveries

Table 3-1 is a summary of average annual CVP South-of-Delta deliveries for the NAA by Sacramento Valley water year index, with Ag Service and M&I deliveries also shown for the NAA with rescheduled water. The inclusion of rescheduled water results in no change to Exchange Contractor or CVP South-of-Delta Refuge deliveries, as Reclamation's rescheduled water guidelines and policy require that rescheduled supplies not affect or interfere with CVP operations and deliveries.

Table 3-1. Average Annual CVP South-of-Delta Deliveries by Water Year Index

Sacramento Valley Water Year Index (TAF)	Exchange Contractors and Schedule II WR	South-of-Delta Refuge	Ag Service	M&I	Total South-of-Delta	Ag Service*	M&I*	Total South-of-Delta*
Wet	875	274	1,601	141	3,074	1,478	139	2,948
Above Normal	875	260	1,184	125	2,626	1,133	124	2,566
Below Normal	856	274	943	120	2,374	900	119	2,330
Dry	875	281	667	111	2,117	694	111	2,144
Critical	741	234	302	95	1,555	321	95	1,574
All Years	853	268	1,029	122	2,453	985	121	2,409

*NAA with rescheduled water

The implementation of rescheduled water operations also requires the need to account for foregone Delta pumping of CVP supplies. As noted in Chapter 2, foregone pumping occurs when rescheduled water is present in CVP San Luis and CVP Delta exports are reduced due to lack of CVP South-of-Delta capacity/storage space to export water. Foregone pumping results in the "spill" of rescheduled water and conversion of that supply to CVP project supply. Table 3-2 summarizes the average annual average foregone Delta pumping volumes by water year index under the NAA when rescheduled water operations are included in the simulation.

Table 3-2. Average CVP Foregone Pumping in the NAA from Rescheduled Water Operations

Sacramento Valley Index	Foregone Pumping (TAF)
Wet	95
Above Normal	15
Below Normal	29
Dry	26
Critical	5
All Years	43

3.1.3 SWP South-of-Delta Deliveries

Table 3-3 is a summary of average annual SWP deliveries for the NAA by Sacramento Valley water year index. Foregone pumping of CVP supply resulting from rescheduled water supplies allows for small increases to SWP exports. However, nearly all of the increase occurs at times that SWP San Luis is full, which results in no change to SWP Table A or Article 56 supplies.

Table 3-3. Average Annual SWP Deliveries by Water Year Index

Sacramento Valley Water Year Index (TAF)	Table A	Article 56	Article 21	Total SWP	Article 21 *	Total SWP*
Wet	3,241	86	107	4,361	125	4,379
Above Normal	2,663	49	70	3,762	76	3,768
Below Normal	2,604	83	29	3,768	29	3,768
Dry	1,866	54	42	2,956	42	2,956
Critical	1,117	19	32	1,992	32	1,992
All Years	2,418	62	64	3,497	71	3,504

*NAA with rescheduled water

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Chapter 4 Non-Structural Alternative

The Non-Structural Alternative would involve operational measures to be implemented by Reclamation that would contribute to the San Luis Expansion project's water supply reliability objective. In the Non-Structural Alternative, Reclamation would change its annual allocation process to reserve up to 310,000 acre-feet of stored CVP supply in San Luis Reservoir at the end of wetter years. This water would be reserved in San Luis Reservoir for CVP South-of-Delta project use and delivery in subsequent drier years. Under this operational configuration, allocated water supply not used by CVP contractors could not be rescheduled for use in a subsequent year.

4.1 Modeling Approach and Assumptions

For the Non-Structural Alternative, the NAA CalSim II model run was input to the post-processor and CVP allocations were reduced in wetter years to reserve up to 310,000 acre-feet for CVP South-of-Delta project use and delivery in drier years. Although the result shown below largely affect CVP South-of-Delta Ag deliveries, this operation is developed based on the CVP M&I shortage policy. Additionally, since this reserved water is a "CVP project supply", water reserved in one year under a particular supply (e.g. Ag Service, M&I, etc.) could be used to meet a different demand in a subsequent year (e.g. Exchange Contractor or Refuge delivery shortages, maintain compliance with CVP M&I shortage policy, or for delivery to meet Ag Service or M&I demands). All other parameters and assumptions for this alternative are identical to those used in the NAA.

Changes and effects on system conditions and deliveries for this alternative are largely identical to those seen under the NAA. Any changes to upstream operations or Delta conditions from the Non-Structural Alternative would not be expected.

4.2 Non-Structural Alternative Results

The Non-Structural Alternative was analyzed over an 82-year period to estimate the changes to the CVP/SWP system. The following sections summarize the effects of the alternative on San Luis Reservoir, CVP and SWP South-of-Delta deliveries, and the CVP/SWP system as a whole. Results are shown in a comparative sense between the Non-Structural Alternative and the NAA.

4.2.1 San Luis Reservoir

Figure 4-1 shows the probability of annual maximum and minimum Total San Luis Reservoir Storage. As demonstrated in the figure, annual maximum storage is equal to or greater than total storage in the NAA for all years. San Luis fills to the maximum storage in approximately 20% of years. Annual minimum storage is also equal to or greater than total storage under the NAA for all years.

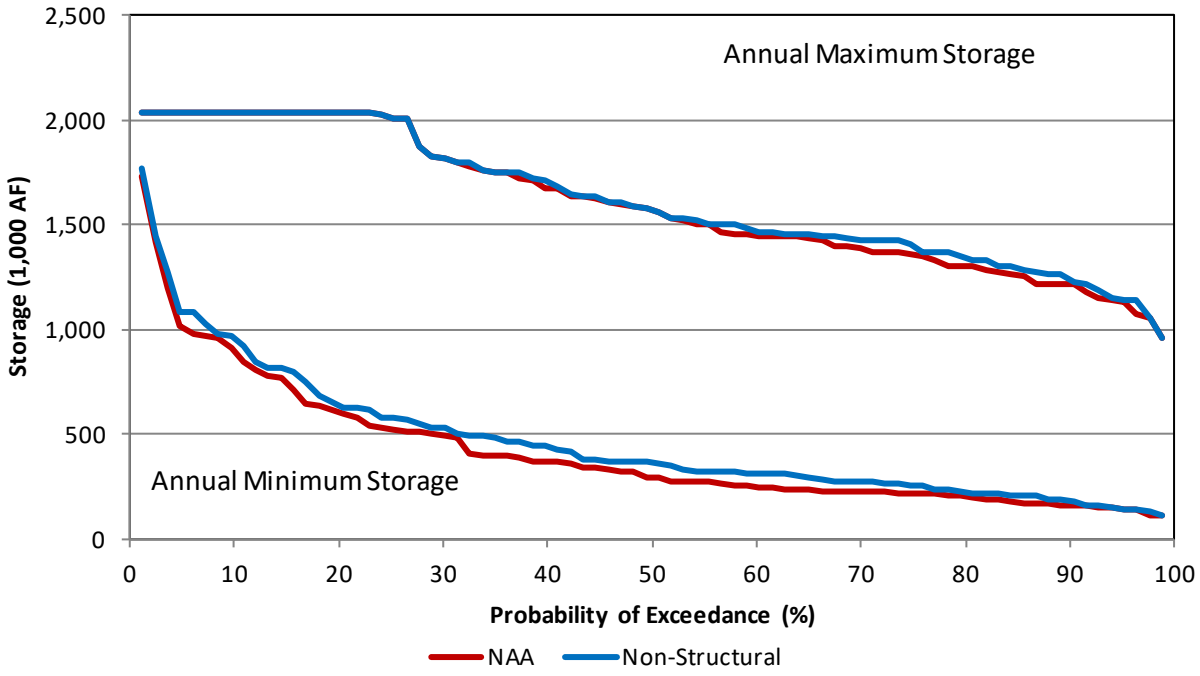


Figure 4-1. Probability of Annual Maximum and Minimum Total San Luis Reservoir Storage

Figure 4-2 shows the probability of annual maximum and minimum CVP San Luis Storage. The annual minimum storage is higher in the top 85% of years and identical to the NAA in the bottom 15% of years. CVP San Luis fills to the maximum capacity in approximately 65% of years, and the annual maximum storage is equal to or greater than storage under the NAA. The increased CVP San Luis storage under the Non-Structural Alternative is a function of the operational objective of the alternative, which seeks to reserve additional supplies in wetter years to improve CVP supplies for project use and delivery in drier years.

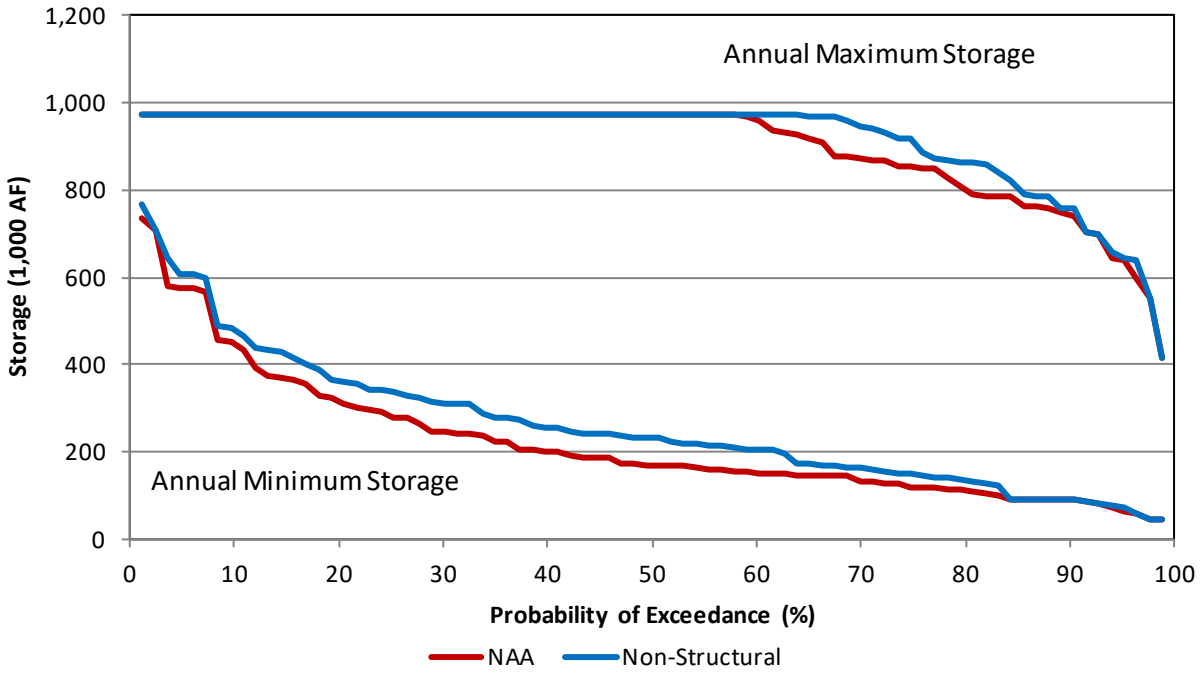


Figure 4-2. Probability of Annual Maximum and Minimum CVP San Luis Reservoir Storage

Effects to SWP San Luis Storage are minimal to non-existent, as any increase to SWP exports from CVP foregone pumping is immediately used as Article 21 supply or for small increases to Table A supplies. Given the lack of change to SWP San Luis storage, please refer to Figure 3-3 for the probability of exceedance for the annual minimum and maximum SWP San Luis Storage.

4.2.2 CVP South-of-Delta Deliveries

As noted above, the Non-Structural Alternative seeks to improve CVP South-of-Delta water supply reliability in drier years by reserving supplies in wetter years. Under this alternative there is no change to CVP Exchange Contractor or CVP South-of-Delta Refuge deliveries. Table 4-1 shows the average change in CVP South-of-Delta Ag Service deliveries by water year index for the NAA, the Non-Structural Alternative, and the change from the NAA. The increase in foregone pumping results in a loss of supply in many years, which results in a reduction in deliveries on an annual average basis and in Wet, Above Normal, and Below Normal water years. The Non-Structural Alternative results in small increases to deliveries in Dry and Critical years. Overall, the Non-Structural Alternative results in a decrease to the annual average deliveries for South-of-Delta Ag Service contractors of 44,000 acre-feet.

Table 4-1. Average CVP South-of-Delta Ag Service Deliveries with Non-Structural Alternative

Sacramento Valley Index	No Action Alternative (TAF)	Non-Structural Alternative (TAF)	Change from NAA (TAF)
Wet	1,478	1,386	-93
Above Normal	1,133	1,085	-48
Below Normal	900	851	-48
Dry	694	695	2
Critical	321	326	5
All Years	985	941	-44

Table 4-2 shows the average change in CVP South-of-Delta M&I deliveries by water year index for the NAA, the Non-Structural Alternative, and the change from the NAA. Deliveries in dry and critical years are maintained, while deliveries on an annual average basis decrease by approximately 1,000 acre-feet. The relatively minor decrease to South-of-Delta M&I contractors is a result of the portion of M&I supply used as part of the potential 310 TAF CVP reserve supply. M&I supplies only make up 2% of the total reserve supply, and thus impacts to deliveries under this alternative are minimal.

Table 4-2. Average CVP South-of-Delta M&I Deliveries with Non-Structural Alternative

Sacramento Valley Index	No Action Alternative (TAF)	Non-Structural Alternative (TAF)	Change from NAA (TAF)
Wet	139	137	-2
Above Normal	124	124	0
Below Normal	119	118	-1
Dry	111	111	0
Critical	95	95	0
All Years	121	120	-1

Table 4-3 shows the average change in CVP foregone Delta pumping by water year index for the NAA, the Non-Structural Alternative, and the change from the NAA. Overall, the annual average volume of foregone pumping increases by 44,000 acre-feet under the Non-Structural Alternative. The increase in foregone pumping from the NAA is a result of the increase in carryover storage in CVP San Luis. The increase in foregone pumping under the Non-Structural Alternative results in some minor increases to SWP exports and Delta outflow.

Table 4-3. Average CVP Foregone Pumping with Non-Structural Alternative

Sacramento Valley Index	No Action Alternative (TAF)	Non-Structural Alternative (TAF)	Change from NAA (TAF)
Wet	95	186	91
Above Normal	15	43	28
Below Normal	29	45	16
Dry	26	54	28
Critical	5	9	5
All Years	43	87	44

4.2.3 SWP South-of-Delta Deliveries

As discussed above, the increase in CVP foregone Delta pumping under the Non-Structural Alternative results in occasional increases to SWP Delta exports. For the most part, this occurs during surplus conditions for the SWP and thus results in an increase to Article 21 supplies. However, this can also potentially result in very minor increases in available Table A supply. Table 4-4 shows average SWP Table A deliveries by water year index for the NAA, the Non-Structural Alternative, and the change from the NAA. Annual average deliveries increase in only handful of years types, resulting in an annual average increase of approximately 1,000 acre-feet.

Table 4-4. Average SWP Table A Deliveries with Non-Structural Alternative

Sacramento Valley Index	No Action Alternative (TAF)	Non-Structural Alternative (TAF)	Change from NAA (TAF)
Wet	3,241	3,241	0
Above Normal	2,663	2,664	0
Below Normal	2,604	2,607	3
Dry	1,866	1,866	0
Critical	1,117	1,120	3
All Years	2,418	2,419	1

As changes to Table A deliveries are small to non-existent in most years, changes to SWP Article 56 deliveries are not expected. The increase in CVP foregone pumping does allow for some additional delivery of Article 21 supplies. Table 4-5 shows average SWP Article 21 deliveries by water year index for the NAA, the Non-Structural Alternative, and the change from the NAA. Overall, annual average Article 21 deliveries increase by approximately 2,000 acre-feet.

Table 4-5. Average SWP Article 21 Deliveries with Non-Structural Alternative

Sacramento Valley Index	No Action Alternative (TAF)	Non-Structural Alternative (TAF)	Change from NAA (TAF)
Wet	125	131	6
Above Normal	76	77	1
Below Normal	29	29	0
Dry	42	42	0
Critical	32	32	0
All Years	71	73	2

4.2.4 CVP/SWP Effects

The Non-Structural Alternative can create small changes in CVP/SWP operations beyond just San Luis Reservoir and the contractors who take delivery of water from the reservoir. These changes have the potential to affect resources in other parts of the system. Therefore, changes in river flows, reservoir storage, Delta outflow, and Delta export operations were quantified and reviewed in support of the environmental documentation. The following tables provide a high-level summary of changes throughout the CVP/SWP system. North of the Delta operations are identical to the NAA, which is expected given that the only change to operations involves CVP San Luis storage objectives and subsequent changes to CVP and SWP Delta exports from foregone CVP Delta pumping. The increase in foregone CVP Delta pumping results in minor changes to Banks pumping and Delta outflow. The only notable difference to overall system conditions is the change in CVP San Luis storage, which is largely expected given the operational objectives of the Non-Structural Alternative. More detailed results were provided and reviewed by resource area specialists and are illustrated in figures located in Attachment B. Table 4-6 provides a summary of the average monthly model results at key locations in the system under the Non-Structural Alternative.

Table 4-6. Summary of Non-Structural Alternative CVP/SWP System Effects

NAA	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Delta Outflow (cfs)	6,747	8,920	25,033	45,224	57,590	45,403	28,838	18,412	11,414	7,966	4,734	6,789
Jones Pumping Plant (cfs)	3,131	3,607	3,609	3,663	3,776	2,968	2,624	2,857	2,957	2,541	3,304	3,237
Banks Pumping Plant (cfs)	2,804	4,981	4,531	3,471	4,065	3,360	3,224	2,485	2,459	5,164	4,527	2,375
Sac. River into Delta (cfs)	11,032	14,332	23,913	31,758	38,755	33,218	24,685	18,640	16,098	17,261	13,487	11,726
Yolo Bypass (cfs)	120	588	4,907	12,219	16,420	9,543	2,664	211	88	50	101	72
Sac. River below Keswick (cfs)	6,412	6,261	7,807	9,378	11,457	8,860	5,702	8,122	10,305	12,822	9,551	6,332
Sac. River at NCP (cfs)	6,612	7,660	11,671	13,838	15,439	14,108	10,528	6,843	6,231	6,743	4,828	6,008
Feather R. blw Thermalito (cfs)	2,209	2,019	3,293	4,898	5,900	6,528	3,070	3,758	4,041	6,964	4,995	1,750
Lower Feather River (cfs)	2,725	2,966	6,101	12,048	14,038	13,835	8,730	7,541	5,948	7,021	5,656	3,417
American R blw Nimbus (cfs)	1,387	2,464	3,938	5,062	6,093	4,356	3,337	3,031	2,837	2,588	1,948	1,681
American R at H St (cfs)	1,230	2,311	3,796	4,899	5,895	4,152	3,057	2,728	2,459	2,125	1,595	1,452
SJ River at Vernalis (cfs)	2,668	2,607	3,368	5,109	6,793	7,290	7,511	5,980	4,099	2,616	1,828	2,213
Shasta Storage (TAF)	2,616	2,626	2,791	3,062	3,330	3,666	3,996	3,961	3,637	3,127	2,822	2,713
Oroville Storage (TAF)	1,672	1,651	1,788	2,019	2,293	2,504	2,768	2,844	2,653	2,189	1,875	1,779
Folsom Storage (TAF)	456	443	468	487	501	593	716	823	760	629	545	493
CVP San Luis Storage (TAF)	290	421	574	715	826	882	874	795	606	372	246	254
SWP San Luis Storage (TAF)	183	251	310	452	593	670	705	628	471	427	344	215
Non-Structural	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Delta Outflow (cfs)	6,755	8,940	25,130	45,311	57,805	45,618	28,867	18,410	11,414	7,966	4,734	6,789
Jones Pumping Plant (cfs)	3,123	3,587	3,512	3,560	3,554	2,732	2,590	2,859	2,957	2,541	3,304	3,237
Banks Pumping Plant (cfs)	2,804	4,981	4,531	3,486	4,071	3,381	3,229	2,485	2,459	5,164	4,527	2,375
Sac. River into Delta (cfs)	11,032	14,332	23,913	31,758	38,755	33,218	24,685	18,640	16,098	17,261	13,487	11,726
Yolo Bypass (cfs)	120	588	4,907	12,219	16,420	9,543	2,664	211	88	50	101	72
Sac. River below Keswick (cfs)	6,412	6,261	7,807	9,378	11,457	8,860	5,702	8,122	10,305	12,822	9,551	6,332
Sac. River at NCP (cfs)	6,612	7,660	11,671	13,838	15,439	14,108	10,528	6,843	6,231	6,743	4,828	6,008
Feather R. blw Thermalito (cfs)	2,209	2,019	3,293	4,898	5,900	6,528	3,070	3,758	4,041	6,964	4,995	1,750
Lower Feather River (cfs)	2,725	2,966	6,101	12,048	14,038	13,835	8,730	7,541	5,948	7,021	5,656	3,417
American R blw Nimbus (cfs)	1,387	2,464	3,938	5,062	6,093	4,356	3,337	3,031	2,837	2,588	1,948	1,681
American R at H St (cfs)	1,230	2,311	3,796	4,899	5,895	4,152	3,057	2,728	2,459	2,125	1,595	1,452
SJ River at Vernalis (cfs)	2,668	2,607	3,368	5,109	6,793	7,290	7,511	5,980	4,099	2,616	1,828	2,213
Shasta Storage (TAF)	2,616	2,626	2,791	3,062	3,330	3,666	3,996	3,961	3,637	3,127	2,822	2,713
Oroville Storage (TAF)	1,672	1,651	1,788	2,019	2,293	2,504	2,768	2,844	2,653	2,189	1,875	1,779
Folsom Storage (TAF)	456	443	468	487	501	593	716	823	760	629	545	493
CVP San Luis Storage (TAF)	341	478	628	765	863	901	887	802	606	387	279	300
SWP San Luis Storage (TAF)	183	251	310	452	593	670	705	628	471	427	344	215
Change from NAA	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Delta Outflow (cfs)	8	20	97	88	216	215	29	-2	0	0	0	0
Jones Pumping Plant (cfs)	-8	-20	-97	-103	-222	-236	-34	2	0	0	0	0
Banks Pumping Plant (cfs)	0	0	0	15	6	21	5	0	0	0	0	0
Sac. River into Delta (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Yolo Bypass (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Sac. River below Keswick (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Sac. River at NCP (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Feather R. blw Thermalito (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Lower Feather River (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
American R blw Nimbus (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
American R at H St (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
SJ River at Vernalis (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Shasta Storage (TAF)	0	0	0	0	0	0	0	0	0	0	0	0
Oroville Storage (TAF)	0	0	0	0	0	0	0	0	0	0	0	0
Folsom Storage (TAF)	0	0	0	0	0	0	0	0	0	0	0	0
CVP San Luis Storage (TAF)	51	57	54	50	38	19	14	7	0	15	33	46
SWP San Luis Storage (TAF)	0	0	0	0	0	0	0	0	0	0	0	0

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Chapter 5 CVP-Only Storage Alternative

The CVP-Only Storage Alternative includes a 130,000 acre-feet increase to the maximum CVP San Luis Reservoir storage. The additional storage in San Luis Reservoir would be Reclamation-owned and would be operated consistent with existing CVP operations and requirements. The new reservoir capacity would be used to store previously stored CVP project water, rescheduled water, and some additional Delta surplus. The maximum quantity of rescheduled water and rescheduling parameters are the same as applied in the NAA.

5.1 Modeling Approach and Assumptions

For the CVP-Only Storage Alternative, the maximum storage size of CVP San Luis was increased by 130,000 acre-feet. No other changes were made to San Luis operations or "rulecurve" logic in CalSim II. As detailed in Chapter 2, for the CVP-Only Storage Alternative, CVP North-of-Delta Ag Service and M&I allocations were fixed to equal allocations made in the NAA. Additionally, Trinity imports were fixed to equal imports made in NAA, along with the refinements to CVP South-of-Delta Ag Service and M&I allocations that were detailed in Chapter 2.

CalSim II output for the CVP-Only Storage alternative were also input to the post-processor to assess the effects of rescheduled water on the CVP-Only Storage Alternative operations and deliveries. The rescheduled water operational assumptions and parameters used in the post-processor for the CVP-Only Storage Alternative are identical to those used in the NAA.

5.2 CVP-Only Storage Alternative Results

The CVP-Only Storage Alternative was analyzed over an 82-year period to estimate the changes to the CVP/SWP system. The following sections summarize the effects of the alternative on San Luis Reservoir, CVP and SWP South-of-Delta deliveries, and the CVP/SWP system as a whole. Results are shown in a comparative sense between the CVP-Only Alternative and the NAA, both of which include rescheduled water operations.

5.2.1 San Luis Reservoir

Figure 5-1 shows the probability of annual maximum and minimum Total San Luis Reservoir Storage. As demonstrated in the figure, annual maximum storage is equal to or greater than total storage in the NAA for nearly all years. San Luis fills to the new maximum storage in approximately 15% of years. Annual minimum storage is essentially equal to or greater than the total storage under the NAA for all years.

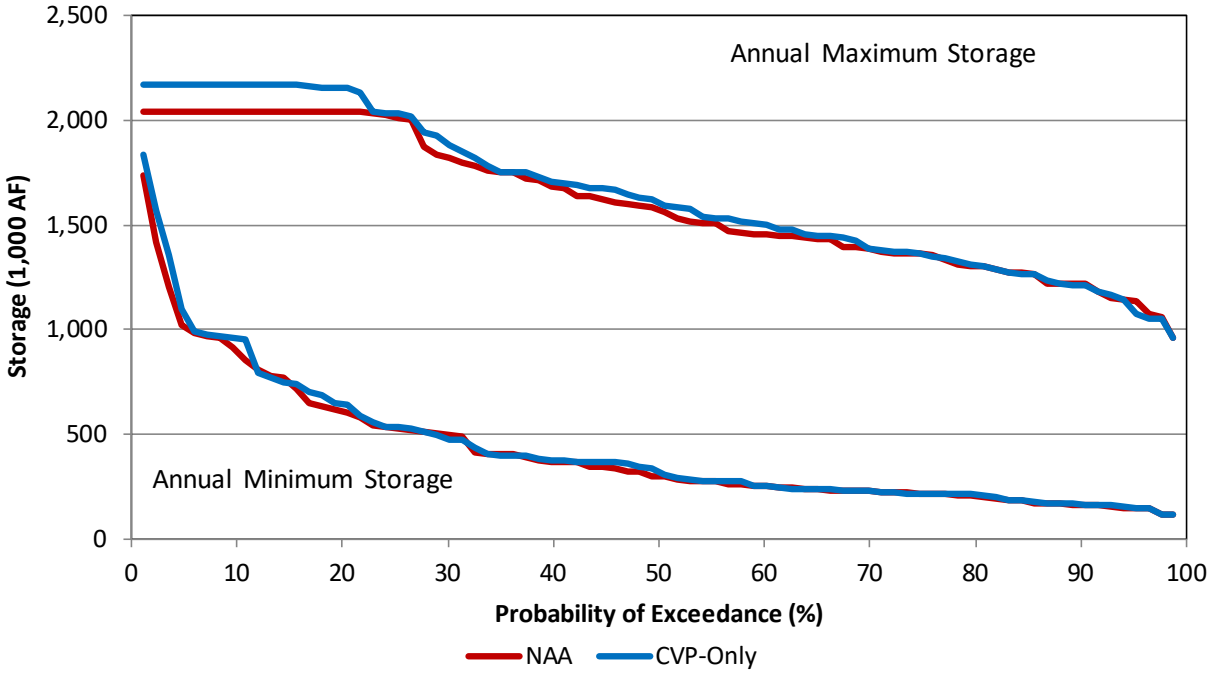


Figure 5-1. Probability of Annual Maximum and Minimum Total San Luis Reservoir Storage

Figure 5-2 shows the probability of annual maximum and minimum CVP San Luis Storage. In general, the annual minimum is essentially the same as the NAA in approximately 60% of years and greater in the remaining 40% of years. CVP San Luis fills to the expanded capacity in 35% of years, and the annual maximum storage is higher in approximately 55% of years compared to the NAA. Annual maximum storage is slightly less in many of the next 25% of years, which is largely a result of a more efficient CVP South-of-Delta delivery and allocation under the alternative. Annual maximum storage is largely unchanged in the final 20% of years. The improvements in nearly all years to CVP San Luis storage results in additional water supply deliveries and reliability for CVP South-of-Delta contractors.

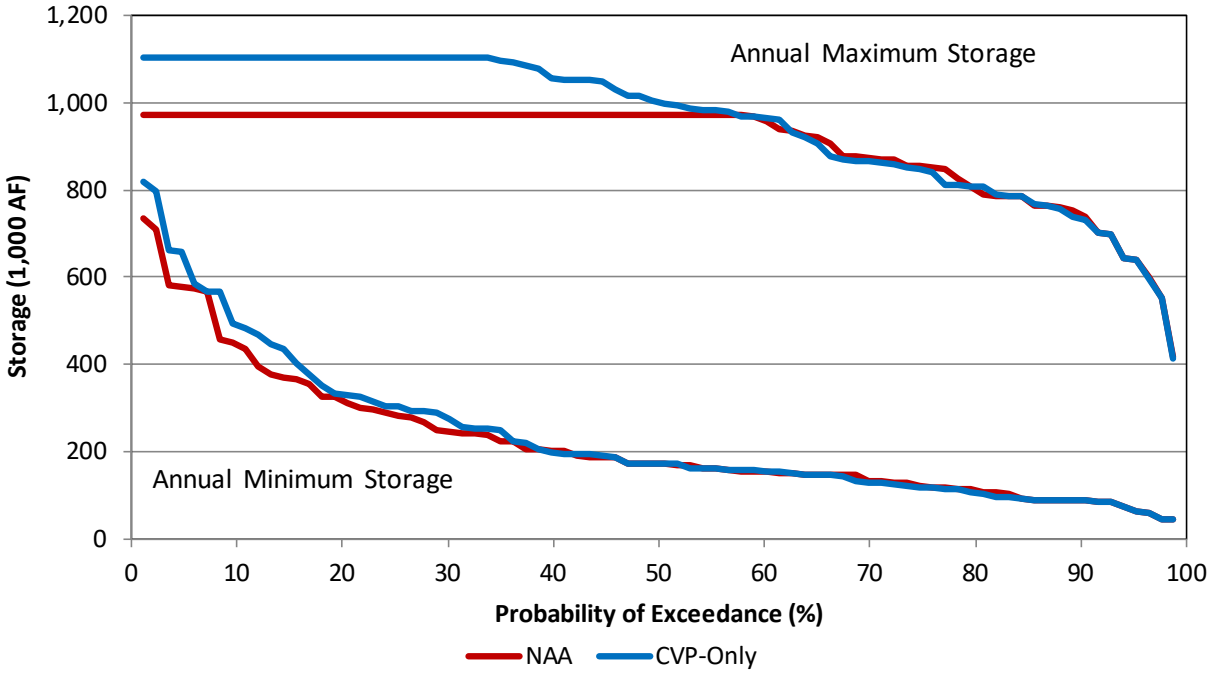


Figure 5-2. Probability of Annual Maximum and Minimum CVP San Luis Reservoir Storage

Figure 5-3 shows the probability of annual maximum and minimum SWP San Luis Storage. In many years, annual maximum SWP San Luis storage is slightly less than seen in the NAA, with SWP San Luis filling in approximately 5% fewer years. Annual minimum SWP San Luis storage is mostly unchanged, although storage under the CVP-Only Alternative is slightly less between the 5 and 40% probability of exceedance range.

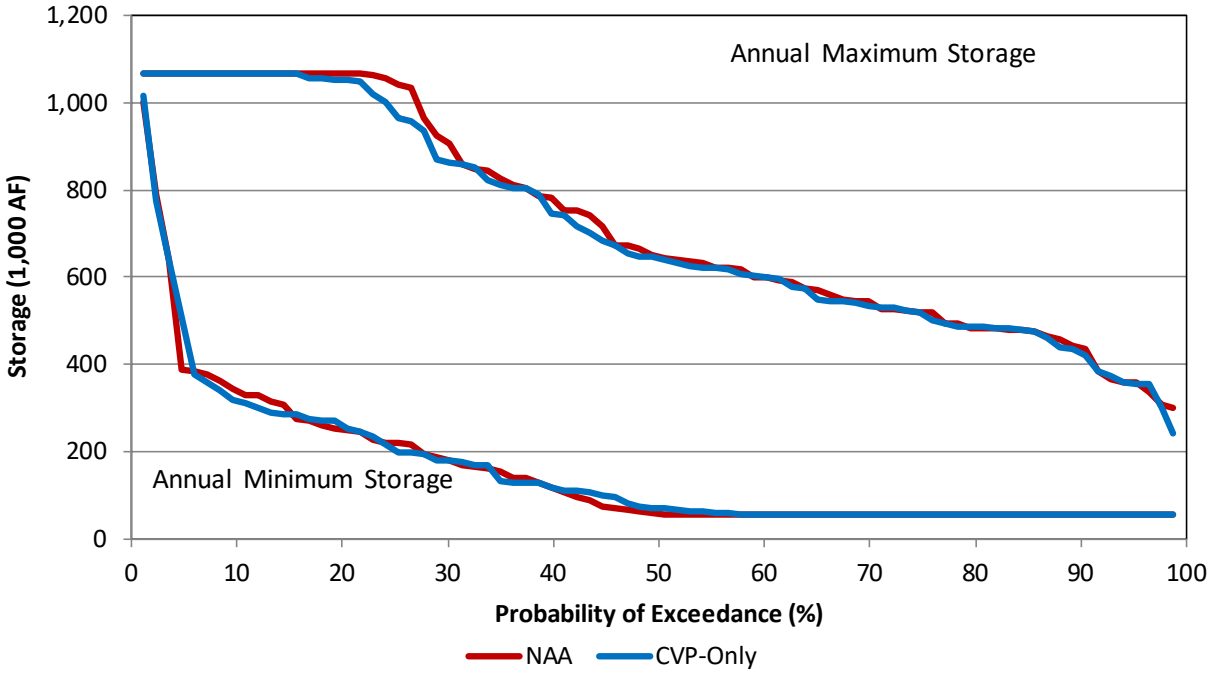


Figure 5-3. Probability of Annual Maximum and Minimum SWP San Luis Reservoir Storage

The reduction in annual maximum and minimum SWP San Luis storage results in slightly reduced SWP South-of-Delta deliveries. The increase in CVP San Luis Reservoir size reduces the frequency that CVP exports are limited due to available South-of-Delta capacity. As noted in Section 2.2.3, the post-processor attempts to avoid reductions in Table A and Article 21 deliveries. Although most of this avoidance is accomplished through changes to CVP and SWP exports, some of this avoidance is achieved through increased deliveries from SWP San Luis Storage to avoid SWP delivery reductions.

5.2.2 CVP South-of-Delta Deliveries

As noted above, the additional storage space created in CVP San Luis allows for additional water supply and increased water supply reliability for CVP South-of-Delta contractors. The CVP-Only Storage Alternative results in no change to CVP Exchange Contractor deliveries. Although changes to CVP South-of-Delta Refuge deliveries are not expected in actual operations, the modeling shows minor increases in refuge delivery. Table 5-1 shows the average changes to CVP South-of-Delta Refuge deliveries by water year index for the NAA, the CVP-Only Storage Alternative, and the change from the NAA.

Table 5-1. Average CVP South-of-Delta Refuge Deliveries with CVP-Only Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP-Only Storage Alternative (TAF)	Change from NAA (TAF)
Wet	274	276	2
Above Normal	260	263	3
Below Normal	274	274	0
Dry	281	281	0
Critical	234	234	0
All Years	268	269	1

Table 5-2 shows the average change in CVP South-of-Delta Ag Service deliveries by water year index for the NAA, the CVP-Only Storage Alternative, and the change from the NAA. As noted above, the additional storage space provides for additional water supply deliveries in all year types, and results in an annual average increase of 33,000 acre-feet to South-of-Delta Ag Service contractors.

Table 5-2. Average CVP South-of-Delta Ag Service Deliveries with CVP-Only Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP-Only Storage Alternative (TAF)	Change from NAA (TAF)
Wet	1,478	1,540	62
Above Normal	1,111	1,138	27
Below Normal	900	931	32
Dry	694	701	7
Critical	321	334	13
All Years	984	1,018	33

Table 5-3 shows the average change in CVP South-of-Delta M&I deliveries by water year index for the NAA, the CVP-Only Storage Alternative, and the change from the NAA. As noted above, the additional storage space provides for additional water supply deliveries in all year types, and results in an annual average increase of approximately 2,000 acre-feet to South-of-Delta M&I contractors.

Table 5-3. Average CVP South-of-Delta M&I Deliveries with CVP-Only Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP-Only Storage Alternative (TAF)	Change from NAA (TAF)
Wet	139	136	-3
Above Normal	124	124	0
Below Normal	119	123	4
Dry	111	116	4
Critical	95	100	4
All Years	121	122	2

Table 5-4 shows the average change in CVP foregone Delta pumping by water year index for the NAA, the CVP-Only Storage Alternative, and the change from the NAA. The reduction in foregone pumping from the NAA acts to provide approximately 50% of the total increase in CVP South-of-Delta deliveries, as the reduction in foregone pumping equates to less "spill" of rescheduled water supply.

Table 5-4. Average CVP Foregone Pumping with CVP-Only Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP-Only Storage Alternative (TAF)	Change from NAA (TAF)
Wet	95	57	-38
Above Normal	15	3	-12
Below Normal	29	13	-16
Dry	26	18	-7
Critical	5	0	-5
All Years	43	25	-18

5.2.3 SWP South-of-Delta Deliveries

As discussed above, the additional storage space in CVP San Luis can result in a reduction in available water supply for the SWP, as CVP exports are capacity constrained less frequently. However, through the additional refinements in the post-processor, many of these reductions were avoided. Table 5-5 shows average SWP Table A deliveries by water year index for the NAA, the CVP-Only Storage Alternative, and the change from the NAA. Annual average deliveries decrease in wet and above normal year types, with an annual average decrease to Table A deliveries of 1,000 acre-feet.

Table 5-5. Average SWP Table A Deliveries with CVP-Only Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP-Only Storage Alternative (TAF)	Change from NAA (TAF)
Wet	3,241	3,234	-9
Above Normal	2,663	2,659	-4
Below Normal	2,604	2,609	5
Dry	1,866	1,866	0
Critical	1,117	1,117	0
All Years	2,418	2,417	-1

Table 5-6 shows average SWP Article 56 deliveries by water year index for the NAA, the CVP-Only Storage Alternative, and the change from the NAA. Given the refinements made to Table A and Article 21 supplies and the minimized change to Table A deliveries, it was assumed that there are no reductions to Article 56 deliveries.

Table 5-6. Average SWP Article 56 Deliveries with CVP-Only Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP-Only Storage Alternative (TAF)	Change from NAA (TAF)
Wet	86	86	0
Above Normal	49	49	0
Below Normal	83	83	0
Dry	54	54	0
Critical	19	19	0
All Years	62	62	0

Table 5-7 shows average SWP Article 21 deliveries by water year index for the NAA, the CVP-Only Storage Alternative, and the change from the NAA. Article 21 deliveries are reduced in some year types and slightly increased in above normal years, resulting in annual average decrease to Article 21 deliveries of 2,000 acre-feet.

Table 5-7. Average SWP Article 21 Deliveries with CVP-Only Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP-Only Storage Alternative (TAF)	Change from NAA (TAF)
Wet	125	125	0
Above Normal	76	86	9
Below Normal	29	28	-1
Dry	42	39	-3
Critical	32	27	-5
All Years	71	69	-2

5.2.4 CVP/SWP Effects

The CVP-Only Storage Alternative can create small changes in CVP/SWP operations beyond just San Luis Reservoir and the contractors who take delivery of water from the reservoir. These changes have the potential to affect resources in other parts of the system. Therefore, changes in river flows, reservoir storage, Delta outflow, and Delta export operations were quantified and reviewed in support of the environmental documentation. The following tables provide a high-level summary of changes throughout the CVP/SWP system. North of the Delta operations are nearly identical, which generally is expected given that Trinity imports and CVP North-of-Delta Ag Service & M&I allocations are fixed. Given the small reduction in available SWP supply, some minor changes occur to Oroville and SWP Delta operations, which do have some minor effects on the system as a whole. Changes to Jones pumping are also relatively small, with most of the increases corresponding to decreases in Banks pumping. More detailed results were provided and reviewed by resource area specialists and are illustrated in figures located in Attachment B. Table 5-8 provides a summary of the average monthly model results at key locations in the system under the CVP-Only Storage Alternative.

Table 5-8. Summary of CVP-Only Storage Alternative CVP/SWP System Effects

NAA	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Delta Outflow (cfs)	6,747	8,920	25,033	45,224	57,590	45,403	28,838	18,412	11,414	7,966	4,734	6,789
Jones Pumping Plant (cfs)	3,131	3,607	3,609	3,663	3,776	2,968	2,624	2,857	2,957	2,541	3,304	3,237
Banks Pumping Plant (cfs)	2,804	4,981	4,531	3,471	4,065	3,360	3,224	2,485	2,459	5,164	4,527	2,375
Sac. River into Delta (cfs)	11,032	14,332	23,913	31,758	38,755	33,218	24,685	18,640	16,098	17,261	13,487	11,726
Yolo Bypass (cfs)	120	588	4,907	12,219	16,420	9,543	2,664	211	88	50	101	72
Sac. River below Keswick (cfs)	6,412	6,261	7,807	9,378	11,457	8,860	5,702	8,122	10,305	12,822	9,551	6,332
Sac. River at NCP (cfs)	6,612	7,660	11,671	13,838	15,439	14,108	10,528	6,843	6,231	6,743	4,828	6,008
Feather R. blw Thermalito (cfs)	2,209	2,019	3,293	4,898	5,900	6,528	3,070	3,758	4,041	6,964	4,995	1,750
Lower Feather River (cfs)	2,725	2,966	6,101	12,048	14,038	13,835	8,730	7,541	5,948	7,021	5,656	3,417
American R blw Nimbus (cfs)	1,387	2,464	3,938	5,062	6,093	4,356	3,337	3,031	2,837	2,588	1,948	1,681
American R at H St (cfs)	1,230	2,311	3,796	4,899	5,895	4,152	3,057	2,728	2,459	2,125	1,595	1,452
SJ River at Vernalis (cfs)	2,668	2,607	3,368	5,109	6,793	7,290	7,511	5,980	4,099	2,616	1,828	2,213
Shasta Storage (TAF)	2,616	2,626	2,791	3,062	3,330	3,666	3,996	3,961	3,637	3,127	2,822	2,713
Oroville Storage (TAF)	1,672	1,651	1,788	2,019	2,293	2,504	2,768	2,844	2,653	2,189	1,875	1,779
Folsom Storage (TAF)	456	443	468	487	501	593	716	823	760	629	545	493
CVP San Luis Storage (TAF)	290	421	574	715	826	882	874	795	606	372	246	254
SWP San Luis Storage (TAF)	183	251	310	452	593	670	705	628	471	427	344	215
CVP-Only Storage Alt.	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Delta Outflow (cfs)	6,761	8,927	25,079	45,287	57,609	45,420	28,801	18,387	11,420	7,967	4,734	6,768
Jones Pumping Plant (cfs)	3,159	3,630	3,641	3,696	3,916	3,150	2,833	2,942	2,970	2,492	3,317	3,246
Banks Pumping Plant (cfs)	2,771	5,003	4,520	3,448	4,045	3,280	3,168	2,449	2,466	5,209	4,535	2,399
Sac. River into Delta (cfs)	11,022	14,358	23,945	31,745	38,762	33,229	24,678	18,640	16,105	17,241	13,490	11,719
Yolo Bypass (cfs)	120	587	4,906	12,216	16,420	9,543	2,665	211	88	48	101	72
Sac. River below Keswick (cfs)	6,442	6,285	7,835	9,363	11,457	8,869	5,694	8,125	10,306	12,762	9,554	6,318
Sac. River at NCP (cfs)	6,643	7,673	11,673	13,825	15,438	14,117	10,520	6,850	6,232	6,683	4,835	5,993
Feather R. blw Thermalito (cfs)	2,168	2,009	3,301	4,908	5,910	6,531	3,070	3,752	4,047	6,980	4,997	1,756
Lower Feather River (cfs)	2,685	2,956	6,109	12,054	14,041	13,836	8,729	7,535	5,953	7,035	5,669	3,423
American R blw Nimbus (cfs)	1,387	2,480	3,934	5,060	6,093	4,357	3,338	3,031	2,837	2,589	1,935	1,681
American R at H St (cfs)	1,227	2,327	3,790	4,897	5,896	4,153	3,058	2,727	2,460	2,121	1,585	1,452
SJ River at Vernalis (cfs)	2,668	2,607	3,368	5,109	6,793	7,290	7,511	5,980	4,099	2,617	1,829	2,213
Shasta Storage (TAF)	2,618	2,626	2,790	3,061	3,330	3,665	3,996	3,961	3,636	3,130	2,825	2,716
Oroville Storage (TAF)	1,672	1,651	1,788	2,018	2,291	2,502	2,766	2,842	2,652	2,186	1,872	1,776
Folsom Storage (TAF)	457	443	468	487	502	593	716	823	760	629	546	494
CVP San Luis Storage (TAF)	303	432	589	733	851	921	926	843	641	395	263	267
SWP San Luis Storage (TAF)	187	256	316	454	592	666	696	621	468	426	346	220
Change from NAA	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Delta Outflow (cfs)	13	6	46	64	19	16	-37	-25	6	1	1	-21
Jones Pumping Plant (cfs)	28	23	32	33	140	182	208	85	13	-49	13	9
Banks Pumping Plant (cfs)	-33	22	-11	-23	-20	-79	-56	-36	6	44	8	24
Sac. River into Delta (cfs)	-10	25	32	-12	6	11	-8	0	7	-19	3	-7
Yolo Bypass (cfs)	0	-1	-1	-3	0	0	0	0	0	-2	0	0
Sac. River below Keswick (cfs)	30	24	27	-16	0	9	-8	3	2	-60	3	-14
Sac. River at NCP (cfs)	31	13	2	-13	-1	9	-9	7	1	-59	7	-15
Feather R. blw Thermalito (cfs)	-41	-10	8	10	10	4	1	-6	7	16	2	5
Lower Feather River (cfs)	-41	-10	8	7	3	1	0	-6	5	14	12	6
American R blw Nimbus (cfs)	-1	16	-4	-2	1	1	1	0	0	1	-13	0
American R at H St (cfs)	-2	16	-6	-2	1	1	1	0	0	-3	-10	0
SJ River at Vernalis (cfs)	0	0	0	0	0	0	0	0	1	1	1	0
Shasta Storage (TAF)	2	0	-2	-1	0	-1	0	-1	-1	3	3	3
Oroville Storage (TAF)	0	0	0	-1	-1	-2	-2	-1	-2	-3	-3	-3
Folsom Storage (TAF)	1	0	0	0	0	0	0	0	0	0	1	1
CVP San Luis Storage (TAF)	13	11	15	18	25	39	53	48	35	23	18	13
SWP San Luis Storage (TAF)	4	5	6	2	-1	-5	-9	-7	-2	-1	2	4

Chapter 6 CVP/SWP Shared Storage Alternative

The CVP/SWP Shared Storage Alternative includes a 130,000 acre-feet increase to the maximum San Luis Reservoir storage, which is split between the CVP and SWP portions of San Luis using the existing storage share. This share (approximately 48% CVP / 52% SWP) results in a 62,000 acre-feet increase in storage for CVP San Luis, and a 68,000 acre-feet increase in storage for SWP San Luis. The additional storage in each side of San Luis Reservoir would be owned and operated by the respective entity according to existing guidelines. For CVP contractors, the maximum quantity of rescheduled water and rescheduling parameters are the same as applied in the NAA and the CVP-Only Storage Alternative.

6.1 Modeling Approach and Assumptions

As noted above, for the CVP/SWP Shared Storage Alternative, the maximum storage size of CVP San Luis and SWP San Luis were increased by 62,000 acre-feet and 68,000 acre-feet, respectively. No other changes were made to San Luis operations or "rulecurve" logic in CalSim II. As detailed in Chapter 2, for the CVP/SWP Shared Storage alternative, CVP North-of-Delta Ag Service and M&I allocations were fixed to equal allocations made in the NAA. Additionally, Trinity imports were fixed to equal imports made in NAA, along with the refinements to CVP South-of-Delta Ag Service and M&I allocations that were detailed in Chapter 2.

CalSim II output for the CVP/SWP Shared Storage alternative were also input to the post-processor to assess the effects of rescheduled water on the CVP/SWP Shared Storage operations and deliveries. The rescheduled water operational assumptions and parameters used in the post-processor for the CVP/SWP Shared Storage alternative are identical to those used in the No Project/No Action Alternative (NAA) and the CVP-Only Storage Alternative. However, given the inclusion of SWP operations and facilities as part of this alternative's operation, the results of this alternative were not passed through the additional delivery reduction refinements section of the post-processor.

6.2 CVP/SWP Shared Storage Alternative Results

The CVP/SWP Shared Storage Alternative was analyzed over an 82-year period to estimate the changes to the CVP/SWP system. The following sections summarize the effects of the alternative on San Luis Reservoir, CVP and SWP South-of-Delta deliveries, and the CVP/SWP system as a whole. Results are shown in a comparative sense between the CVP/SWP Shared Alternative and the NAA, both of which include rescheduled water operations.

6.2.1 San Luis Reservoir

Figure 6-1 shows the probability of annual maximum and minimum Total San Luis Reservoir Storage. As demonstrated in the figure, annual maximum storage is equal to or greater than total storage in the NAA for nearly all years. San Luis fills to the new maximum storage in nearly 20% of years. Annual minimum storage is also equal to or greater than total storage in the NAA for nearly all years, but generally is equal to the annual minimum storage seen under the NAA.

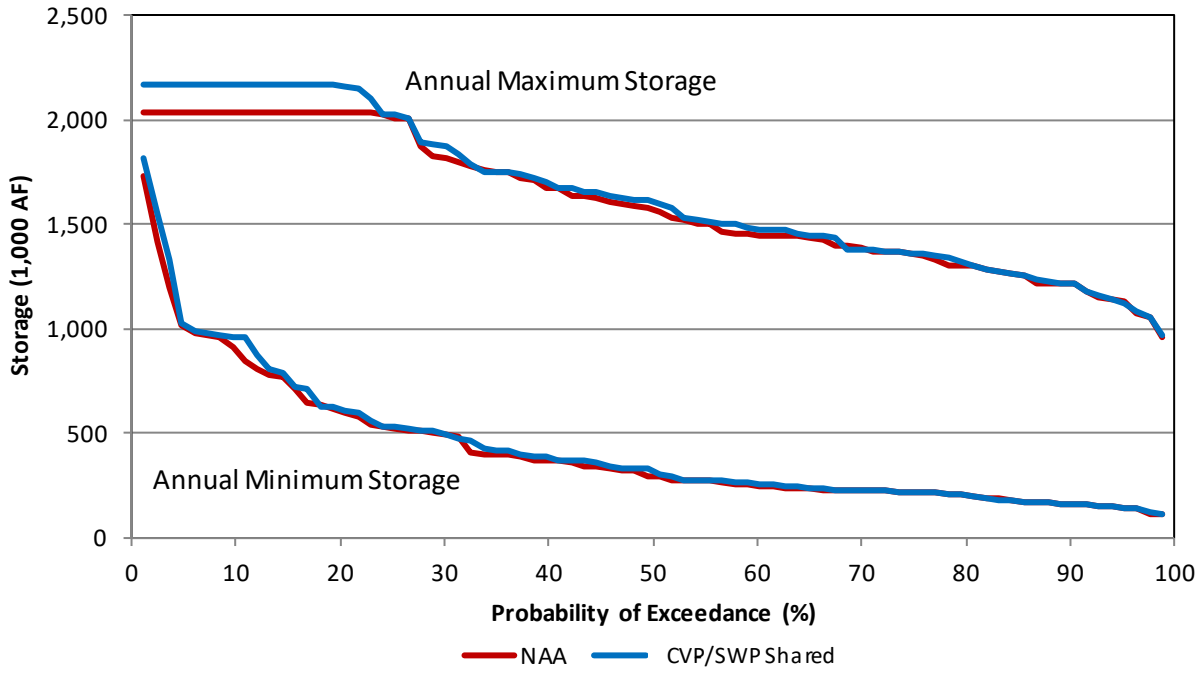


Figure 6-1. Probability of Annual Maximum and Minimum Total San Luis Reservoir Storage

Figure 6-2 shows the probability of annual maximum and minimum CVP San Luis Storage. In general, the annual minimum is essentially equal to storage under the NAA in approximately 60% of years and greater in the other 40% of years. CVP San Luis fills to the expanded capacity in 45% of years, and the annual maximum storage is higher in approximately 55% of years compared to the NAA. The increase to CVP San Luis storage in nearly all years results in additional water supply deliveries and reliability to CVP South-of-Delta contractors.

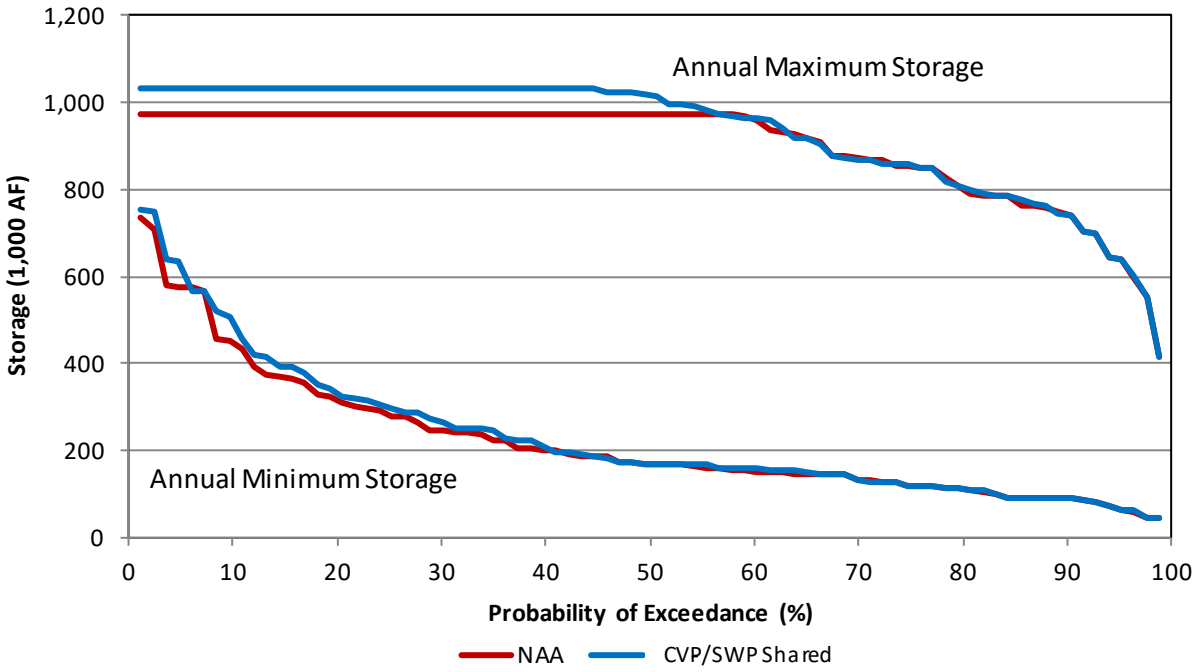


Figure 6-2. Probability of Annual Maximum and Minimum CVP San Luis Reservoir Storage

Figure 6-3 shows the probability of annual maximum and minimum SWP San Luis Storage. In about 70% of years, annual maximum SWP San Luis storage is essentially equal to storage seen in the NAA, and SWP San Luis fills to the expanded storage in approximately 20% percent of years. Annual minimum SWP San Luis storage is mostly unchanged, but generally slightly higher in the 5 to 50% exceedance probability range.

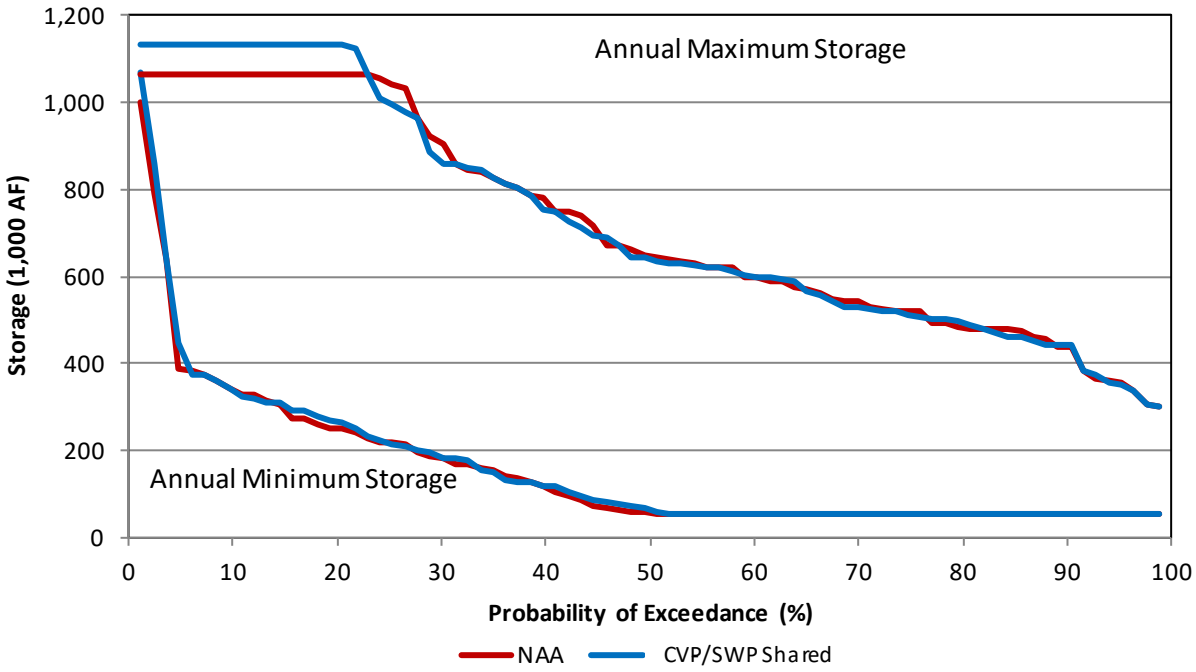


Figure 6-3. Probability of Annual Maximum and Minimum SWP San Luis Reservoir Storage

When there is a reduction in annual maximum SWP San Luis storage, there is a corresponding net reduction to total SWP South-of-Delta deliveries. The increase in CVP San Luis Reservoir size reduces the frequency that CVP exports are limited due to available CVP South-of-Delta capacity. This reduces the volume of unused federal share that the SWP is able to export under the NAA, which subsequently reduces the available SWP water supply in some years. The additional storage space in SWP San Luis also results in a conversion of some Article 21 supply under the NAA to Table A supply under the CVP/SWP Shared Alternative.

6.2.2 CVP South-of-Delta Deliveries

As noted above, the additional storage space created in CVP San Luis allows for additional water supply and increased water supply reliability for CVP South-of-Delta contractors. The CVP/SWP Shared Storage Alternative results in no change to CVP South-of-Delta Exchange Contractor deliveries. Although changes to CVP South-of-Delta Refuge deliveries are not expected in actual operations, the modeling shows minor increases to CVP South-of-Delta Refuge deliveries. Table 6-1 shows the changes to average CVP South-of-Delta Refuge deliveries by water year index for the NAA, the CVP/SWP Shared Storage Alternative, and the change from the NAA.

Table 6-1. Average CVP South-of-Delta Refuge Deliveries with CVP/SWP Shared Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP/SWP Shared Storage Alternative (TAF)	Change from NAA (TAF)
Wet	274	275	1
Above Normal	260	262	2
Below Normal	274	274	0
Dry	281	281	0
Critical	234	234	0
All Years	268	268	1

Table 6-2 shows the change in average CVP South-of-Delta Ag Service deliveries by water year index for the NAA, the CVP/SWP Shared Storage Alternative, and the change from the NAA. As noted above, the additional storage space provides for additional water supply deliveries in all year types, and results in a 25,000 acre-feet increase in annual average CVP South-of-Delta Ag Service deliveries.

Table 6-2. Average CVP South-of-Delta Ag Service Deliveries with CVP/SWP Shared Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP/SWP Shared Storage Alternative (TAF)	Change from NAA (TAF)
Wet	1,478	1,520	41
Above Normal	1,133	1,164	31
Below Normal	900	927	27
Dry	694	706	12
Critical	321	336	15
All Years	985	1,011	25

Table 6-3 shows the change in average CVP South-of-Delta M&I deliveries by water year index for the NAA, the CVP/SWP Shared Storage Alternative, and the change from the NAA. As noted above, the additional storage space provides for additional water supply deliveries in all year types, and results in an annual average increase of approximately 1,000 acre-feet to South-of-Delta M&I contractors.

Table 6-3. Average CVP South-of-Delta M&I Deliveries with CVP/SWP Shared Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP/SWP Shared Storage Alternative (TAF)	Change from NAA (TAF)
Wet	139	140	2
Above Normal	124	126	1
Below Normal	119	121	2
Dry	111	112	1
Critical	95	96	1
All Years	121	122	1

Table 6-4 shows the change in average CVP Foregone pumping by water year index for the NAA, the CVP/SWP Shared Storage Alternative, and the change from the NAA. The reduction in foregone pumping from the NAA acts to provide approximately 35% of the total increase in CVP South-of-Delta deliveries, as the reduction in foregone pumping equates to less "spill" of rescheduled water supply.

Table 6-4. Average CVP Foregone Pumping with CVP/SWP Shared Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP/SWP Shared Storage Alternative (TAF)	Change from NAA (TAF)
Wet	95	78	-16
Above Normal	15	3	-12
Below Normal	29	21	-8
Dry	26	24	-2
Critical	5	0	-5
All Years	43	34	-9

6.2.3 SWP South-of-Delta Deliveries

As discussed above, the additional storage space in CVP San Luis results in a reduction of available water supply for the SWP. Additionally, the increase in storage capacity in SWP San Luis allows for the conversion of some water that was Article 21 supply in the NAA to Table A supply in the CVP/SWP Shared Alternative. The increased storage of SWP San Luis reduces the frequency that SWP exports and deliveries are capacity constrained south of the Delta. All of these effects act to increase Table A deliveries but reduce Article 21 supplies, as compared to the NAA, which overall results in a net reduction in total SWP deliveries.

Table 6-5 shows average SWP Table A deliveries by water year index for the NAA, the CVP/SWP Shared Storage Alternative, and the change from the NAA. Annual average deliveries increase in all year types, resulting in an annual average increase to Table A deliveries of 9,000 acre-feet.

Table 6-5. Average SWP Table A Deliveries with CVP/SWP Shared Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP/SWP Shared Storage Alternative (TAF)	Change from NAA (TAF)
Wet	3,241	3,247	6
Above Normal	2,663	2,687	24
Below Normal	2,604	2,613	9
Dry	1,866	1,871	6
Critical	1,117	1,118	1
All Years	2,418	2,426	9

Table 6-6 shows average SWP Article 56 deliveries by water year index for the NAA, the CVP/SWP Shared Storage Alternative, and the change from the NAA. Overall, minimal impacts are seen to Article 56 deliveries as the additional SWP San Luis storage results in a slightly lower probability of Article 56 "spills". The additional Table A supply also results in a slightly increased potential for Article 56 supply.

Table 6-6. Average SWP Article 56 Deliveries with CVP/SWP Shared Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP/SWP Shared Storage Alternative (TAF)	Change from NAA (TAF)
Wet	86	92	6
Above Normal	49	49	0
Below Normal	83	84	1
Dry	54	53	0
Critical	19	15	-4
All Years	62	63	1

Table 6-7 shows average SWP Article 21 deliveries by water year index for the NAA, the CVP/SWP Shared Storage Alternative, and the change from the NAA. On average, Article 21 deliveries are reduced in all year types. The additional storage space in SWP San Luis and reduced frequency and volume of CVP foregone pumping results in a reduced frequency in availability and quantity of Article 21 supply.

Table 6-7. Average SWP Article 21 Deliveries with CVP/SWP Shared Storage Alternative

Sacramento Valley Index	No Action Alternative (TAF)	CVP/SWP Shared Storage Alternative (TAF)	Change from NAA (TAF)
Wet	125	101	-24
Above Normal	76	58	-18
Below Normal	29	15	-14
Dry	42	32	-10
Critical	32	23	-9
All Years	71	54	-16

6.2.4 CVP/SWP Effects

The CVP/SWP Shared Storage Alternative can create small changes in CVP/SWP operations beyond just San Luis Reservoir and the contractors who take delivery of water from the reservoir. These changes have the potential to affect resources in other parts of the system. Therefore, changes in river flows, reservoir storage, Delta outflow, and Delta export operations were quantified and reviewed in support of the environmental documentation. The following tables provide a high-level summary of changes throughout the CVP/SWP system. North of the Delta operations are nearly identical, which generally is expected given that Trinity imports and CVP North-of-Delta Ag Service & M&I allocations are fixed. Given the effects on available SWP supply, some changes occur to Oroville and SWP Delta operations, which do have some minor effects on the system as a whole. Changes to Jones pumping are also relatively small, with most of the increases corresponding to decreases in Banks pumping. More detailed results were provided and reviewed by resource area specialists and are illustrated in figures located in Attachment B. Table 6-8 is a summary of the average monthly model results at key locations in the system under the CVP/SWP Shared Storage Alternative.

Table 6-8. Summary of CVP/SWP Shared Storage Alternative CVP/SWP System Effects

NAA	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Delta Outflow (cfs)	6,747	8,920	25,033	45,224	57,590	45,403	28,838	18,412	11,414	7,966	4,734	6,789
Jones Pumping Plant (cfs)	3,131	3,607	3,609	3,663	3,776	2,968	2,624	2,857	2,957	2,541	3,304	3,237
Banks Pumping Plant (cfs)	2,783	4,550	4,423	3,461	4,056	3,313	3,224	2,485	2,430	4,750	4,025	2,263
Sac. River into Delta (cfs)	11,032	14,332	23,913	31,758	38,755	33,218	24,685	18,640	16,098	17,261	13,487	11,726
Yolo Bypass (cfs)	120	588	4,907	12,219	16,420	9,543	2,664	211	88	50	101	72
Sac. River below Keswick (cfs)	6,412	6,261	7,807	9,378	11,457	8,860	5,702	8,122	10,305	12,822	9,551	6,332
Sac. River at NCP (cfs)	6,612	7,660	11,671	13,838	15,439	14,108	10,528	6,843	6,231	6,743	4,828	6,008
Feather R. blw Thermalito (cfs)	2,209	2,019	3,293	4,898	5,900	6,528	3,070	3,758	4,041	6,964	4,995	1,750
Lower Feather River (cfs)	2,725	2,966	6,101	12,048	14,038	13,835	8,730	7,541	5,948	7,021	5,656	3,417
American R blw Nimbus (cfs)	1,387	2,464	3,938	5,062	6,093	4,356	3,337	3,031	2,837	2,588	1,948	1,681
American R at H St (cfs)	1,230	2,311	3,796	4,899	5,895	4,152	3,057	2,728	2,459	2,125	1,595	1,452
SJ River at Vernalis (cfs)	2,668	2,607	3,368	5,109	6,793	7,290	7,511	5,980	4,099	2,616	1,828	2,213
Shasta Storage (TAF)	2,616	2,626	2,791	3,062	3,330	3,666	3,996	3,961	3,637	3,127	2,822	2,713
Oroville Storage (TAF)	1,672	1,651	1,788	2,019	2,293	2,504	2,768	2,844	2,653	2,189	1,875	1,779
Folsom Storage (TAF)	456	443	468	487	501	593	716	823	760	629	545	493
CVP San Luis Storage (TAF)	290	421	574	715	826	882	874	795	606	372	246	254
SWP San Luis Storage (TAF)	183	251	310	452	593	670	705	628	471	427	344	215
CVP/SWP Shared Storage Alt.	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Delta Outflow (cfs)	6,746	8,920	25,033	45,197	57,555	45,351	28,740	18,390	11,421	7,954	4,737	6,791
Jones Pumping Plant (cfs)	3,151	3,607	3,646	3,706	3,855	3,128	2,735	2,892	2,952	2,528	3,291	3,248
Banks Pumping Plant (cfs)	2,778	4,556	4,408	3,439	4,041	3,301	3,166	2,472	2,410	4,740	4,056	2,281
Sac. River into Delta (cfs)	11,040	14,334	23,913	31,748	38,769	33,221	24,678	18,637	16,079	17,248	13,503	11,759
Yolo Bypass (cfs)	120	586	4,904	12,222	16,416	9,540	2,664	211	88	48	101	72
Sac. River below Keswick (cfs)	6,425	6,263	7,811	9,380	11,465	8,862	5,694	8,121	10,302	12,818	9,542	6,329
Sac. River at NCP (cfs)	6,625	7,657	11,672	13,831	15,446	14,113	10,520	6,843	6,229	6,741	4,819	6,006
Feather R. blw Thermalito (cfs)	2,203	2,012	3,288	4,896	5,910	6,528	3,070	3,757	4,026	6,950	5,015	1,775
Lower Feather River (cfs)	2,720	2,959	6,097	12,042	14,042	13,832	8,730	7,540	5,932	7,010	5,684	3,442
American R blw Nimbus (cfs)	1,388	2,470	3,936	5,059	6,093	4,356	3,337	3,030	2,835	2,579	1,946	1,691
American R at H St (cfs)	1,229	2,317	3,792	4,897	5,896	4,152	3,058	2,727	2,457	2,116	1,592	1,459
SJ River at Vernalis (cfs)	2,668	2,607	3,368	5,109	6,793	7,290	7,511	5,980	4,099	2,616	1,829	2,213
Shasta Storage (TAF)	2,616	2,625	2,791	3,061	3,329	3,665	3,996	3,961	3,636	3,127	2,823	2,713
Oroville Storage (TAF)	1,672	1,652	1,789	2,020	2,293	2,505	2,769	2,845	2,655	2,191	1,876	1,779
Folsom Storage (TAF)	456	442	468	487	501	593	716	823	760	629	546	493
CVP San Luis Storage (TAF)	300	430	585	728	842	906	903	822	625	387	256	263
SWP San Luis Storage (TAF)	188	255	313	456	598	680	714	636	477	432	350	222
Change from NAA	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Delta Outflow (cfs)	-2	-1	0	-27	-35	-52	-97	-23	7	-12	3	2
Jones Pumping Plant (cfs)	20	1	37	43	79	160	111	36	-5	-14	-13	11
Banks Pumping Plant (cfs)	-4	7	-15	-22	-15	-13	-58	-13	-20	-11	31	19
Sac. River into Delta (cfs)	8	2	0	-10	14	3	-8	-3	-20	-13	16	33
Yolo Bypass (cfs)	0	-2	-3	3	-4	-4	0	0	0	-2	0	0
Sac. River below Keswick (cfs)	12	1	4	2	7	2	-8	-1	-2	-4	-10	-3
Sac. River at NCP (cfs)	13	-2	1	-7	6	5	-8	-1	-2	-2	-8	-2
Feather R. blw Thermalito (cfs)	-6	-7	-4	-2	9	0	1	0	-14	-14	20	25
Lower Feather River (cfs)	-6	-7	-4	-6	3	-3	0	-1	-16	-11	28	25
American R blw Nimbus (cfs)	1	7	-3	-3	1	1	0	-1	-2	-9	-2	10
American R at H St (cfs)	-1	6	-4	-3	1	1	0	-1	-2	-9	-2	7
SJ River at Vernalis (cfs)	0	0	0	0	0	0	0	0	0	0	0	0
Shasta Storage (TAF)	0	0	-1	-1	-1	-1	-1	-1	-1	0	0	0
Oroville Storage (TAF)	0	1	1	1	1	1	1	1	1	2	1	0
Folsom Storage (TAF)	0	0	0	0	0	0	0	0	0	1	1	0
CVP San Luis Storage (TAF)	10	9	11	13	16	24	30	27	19	14	11	9
SWP San Luis Storage (TAF)	5	4	3	4	5	10	9	9	6	5	6	6

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Chapter 7 Investor-Directed Storage Alternative – Configurations A and B

The Investor-Directed Storage Alternative – with Configurations A and B ("Investor A/B") includes a 130,000 acre-feet increase in the maximum San Luis Reservoir Storage. However, as opposed to the CVP-Only and CVP/SWP Shared Storage Alternatives, the use of the additional storage capacity would be primarily investor-directed. The remaining expanded capacity, when not in use by the investor water districts, would be available to Reclamation to store additional Delta surplus. Under this alternative, the maximum annual rescheduled quantity would remain 180,000 acre-feet (identical to the NAA, CVP-Only, and CVP/SWP Shared Alternatives). The delivery of any water supply yielded from storing Delta surplus in the additional storage space would be delivered proportionally among the investor group of districts. Under this alternative, when foregone pumping occurs and CVP contractor rescheduled supplies are "spilled", the investor-directed storage is able to take control of the spilled rescheduled water, if space is available.

The results presented in this chapter summarize the effects of the alternative on the system and the resulting deliveries to the investors as a single block of water. At this point in the analysis of the project, the actual investors and their respective share of the project yield are still being determined, with additional economic and feasibility studies being completed to better inform potential investors. In the feasibility document, the following two configurations of investor ownership (by %) are being completed to provide additional bookends for the economic and feasibility analyses:

- Configuration A: 10% Ag, 90% M&I, 0% Refuge
- Configuration B: 78% Ag, 7% M&I, 15% Refuge

Accordingly, it is not yet appropriate to report changes to CVP South-of-Delta Ag Service, M&I, and Refuge deliveries in this document for this alternative as compared to the NAA. Rather, changes to total CVP South-of-Delta deliveries will be reported as the final investor group will be comprised of CVP South-of-Delta contractors, and the benefits of the project will be shared among the investor group.

7.1 Modeling Approach and Assumptions

For the Investor-Directed Storage Alternative, the NAA CalSim II model run was input to the post-processor and the additional 130,000 acre-feet of additional storage was operated in the post-processor model to capture available Delta surplus and to take control of "spilled" rescheduled water supplies. The total yield of this operation was then apportioned to the project investor districts at the percentages defined in the two feasibility options noted above. All other model parameters used in the post-processor were identical to those used for the NAA, CVP-Only, and CVP/SWP Shared alternatives.

Changes and effects on system conditions and deliveries for this alternative are identical to those seen under the CVP-Only Storage Alternative, as the capture of additional Delta surplus uses CVP export facilities and is operated at the same frequencies and under the same conditions as those seen under the CVP-Only Alternative. Any changes to upstream operations or Delta conditions from the CVP-Only Alternative would not be expected.

7.2 Investor A/B Alternative Results

The Investor A/B Alternative was analyzed over an 82-year period to estimate the changes to the CVP/SWP system. The following sections summarize the effects of the alternative on San Luis Reservoir, investor deliveries, and the CVP/SWP system as a whole. Results are shown in a comparative sense between the Investor A/B Alternative and the NAA, both of which include rescheduled water operations.

7.2.1 San Luis Reservoir

Changes to the annual maximum and minimum San Luis Reservoir Storage under the Investor A/B Alternative are identical to those seen under the CVP-Only Alternative. As such, please refer to Figure 5-1, 5-2, and 5-3 for changes to annual maximum and minimum Total San Luis Reservoir Storage, CVP San Luis Reservoir Storage, and SWP San Luis Reservoir Storage, respectively.

7.2.2 CVP South-of-Delta Deliveries

As noted above, CVP South-of-Delta deliveries to contractors who are not investors under this alternative are identical to the deliveries under the NAA. As such, please refer to the deliveries noted in Table 3-1 (with rescheduled water) for reference. Deliveries for the project investors (CVP contractors) are summarized in Section 7.2.4.

7.2.3 SWP South-of-Delta Deliveries

As noted above, SWP deliveries under this alternative are identical to those seen under the CVP-Only Alternative. For reference please refer to the deliveries noted in Table 5-5, Table 5-6, and Table 5-7 for a comparison to the NAA.

7.2.4 Investor Deliveries

As the final investor participation is still being determined, the total delivery of investor water is summarized as an aggregated total. When the final investor participation is determined, the total deliveries presented here will be delivered proportionally to each investor.

Table 7-1 shows the average Investor Deliveries under the Investor A/B by water year index. The total delivery volume is comparable to the total change in CVP South-of-Delta deliveries seen under the CVP-Only Alternative. As much of the additional storage space in San Luis is used for storage of spilled rescheduled water and additional Delta surplus, the majority of investor deliveries occur in Below Normal, Above Normal, and Wet Years.

Table 7-1. Average Project Investor Deliveries with Investor A/B Storage Alternative

Sacramento Valley Index	Investor A/B Storage Alternative (TAF)
Wet	63
Above Normal	27
Below Normal	33
Dry	7
Critical	14
All Years	35

As the investor-directed storage space is able to capture spilled CVP rescheduled supplies, the total volume of foregone pumping is reduced from the NAA. Table 7-2 shows the change in average CVP foregone pumping by water year index for the NAA, the Investor A/B Alternative, and the change from the NAA. The reduction in foregone pumping from the NAA is identical to foregone pumping under the CVP-Only alternative. The reduction in foregone pumping compared to the NAA acts to provide approximately 50% of the total increase in CVP South-of-Delta deliveries, as the reduction in foregone pumping equates to less "spill" of rescheduled water supply.

Table 7-2. Average CVP Foregone Pumping with Investor A/B Alternative

Sacramento Valley Index	No Action Alternative (TAF)	Investor A/B Alternative (TAF)	Change from NAA (TAF)
Wet	95	57	-38
Above Normal	15	3	-12
Below Normal	29	13	-16
Dry	26	18	-12
Critical	5	0	-5
All Years	43	25	-18

7.2.5 CVP/SWP Effects

The Investor A/B Storage Alternative can create small changes in CVP/SWP operations beyond just San Luis Reservoir and contractors who take delivery of water from the reservoir. These changes have the potential to affect resources in other parts of the system. Therefore, changes in river flows, reservoir storage, Delta outflow, and Delta export operations were quantified and reviewed in support of the environmental documentation. Overall changes are identical to those seen under the CVP-Only Alternative. Please refer to Table 5-8 for quantification of these changes at the locations identified above.

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Chapter 8 Investor-Directed Storage Alternative – Configurations C and D

The Investor-Directed Storage Alternative – Configurations C and D ("Investor C/D") includes a 130,000 acre-feet increase in the maximum San Luis Reservoir Storage. However, as opposed to the CVP-Only and CVP/SWP Shared Storage Alternatives, the use of the additional storage capacity would be primarily investor-directed. The remaining expanded capacity, when not in use by the investor districts, would be available to Reclamation to store additional Delta surplus.

Under this alternative, as opposed to the Investor A/B Alternative, the maximum annual rescheduled quantity would increase by 130,000 acre-feet to a maximum of 310,000 acre-feet. As in the Investor A/B Alternative, the delivery of any water supply yielded from storing Delta surplus in the additional storage space would be delivered proportionally among the investor group. Likewise, under this alternative, when foregone pumping occurs and CVP contractor reschedule supplies are "spilled", the investor-directed storage is able to take control of the spilled rescheduled water. The increase in the rescheduled quantity allows for a different operational objective as opposed to the Investor A/B alternative. The operation in Investor A/B could be characterized as one that maximizes total water supply yield. Whereas the operation in Configurations C and D can be characterized as one that maximizes water supply reliability, by maximizing dry and critical year water supplies. By increasing the annual rescheduled water volume, additional supplies are kept in storage in wetter years for subsequent use in drier years. While this does provide for additional dry and critical year water supplies, it provides for less capture of foregone pumping resulting from CVP rescheduled supplies.

As noted in Chapter 7, the results presented in this chapter summarize the effects of the alternative on the system and the resulting deliveries to the investors as a single block of water. For the feasibility and economic analyses, the same two investor sharing configurations are being studied with the primary difference between A and C, and B and D being the maximum allowed volume of rescheduled water:

- Configuration C: 78% Ag, 7% M&I, 15% Refuge
- Configuration D: 10% Ag, 90% M&I, 0% Refuge

Accordingly, it is not yet appropriate to report changes to CVP South-of-Delta Ag Service, M&I, and Refuge deliveries in this document for this alternative as compared to the NAA. Rather, changes to total CVP South-of-Delta deliveries will be reported as the final investor group will be comprised of CVP South-of-Delta contractors, and the benefits of the project will be shared among the investor group.

8.1 Modeling Approach and Assumptions

For the Investor-Directed Storage Alternative – Configurations C and D, the NAA CalSim II model run was input to the post-processor and the additional 130,000 acre-feet of additional storage was operated in the spreadsheet to capture available Delta surplus and to take control of "spilled" rescheduled water supplies. The total yield of this operation was then apportioned to the project investors at the percentages defined in the two feasibility options noted above. The primary difference in the modeling of this alternative from all other alternatives is the increase of the annual rescheduling guidelines to allow up to 310,000 acre-feet of rescheduled water. All other parameters and post-processor inputs were identical to the other alternatives.

Changes and effects on system conditions and deliveries for this alternative would be essentially identical to those seen under the CVP-Only Storage Alternative, as the capture of additional Delta surplus would use CVP export facilities and would be operated at the same frequencies and under the same conditions as those seen under the CVP-Only Alternative. Any changes to upstream operations or Delta conditions from the CVP-Only Alternative would not be expected.

8.2 Investor C/D Alternative Results

The Investor C/D Alternative was analyzed over an 82-year period to estimate the changes to the CVP/SWP system. The following sections summarize the effects of the alternative on San Luis Reservoir, investor deliveries, and the CVP/SWP system as a whole. Results are shown in a comparative sense between the Investor C/D Alternative and the NAA, both of which include rescheduled water operations.

8.2.1 San Luis Reservoir

Figure 8-1 shows the probability of annual maximum and minimum Total San Luis Reservoir Storage Under the Investor C/D Alternative. Similar to Investor A/B, under this alternative, SWP San Luis Storage will be identical to SWP San Luis Storage under the CVP-Only Alternative. However, under Investor C/D, the CVP plus investor-directed storage will often be higher than CVP San Luis Storage seen under the CVP-Only Alternative. Since the operational objective of this alternative is to maintain additional storage and supply for drier years, additional project supplies will be rescheduled in non-dry and non-critical years in order to support greater withdrawals from storage in dry and critical years.

As such, the annual maximum and minimum results for Total San Luis Reservoir Storage are higher in nearly all years under Investor C/D, with San Luis Reservoir filling to the new maximum storage in nearly 20% of years, and generally higher in almost all years.

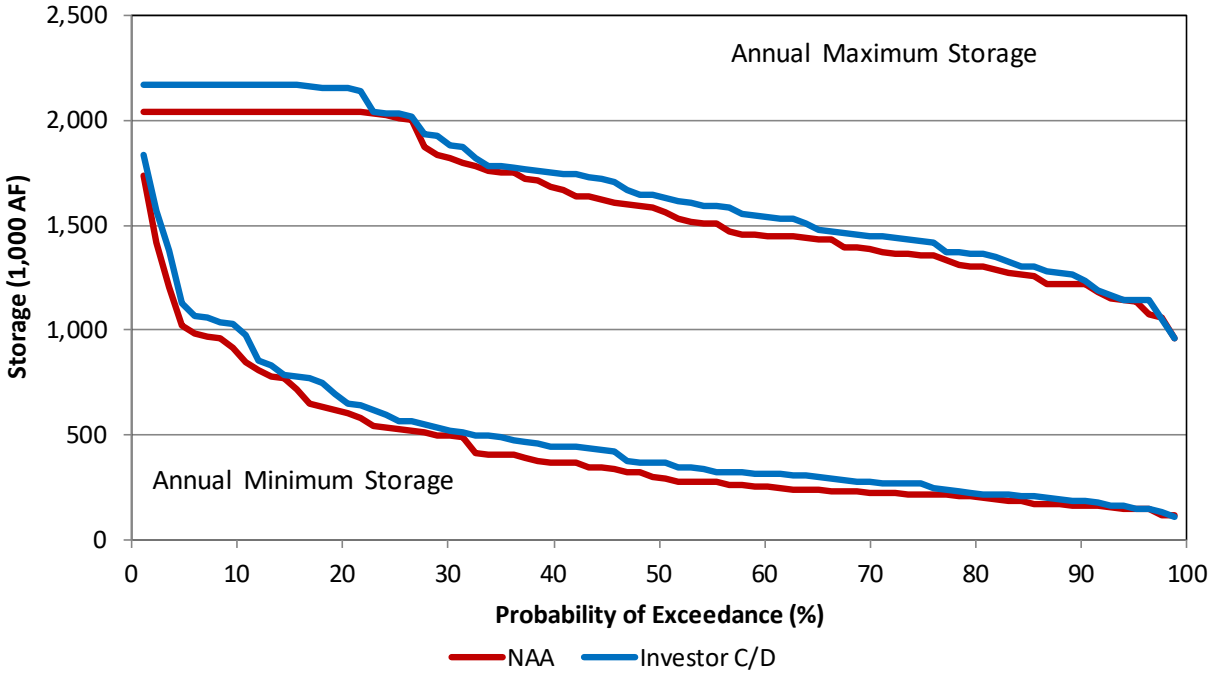


Figure 8-1. Probability of Annual Maximum and Minimum Total San Luis Reservoir Storage

To better demonstrate the increase in storage under the Investor C/D Alternative, the exceedance probability of annual maximum and minimum storage for combined CVP San Luis Storage plus the Investor-Directed Storage compared to CVP San Luis Storage under the NAA are shown in Figure 8-2. The annual maximum storage is higher in all but 4 years under the Investor C/D Alternative, and the annual maximum is on average 85,000 acre-feet higher. The annual minimum storage is higher in 85% of years and is on average 50,000 acre-feet higher.

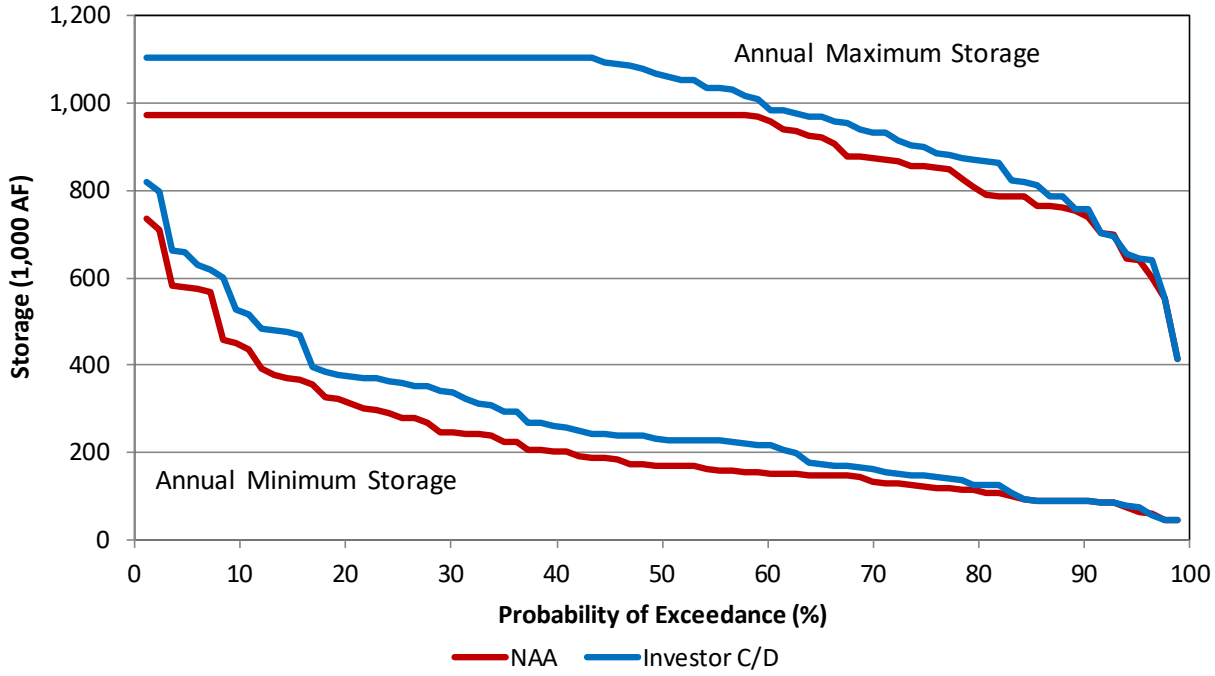


Figure 8-2. Probability of Annual Maximum and Minimum CVP San Luis + Investor-Directed Storage with the Investor C/D Alternative

As noted above, annual maximum and minimum SWP San Luis Storage results for the Investor C/D Alternative are essentially identical to the results under the CVP-Only Alternative. Please refer to Figure 5-3 to compare the probability of exceedance for the annual minimum and maximum SWP San Luis Storage.

8.2.2 CVP South-of-Delta Deliveries

As noted above, CVP South-of-Delta deliveries to contractors who are not investors under this alternative are identical to the deliveries under the NAA. As such, please refer to the deliveries noted in Table 3-1 (with rescheduled water) for reference. Deliveries for the project investors (CVP contractors) are summarized in Section 8.2.4.

8.2.3 SWP South-of-Delta Deliveries

As noted above, SWP deliveries under this alternative are identical those seen under the CVP-Only Alternative. For reference please refer to the deliveries noted in Table 5-5, Table 5-6, and Table 5-7 for a comparison to the NAA.

8.2.4 Investor Deliveries

As the final investor participation is still being determined, the total delivery of investor water is summarized as an aggregated total. When the final investor participation is determined, the total deliveries presented here will be delivered proportionally to each investor.

Table 8-1 shows the average South-of-Delta Investor Deliveries under the Investor C/D by water year index. The total delivery volume is noticeably less compared to the Investor A/B Alternative and the Total South-of-Delta CVP delivery difference in the CVP-Only Alternative. As the primary goal of this alternative is to improve dry and critical year deliveries, annual average deliveries are expected to decrease, as more water is rescheduled rather than being delivered. As compared to the Investor A/B Alternative, deliveries in Wet, Above Normal, and Below Normal years are less, while deliveries in dry and critical years are greater.

Table 8-1. Average Project Investor Deliveries with Investor C/D Storage Alternative

Sacramento Valley Index	Investor C/D Storage Alternative (TAF)
Wet	-9
Above Normal	-1
Below Normal	-3
Dry	28
Critical	30
All Years	10

Although the investor-directed storage space is able to capture spilled CVP rescheduled supplies, the increase to average CVP San Luis Storage results in a slight increase to the annual average volume of foregone pumping as compared to the NAA. Table 8-2 shows the change in average CVP foregone pumping by water year index for the NAA, the Investor C/D Alternative, and the change from the NAA.

Table 8-2. Average CVP Foregone Pumping with Investor C/D Alternative

Sacramento Valley Index	No Action Alternative (TAF)	Investor C/D Alternative (TAF)	Change from NAA (TAF)
Wet	95	120	26
Above Normal	15	8	-6
Below Normal	29	15	-14
Dry	26	32	6
Critical	5	2	-3
All Years	43	50	6

8.2.5 CVP/SWP Effects

The Investor C/D Storage Alternative can create small changes in CVP/SWP operations beyond just San Luis Reservoir and contractors who take delivery of water from the reservoir. These changes have the potential to affect resources in other parts of the system. Therefore, changes in river flows, reservoir storage, Delta outflow, and Delta export operations were quantified and reviewed in support of the environmental documentation. The following tables provide a high-level summary of changes throughout the CVP/SWP system. Overall, changes from the NAA are nearly identical to those seen in the CVP-Only and Investor A/B Alternatives, with the only noticeable

difference being average monthly CVP San Luis Storage, a smaller increase to Jones exports, and small changes to Delta Outflow. This is largely expected as the operational objectives of this alternative will keep Jones exports similar, although there is additional foregone pumping since there is generally more water (and thus less available space) San Luis storage. More detailed results were provided and reviewed by resource area specialists and are illustrated in figures located in Attachment B. Table 8-3 provides a summary of the average monthly model results at key locations in the system under the Investor C/D Alternative.

Table 8-3. Summary of Investor C/D Alternative CVP/SWP System Effects

NAA	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Delta Outflow (cfs)	6,747	8,920	25,033	45,224	57,590	45,403	28,838	18,412	11,414	7,966	4,734	6,789
Jones Pumping Plant (cfs)	3,131	3,607	3,609	3,663	3,776	2,968	2,624	2,857	2,957	2,541	3,304	3,237
Banks Pumping Plant (cfs)	2,804	4,981	4,531	3,471	4,065	3,360	3,224	2,485	2,459	5,164	4,527	2,375
Sac. River into Delta (cfs)	11,032	14,332	23,913	31,758	38,755	33,218	24,685	18,640	16,098	17,261	13,487	11,726
Yolo Bypass (cfs)	120	588	4,907	12,219	16,420	9,543	2,664	211	88	50	101	72
Sac. River below Keswick (cfs)	6,412	6,261	7,807	9,378	11,457	8,860	5,702	8,122	10,305	12,822	9,551	6,332
Sac. River at NCP (cfs)	6,612	7,660	11,671	13,838	15,439	14,108	10,528	6,843	6,231	6,743	4,828	6,008
Feather R. blw Thermalito (cfs)	2,209	2,019	3,293	4,898	5,900	6,528	3,070	3,758	4,041	6,964	4,995	1,750
Lower Feather River (cfs)	2,725	2,966	6,101	12,048	14,038	13,835	8,730	7,541	5,948	7,021	5,656	3,417
American R blw Nimbus (cfs)	1,387	2,464	3,938	5,062	6,093	4,356	3,337	3,031	2,837	2,588	1,948	1,681
American R at H St (cfs)	1,230	2,311	3,796	4,899	5,895	4,152	3,057	2,728	2,459	2,125	1,595	1,452
SJ River at Vernalis (cfs)	2,668	2,607	3,368	5,109	6,793	7,290	7,511	5,980	4,099	2,616	1,828	2,213
Shasta Storage (TAF)	2,616	2,626	2,791	3,062	3,330	3,666	3,996	3,961	3,637	3,127	2,822	2,713
Oroville Storage (TAF)	1,672	1,651	1,788	2,019	2,293	2,504	2,768	2,844	2,653	2,189	1,875	1,779
Folsom Storage (TAF)	456	443	468	487	501	593	716	823	760	629	545	493
CVP San Luis Storage (TAF)	290	421	574	715	826	882	874	795	606	372	246	254
SWP San Luis Storage (TAF)	183	251	310	452	593	670	705	628	471	427	344	215
Investor Storage C/D	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Delta Outflow (cfs)	6,766	8,960	25,228	45,417	57,879	45,751	28,902	18,384	11,420	7,967	4,734	6,768
Jones Pumping Plant (cfs)	3,154	3,596	3,534	3,631	3,706	2,946	2,793	2,943	2,970	2,492	3,317	3,246
Banks Pumping Plant (cfs)	2,771	5,008	4,521	3,471	4,061	3,293	3,169	2,449	2,466	5,209	4,535	2,399
Sac. River into Delta (cfs)	11,022	14,358	23,945	31,745	38,762	33,229	24,678	18,640	16,105	17,241	13,490	11,719
Yolo Bypass (cfs)	120	587	4,906	12,216	16,420	9,543	2,665	211	88	48	101	72
Sac. River below Keswick (cfs)	6,442	6,285	7,835	9,363	11,457	8,869	5,694	8,125	10,306	12,762	9,554	6,318
Sac. River at NCP (cfs)	6,643	7,673	11,673	13,825	15,438	14,117	10,520	6,850	6,232	6,683	4,835	5,993
Feather R. blw Thermalito (cfs)	2,168	2,009	3,301	4,908	5,910	6,531	3,070	3,752	4,047	6,980	4,997	1,756
Lower Feather River (cfs)	2,685	2,956	6,109	12,054	14,041	13,836	8,729	7,535	5,953	7,035	5,669	3,423
American R blw Nimbus (cfs)	1,387	2,480	3,934	5,060	6,093	4,357	3,338	3,031	2,837	2,589	1,935	1,681
American R at H St (cfs)	1,227	2,327	3,790	4,897	5,896	4,153	3,058	2,727	2,460	2,121	1,585	1,452
SJ River at Vernalis (cfs)	2,668	2,607	3,368	5,109	6,793	7,290	7,511	5,980	4,099	2,617	1,829	2,213
Shasta Storage (TAF)	2,618	2,626	2,790	3,061	3,330	3,665	3,996	3,961	3,636	3,130	2,825	2,716
Oroville Storage (TAF)	1,672	1,651	1,788	2,018	2,291	2,502	2,766	2,842	2,652	2,186	1,872	1,776
Folsom Storage (TAF)	457	443	468	487	502	593	716	823	760	629	546	494
CVP San Luis Storage (TAF)	352	488	645	786	900	956	952	856	641	409	293	310
SWP San Luis Storage (TAF)	187	256	316	454	592	666	696	621	469	426	346	220
Change from NAA	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Delta Outflow (cfs)	18	40	194	194	290	348	64	-28	6	1	1	-21
Jones Pumping Plant (cfs)	23	-11	-74	-32	-70	-23	169	86	13	-49	13	9
Banks Pumping Plant (cfs)	-33	27	-11	0	-3	-67	-55	-36	6	44	8	24
Sac. River into Delta (cfs)	-10	25	32	-12	6	11	-8	0	7	-19	3	-7
Yolo Bypass (cfs)	0	-1	-1	-3	0	0	0	0	0	-2	0	0
Sac. River below Keswick (cfs)	30	24	27	-16	0	9	-8	3	2	-60	3	-14
Sac. River at NCP (cfs)	31	13	2	-13	-1	9	-9	7	1	-59	7	-15
Feather R. blw Thermalito (cfs)	-41	-10	8	10	10	4	1	-6	7	16	2	5
Lower Feather River (cfs)	-41	-10	8	7	3	1	0	-6	5	14	12	6
American R blw Nimbus (cfs)	-1	16	-4	-2	1	1	1	0	0	1	-13	0
American R at H St (cfs)	-2	16	-6	-2	1	1	1	0	0	-3	-10	0
SJ River at Vernalis (cfs)	0	0	0	0	0	0	0	0	1	1	1	0
Shasta Storage (TAF)	2	0	-2	-1	0	-1	0	-1	-1	3	3	3
Oroville Storage (TAF)	0	0	0	-1	-1	-2	-2	-1	-2	-3	-3	-3
Folsom Storage (TAF)	1	0	0	0	0	0	0	0	0	0	1	1
CVP San Luis Storage (TAF)	62	67	71	71	74	74	78	61	35	36	48	56
SWP San Luis Storage (TAF)	4	5	6	3	-1	-4	-9	-7	-2	-1	2	5

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Attachment A
CalSim II Assumptions for
No Project/No Action Conditions

	Period of Simulation: 82 years (1922-2003)
	Future Level Study
HYDROLOGY	
Level of Development	ELY Q5 projected changes in temperature and precipitation; Sea level rise increased 15cm; modified inflows based on historical hydrology and projected climate condition; Projected 2030 level of development[1]
Sacramento River Region Demands	
CVP	Land use based, limited by full contract
SWP (FRSA)	Land use based, limited by full contract
Non-Project	Land use based
Woodland-Davis Clean Water Agency	Included
Antioch	Pre-1914 water right
CVP Refuges	Firm Level 2 water needs
American River Basin Demands	
Water rights	2025 Level
CVP	2025 Level, full contracts except for Settlement Contractors at historical diversions, including Freeport Regional Water Project
San Joaquin River Basin Demands	
Friant Unit	Limited by contract amounts, based on current allocation policy
Lower Basin	Land use based with district level operations and constraints
Stanislaus River Basin	Land use based, Stepped Release Plan (SRP)
South of Delta Demands	
CVP	Full contract
Contra Costa Water District	195 taf/yr
SWP (with North Bay Aqueduct)	4.1 maf/yr
SWP Article 21 Demand	Metropolitan Water District of Southern California up to 200 taf/month (Dec-Mar), KCWA demand up to 180 taf/month and others up to 34 taf/month
FACILITIES	
Red Bluff Diversion Dam	Diversion dam gates out all year, Pumping Plant operated to deliver CVP water
Fremont Weir	Notched Fremont Weir as represented in Yolo Bypass Salmonid Habitat Restoration and Fish Passage EIS/EIR Alternative 1 (preferred alternative)
Freeport Regional Water Project	Included with diversions to EBMUD
Banks Pumping Capacity	Physical capacity is 10,300 cfs, 6,680 cfs permitted capacity up to 8,500 cfs (Dec 15th–Mar 15th) depending on Vernalis flow conditions[2] additional capacity of 500 cfs (up to 7,180 cfs) allowed for Jul–Sep for reducing impact of NMFS biological opinion on SWP
Jones Pumping Capacity	Exports up to 4,600 cfs permit capacity in all months
Delta-Mendota Canal-California Aqueduct Intertie	Included with 400 cfs capacity
Los Vaqueros Reservoir Capacity	160 taf
South Bay Aqueduct	South Bay Aqueduct rehabilitation; 430 cfs

	Period of Simulation: 82 years (1922-2003)
	Future Level Study
REGULATORY STANDARDS	
Trinity River	
Minimum Flow below Lewiston Dam	Trinity EIS Preferred Alternative (369-815 taf/yr)
Trinity River Fall Augmentation Flows	420 cfs August 1 through September 30 in all but wet years
Trinity Reservoir End-of-September Minimum Storage	Trinity EIS Preferred Alternative (600 TAF as able)
Clear Creek	
Minimum Flow below Whiskeytown Dam	Downstream water rights, 1963 Reclamation Proposal to USFWS and NPS, predetermined Central Valley Project Improvement Act 3406(b)(2) flows and NMFS biological opinion (June 2009) Action I.1.1
Upper Sacramento River	
Shasta Lake End-of-September Minimum Storage	1900 TAF in non-critically dry years (not explicitly modeled – achieved through project allocation profiles when hydrologically feasible)
Minimum Flow below Keswick Dam	Flows for SWRCB Water Rights Order 90-5 and 1993 Winter-run biological opinion temperature control, predetermined Central Valley Project Improvement Act 3406(b)(2) flows, and NMFS biological opinion (Jun 2009), Action I.2.2
Feather River	
Minimum Flow below Thermality Diversion Dam	2006 Settlement Agreement (700/800 cfs)
Minimum Flow below Thermality After bay outlet	1983 DWR, DFG Agreement (750-1700 cfs)
Yuba River	
Minimum flow below Daguerre Point Dam	D-1644 Operations (Lower Yuba River Accord)
American River	
Minimum Flow below Nimbus Dam	American River Flow Management per 2017 Water Forum Agreement with a planning minimum end of September storage target of 275 TAF
Minimum Flow at H Street Bridge	SWRCB D-893
Lower Sacramento River	
Minimum Flow near Rio Vista	SWRCB D-1641
Mokelumne River	
Minimum Flow below Camanche Dam	Federal Energy Regulatory Commission 2916-029, 1996 Joint Settlement Agreement (100 – 325 cfs)
Minimum Flow below Woodbridge Diversion Dam	Federal Energy Regulatory Commission 2916-029, 1996 Joint Settlement Agreement (25 – 300 cfs)
Stanislaus River	
Minimum Flow below Goodwin Dam	Flows per New Melones SRP
Minimum Dissolved Oxygen	SWRCB D-1422

	Period of Simulation: 82 years (1922-2003)
	Future Level Study
REGULATORY STANDARDS	
Merced River	
Minimum Flow below Crocker-Huffman Diversion Dam	Davis-Grunsky (180 – 220 cfs, Nov – Mar) and Cowell Agreement
Minimum Flow at Shaffer Bridge	Federal Energy Regulatory Commission 2179 (25-100 cfs)
Tuolumne River	
Minimum Flow at Lagrange Bridge	Federal Energy Regulatory Commission 2299-024, 1995 Settlement Agreement (94-301 taf/yr)
San Joaquin River	
San Joaquin River Restoration	Full flows
Maximum Salinity near Vernalis	Stanislaus contribution per D-1641
Minimum Flow near Vernalis	Stanislaus contribution per D-1641
Sacramento River-San Joaquin River Delta	
Delta Outflow Index (Flow and Salinity)	SWRCB D-1641
Delta Cross Channel Gates	SWRCB D-1641, model representation same as NMFS biological opinion (Jun 2009) Action 4.1.2
Delta Exports	SWRCB D-1641 Vernalis flow-based export limits Apr 1 – May 31 (additional 500 cfs allowed Jul – Sep for reducing impact on SWP)
Combined Flow in Old and Middle River	OMR target of -5,000 cfs January through June except for 5 day of -2,000 cfs when turbidity bridge occurs and 7 days of -6,000 cfs when increased pumping due to storm is possible, and -3,500 cfs in April and May of AN and BN years; followed by "first flush" action only if it occurs in December (14 days -2,000 cfs)
OPERATIONS CRITERIA	
Subsystem	
Upper Sacramento River	
Flow Objective for Navigation (Wilkins Slough)	Flow objective for Wilkins Slough based on month, CVP allocation, and Shasta storage condition to reflect CVP operations for local delivery
American River	
Folsom Dam Flood Control	Variable 400/670 without outlet modifications
Feather River	
Flow at Mouth	Maintain DFG/DWR flow target above Verona or 2800 cfs Apr-Sep, dependent on Oroville inflow and FRSA allocation
System-wide	
CVP Water Allocation	
CVP Settlement and Exchange	100% (75% in Shasta Critical years)
CVP Refuges	100% (75% in Shasta Critical years)
CVP Agriculture	100% - 0% based on supply; South-of-Delta allocations are additionally limited due to D-1641 and OMR action
CVP Municipal & Industrial	100% - 50% based on supply; South-of-Delta allocations are additionally limited to D-1641 and OMR action

	Period of Simulation: 82 years (1922-2003)
	Future Level Study
OPERATIONS CRITERIA	
SWP Water Allocation	
North of Delta (FRSA)	Contract specific
South of Delta	Based on supply, equal prioritization between Ag and M&I based on Monterey Agreement; allocations are additionally limited due to D-1641 and OMR action
CVP/SWP Coordinated Operations	
Sharing of Responsibility for In Basin Use	Revised Coordinated Operations Agreement
Sharing of Surplus Flows	Revised Coordinated Operations Agreement
Sharing of Restricted Export Capacity	Revised Coordinated Operations Agreement
Transfers	
Lower Yuba River Accord[3]	Yuba River acquisitions for reducing impact of D-1641 and OMR Action export restrictions on SWP

[1] The Sacramento Valley hydrology used in the Future Conditions CalSim II model reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Development of future-level projected land-use assumptions are being coordinated with the California Water Plan Update for future models.

[2] Current US Army Corps of Engineers permit for Harvey O. Banks Pumping Plant allows for an average diversion rate of 6,680 cfs in all months. Diversion rate can increase up to 1/3 of the rate of San Joaquin River flow at Vernalis during Dec 15th–Mar 15th up to a maximum diversion of 8,500 cfs, if Vernalis flow exceeds 1,000 cfs.

[3] Acquisitions of Component 1 water under the Lower Yuba River Accord and use of 500 cfs dedicated capacity at Banks Pumping Plant during Jul–Sep, are assumed to be used to reduce as much of the effect of the April–May Delta export actions on SWP contractors as possible.

Attachment B
Comparison of NAA and Project Alternatives

Figure 1: Comparison of Trinity Storage for Non-Structural Alternative

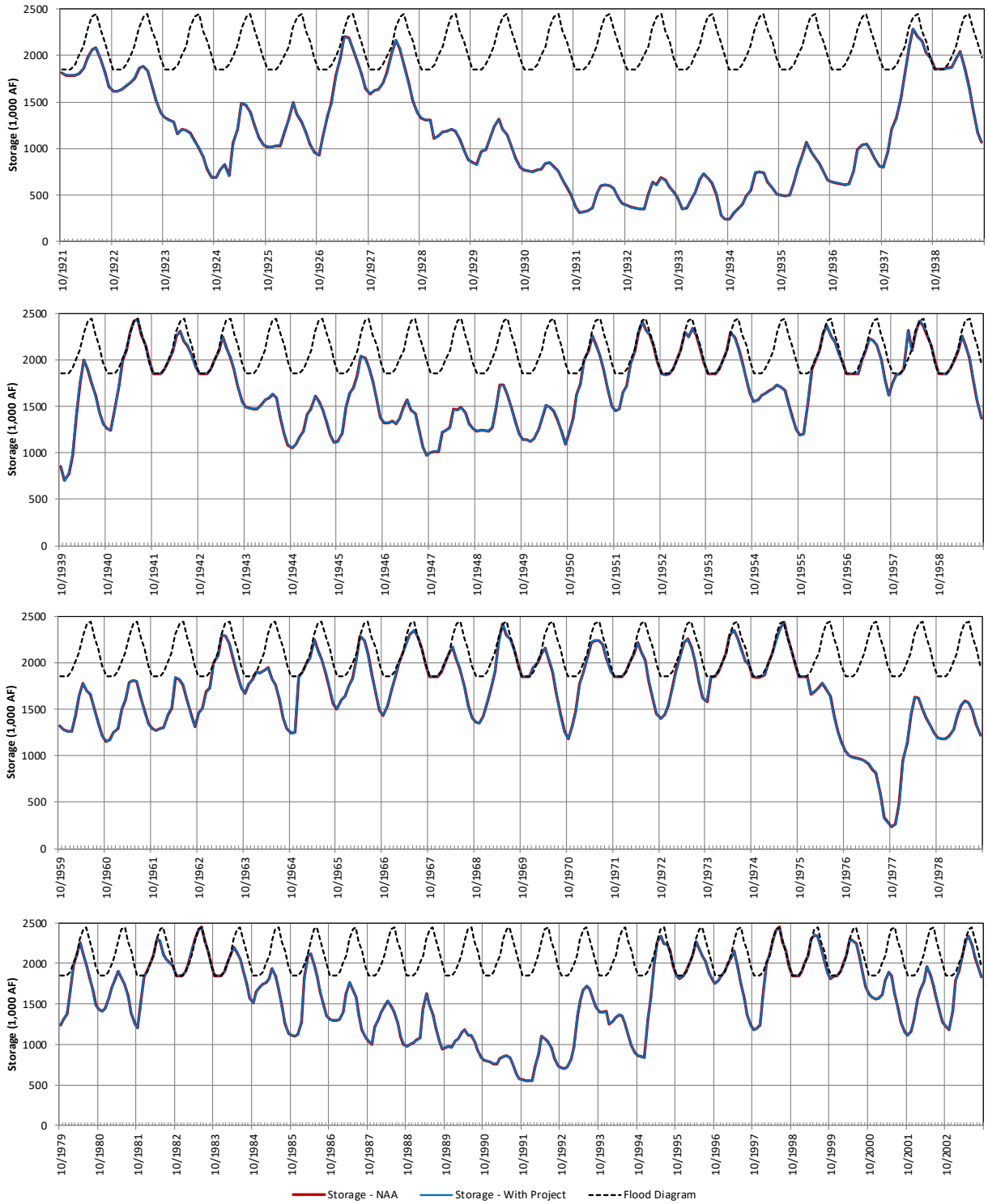


Figure 2: Comparison of Shasta Storage for Non-Structural Alternative

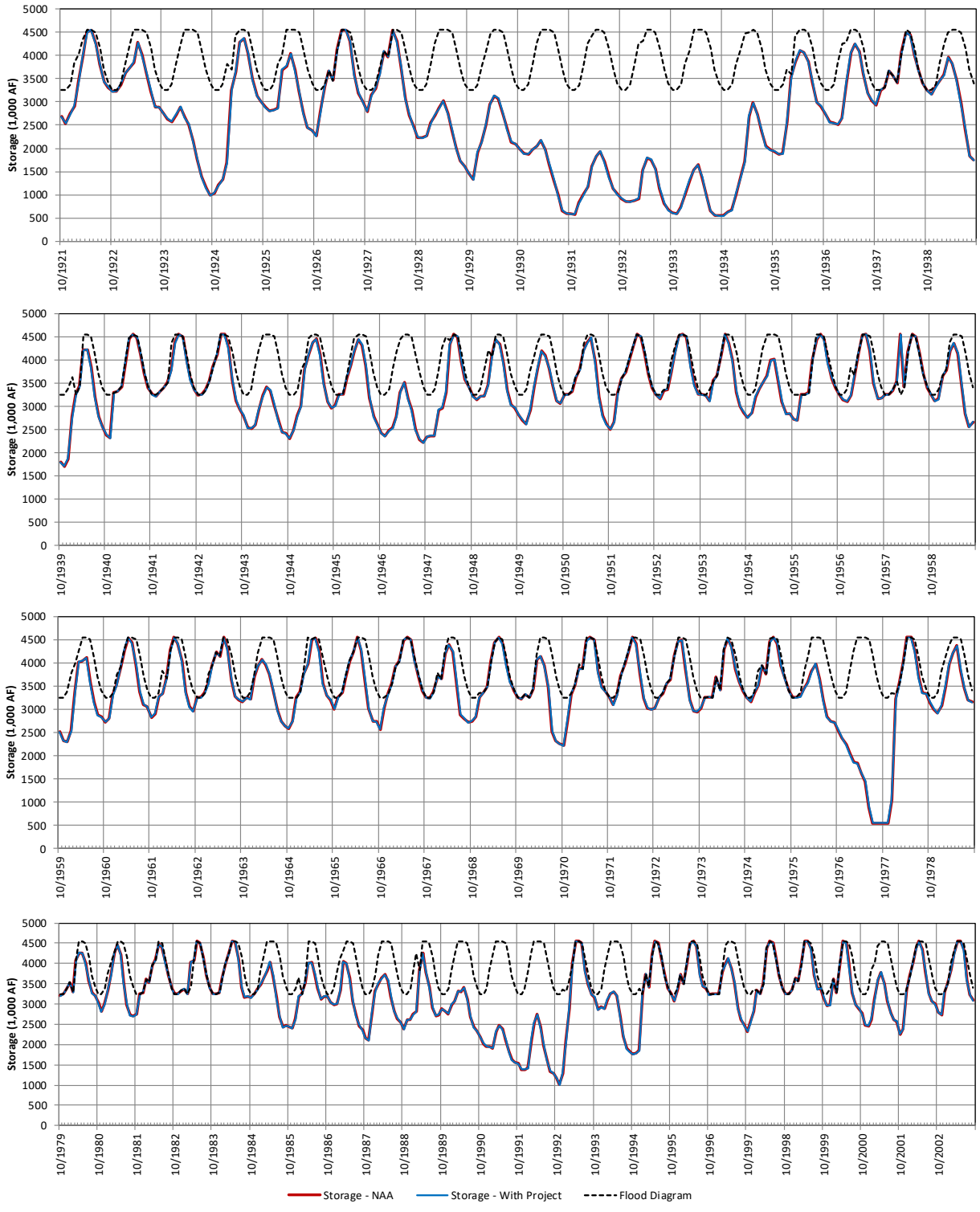


Figure 3: Comparison of Folsom Storage for Non-Structural Alternative

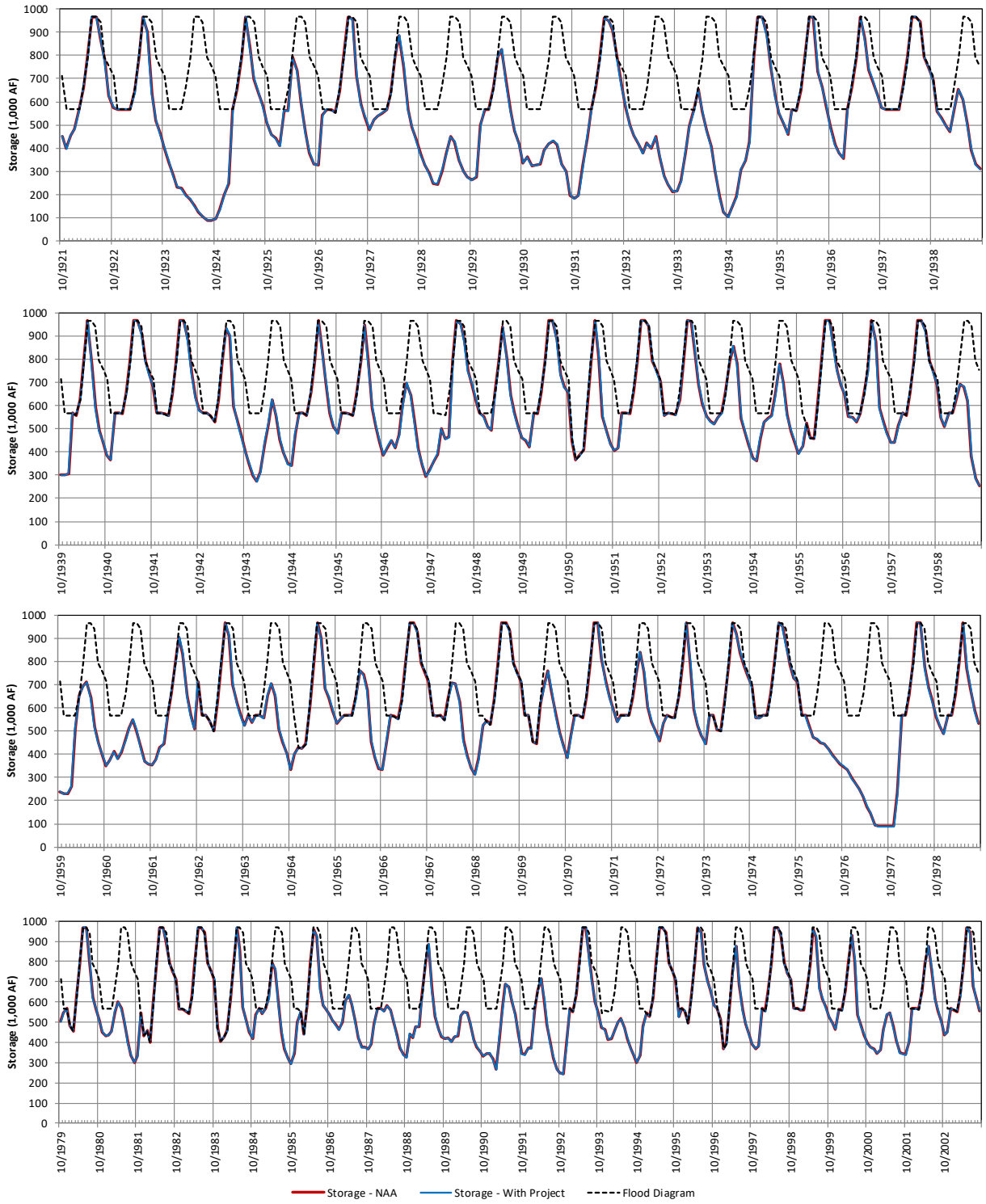


Figure 4: Comparison of Oroville Storage for Non-Structural Alternative

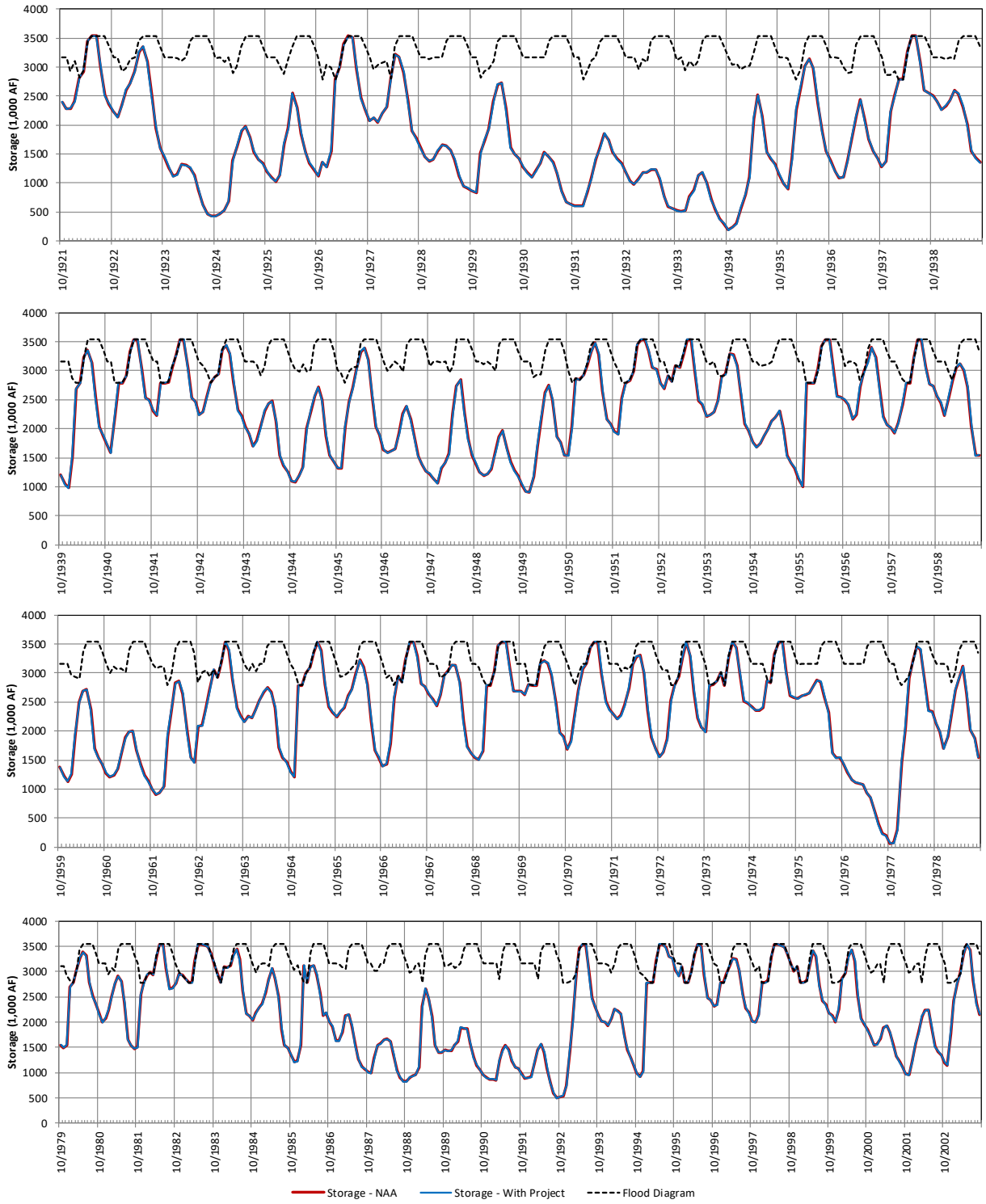


Figure 5: Comparison of Sacramento River below Keswick Flow for Non-Structural Alternative

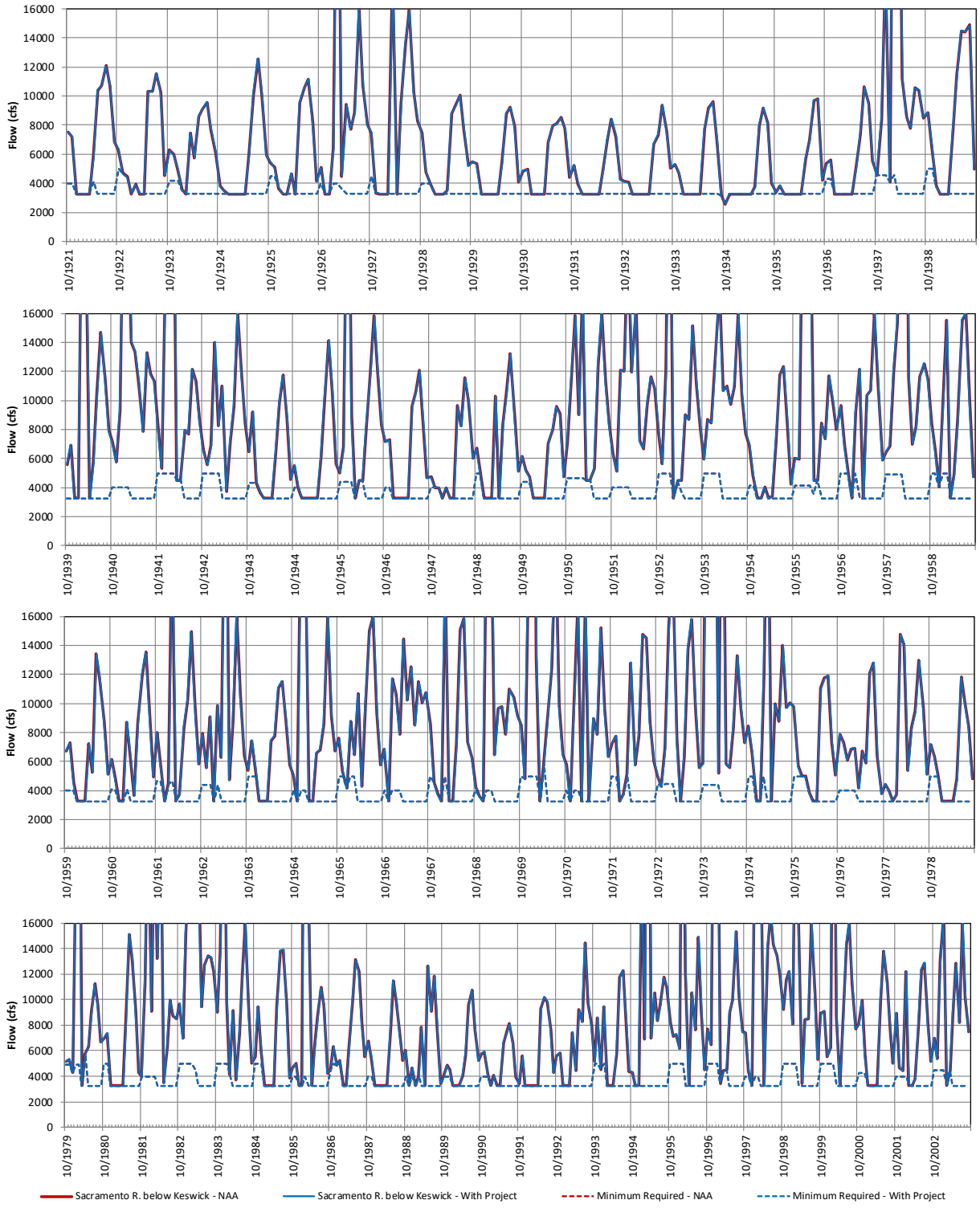


Figure 6: Comparison of Sacramento River at Wilkins Slough Flow for Non-Structural Alternative

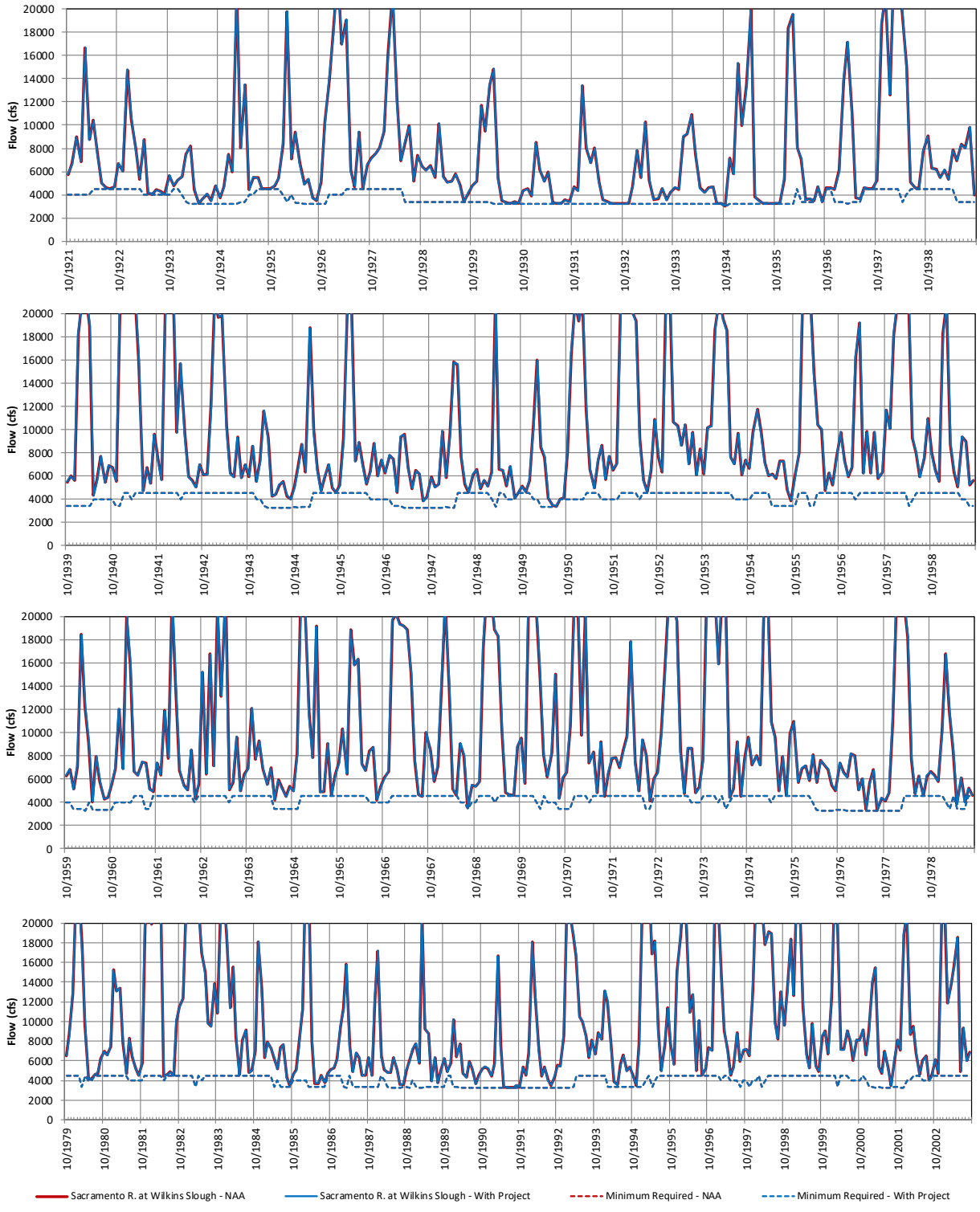


Figure 7: Comparison of American River below Nimbus Flow for Non-Structural Alternative

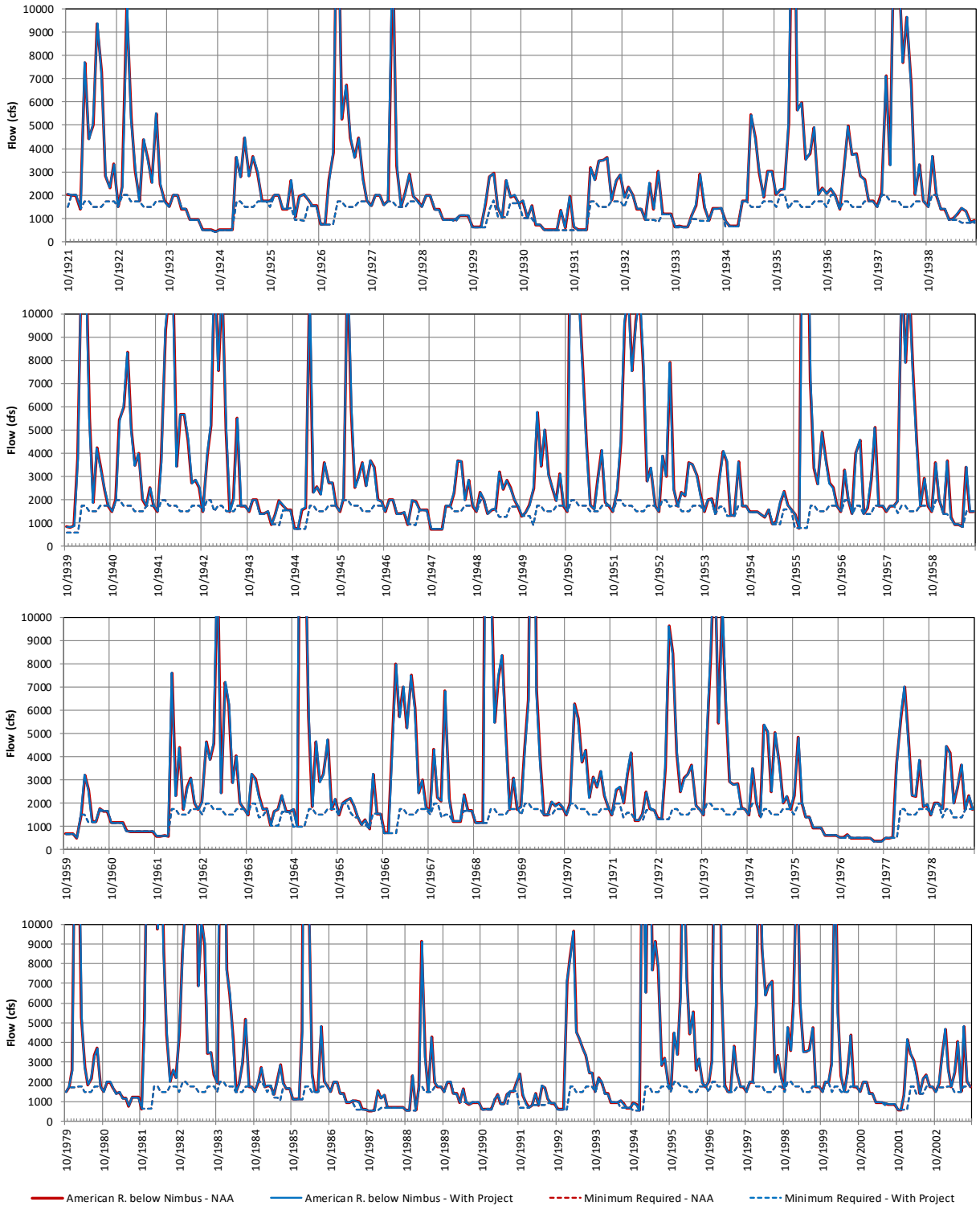


Figure 8: Comparison of Lower Feather River Flow for Non-Structural Alternative

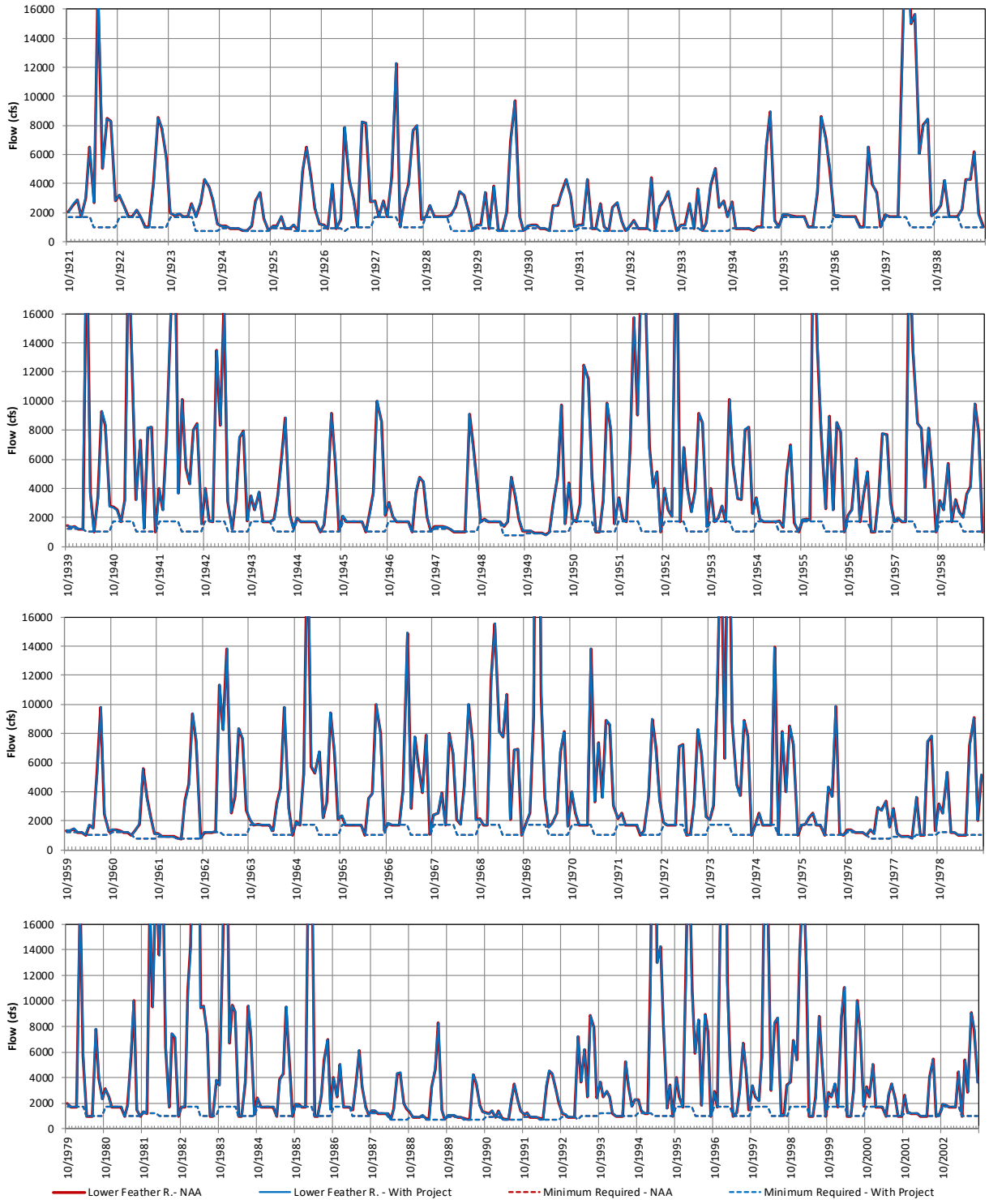


Figure 9: Comparison of Delta Inflow for Non-Structural Alternative

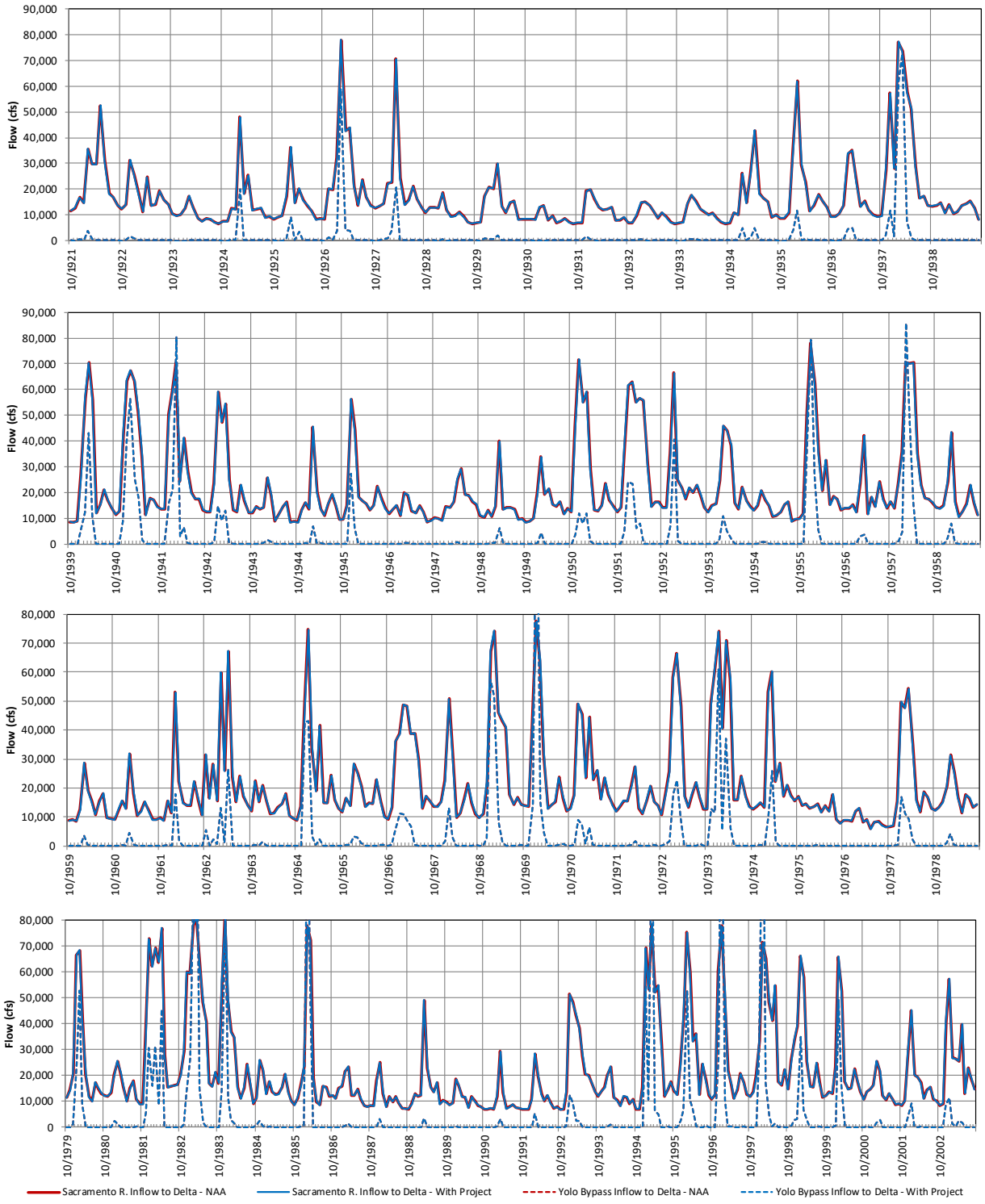


Figure 10: Comparison of Delta Outflow for Non-Structural Alternative

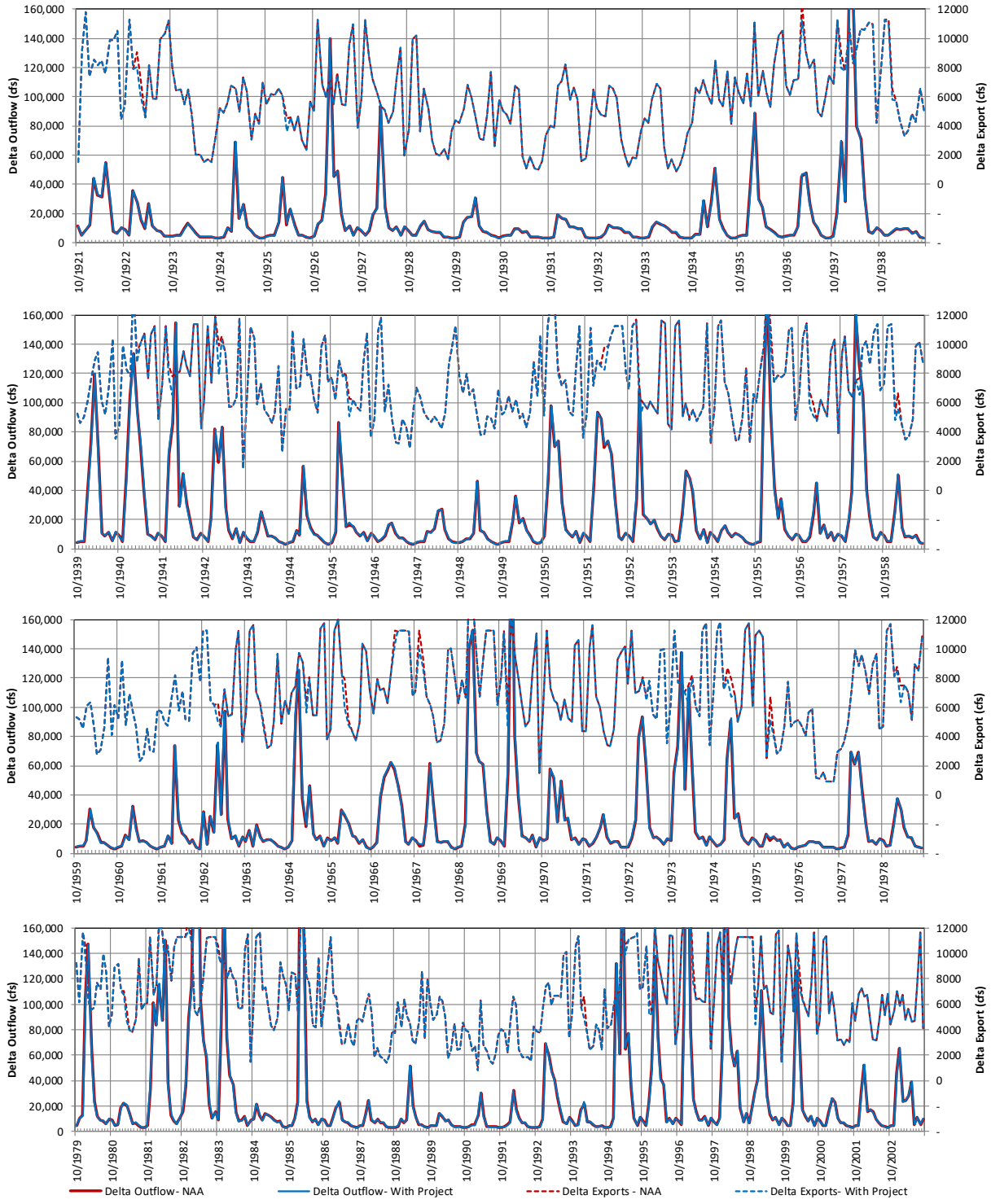


Figure 11: Comparison of San Luis Reservoir Storage for Non-Structural Alternative

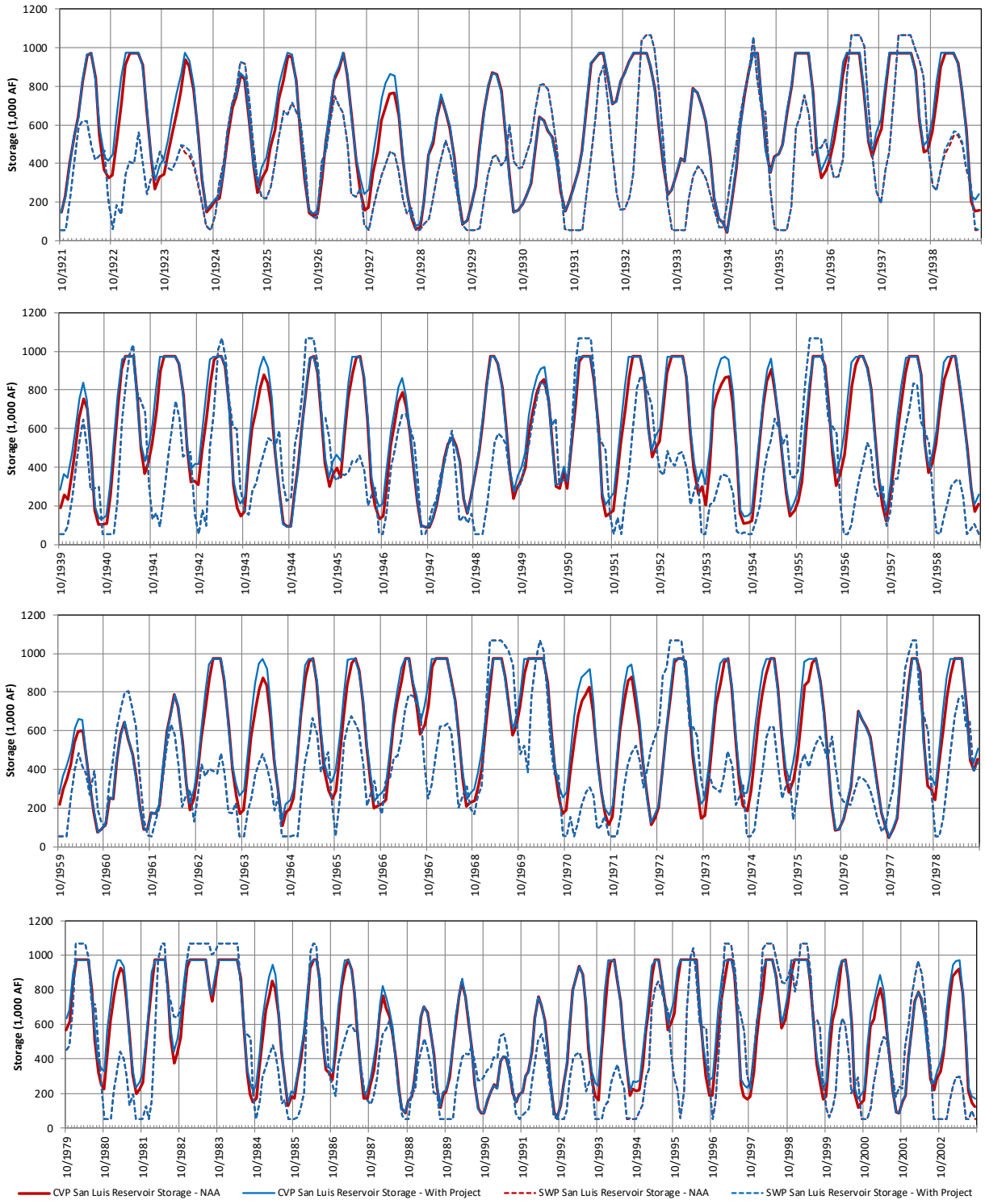


Figure 12: Comparison of Trinity Storage for CVP-Only Storage Alternative

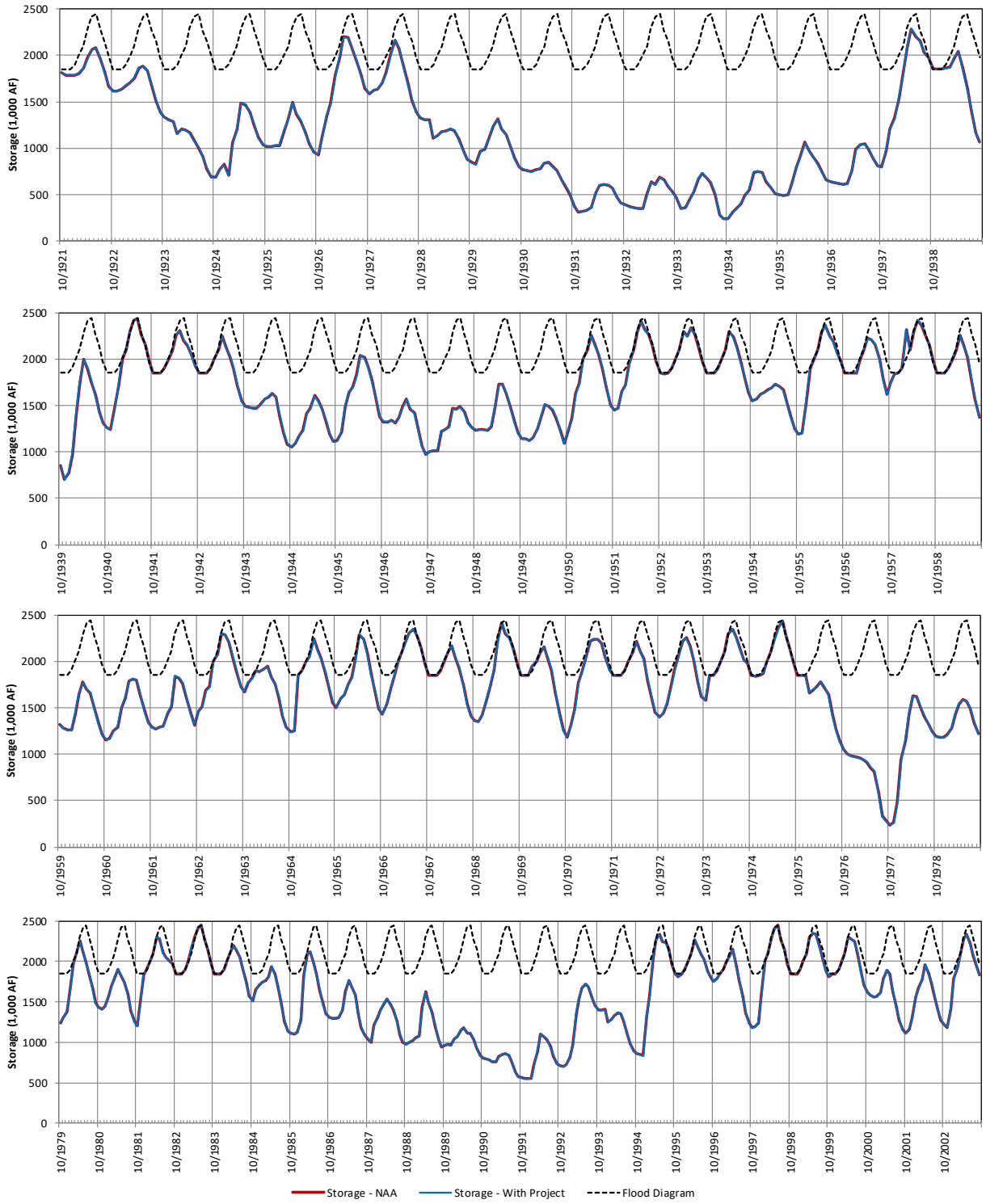


Figure 13: Comparison of Shasta Storage for CVP-Only Storage Alternative

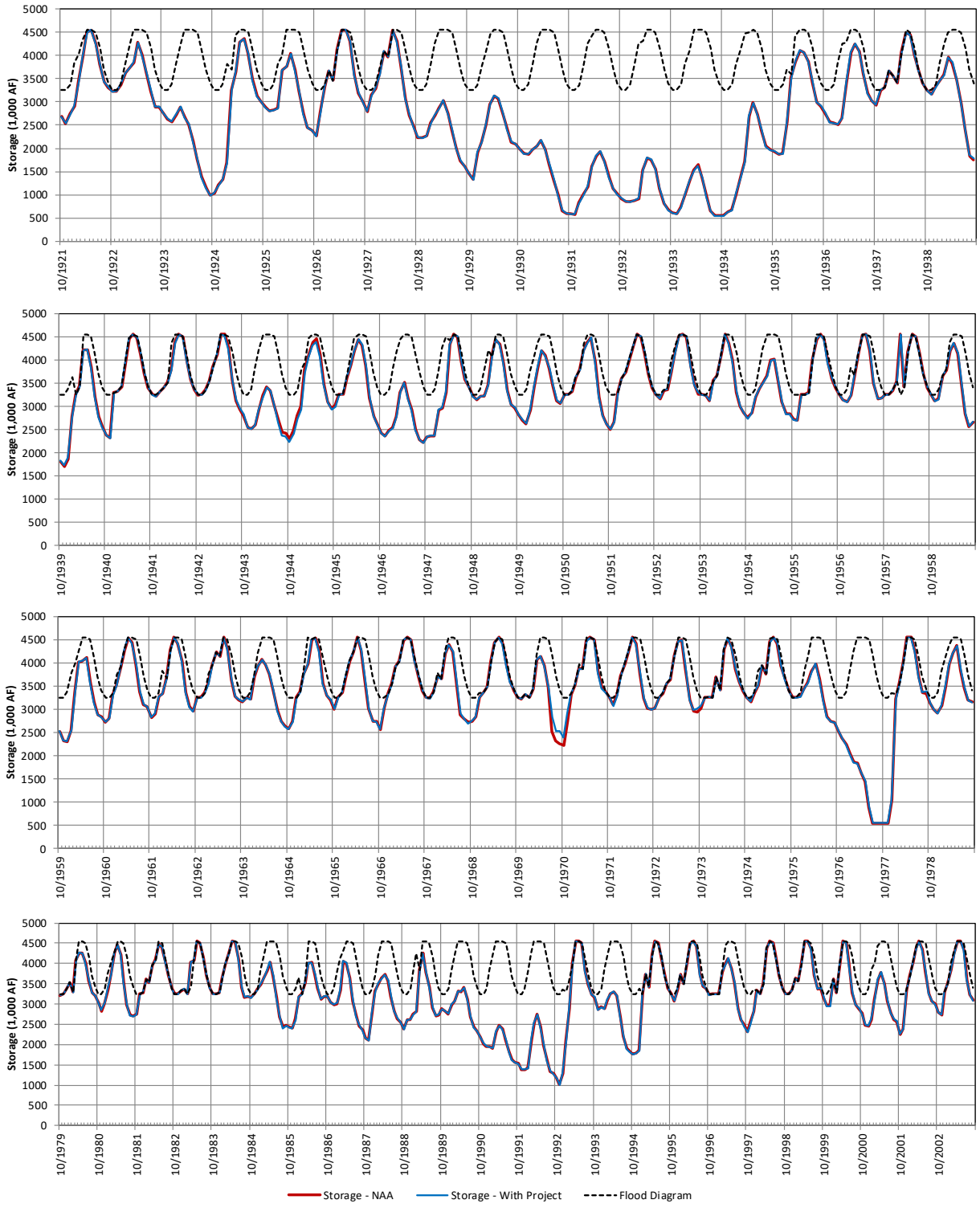


Figure 14: Comparison of Folsom Storage for CVP-Only Storage Alternative

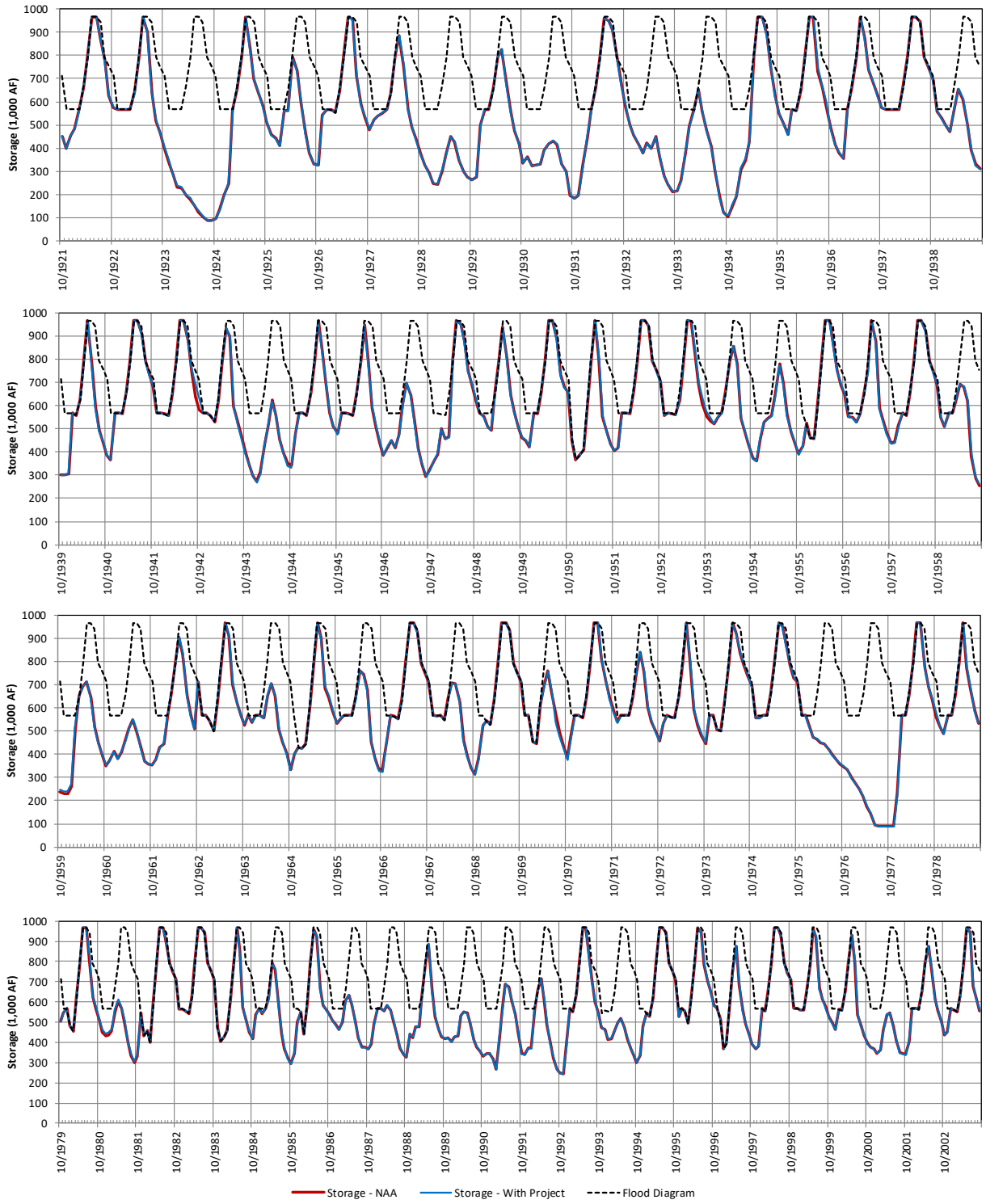


Figure 15: Comparison of Oroville Storage for CVP-Only Storage Alternative

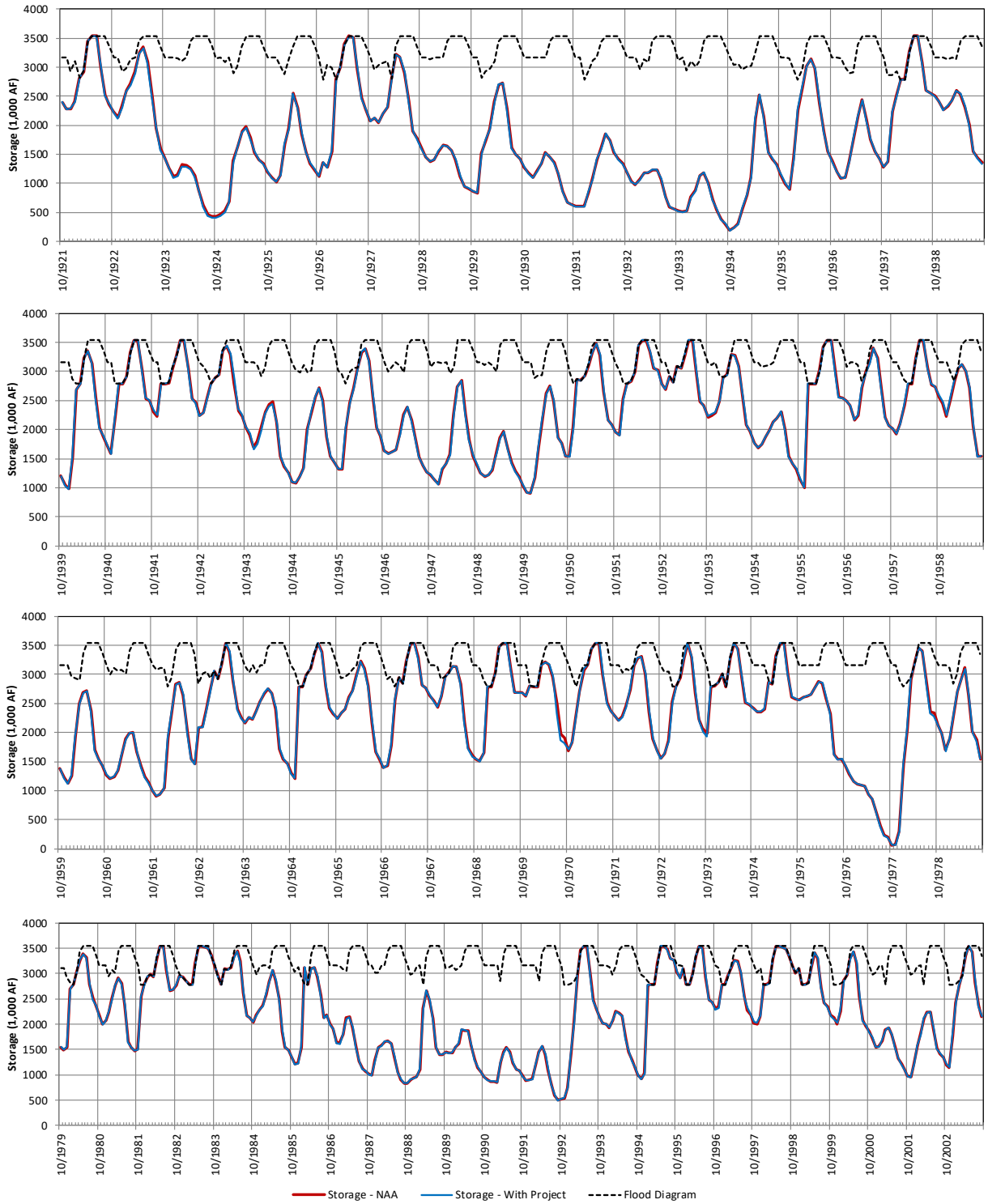


Figure 16: Comparison of Sacramento River below Keswick Flow for CVP-Only Storage Alternative

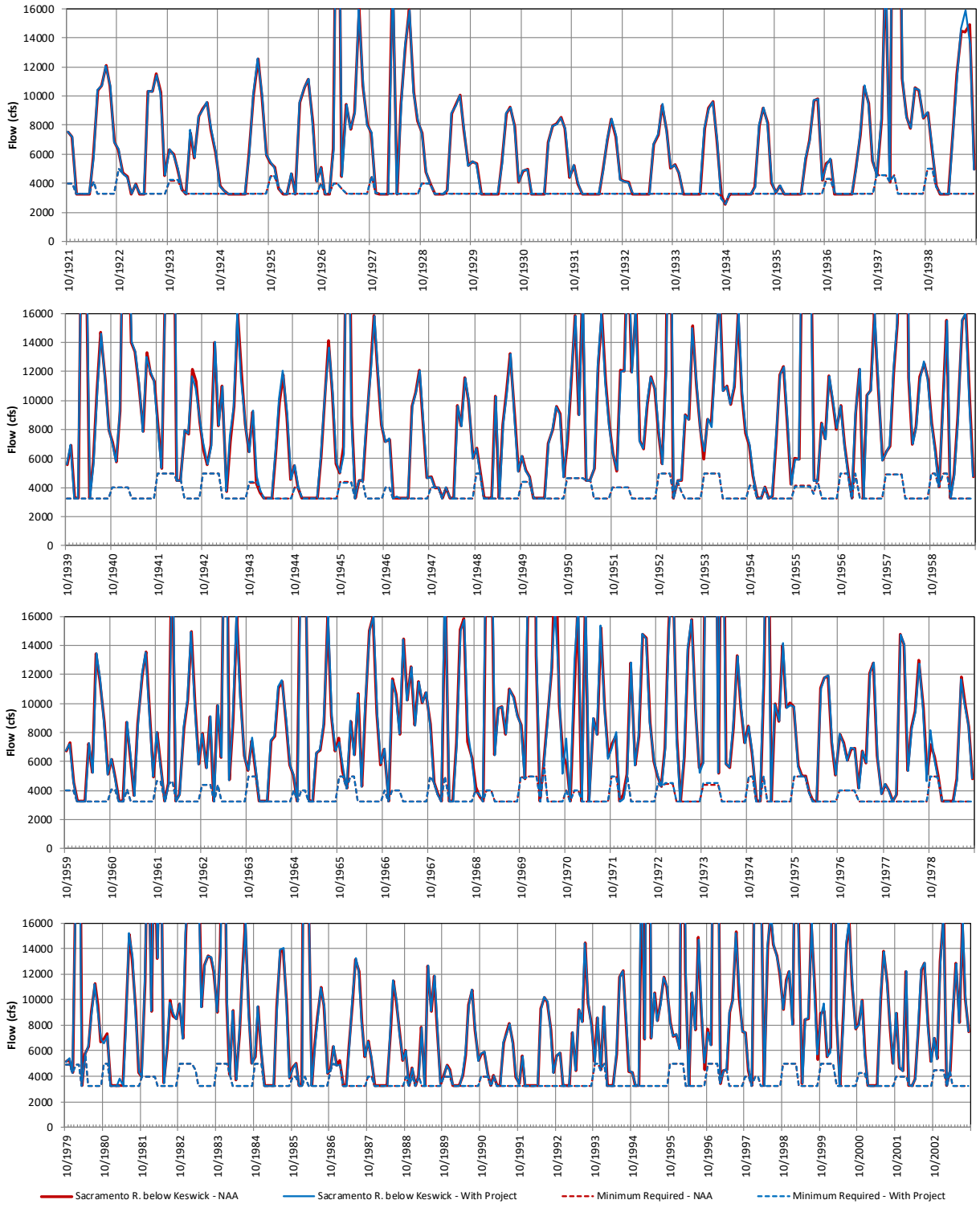


Figure 17: Comparison of Sacramento River at Wilkins Slough Flow for CVP-Only Storage Alternative

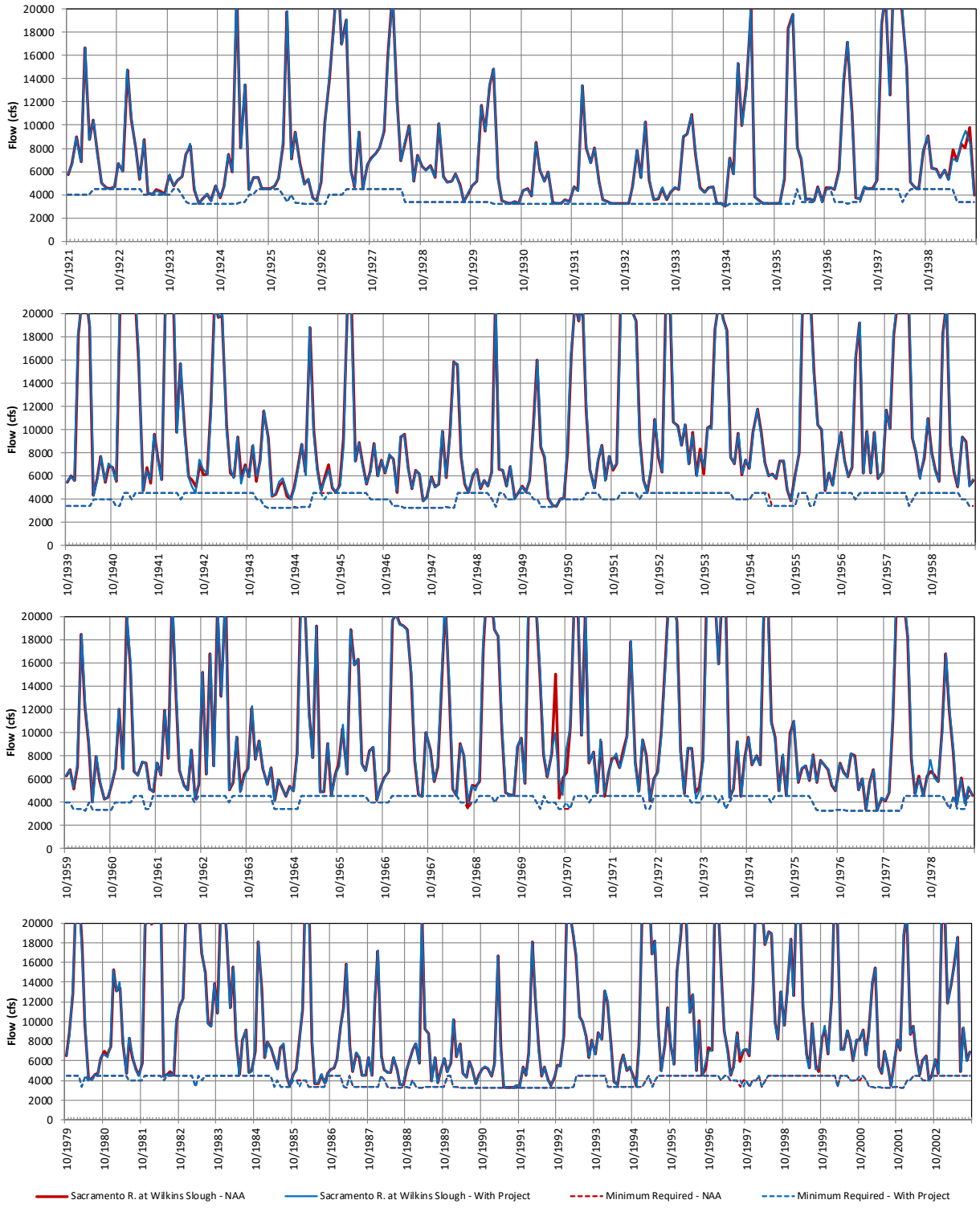


Figure 18: Comparison of American River below Nimbus Flow for CVP-Only Storage Alternative

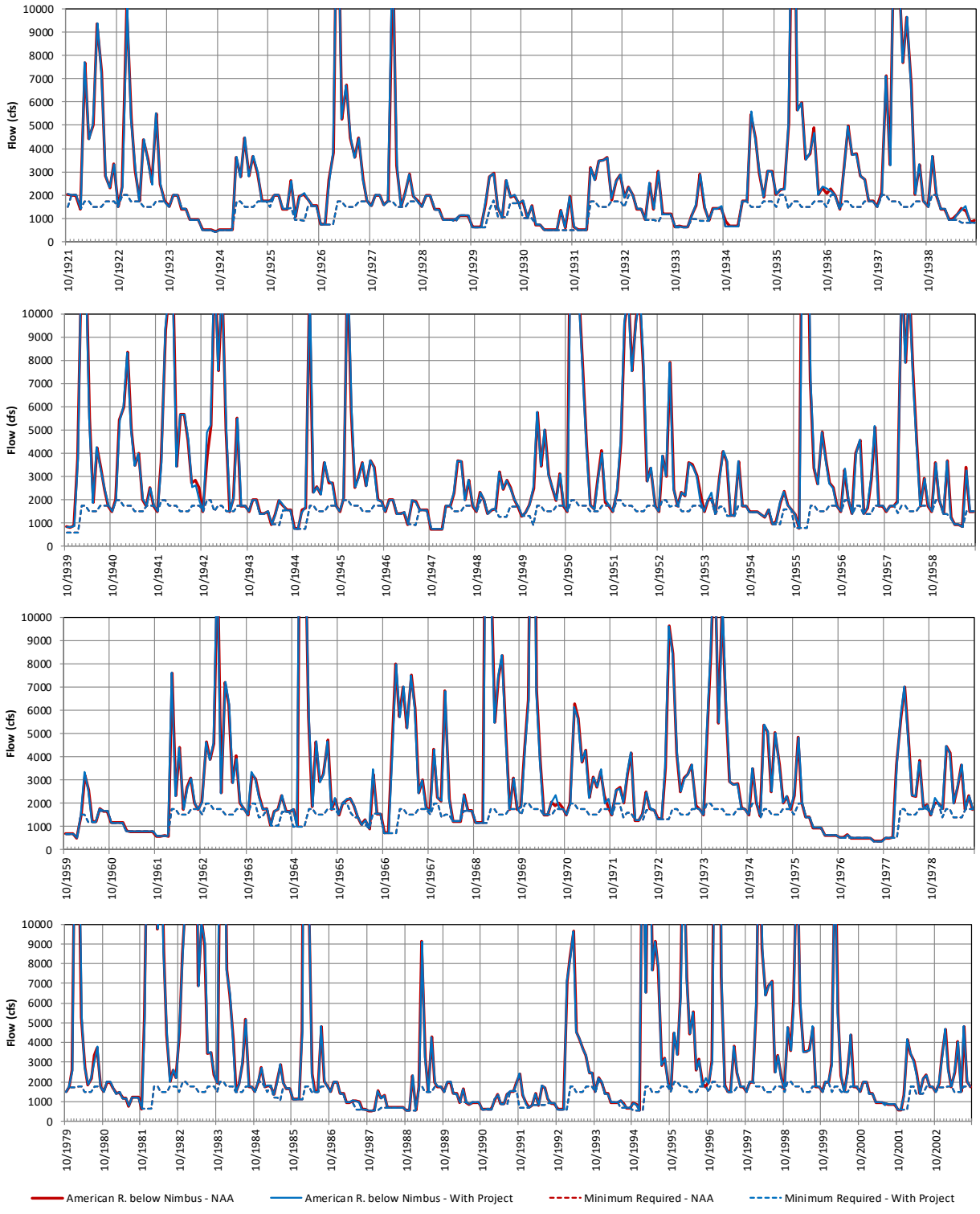


Figure 19: Comparison of Lower Feather River Flow for CVP-Only Storage Alternative

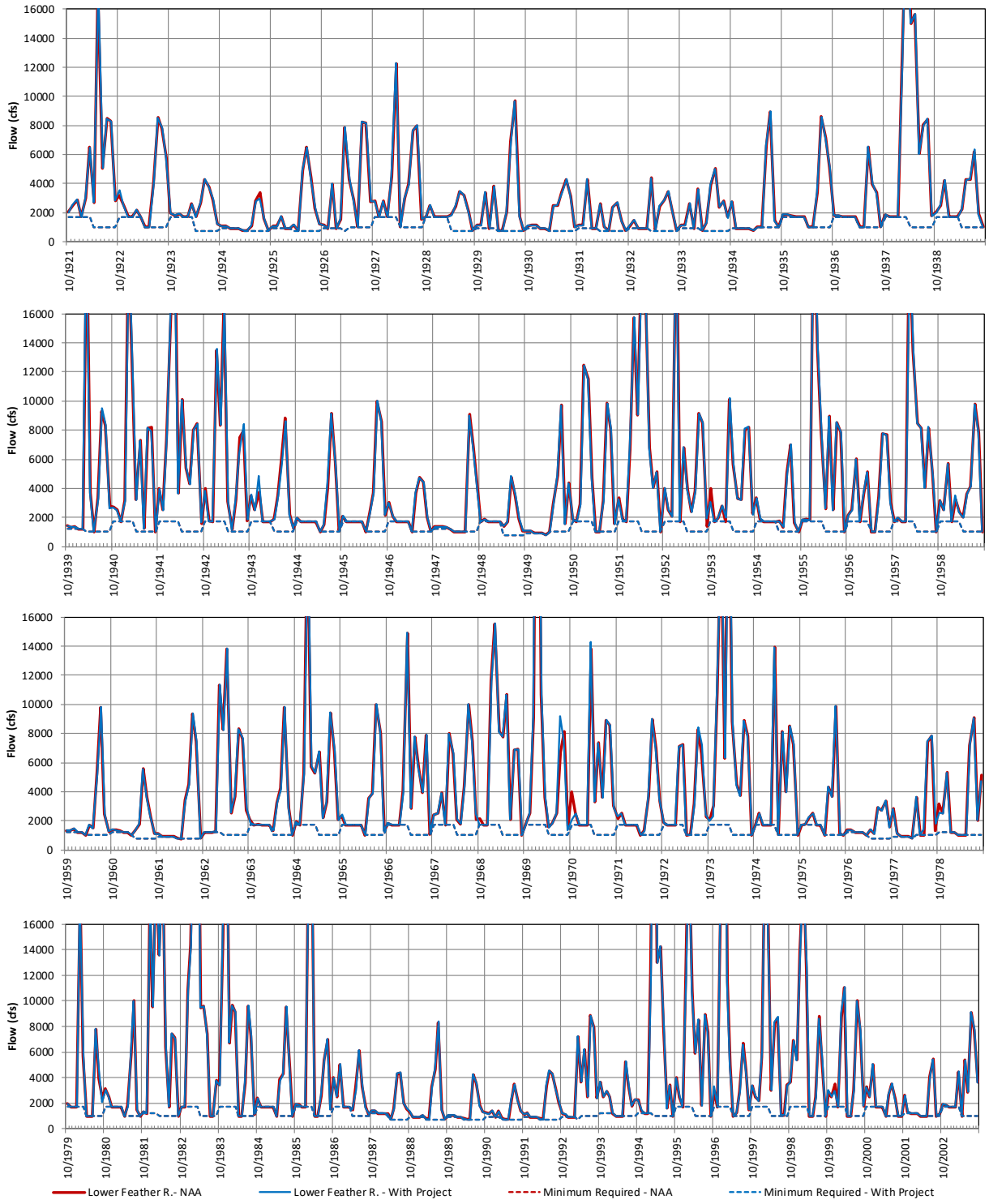


Figure 20: Comparison of Delta Inflow for CVP-Only Storage Alternative

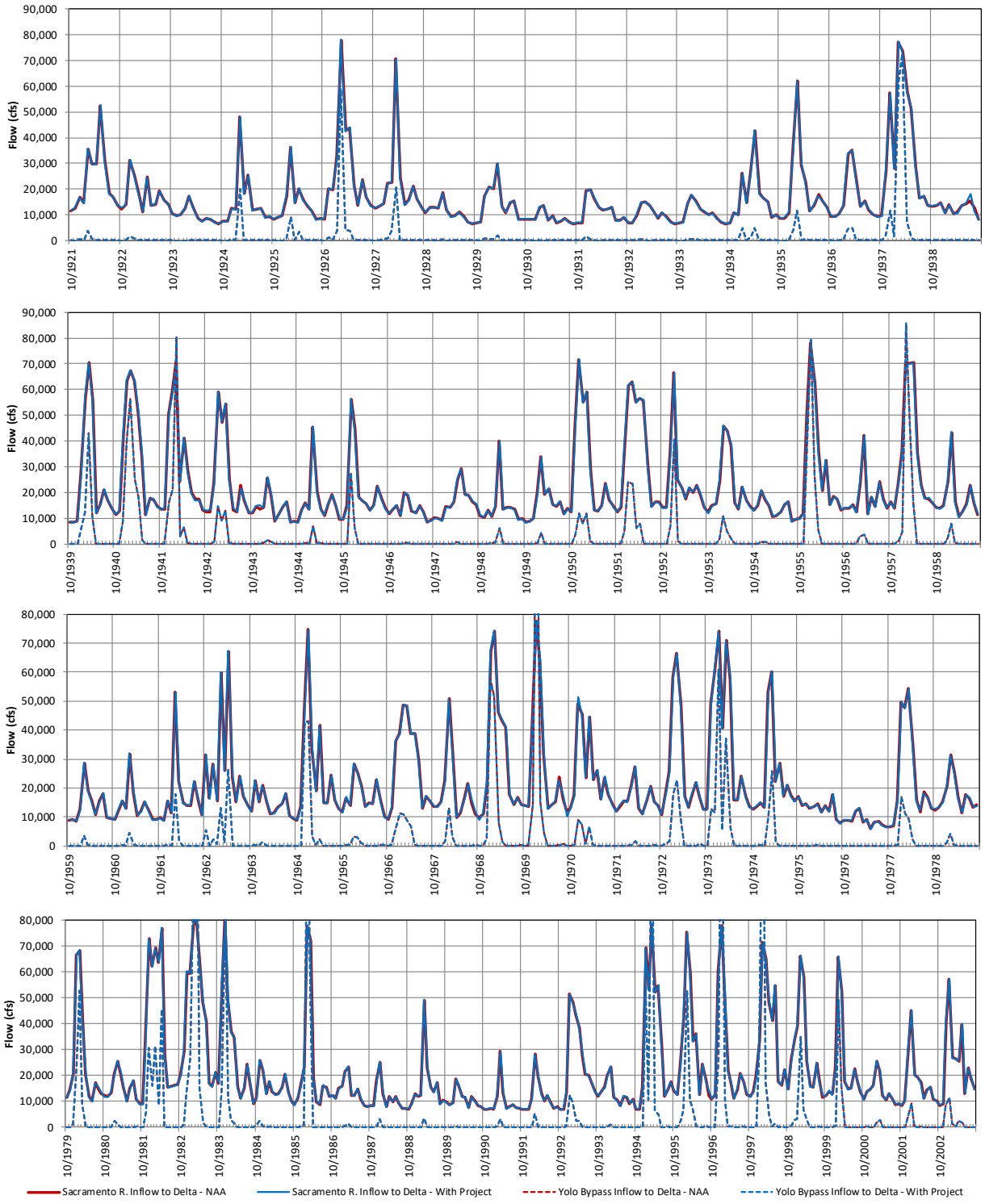


Figure 21: Comparison of Delta Outflow for CVP-Only Storage Alternative

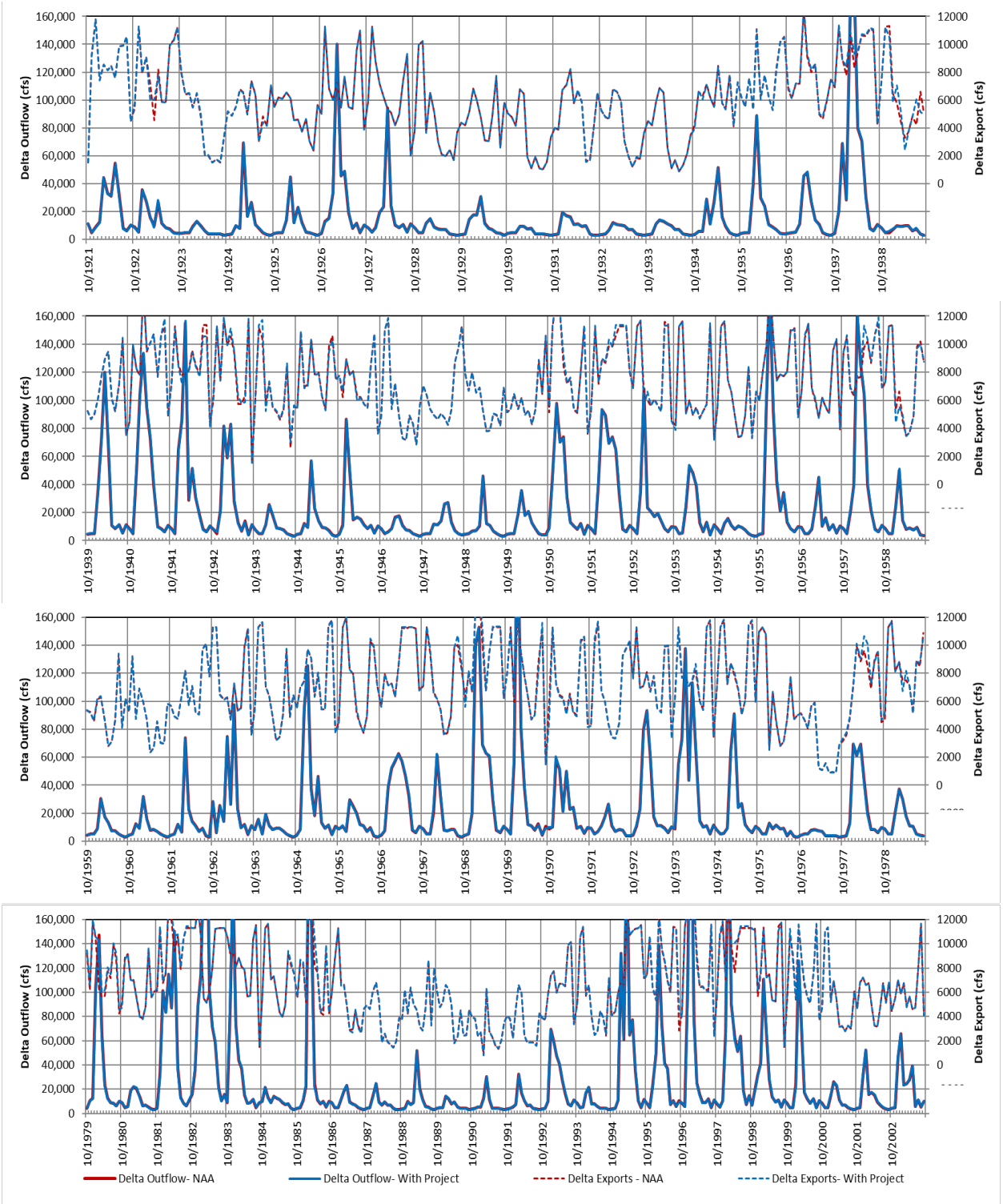


Figure 22: Comparison of San Luis Reservoir Storage for CVP-Only Storage Alternative

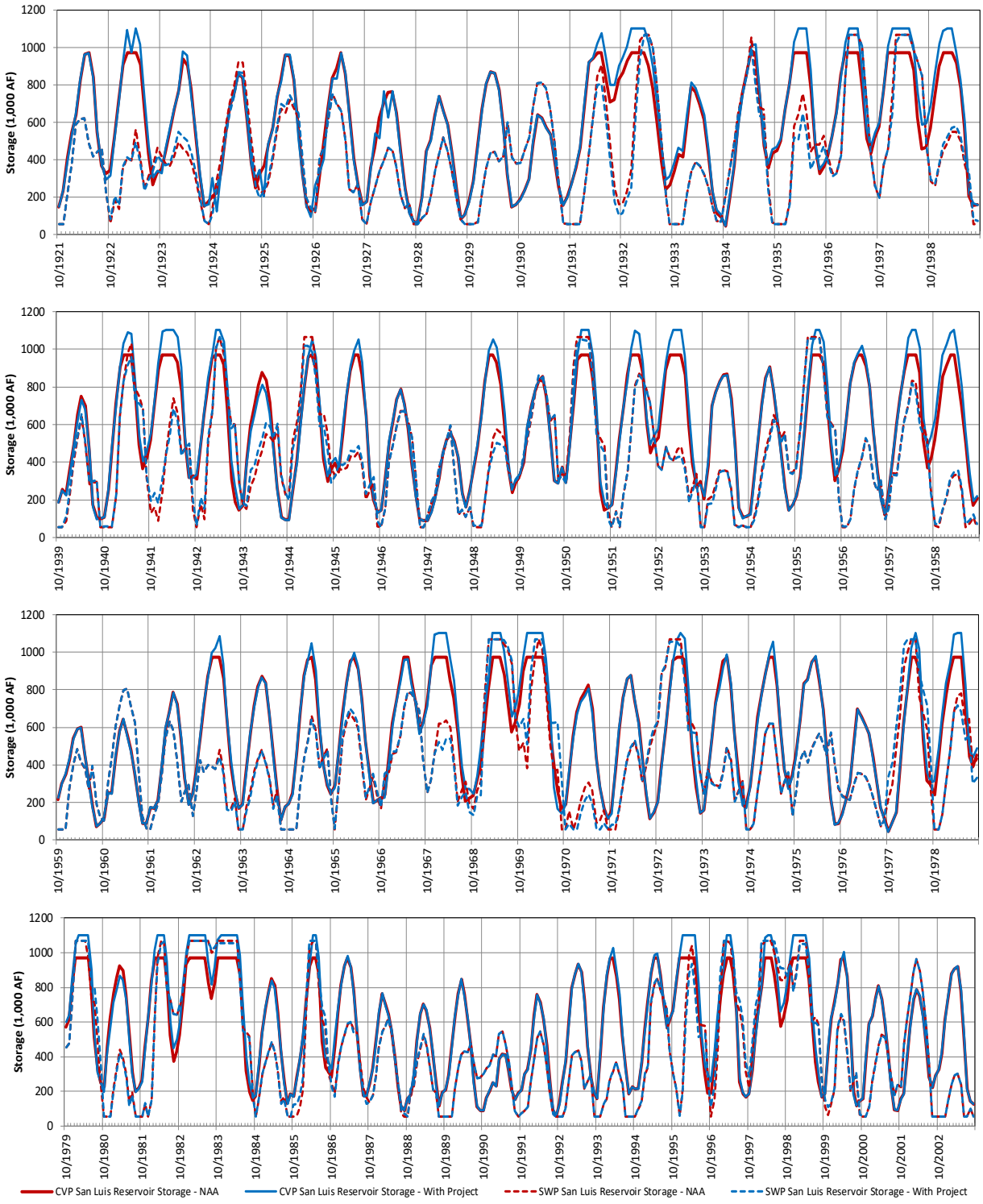


Figure 23: Comparison of Trinity Storage for CVP/SWP Shared Storage Alternative

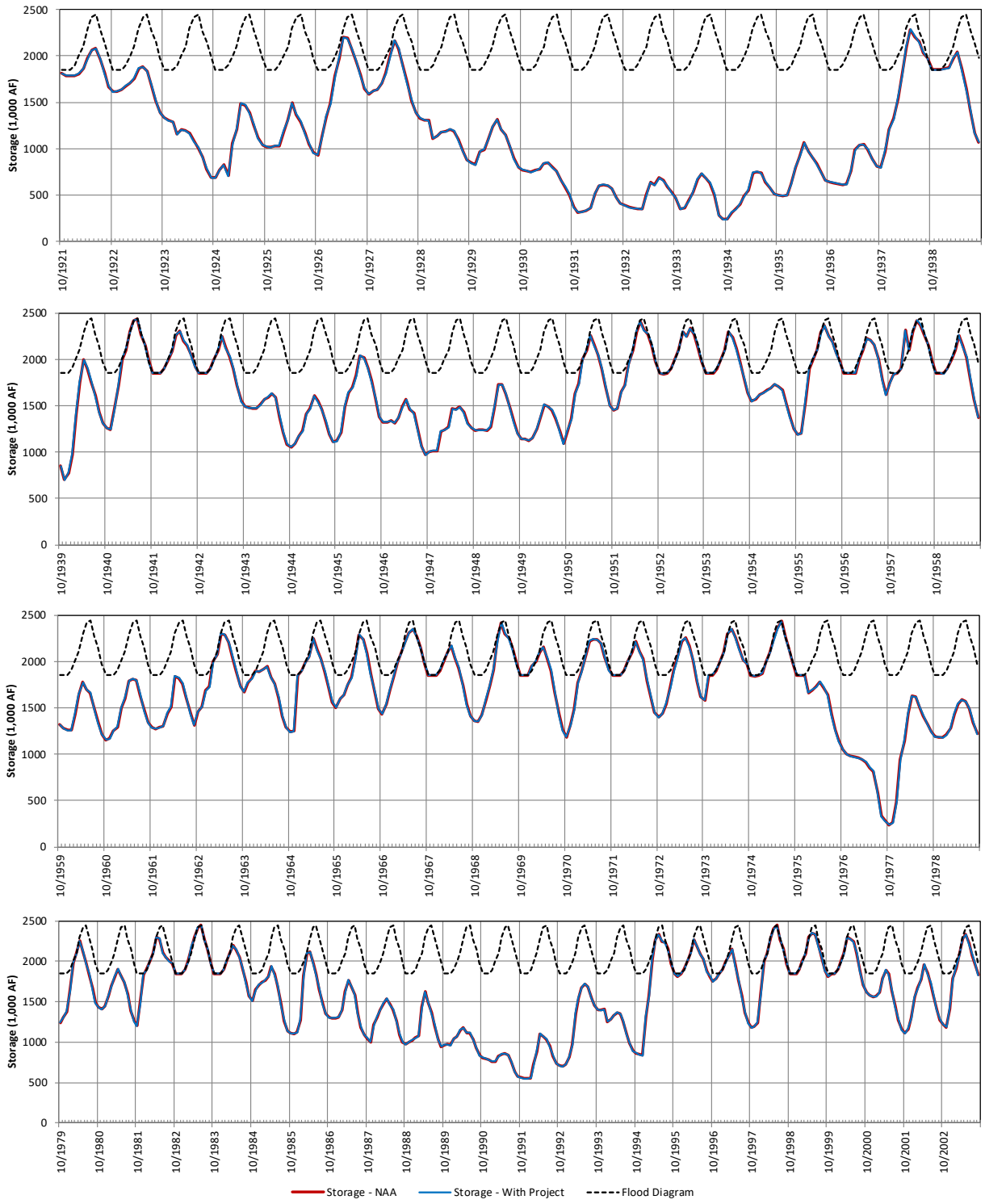


Figure 24: Comparison of Shasta Storage for CVP/SWP Shared Storage Alternative

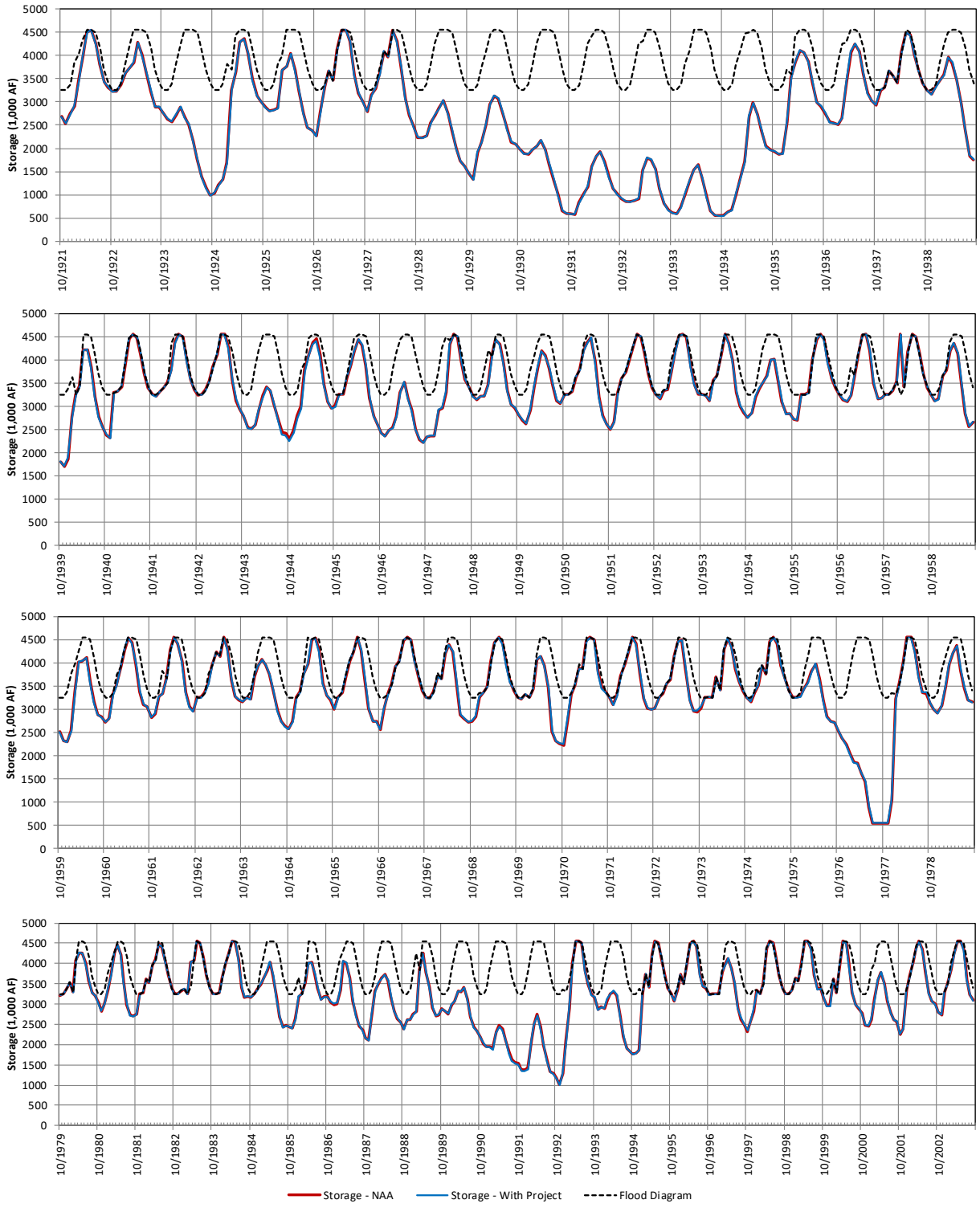


Figure 25: Comparison of Folsom Storage for CVP/SWP Shared Storage Alternative

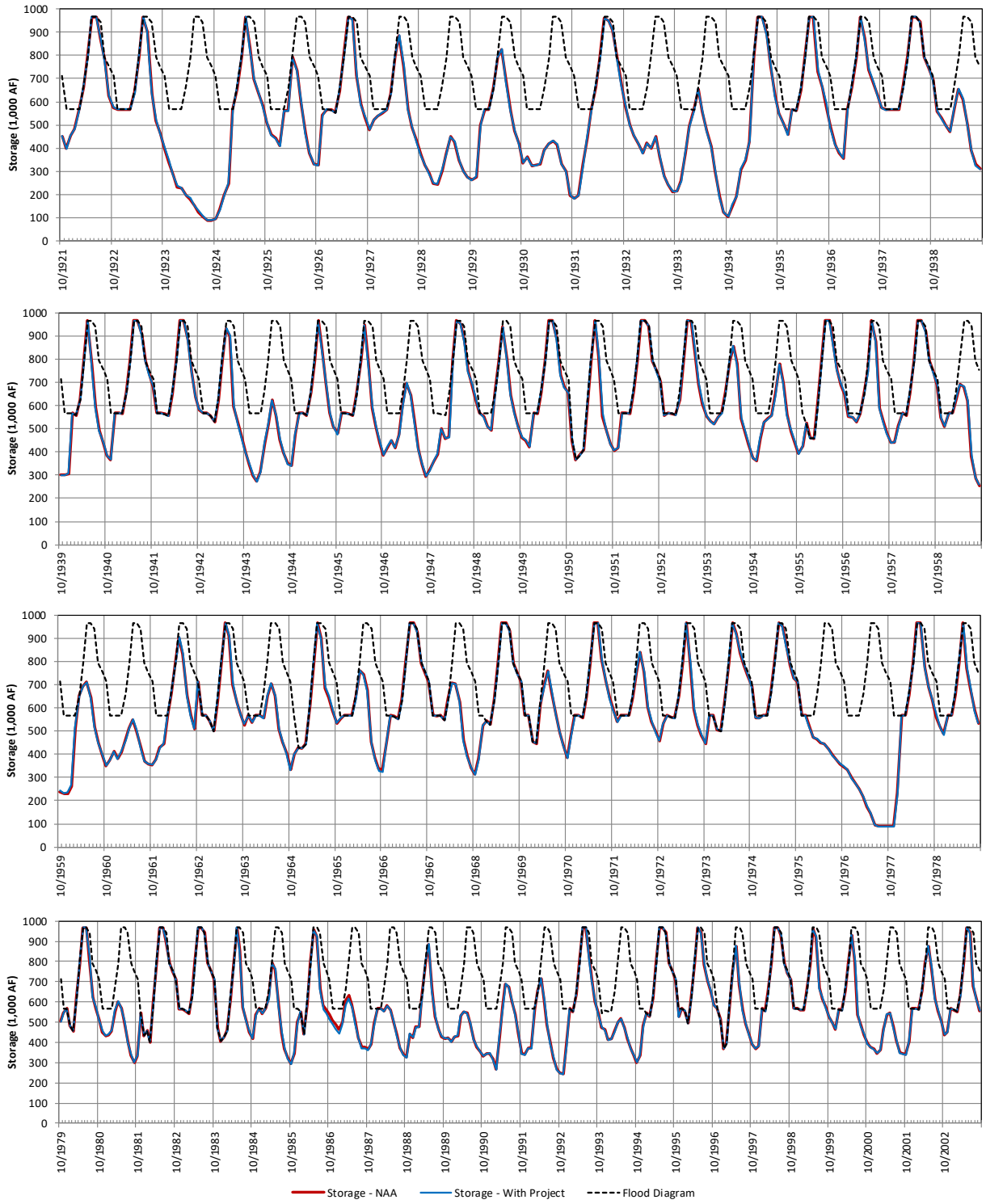


Figure 26: Comparison of Oroville Storage for CVP/SWP Shared Storage Alternative

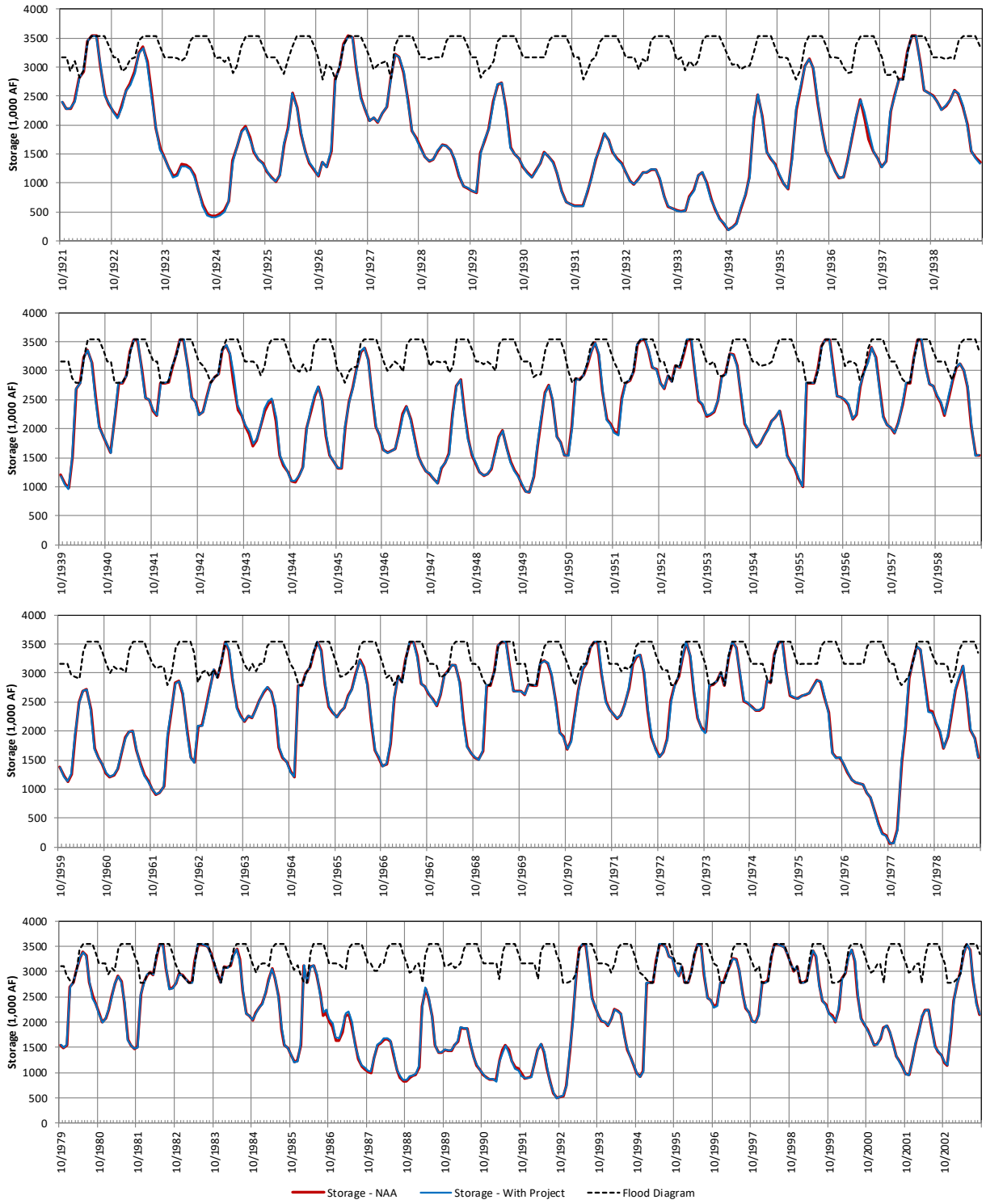


Figure 27: Comparison of Sacramento River below Keswick Flow for CVP/SWP Shared Storage Alternative

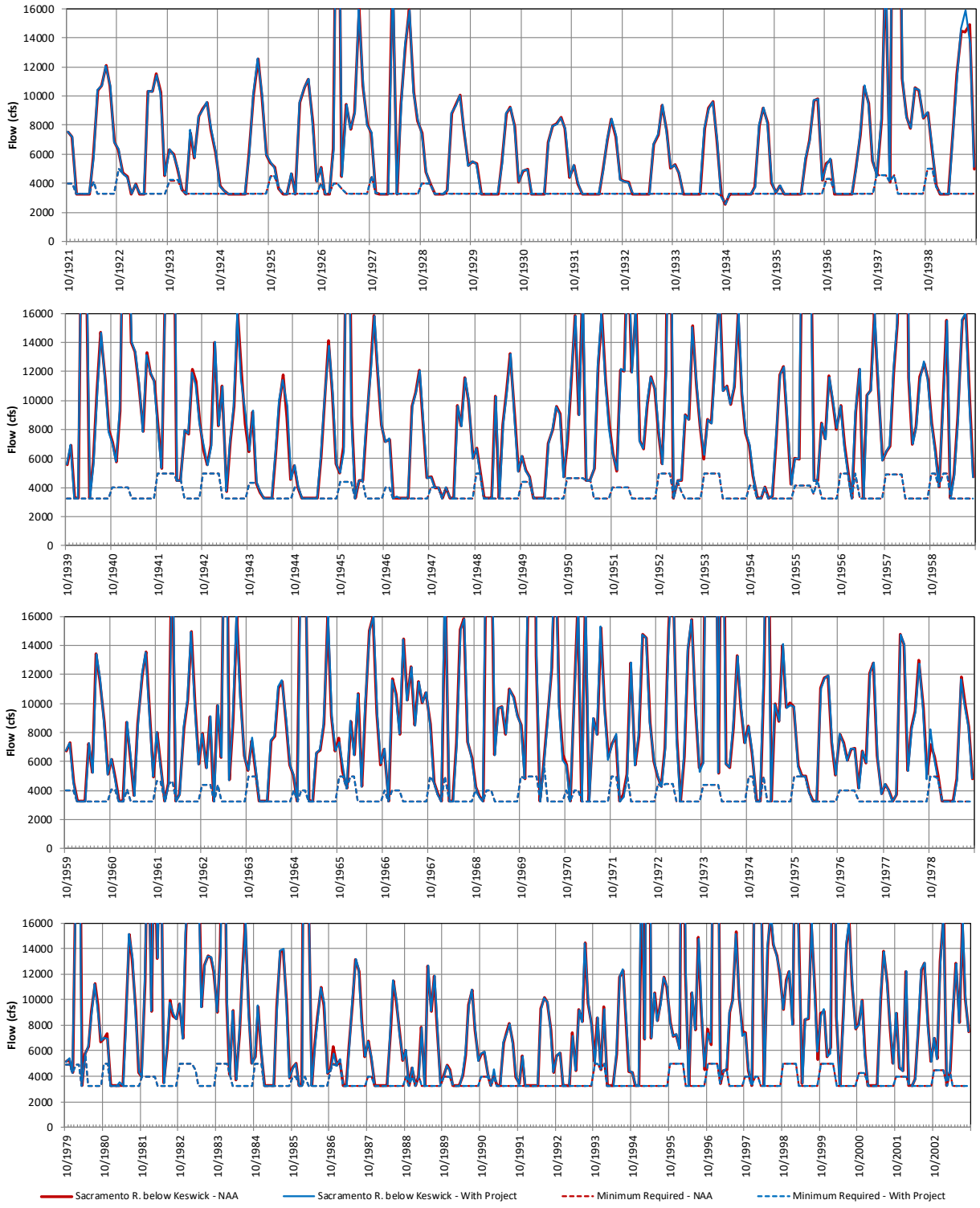


Figure 28: Comparison of Sacramento River at Wilkins Slough Flow for CVP/SWP Shared Storage Alternative

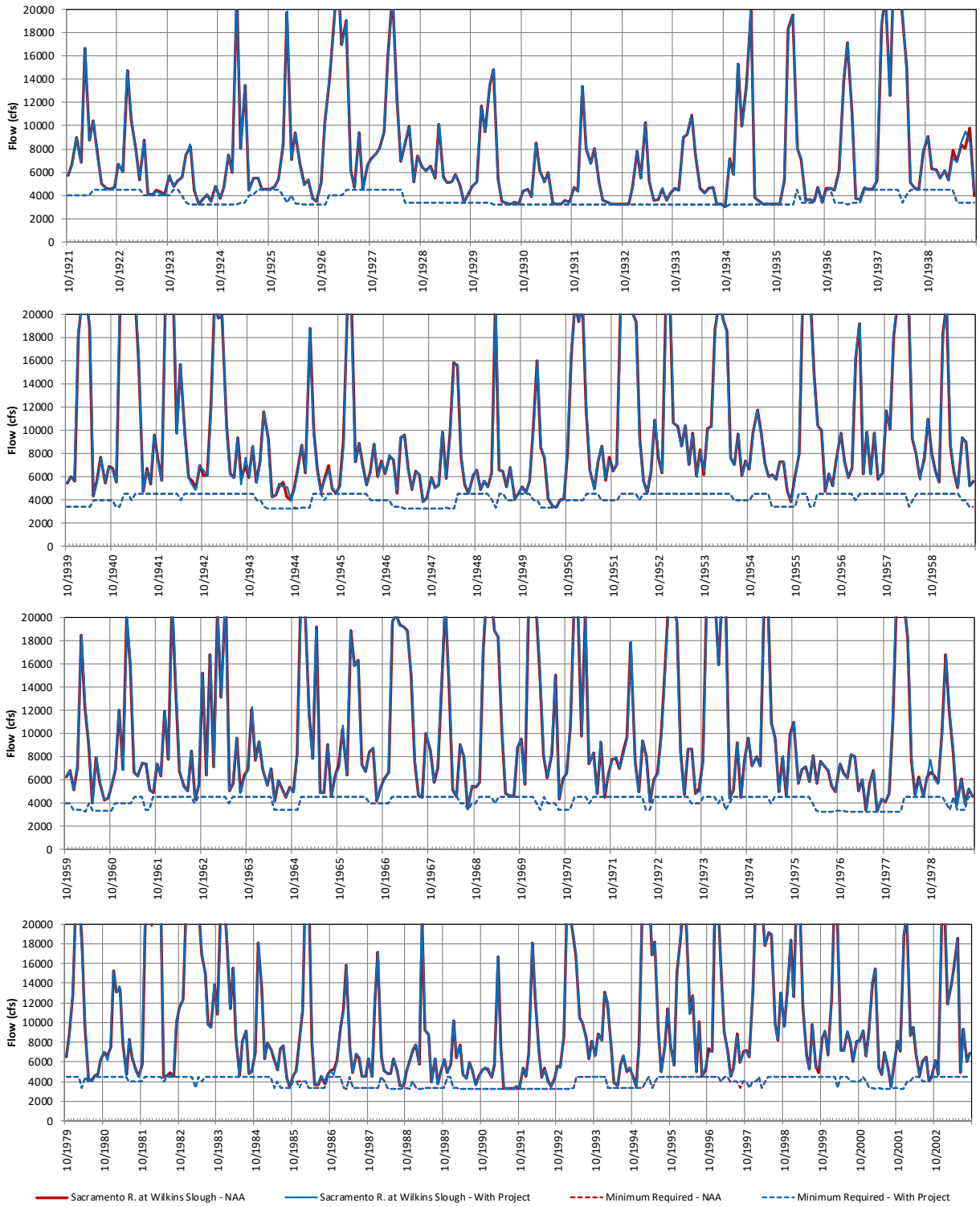


Figure 29: Comparison of American River below Nimbus Flow for CVP/SWP Shared Storage Alternative

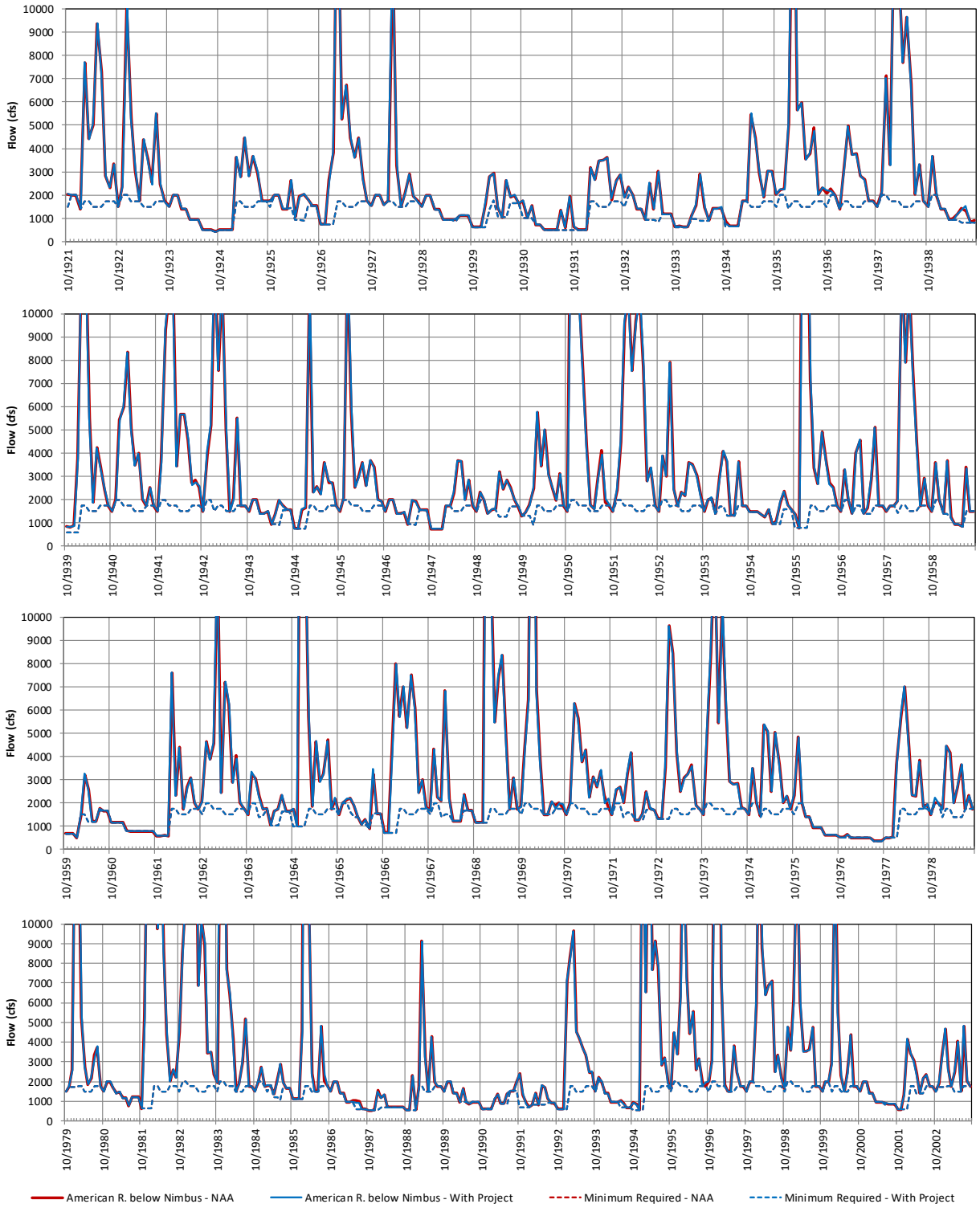


Figure 30: Comparison of Lower Feather River Flow for CVP/SWP Shared Storage Alternative

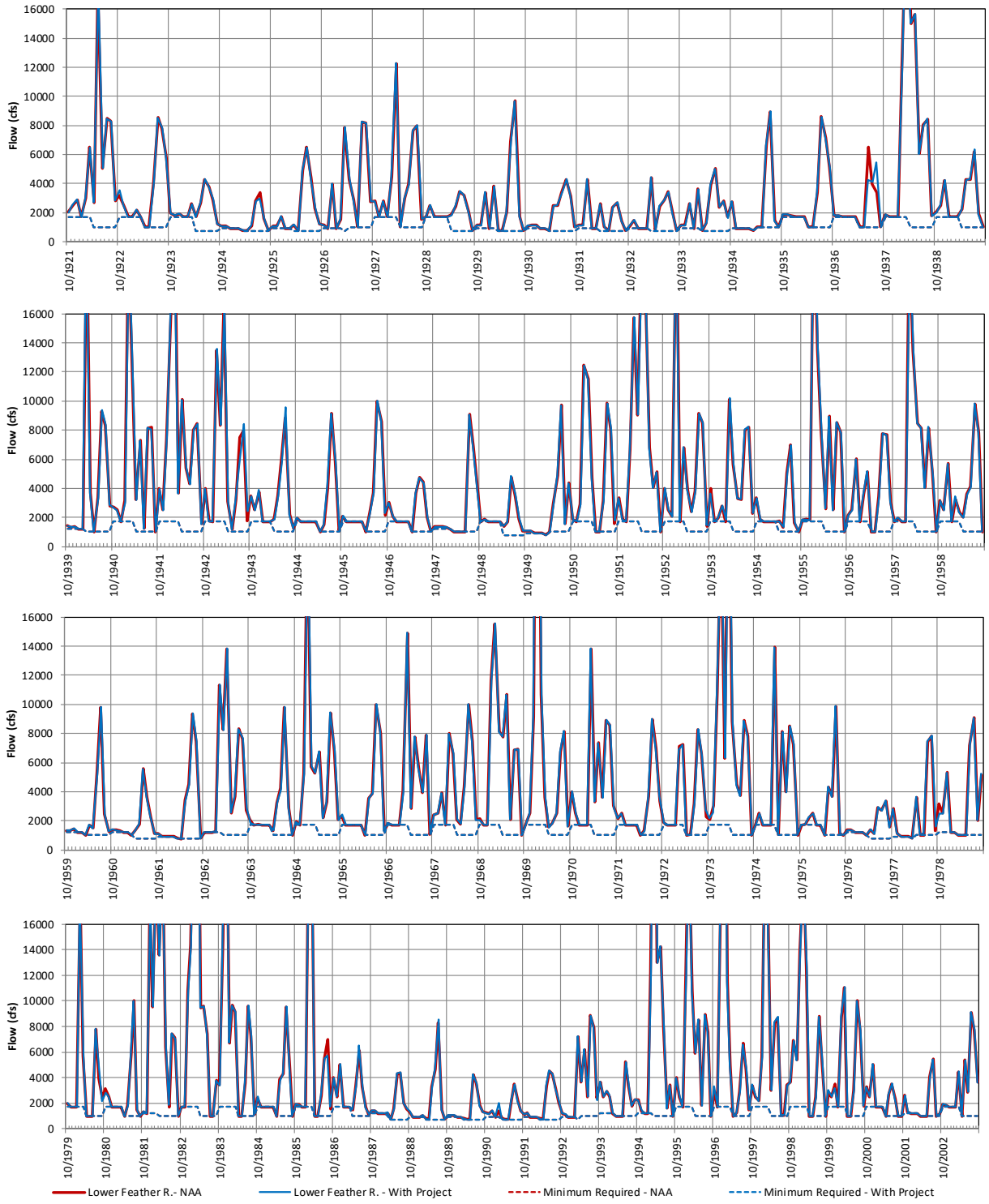


Figure 31: Comparison of Delta Inflow for CVP/SWP Shared Storage Alternative

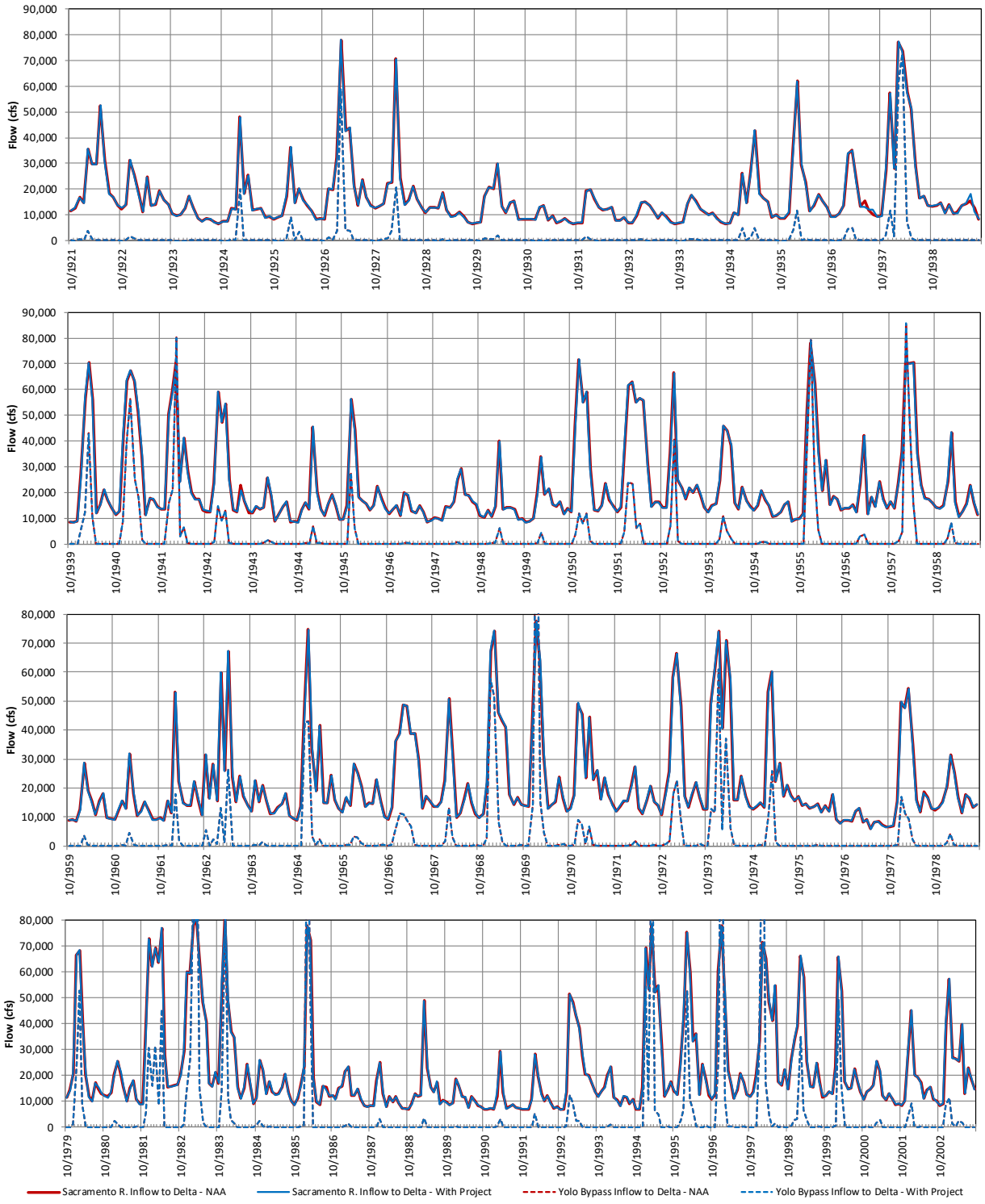


Figure 32: Comparison of Delta Outflow for CVP/SWP Shared Storage Alternative

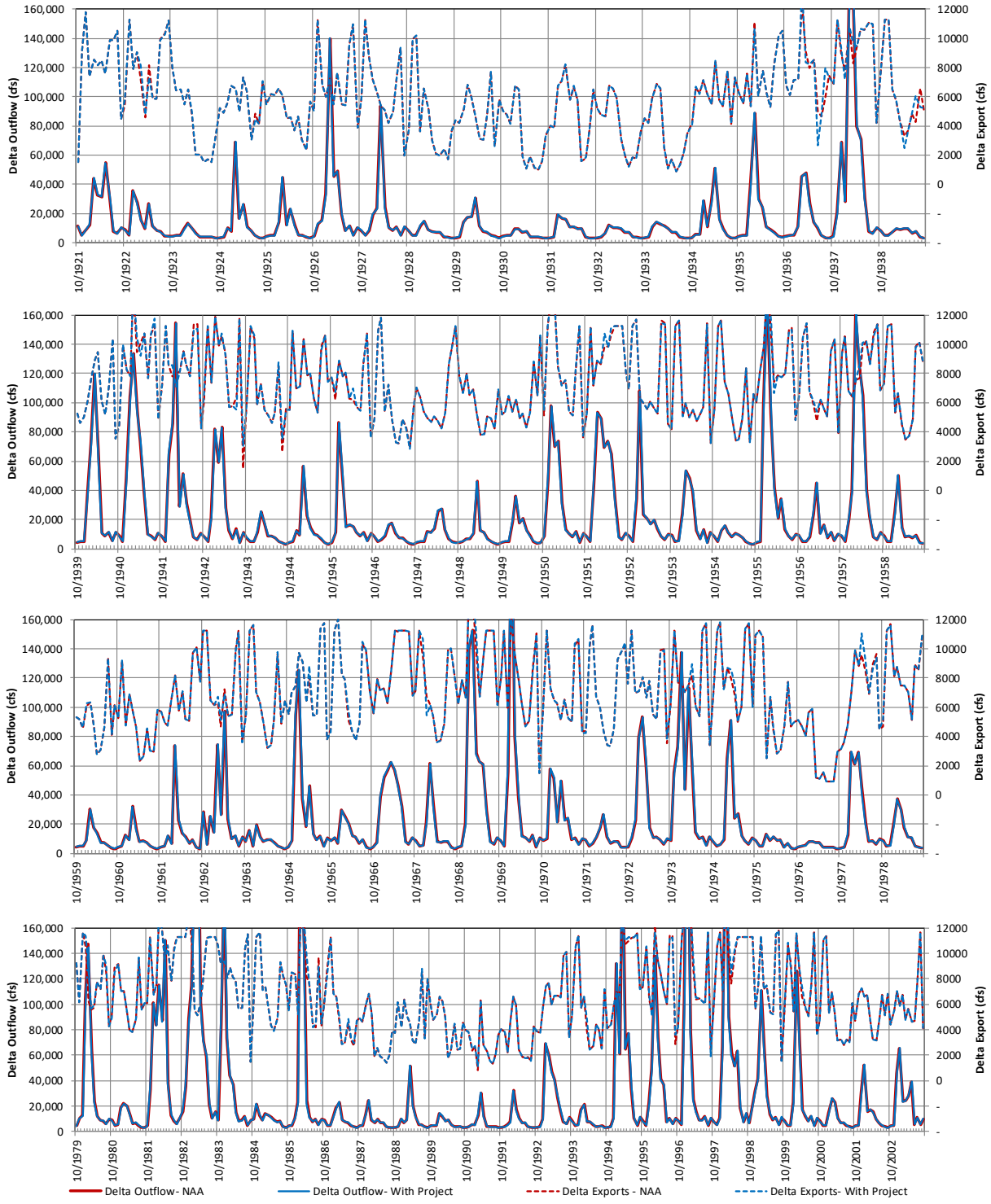


Figure 33: Comparison of San Luis Reservoir Storage for CVP/SWP Shared Storage Alternative

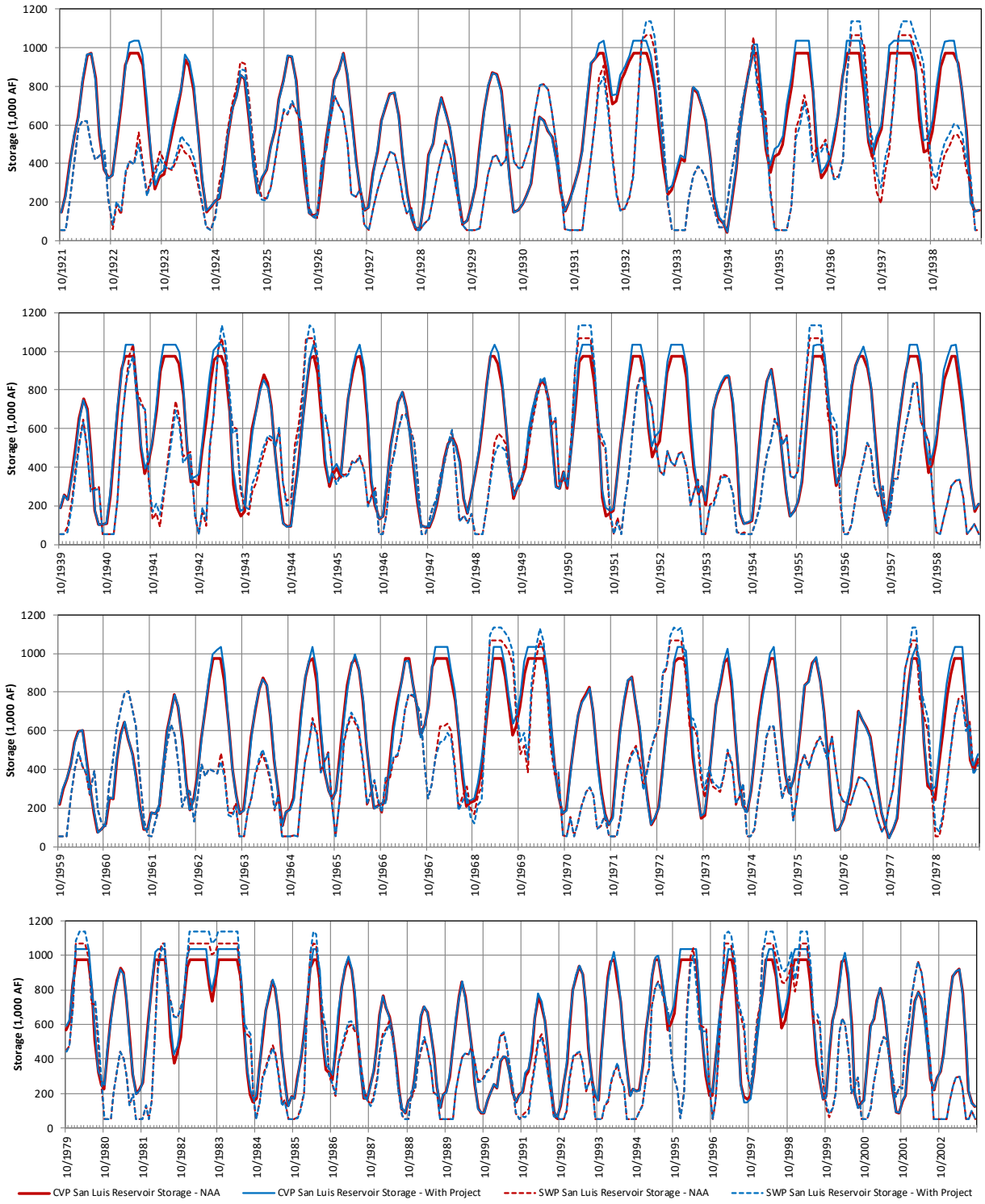


Figure 34: Comparison of Trinity Storage for Investor A/B Alternative

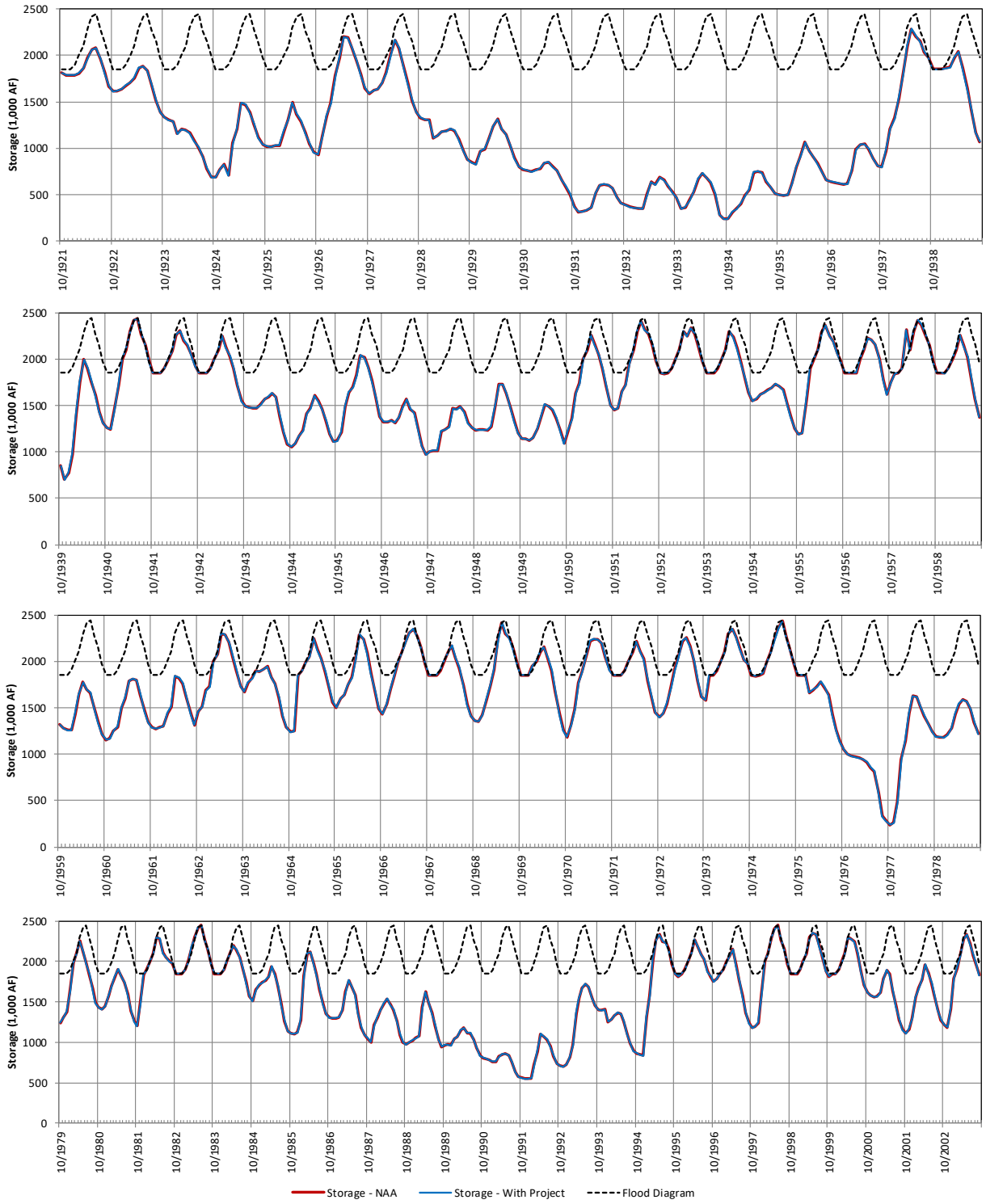


Figure 35: Comparison of Shasta Storage for Investor A/B Alternative

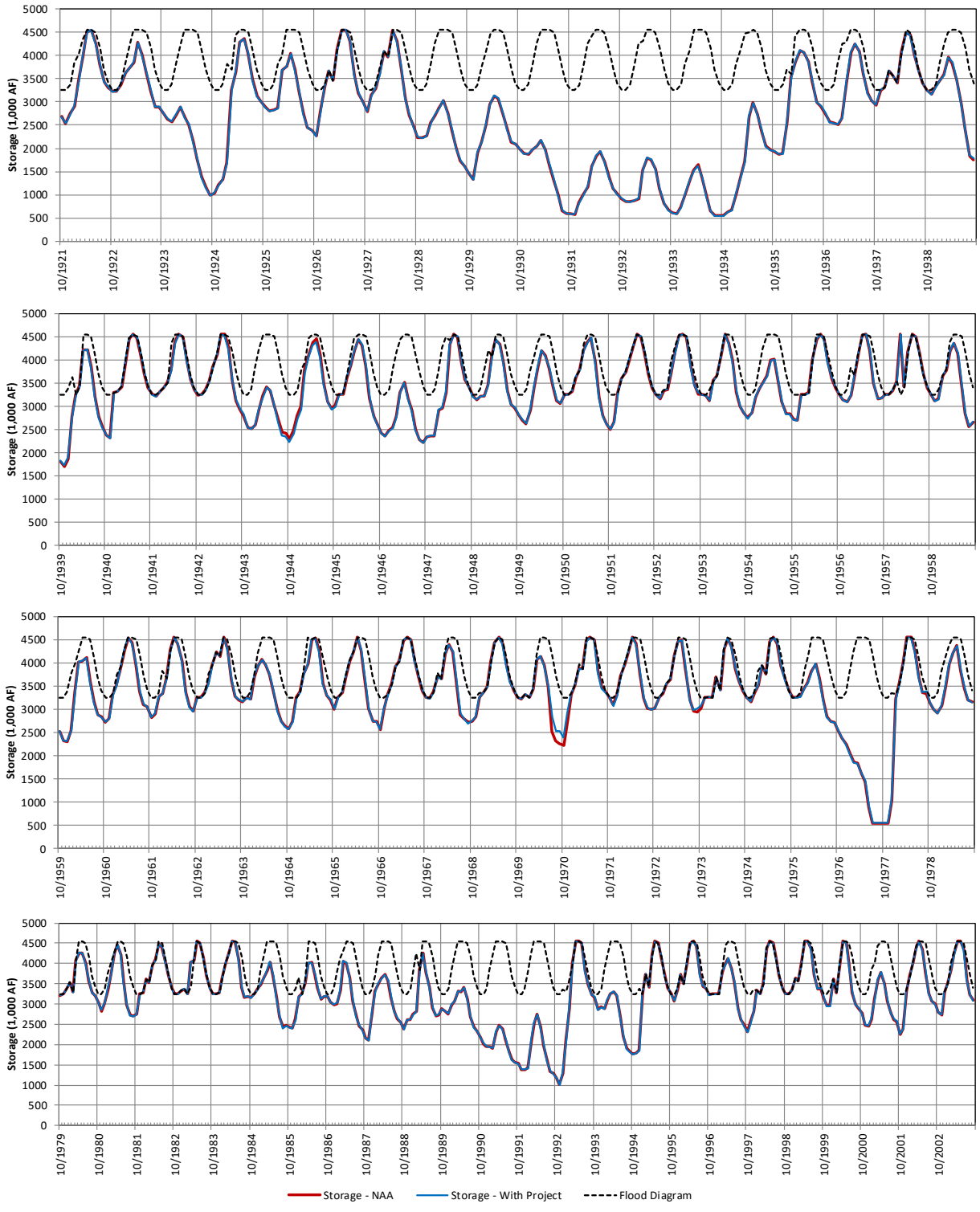


Figure 36: Comparison of Folsom Storage for Investor A/B Alternative

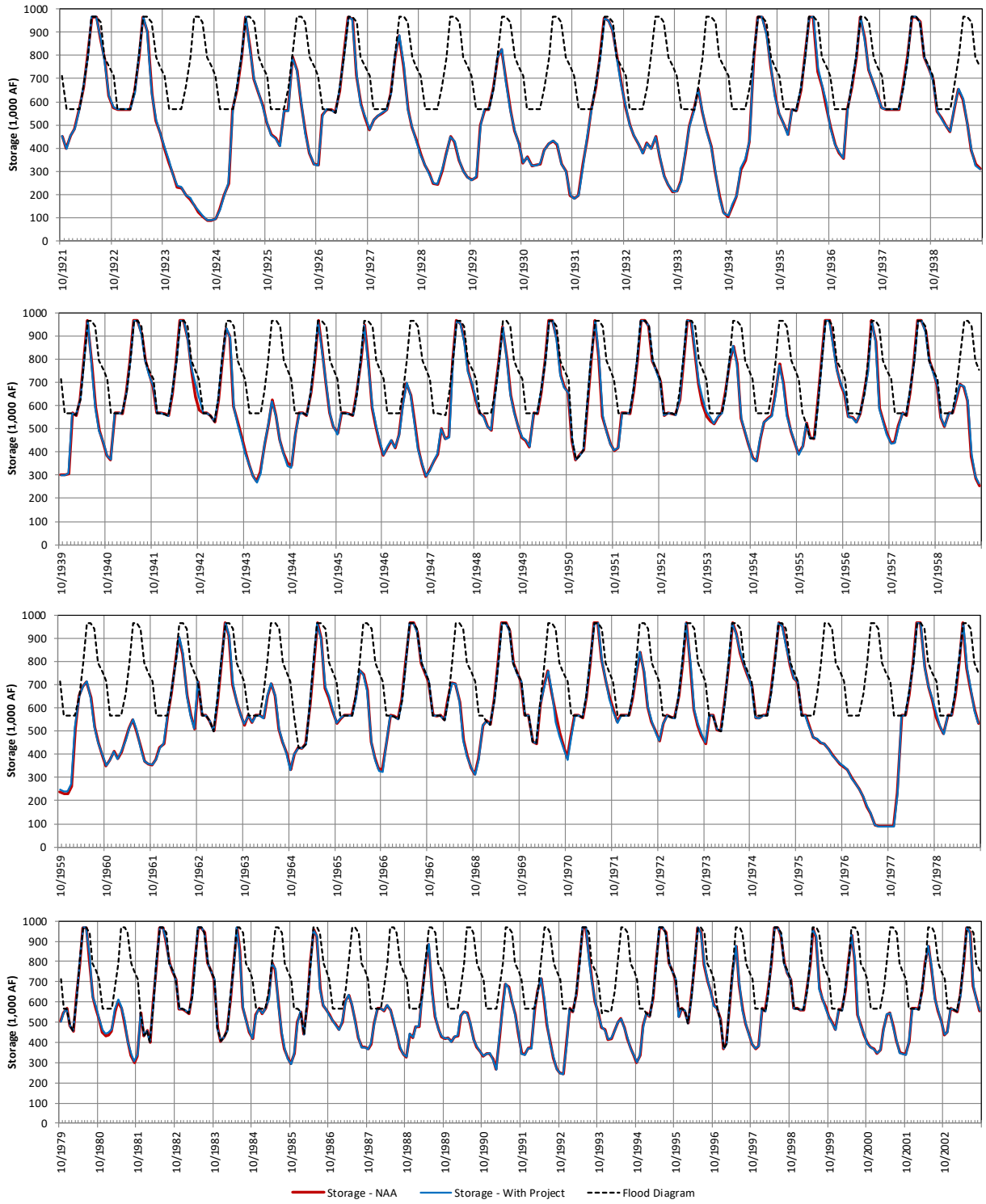


Figure 37: Comparison of Oroville Storage for Investor A/B Alternative

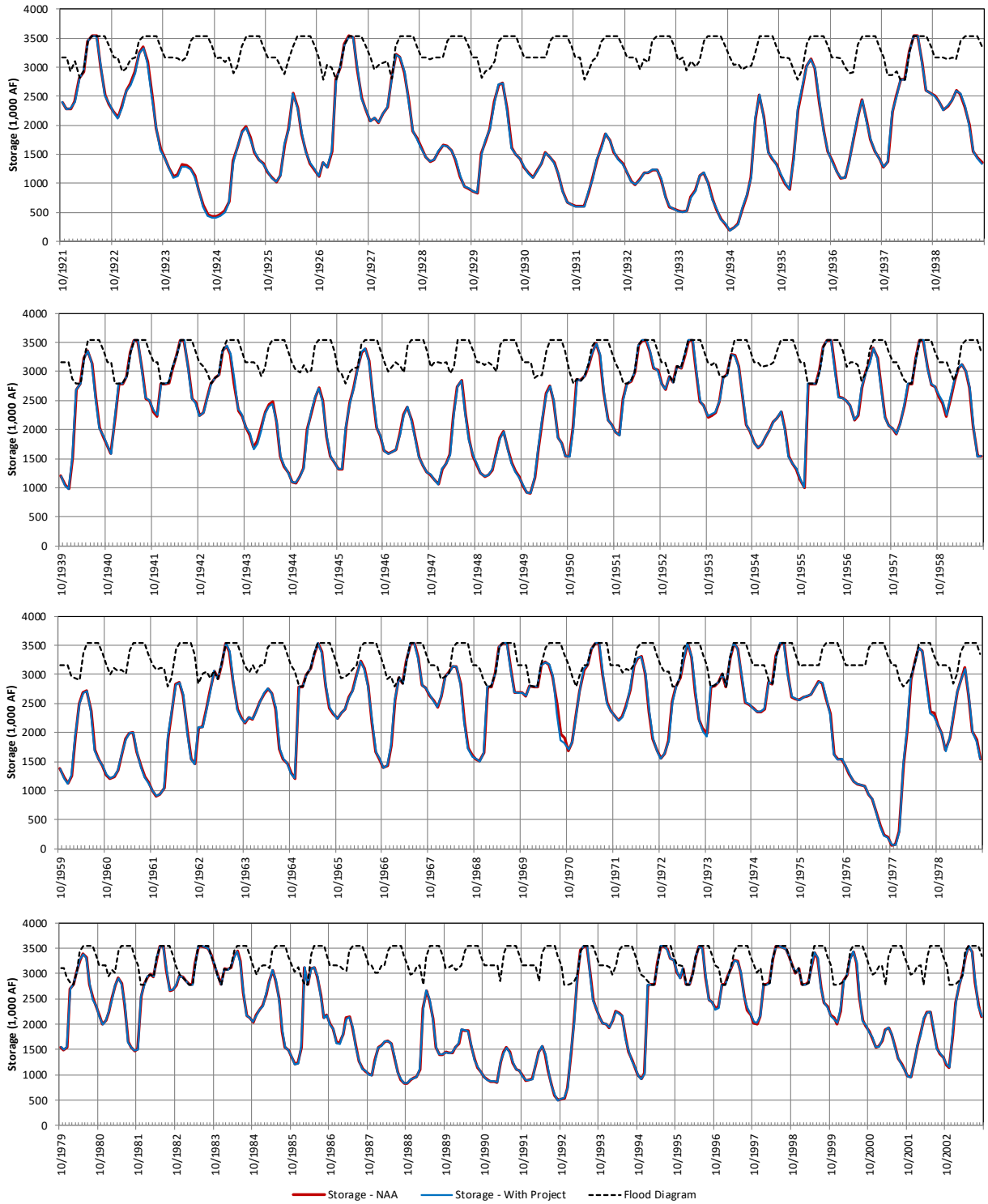


Figure 38: Comparison of Sacramento River below Keswick Flow for Investor A/B Alternative

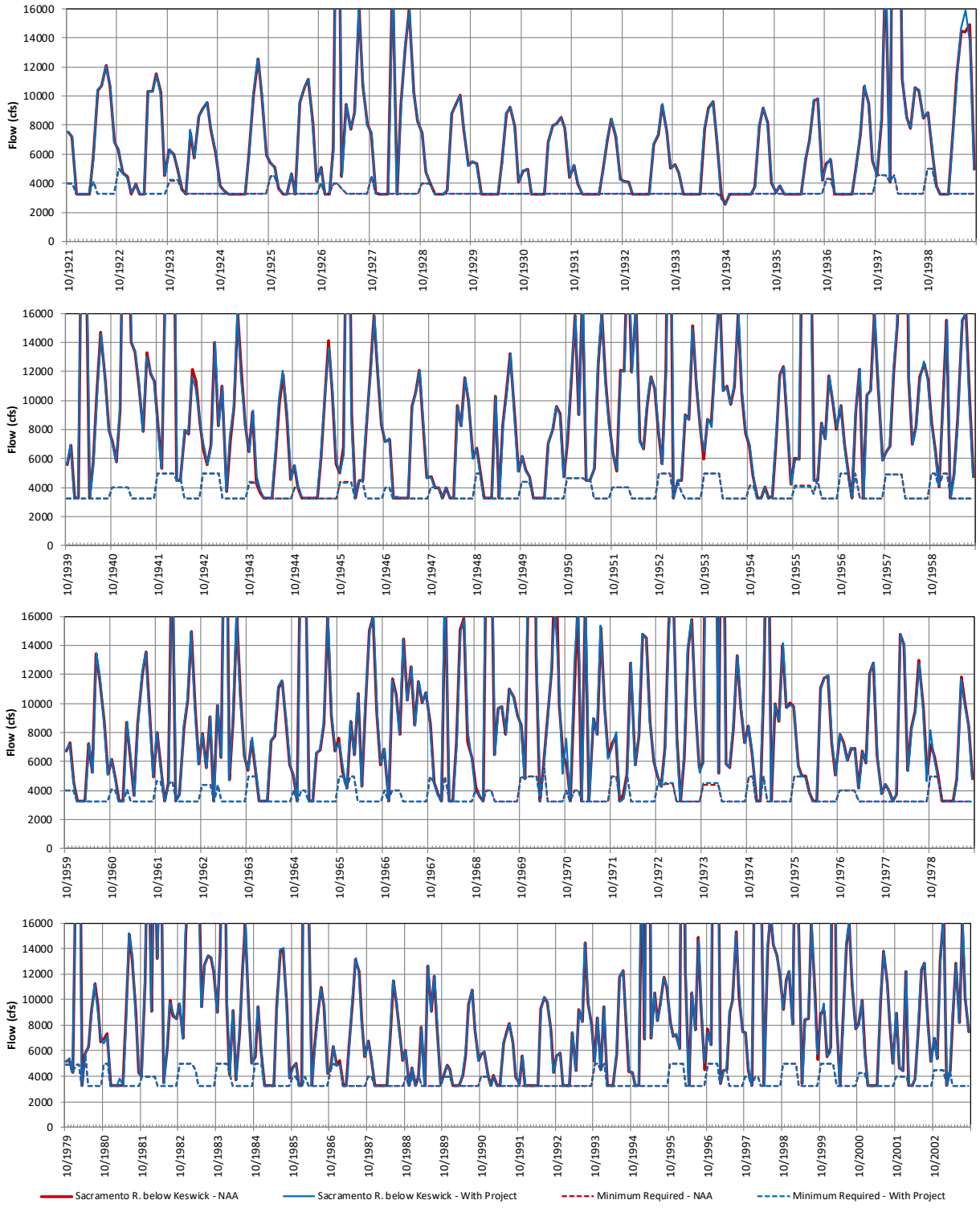


Figure 39: Comparison of Sacramento River at Wilkins Slough Flow for Investor A/B Alternative

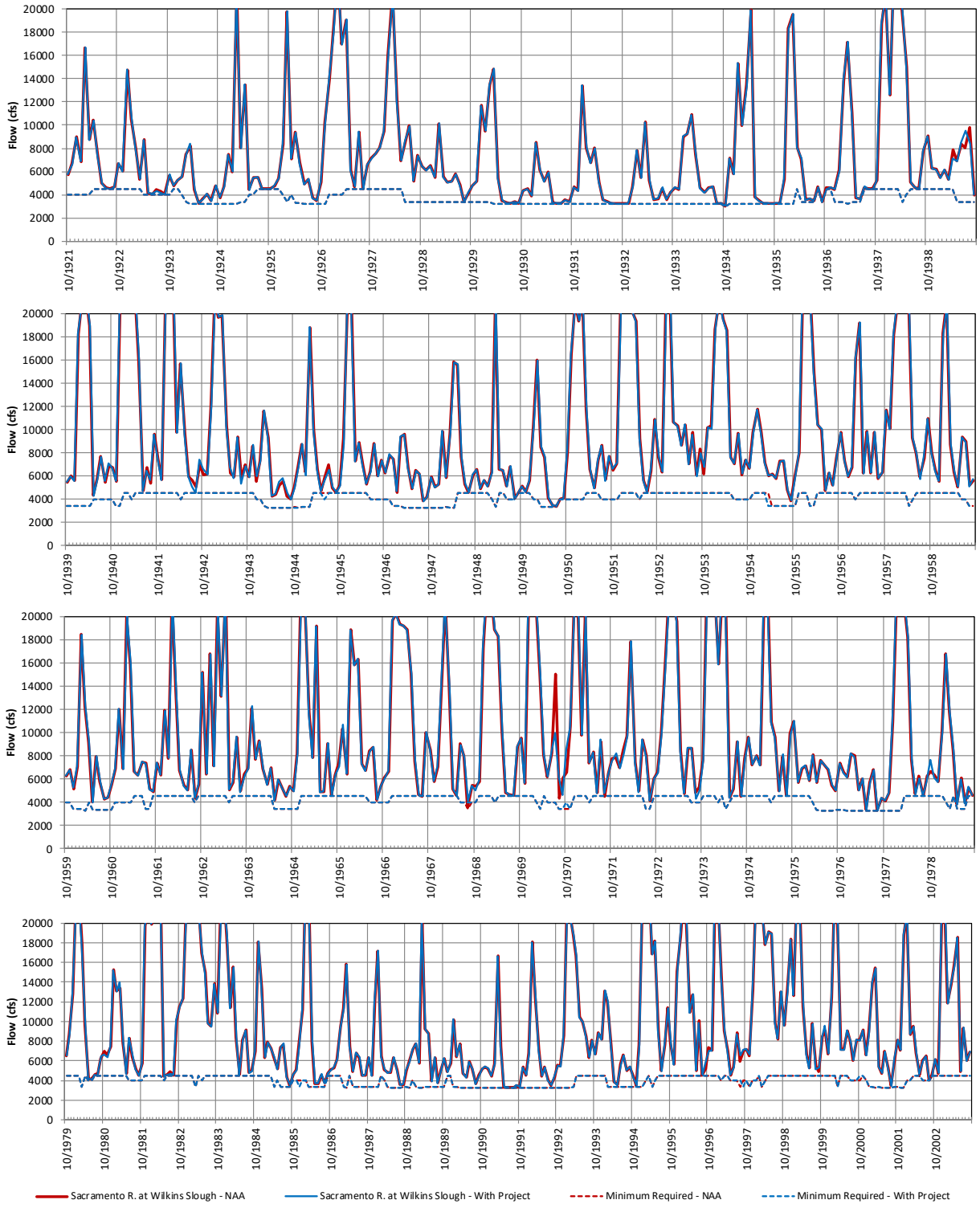


Figure 40: Comparison of American River below Nimbus Flow for Investor A/B Alternative

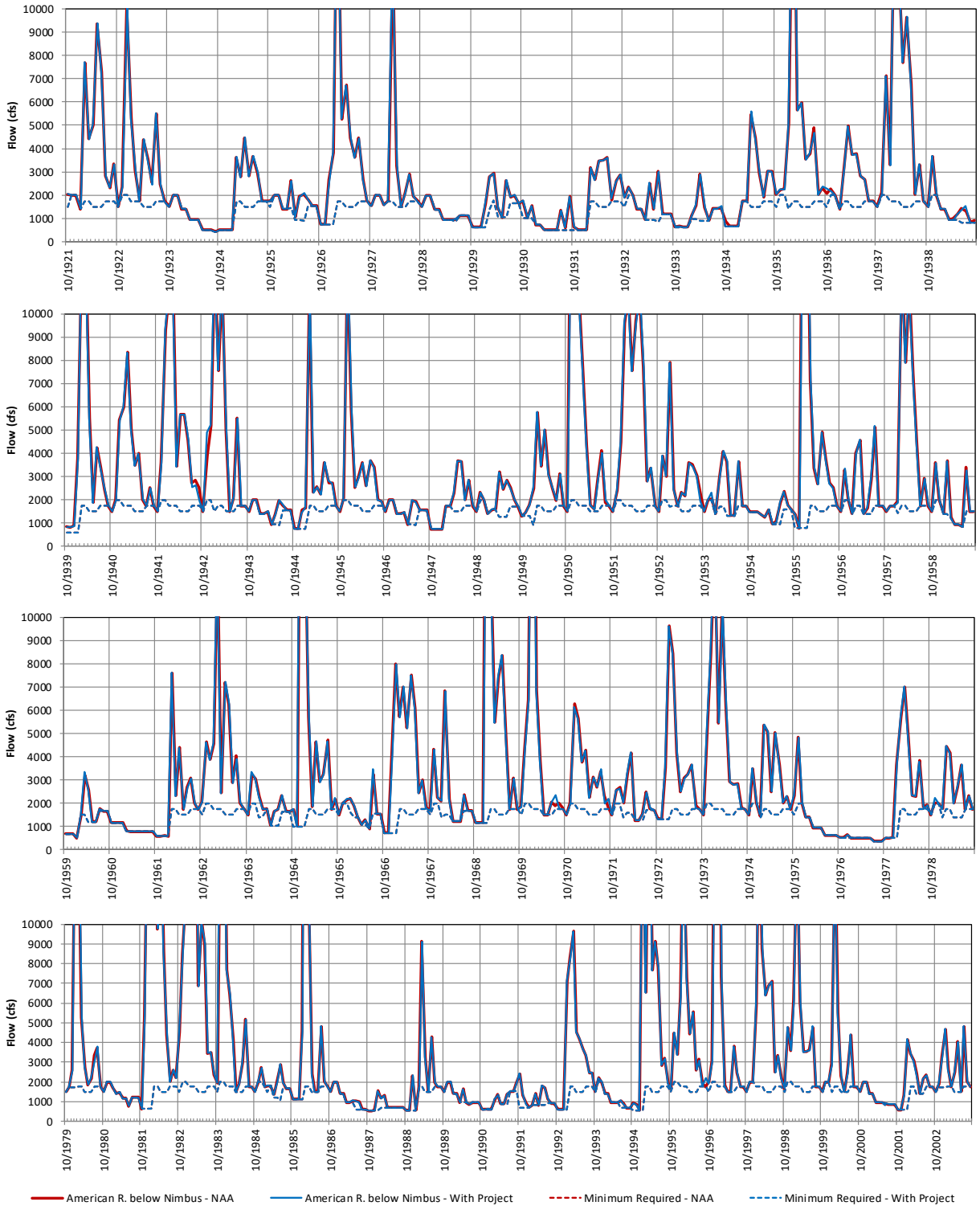


Figure 41: Comparison of Lower Feather River Flow for Investor A/B Alternative

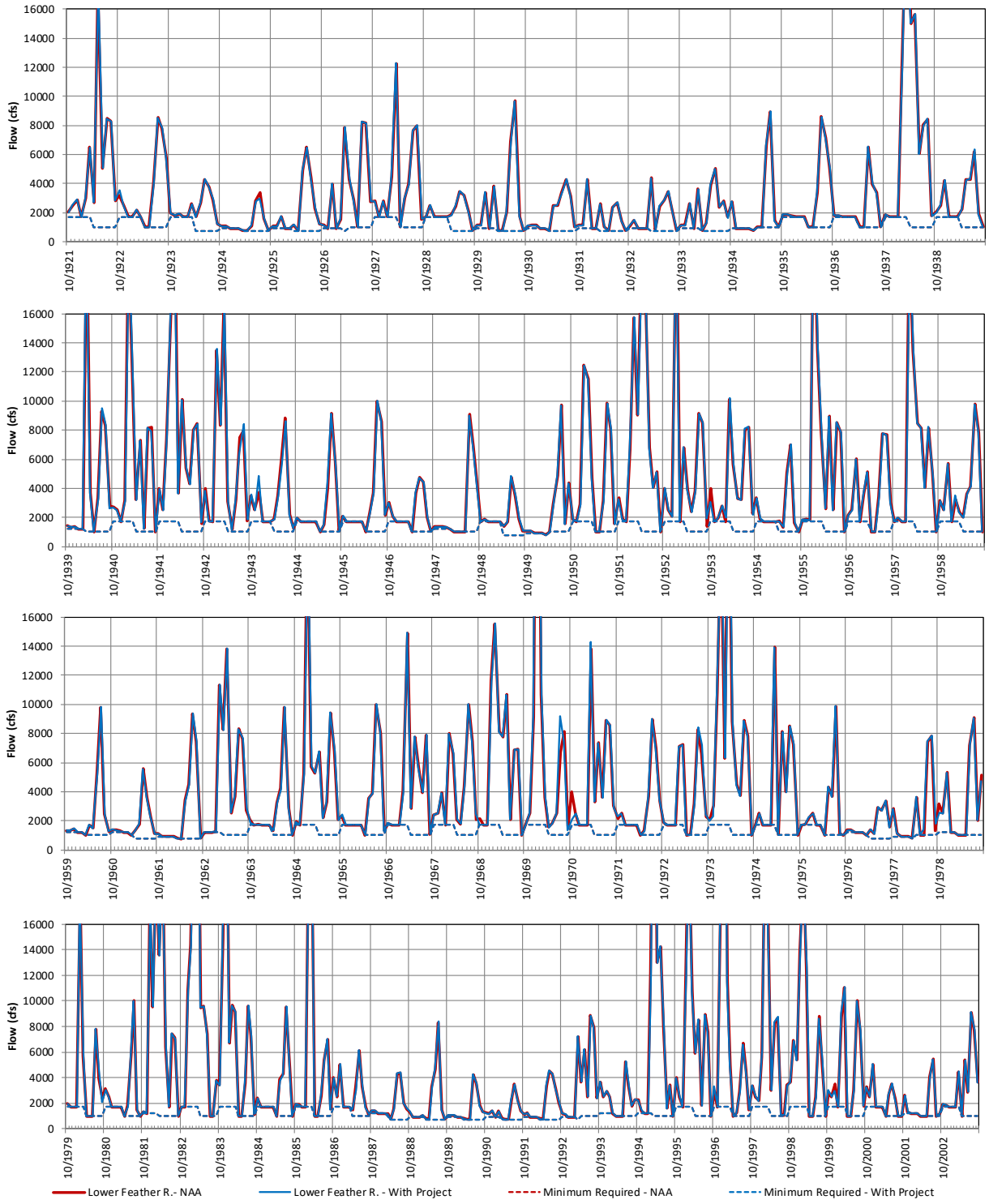


Figure 42: Comparison of Delta Inflow for Investor A/B Alternative

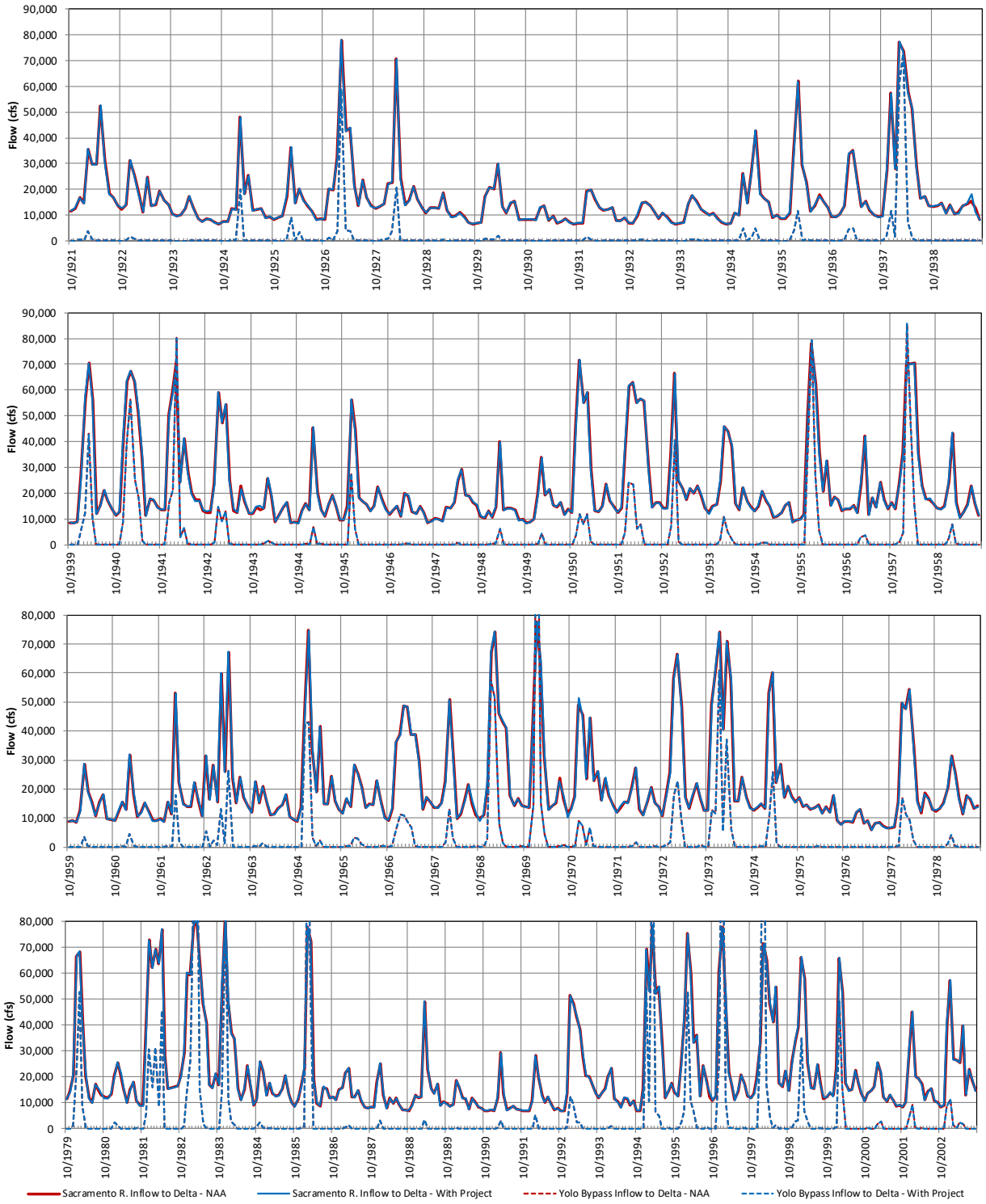


Figure 43: Comparison of Delta Outflow for Investor A/B Alternative

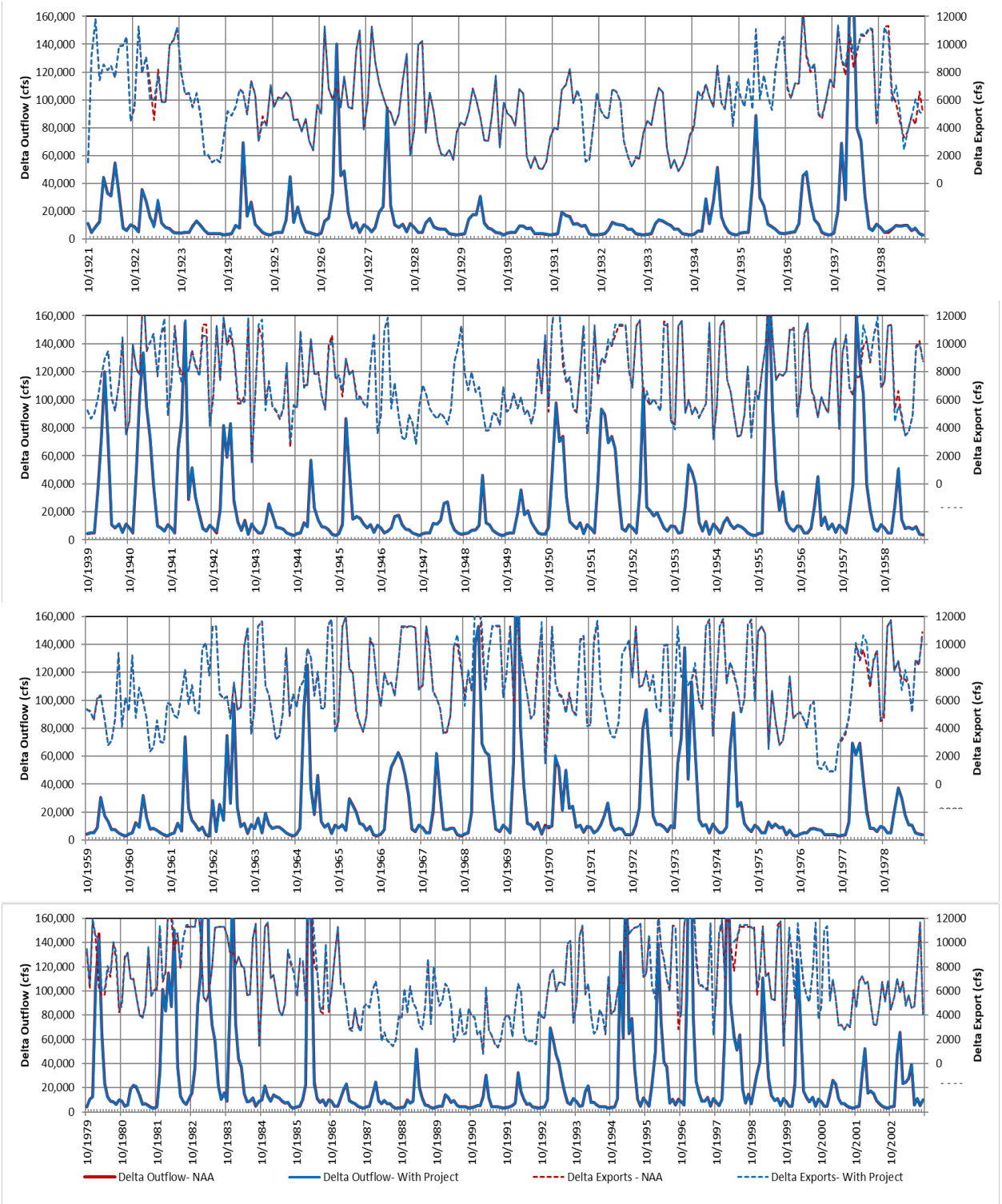


Figure 44: Comparison of San Luis Reservoir Storage for Investor A/B Alternative

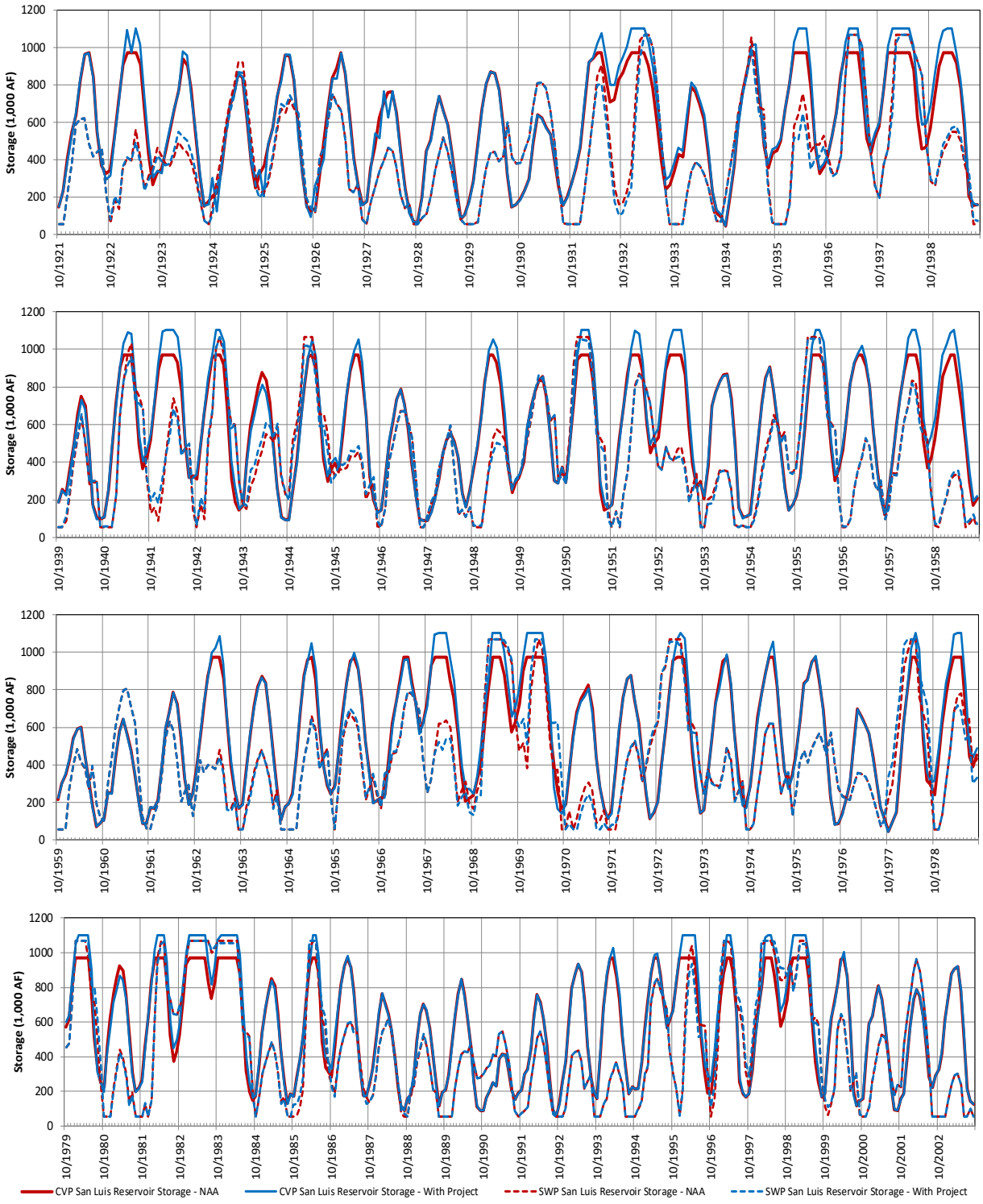


Figure 45: Comparison of Trinity Storage for Investor C/D Alternative

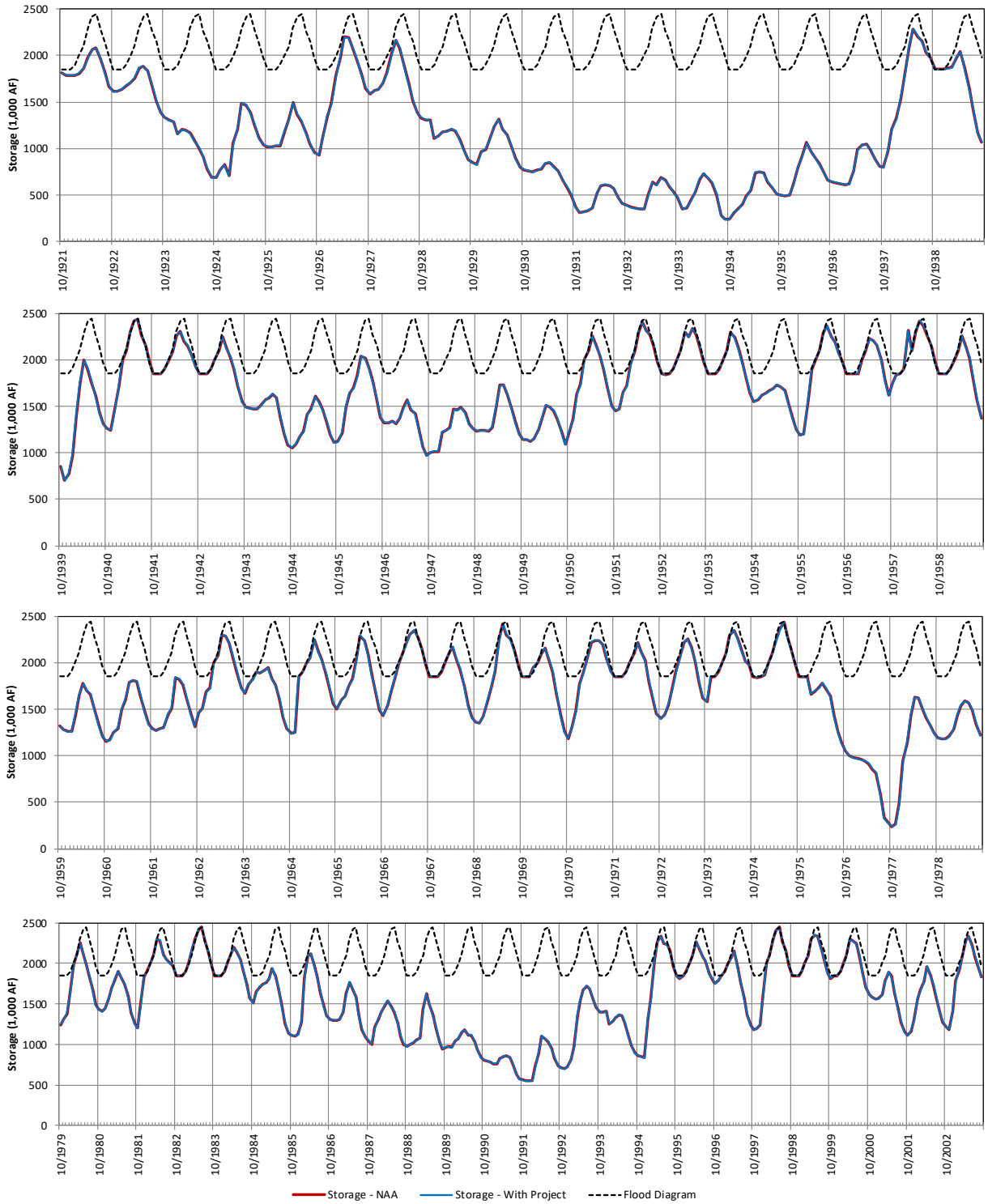


Figure 46: Comparison of Shasta Storage for Investor C/D Alternative

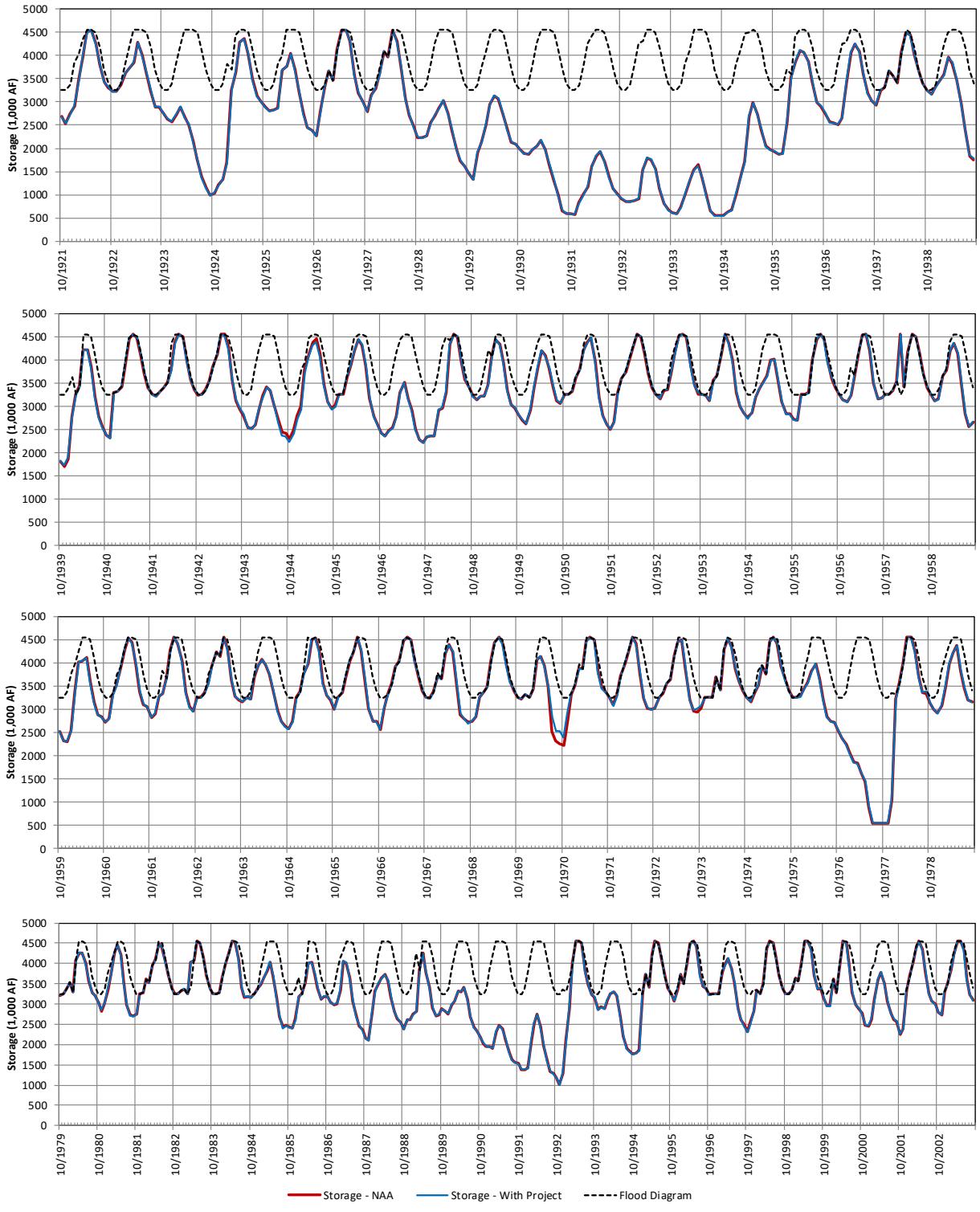


Figure 47: Comparison of Folsom Storage for Investor C/D Alternative

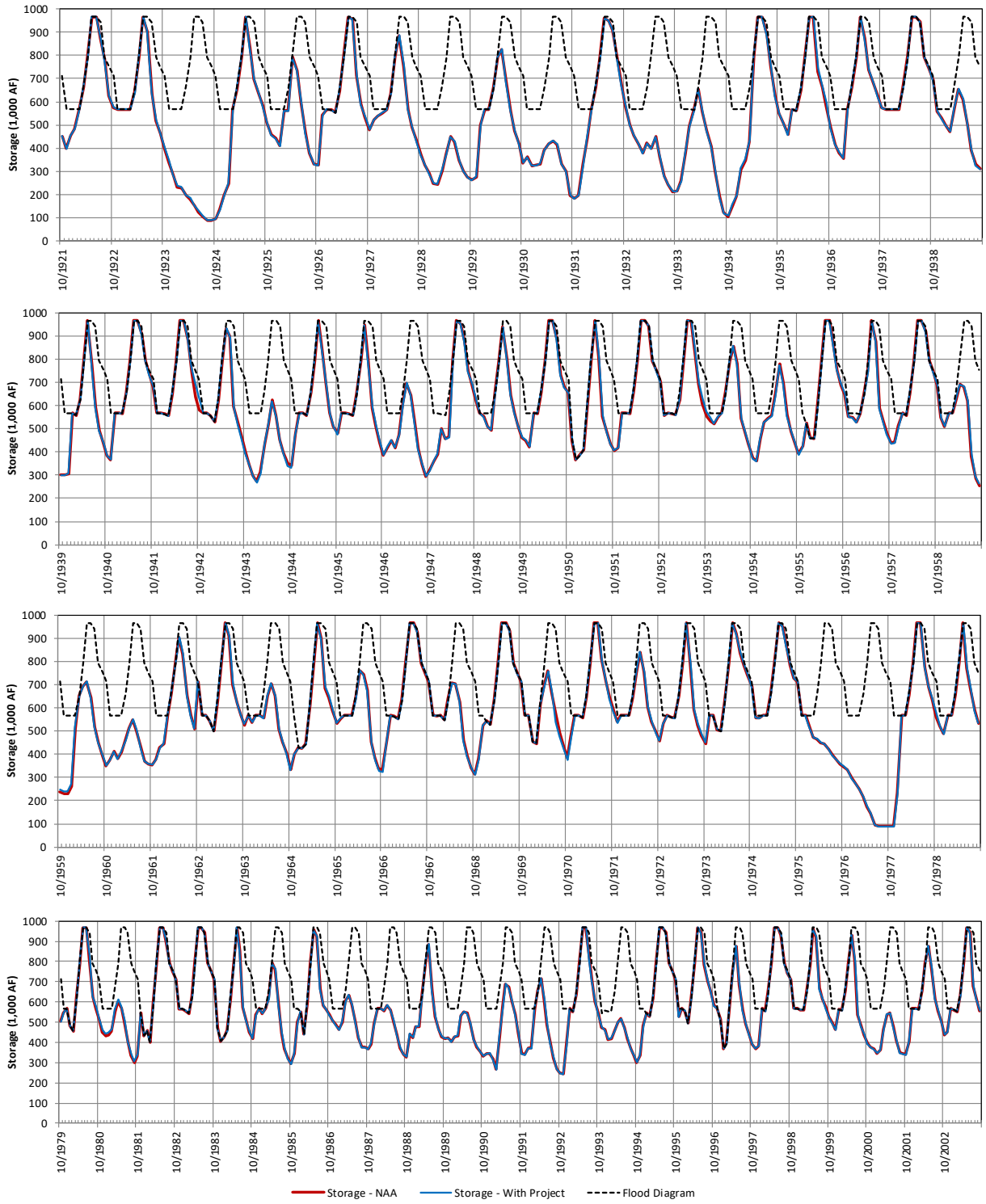


Figure 48: Comparison of Oroville Storage for Investor C/D Alternative

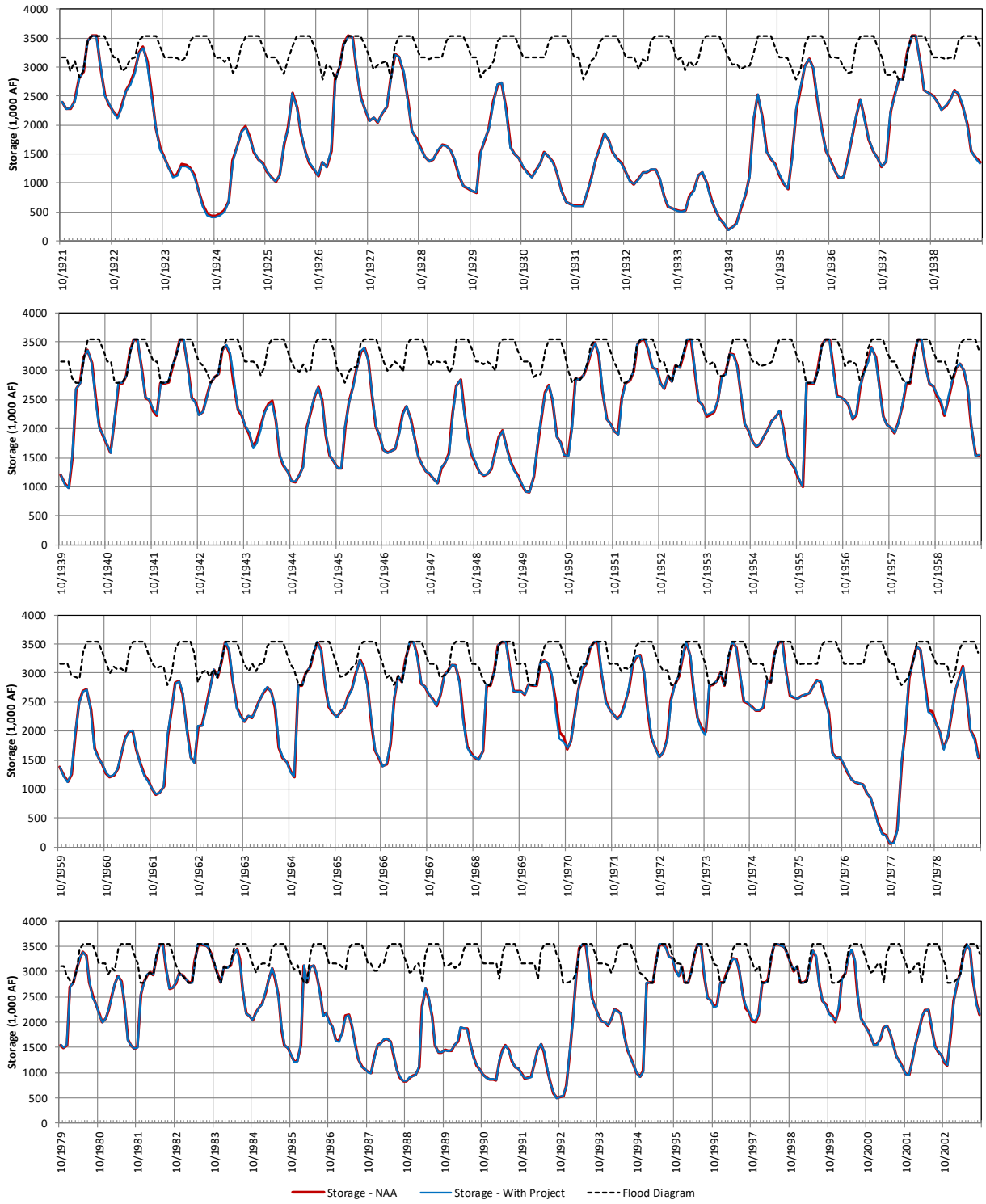


Figure 49: Comparison of Sacramento River below Keswick Flow for Investor C/D Alternative

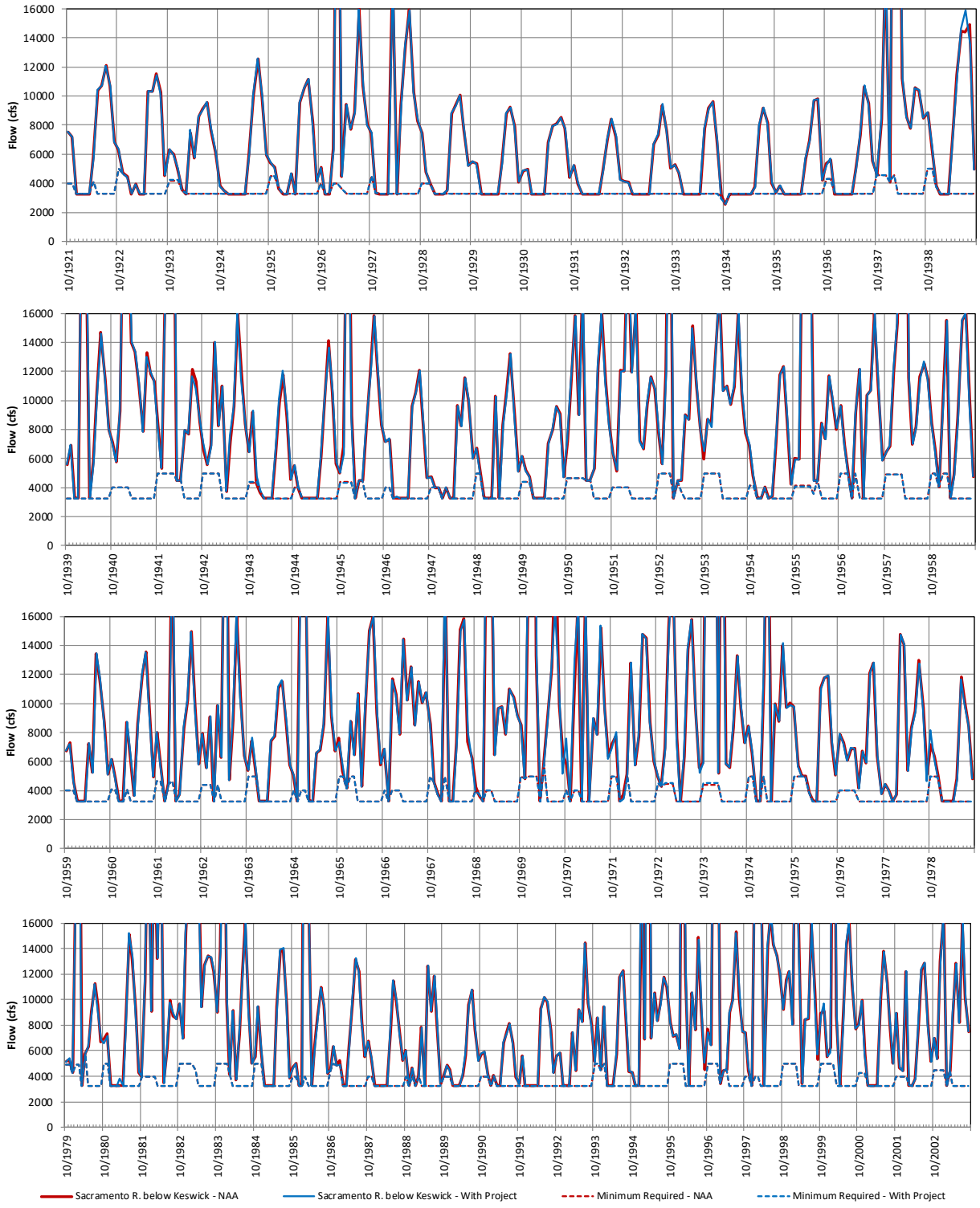


Figure 50: Comparison of Sacramento River at Wilkins Slough Flow for Investor C/D Alternative

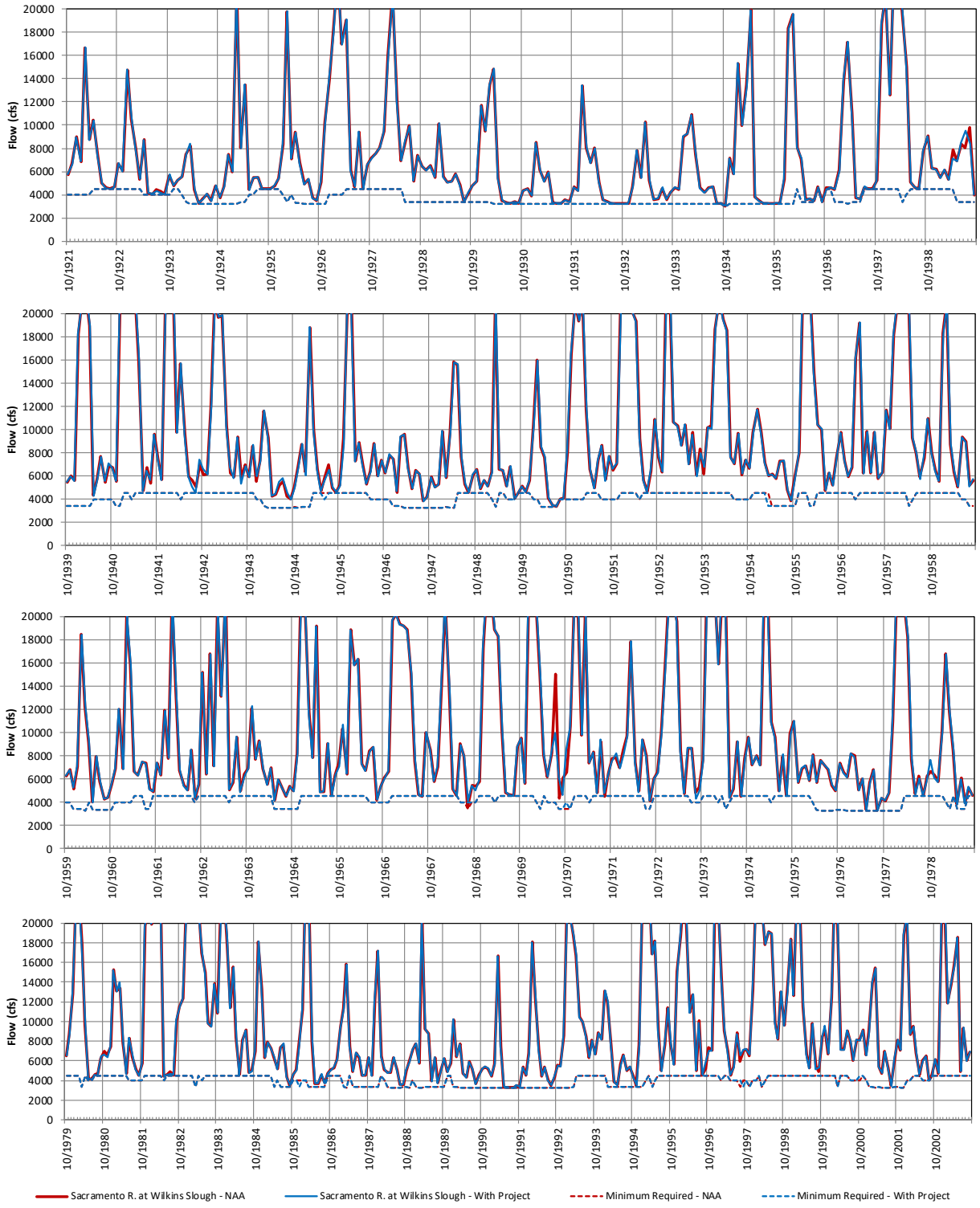


Figure 51: Comparison of American River below Nimbus Flow for Investor C/D Alternative

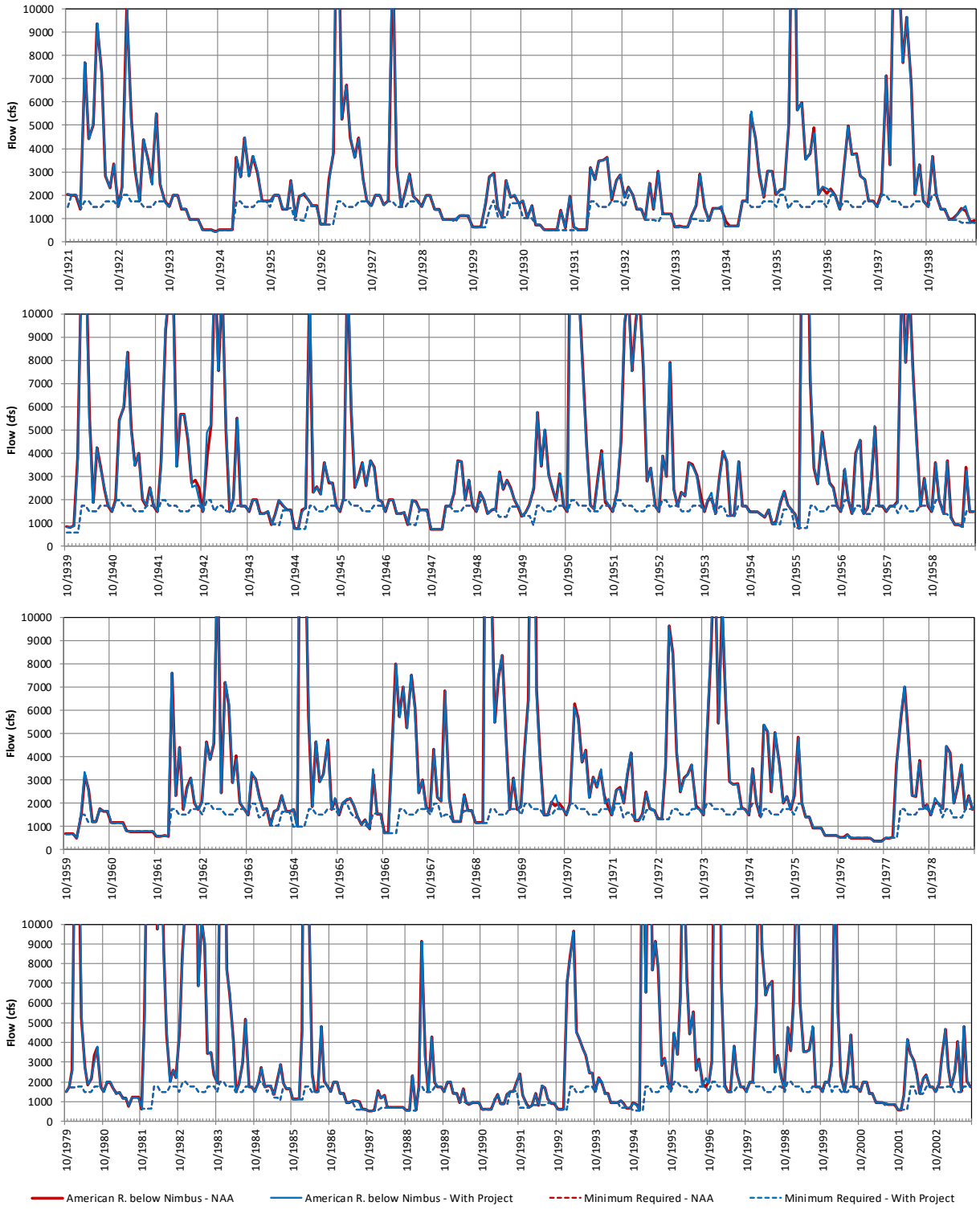


Figure 52: Comparison of Lower Feather River Flow for Investor C/D Alternative

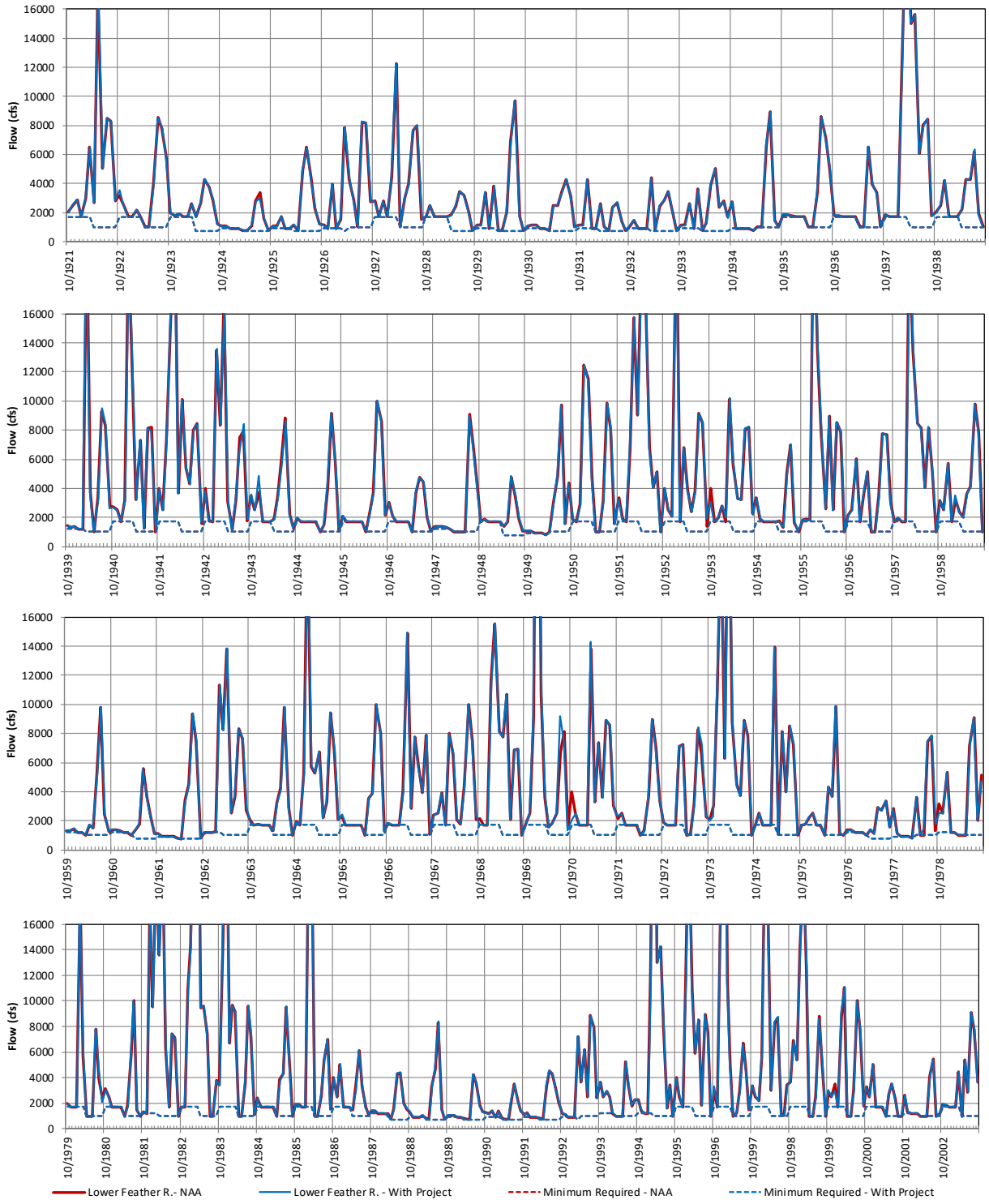


Figure 53: Comparison of Delta Inflow for Investor C/D Alternative

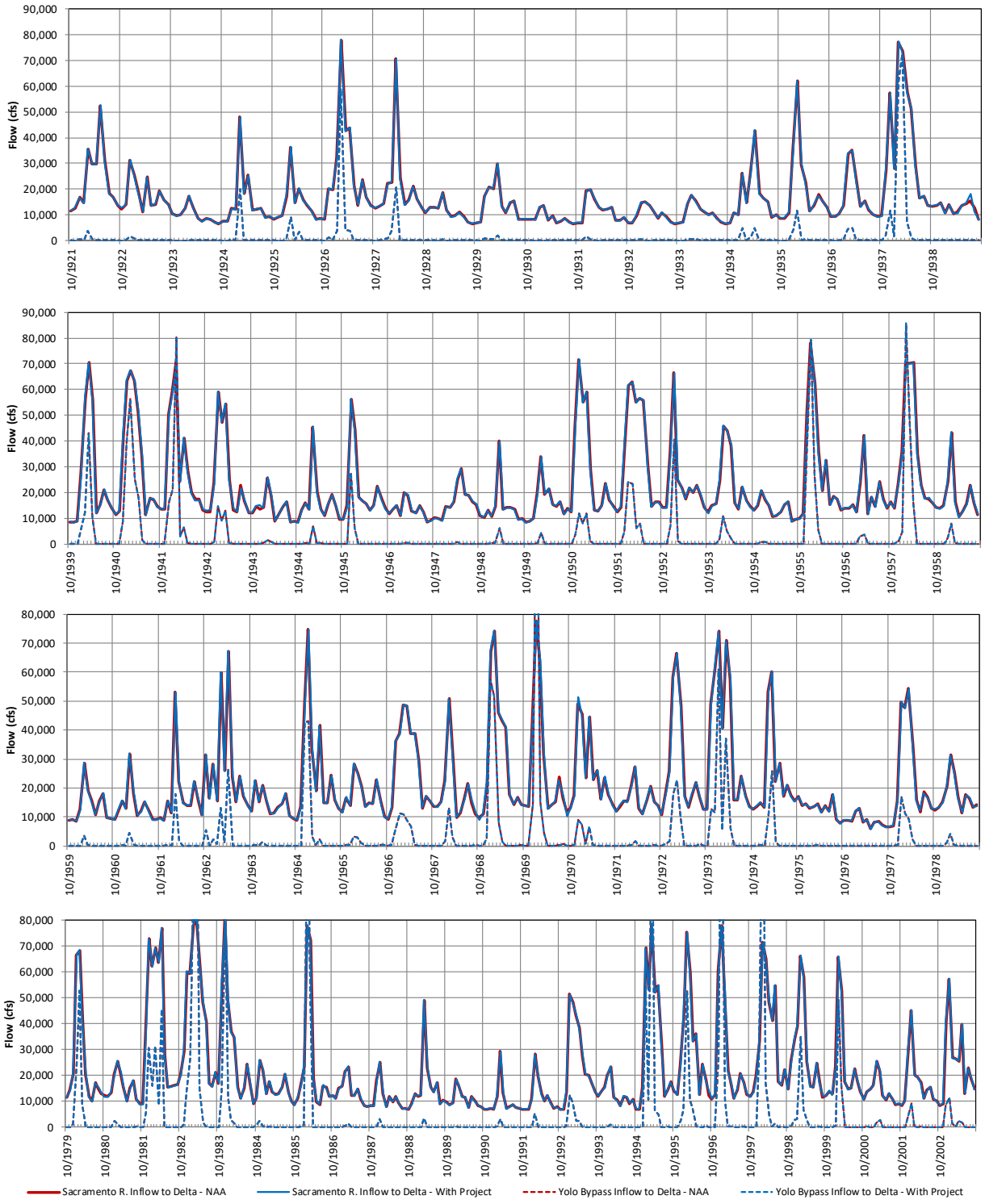


Figure 54: Comparison of Delta Outflow for Investor C/D Alternative

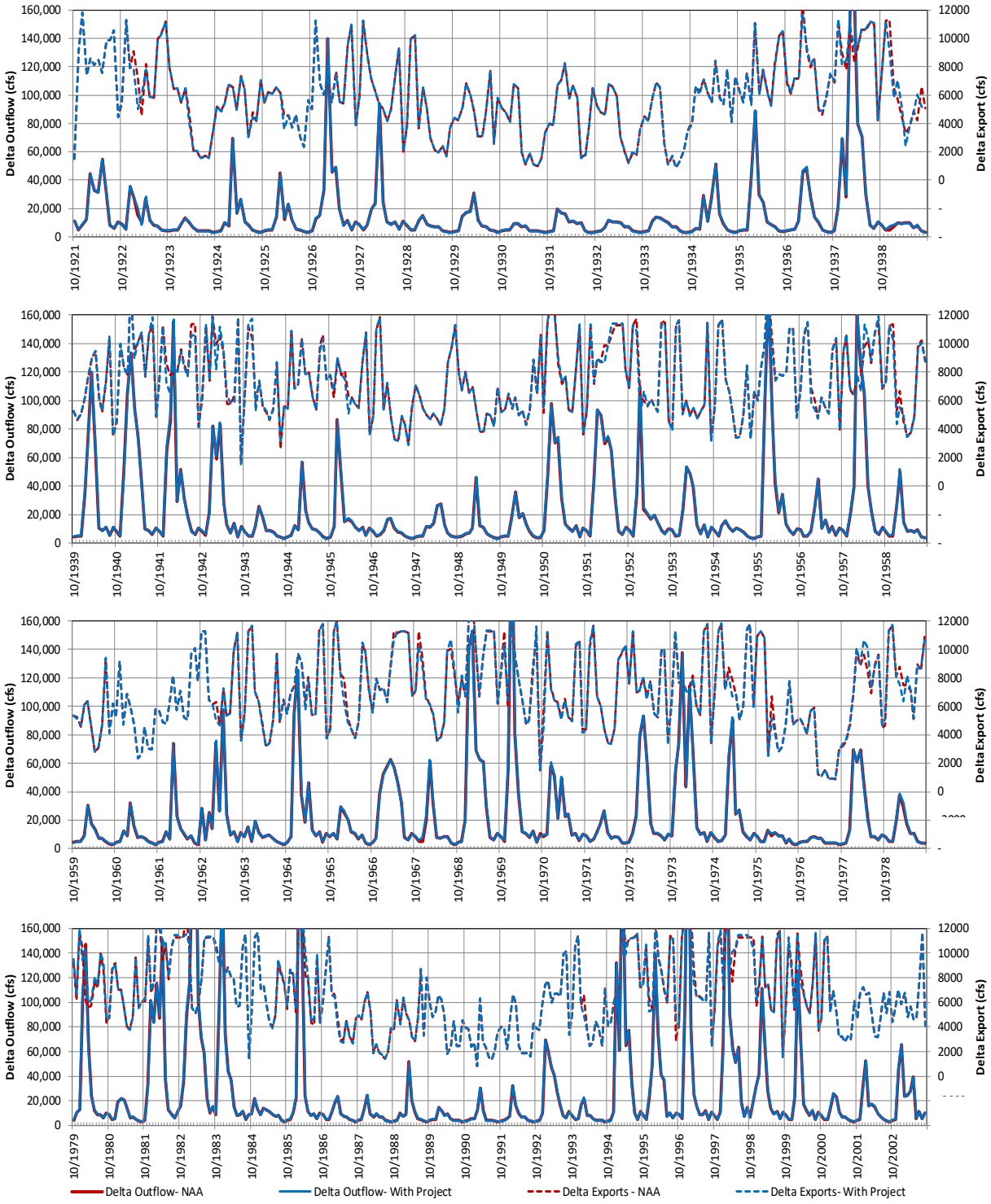
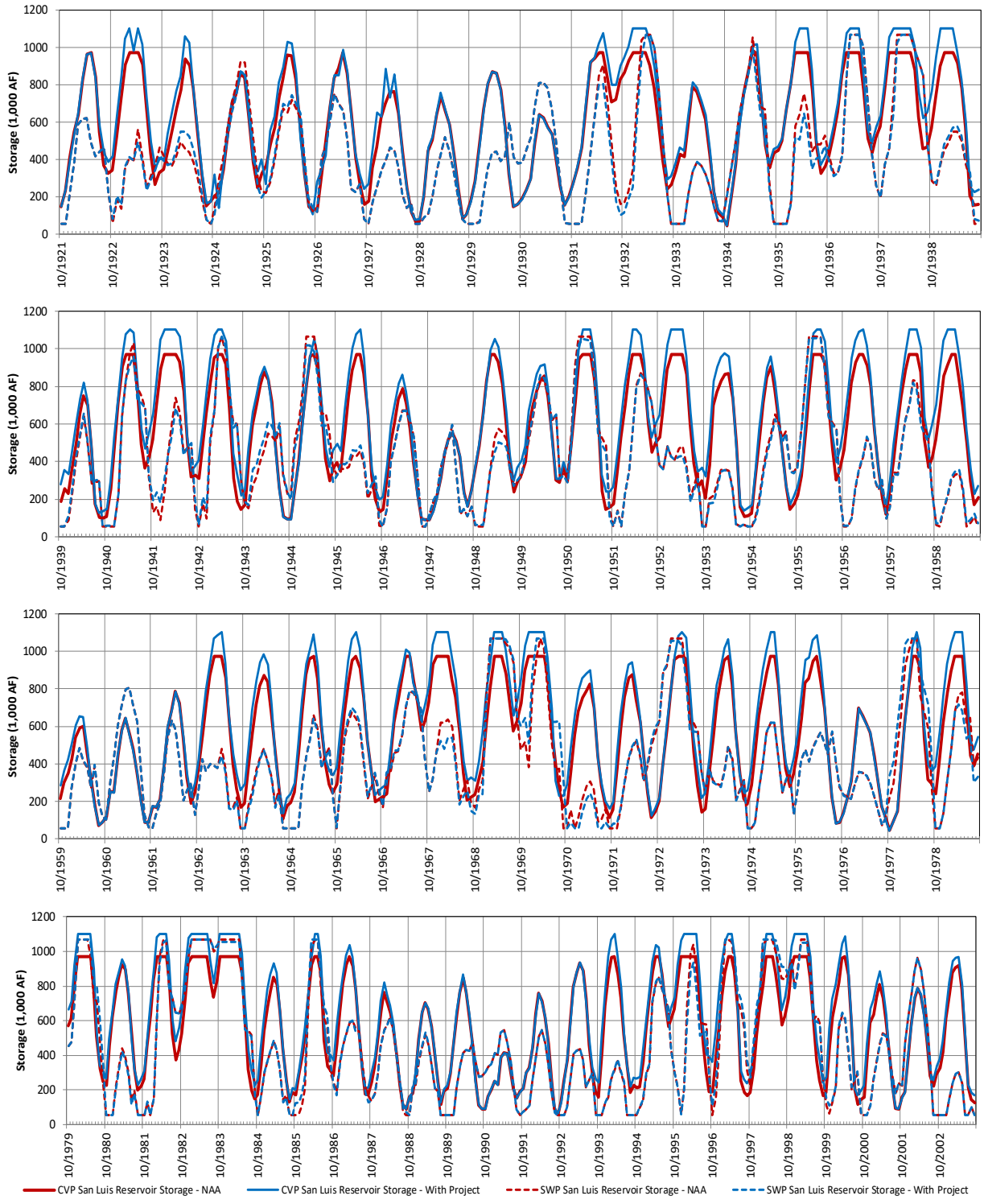


Figure 55: Comparison of San Luis Reservoir Storage for Investor C/D Alternative



B.F. Sisk Dam Raise and Reservoir Expansion Project

Final Feasibility Report

Appendix A2: Statewide Agriculture Production Report

BUREAU OF RECLAMATION

SAN LUIS & DELTA-MENDOTA WATER AUTHORITY

December 2020

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Chapter 1 Introduction

This technical appendix describes the agricultural economic model used in the analysis of B.F. Sisk Dam Raise and Reservoir Expansion Project alternatives. The scenarios evaluated for the feasibility study include Future No Action Alternative (NAA), and eight policy alternatives. The CalSim modeling technical appendix (Appendix B) provides additional details regarding the development of the alternatives and the water supply delivered to agricultural users under each alternative.

The Statewide Agricultural Production (SWAP) model is used to evaluate the effects of changes in water supply to agriculture in Central Valley regions. As water supply conditions change within a region as a result of the project alternatives, growers may change the cropping pattern, fallow land, and adjust input use in the production of crops. The SWAP model evaluates these effects; results for each alternative are compared to the results of the NAA to quantify changes in agricultural production, irrigated acreage, water use, and gross farm revenues.

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Chapter 2 SWAP Model Overview

The SWAP model is a regional agricultural production and economic optimization model that simulates the decisions of farmers in California's Central Valley. It is the most current in a series of California agricultural production models, originally developed by researchers at the University of California at Davis in collaboration with the California Department of Water Resources (DWR) with additional funding provided by the United States Bureau of Reclamation (Reclamation).

The SWAP model has been peer-reviewed (Howitt et al. 2012) and its predecessor, the Central Valley Production Model (CVPM), have been used for numerous policy analyses and impact studies over the past 20 years, including the impacts of the Central Valley Project Improvement Act (Reclamation and United States Fish and Wildlife Service 1999), Upper San Joaquin Basin Storage Investigation (Reclamation 2008), the State Water Project (SWP) drought impact analysis (Howitt et al. 2009a), and the economic implications of Delta conveyance options (Lund et al. 2007).

2.1 SWAP Model Mechanics

The SWAP model data coverage is most detailed in the Central Valley. The model assumes that farmers maximize profit subject to resource, technical, and market constraints. Farmers sell and buy in competitive markets, and no one farmer can affect or control the price of any commodity. The model selects those crops, water supplies, and other inputs that maximize profit subject to constraints on water and land, and subject to economic conditions regarding prices, yields, and costs. The competitive market is simulated by maximizing the sum of consumer and producer surplus subject to the following characteristics of production, market conditions, and available resources:

- Constant Elasticity of Substitution (CES) production functions for every crop in every region. CES has four inputs: land; labor; water; and other supplies. CES production functions allow for limited substitution between inputs, which allows the model to estimate both total input use and input use intensity. Parameters are calculated using a combination of prior information and the method of Positive Mathematical Programming (PMP) (Howitt 1995).
- Groundwater pumping cost including depth to groundwater.
- California state-wide commodity demand functions.
- Resource constraints on land, labor, water, and other input availability by region.

The SWAP model incorporates project water supplies (SWP and CVP), other local water supplies, and groundwater. As conditions change within a SWAP region (e.g., the quantity of available project water supply increases or the cost of groundwater pumping increases), the model optimizes production by adjusting the crop mix, water sources and quantities used, and other inputs. It also fallows land when that appears to be the most cost-effective response to resource conditions.

The SWAP model is used to compare the long-term response of agriculture to potential changes in SWP and CVP irrigation water delivery, other surface or groundwater conditions, or other economic values or restrictions.

Results from Reclamation's and DWR's operations planning model, CalSim II, are used as inputs into SWAP through a standardized data linkage tool. The CalSim II data file for each alternative includes nine water year types of which five were included in the SWAP model inputs. The water year types include: wet; above normal; below normal; dry; and critical conditions. For each alternative and water year type, the CalSim II model provides the SWAP model with CVP and SWP farm-gate irrigation water deliveries for each SWAP model region.

2.2 SWAP Model Theory

The SWAP model self-calibrates using a three-step procedure based on PMP (Howitt 1995) and the assumption that farmers behave as profit-maximizing agents. In a traditional optimization model, profit-maximizing farmers would simply allocate all land, up until resource constraints become binding, to the most valuable crop(s). In other words, a traditional model would have a tendency for overspecialization in production activities relative to what is observed empirically. The method of PMP incorporates information on the marginal production conditions that farmers face, allowing the model to exactly replicate a base year of observed input use and output. Marginal conditions may include inter-temporal effects of crop rotation, proximity to processing facilities, management skills, farm-level effects such as risk and input smoothing, and heterogeneity in soil and other physical capital. In the SWAP model, PMP is used to translate these unobservable marginal conditions, in addition to observed average conditions, into a cost function.

Unobserved marginal production conditions are incorporated into the SWAP model through increasing land costs. Additional land brought into production is of lower quality and, as such, requires higher production costs, captured with an exponential "PMP" cost function. The PMP cost function is both region and crop specific, reflecting differences in production across crops and heterogeneity across regions. Functions are calibrated using information from acreage response elasticities and shadow values of calibration and resource constraints. The information is incorporated in such a way that the average cost data reflected in standard crop budgets (known data) are unaffected.

PMP is fundamentally a three-step procedure for model calibration that assumes farmers optimize input use for maximization of profits. In the first step, a linear profit-maximization program is solved. In addition to basic resource availability and non-negativity constraints, a set of calibration constraints is added to restrict land use to observed values. In the second step, the dual (shadow) values from the calibration and resource constraints are used to derive the parameters for the exponential PMP cost function and CES production function. In the third step, the calibrated CES and PMP cost function are combined into a full profit maximization program. The exponential PMP cost function captures the marginal decisions of farmers through the increasing cost of bringing additional land into production (e.g., through decreasing quality). Other input costs (supplies, land, and labor) enter linearly into the objective function in both the first and third step.

The SWAP model, and calibration by PMP, is a complicated process, thus sequential testing is very useful for model validation, diagnosing problems, and debugging the model. At each stage in the

SWAP model there is a corresponding model check. In other words, the calibration procedure has particular emphasis on the sequential calibration process and a parallel set of diagnostic tests to check model performance. Diagnostic tests are discussed in Howitt et al. (2012).

2.3 Constant Elasticity of Substitution Production Function

Crop production in the SWAP model is represented by a CES production function for each region and crop. In general, a production function is a mathematical specification used to capture the relationship between inputs and output. For example, land, labor, water, and other inputs are combined to produce output of any crop. CES production functions in the SWAP model are specific to each region, thus regional input use is combined to determine regional production for each crop. The calibration routine in SWAP guarantees that both input use and output exactly match a base year of observed data.

The generalized CES production function allows for limited substitution among inputs (Beattie and Taylor 1985). This is consistent with observed farmer production practices (farmers are able to substitute among inputs in order to achieve the same level of production). For example, farmers may substitute labor for chemicals by reducing herbicide application and increasing manual weed control. Or, farmers can substitute labor for water by managing an existing irrigation system more intensively in order to increase efficiency. The CES function used in the SWAP model is non-nested, thus the elasticity of substitution is the same between all inputs.

2.4 Crop Demand Functions

The SWAP model is specified with downward-sloping California state-wide demand functions. The demand curve represents willingness-to-pay for a given level of crop production. All else constant, as production of a crop increases the price of that crop is expected to fall. The extent of the price decrease depends on the elasticity of demand or, equivalently, the price flexibility. The latter refers to the percentage change in crop price due to a percent change in production. The SWAP model is specified with linear demand functions.

2.4.1 Demand Shifts

Crop demands are expected to shift in the future due to increased population, higher real incomes, changes in tastes and preferences, and related factors. The key changes that are included in the analysis of SLLPIP alternatives are population and real income. An increase in real income is expected to increase demand for agricultural products. Similarly, population increases are expected to increase crop demand. Changes in consumer tastes and preferences will have an indeterminate effect on demand and are not included in this analysis.

Increases in demand for crops produced in California may be partially offset by other production regions depending on changing export market conditions. For example, today California is the dominant producer of almonds but this may change if other regions increase production. Thus an increase in almond demand could be partially met by other regions. However, additional demand growth from markets like China may offset this effect. The net effect is indeterminate. In the absence of data or studies demonstrating which effect would dominate, California export share is

assumed to remain constant for all crops in the future. This assumption is consistent with peer-reviewed publications for the California Energy Commission (CEC) and the academic journal *Climatic Change,* in addition to the 2009 DWR Water Plan (Howitt et al. 2009a, Howitt et al. 2009b).

Crop demands are linear in the SWAP model and population and real income changes induce a parallel shift in demand. Demand shifts are included for all of the alternative scenarios evaluated for the SLLPIP, including the No Action Alternative. Consequently, comparisons of NAA to each action alternative relates identical future market conditions.

For purposes of the demand shift analysis, a distinction is made between two types of crops grown in California, California specific crops and global commodities. Global commodity crops include grain rice, and corn[1]; all other crop groups are classified as California crops. Global commodity crops are those for which there is no separate demand for California's production. For these crops, California faces a perfectly elastic demand, and is thus a price taker. For California specific crops, California faces a downward sloping demand for a market that is driven by conditions in the United States and international export markets.

[1] Rice demand is very elastic, but not perfectly elastic. For purposes of the demand shifting analysis, it is assumed to be perfectly elastic.

Chapter 3 SWAP Model Data

The SWAP model requires a wide range of data to simulate the supply and demand for statewide agricultural production. The necessary data are not available from a single source and are instead compiled from various publicly available sources, including state and federal agencies, academic publications, and water district reports. A SWAP model data update was completed between 2009 and 2011 under contract with Reclamation. The model data and code was updated under contract with the California Department of Food and Agriculture. The model update completed in 2011 is known as SWAP version 6.1 and this version was used for analysis of the alternatives. Importantly, SWAP version 6.1 is used because it includes a National Economic Development (NED) post-processing routine which ensures benefits are consistent with federal guidelines.

3.1 SWAP Regions and Crop Definitions

The SWAP model includes 27 base regions in the Central Valley. For this analysis, a region representing the San Felipe Unit was added to account for changes in CVP water deliveries from San Luis Reservoir. All regions are included in the analysis of the project alternatives.

Table 1 summarizes some of the major water users in each of the regions.

Table 1. SWAP Model Region Summary

Region	Major Surface Water Users
1	CVP Users: Anderson Cottonwood Irrigation District (ID), Clear Creek Community Services District, Bella Vista Water District (WD), and miscellaneous Sacramento River water users.
2	CVP Users: Corning Canal, Kirkwood WD, Tehama, and miscellaneous Sacramento River water users.
3a	CVP Users: Glenn Colusa ID, Provident ID, Princeton-Codora ID, Maxwell ID, and Colusa Basin Drain Municipal Water Company (MWC).
3b	Tehama Colusa Canal Service Area. CVP Users: Orland-Artois WD, and Westside WD.
4	CVP Users: Princeton-Codora-Glenn ID, Colusa Irrigation Company, and miscellaneous Sacramento River water users.
5	Most Feather River Region riparian and appropriative users.
6	Yolo and Solano Counties. CVP Users: Conaway Ranch and miscellaneous Sacramento River water users.
7	Sacramento County north of American River. CVP Users: Natomas Central MWC, miscellaneous Sacramento River water users, Pleasant Grove-Verona WMC, and Placer County Water Agency.
8	Sacramento County south of American River and northern San Joaquin County.
9	Direct diverters within the Delta region. CVP Users: Banta Carbona ID, West Side WD, and Plainview.

Region	Major Surface Water Users
10	Delta Mendota service area. CVP Users: Panoche WD, Pacheco WD, Del Puerto WD, Hospital WD, Sunflower WD, San Joaquin River Exchange Contractors.
11	Stanislaus River water rights: Modesto ID, Oakdale ID, and South San Joaquin ID.
12	Turlock ID.
13	Merced ID. CVP Users: Madera ID, Chowchilla WD, and Gravely Ford.
14a	CVP Users: Westlands WD.
14b	Southwest corner of Kings County
15a	Tulare Lake Bed. CVP Users: Fresno Slough WD., James ID, Tranquillity ID, Traction Ranch, Laguna WD, and Reclamation District 1606.
15b	Dudley Ridge WD and Devils Den (Castaic Lake)
16	Eastern Fresno County. CVP Users: Friant-Kern Canal, Fresno ID, Garfield WD, and International WD.
17	CVP Users: Friant-Kern Canal, Hills Valley ID, Tri-Valley WD, and Orange Cove.
18	CVP Users: Friant-Kern Canal, County of Fresno, Lower Tule River ID, Pixley ID, and Tulare ID.
19a	SWP Service Area, including Belridge Water Storage District (WSD), Berrenda Mesa WD.
19b	SWP Service Area, including Semitropic WSD.
20	CVP Users: Friant-Kern Canal. Shafter-Wasco, and South San Joaquin ID.
21a	CVP Users: Cross Valley Canal and Friant-Kern Canal
21b	Arvin Edison WD.
21c	SWP service area: Wheeler Ridge-Maricopa WSD.
22	San Felipe Unit

Note: the list above does not include all water users. It is intended only to indicate the major users or categories of users. All regions in the Central Valley also include private groundwater pumpers.

Crops are aggregated into 20 crop groups which are the same across all regions. Each crop group represents a number of individual crops, but many are dominated by a single crop. Irrigated acres represent acreage of all crops within the group, production costs and returns are represented by a single proxy crop for each group. The current 20 crop groups were defined in collaboration with DWR and were last updated in 2011. Crop group definitions and the corresponding proxy crop are shown in Table 2.

Table 2. SWAP Model Crop Groups

SWAP Definition	Proxy Crop	Other Crops
Almonds and Pistachios	Almonds	Pistachios
Alfalfa	Alfalfa Hay	
Corn	Grain Corn	Corn Silage
Cotton	Pima Cotton	Upland Cotton
Cucurbits	Summer Squash	Melons, Cucumbers, Pumpkins
Dry Beans	Dry Beans	Lima Beans
Fresh Tomatoes	Fresh Tomatoes	
Grain	Wheat	Oats, Sorghum, Barley

SWAP Definition	Proxy Crop	Other Crops
Onions and Garlic	Dry Onions	Fresh Onions, Garlic
Other Deciduous	Walnuts	Peaches, Plums, Apples
Other Field	Sudan Grass Hay	Other Silage
Other Truck	Broccoli	Carrots, Peppers, Lettuce, Other Vegetables
Pasture	Irrigated Pasture	
Potatoes	White Potatoes	
Processing Tomatoes	Processing Tomatoes	
Rice	Rice	
Safflower	Safflower	
Sugar Beet	Sugar Beets	
Subtropical	Oranges	Lemons, Miscellaneous Citrus, Olives
Vine	Wine Grapes	Table Grapes, Raisins

3.2 Crop Prices and Yields

The SWAP model is designed to calibrate to the actual conditions growers faced in the calibration year. Growers make current planting decisions based on expectations of prices. The SWAP model does not attempt to model how growers form their price expectations; as an approximation, SWAP uses an average of county-level crop prices. Data for county-level crop prices are obtained from the respective County Agricultural Commissioners' annual crop reports.

3.3 Crop Yields

Crop yields for each crop group in the SWAP model correspond to the proxy crops listed in Table 2 and are based on best management practices. The corresponding costs of production, discussed in Section 3.4, are based on cost studies that also reflect best management practices. Thus, crop yields in SWAP are slightly higher than those estimated by calculating county averages but are more consistent with the production costs. Crop yield data are compiled from the University of California Cooperative Extension (UCCE) production cost budgets prepared by University of California at Davis (UC Davis) and Extension Researchers. Yields for each region are based on the most recent proxy crop cost study available in the closest region. For example, if a cost study is not available for a particular crop in the Sacramento Valley, the North San Joaquin Valley study may be used.

3.4 Crop Cost of Production Budgets

Land, labor, and other supply costs of production are obtained from the same UCCE crop budgets used to estimate crop yields. Each UCCE budget uses interest rates for capital recovery and interest on operating capital specific to the year of the study. These range from four percent to over eight percent and, as such, require adjustment to a common base year interest rate. A common rate of six percent is used for all data.

Land costs are derived from the respective UCCE crop budget and include land-related cash overhead plus rent and land capital recovery costs. Where appropriate, interest rates are adjusted as described above.

The labor cost category in the SWAP model includes both machine and non-machine labor. Labor wages per hour differ for machine and non-machine labor and, as such, are reported separately in the UCCE budgets. Both machine and non-machine labor costs include overhead to the farmer of federal and state payroll taxes, workers' compensation, and a small percentage for other benefits which varies by budget. Additionally, a percentage premium (typically around 20 percent) is added to machine labor costs to account for equipment set-up, moving, maintenance, breaks, and field repair. The sum of these components, reported on a per acre basis, is used as input data into the SWAP model.

The supply cost category in the SWAP model includes all inputs not explicitly included in the other three input categories (land, labor, and water), including fertilizers, herbicides, insecticide, fungicide, rodenticide, seed, fuel, and custom costs. Additionally, machinery, establishment costs, buildings, and irrigation system capital recovery costs are included. Each sub-category of supply costs is broken down in detail in the respective crop budget. For example, safflower in the Sacramento Valley requires pre-plant Nitrogen as aqua ammonia at 100 pounds per acre in fertilizer costs. Application of Roundup in February and Treflan in March account for herbicide costs. The sum of these individual components, on a per acre basis, is used as base supply input cost data in the SWAP model.

3.5 Surface and Groundwater

The SWAP model includes five types of surface water: SWP delivery; three categories of CVP delivery; and local surface water delivery or direct diversion. The three categories of CVP deliveries are: water service contract, including Friant Class 1 (CVP1); Friant Class 2 (CL2); and water rights settlement and exchange delivery[2]. Water supply data in the calibration year for SWAP version 6.1 are derived from various sources, described below. CVP and SWP deliveries for the alternatives are from the CalSim II model.

The volume of deliveries for each water source is estimated using data from DWR, Reclamation, and water district reports. CVP water deliveries were derived from Reclamation operations data. Contract deliveries were obtained from Reclamation; the difference between total and contract deliveries indicates deliveries for water rights settlements. SWP water deliveries are obtained from DWR Bulletin 132 (DWR 2013). Kern County Water Agency provides additional details on SWP deliveries to member agencies by region. Local surface water deliveries were obtained from individual district records and reports, DWR water balance estimates prepared for the California

[2] CVP Settlement water is delivered to districts and individuals in the Sacramento Valley based on their pre-CVP water rights on the Sacramento River, and San Joaquin River Exchange water is pumped from the Delta and delivered to four districts in the San Joaquin Valley in exchange for water rights diversion eliminated when Friant Dam was constructed. These two delivery categories are geographically distinct but for convenience are combined into one water supply category in SWAP.

Water Plan Update (DWR 2009), and, where needed, data from the CVPM model. CVPM data were, in turn, provided by the Central Valley Ground-Surface Water Model.

A key source of irrigation water, and often the costliest, is groundwater pumping. The groundwater pumping capacity estimates within SWAP are from a 2014 analysis by DWR in consultation with individual districts. Groundwater pumping capacity is intended to represent the maximum that a region can pump in a year given the aquifer characteristics and existing well capacities.

Groundwater pumping costs are divided among fixed, energy, and operations and maintenance (O&M) components in the SWAP model. Energy and O&M components are variable. Energy costs depend on the price of electricity. The SWAP model version 6 uses the same unit cost of electricity per kilowatt-hour across all regions. Base electricity costs are derived from Pacific Gas and Electric Company (PG&E) rate books and consultation with power officials at the Fresno, California office. Energy cost is 22 cents per kilowatt-hour, which is an average of PG&E's AG-1B and AG-4B rates (PG&E Various Years). Overall well efficiency is assumed to be 70 percent.

3.6 Crop Water Requirements

Applied water is the amount of water applied by the irrigation system to an acre of a given crop for production in a typical year. Variation in rainfall and other climate effects will alter this requirement. Additionally, farmers may stress irrigate crops or substitute other inputs in order to reduce applied water. The latter effect is handled endogenously by the SWAP model through the respective CES production functions. Applied water per acre (base) requirements for crops in the SWAP model are derived from DWR estimates. DWR estimates are based on Detailed Analysis Units (DAU). An average of DAUs within a SWAP region is used to generate a SWAP region specific estimate of applied water per acre for SWAP crops.

3.7 Elasticities

SWAP uses a number of economic response parameters, called elasticities, to estimate rates of change in variables. An elasticity is the percent change in a variable, per unit of percent change in another variable or parameter. Acreage response elasticity is one component of supply response. It is the percentage change in acreage of a crop from a one percent change in that crop's price. The SWAP model contains both long run and short run estimates, and the analyst decides which of the elasticities to use.

3.7.1 SWAP Model Data Sources

The SWAP model version 6.1 uses a base year of 2010 for calibration. The calibration year is used to calibrate the underlying economic parameters in the model and does not represent current conditions used in the alternatives analysis. The calibration year is simply intended to represent "average" production conditions in the Central Valley. The year 2010 was neither abnormally dry nor wet, and crop markets had been relatively stable. Table 3 summarizes input data and sources used in the SWAP model.

Table 3. SWAP Model Input Data Summary

Input	Source	Notes
Land Use	DWR	Base year 2005
Crop Prices	County Agricultural Commissioners	By proxy crop using 2005—2007 average prices
Crop Yields	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Interest Rates	UCCE Crop Budgets	All interest rates normalized to year 2010
Land Costs	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Other Supply Costs	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Labor Costs	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Surface Water Costs	Reclamation, DWR, Individual Districts	By SWAP model region
Groundwater Costs	PG&E, Individual Districts	Total cost per acre-foot includes fixed, O&M, and energy cost
Irrigation Water	DWR	Average crop irrigation water requirements in acre-feet per acre
Available Water	CVPM, DWR, Reclamation, Individual Districts	By SWAP model region and water supply source
Elasticities	Green et al. 2006	California estimates

3.8 Linkage to Other Models

The SWAP model has important interactions with other models. In particular, CalSim II, DWR's project operations model for the SWP and the CVP, is used to estimate SWP and CVP supplies which are inputs into SWAP. An existing linkage tool has been developed to translate CalSim II delivery output to a corresponding SWAP input (on-farm applied water) file. Changes in depth to groundwater affect pumping costs and agricultural revenues. Changes in groundwater depth and resulting changes in groundwater pumping costs can be included from other model, such as CVHM or C2VSim, output, if those models are run concurrently for the project.

Chapter 4 Implementing the SWAP Model for the Project Alternatives

Scenario analysis using the SWAP model can focus on a single point in time or on several future points. With reasonable interpolation, this approach will create a true time sequence to calculate net present value of a stream of costs or benefits. The alternatives for the project alternatives were evaluated using a 2030 level of development.

The SWAP model is used to compare responses to changes in irrigation water delivery under the SLLPIP alternatives. Results from the CalSim II model are used as inputs into SWAP through a standardized data linkage tool. This linkage tool is used for the NAA and the alternatives. The CalSim II data file for each scenario includes nine water year types, of which two are included in the SWAP model inputs. For each alternative and water year type, the CalSim II model provides the SWAP model with CVP and SWP on-farm water deliveries for each SWAP model region. Water supply for average and dry conditions are applied in this analysis.

4.1 Fixed Crop Prices Objective Function

The SWAP model can be used to estimate crop prices endogenously using the acreage response elasticities described above or a fixed crop price model can be applied. This analysis applies a fixed crop price objective function to estimate benefits given the relatively small changes in overall agricultural water supply resulting from the project alternatives.

4.2 Electricity Costs

Groundwater is typically the most expensive water supply. Real power costs are expected to increase in the future, and groundwater relies heavily on the cost of electricity for pumping. Energy pumping costs are escalated according to future marginal power cost estimates for the year 2030.

A marginal power cost escalator is determined for the year 2030 and applied to the energy cost component of groundwater costs. The cost escalator is the ratio of the expected future power cost in 2030 to the base power cost in 2010, in 2010 dollars per megawatt hour. Expected future power costs are calculated using the DWR Forward Price Projections analysis using wholesale power costs (DWR 2011). This calculates an average power cost for each month as the average of the peak (upper bound) and off-peak (lower bound) rates. An average of the monthly costs generates an average yearly cost. This cost is used to generate the power cost escalator by taking the ratio of the future year average to the current year average. The power cost escalator for 2030 is 1.51.

4.3 Groundwater Volume and Depth

As described above, the SWAP model includes groundwater pumping volume constraints that reflect aquifer conditions and well pumping capacities in 2014. For this analysis, the endogenous groundwater pumping volume for each region from the NAA was applied as the groundwater pumping limits for each of the alternatives. As such, no additional groundwater pumping is allowed to offset reductions in surface water deliveries. This approach was followed to account for the potential future limits on groundwater pumping due to the Sustainable Groundwater Management Act (SGMA). The effects of SGMA on future groundwater availability for agricultural uses are not known at this time so this approach is an approximation.

The SWAP model can be linked to a groundwater model to estimate change in depth to groundwater, both static and dynamic, to estimate the additional lift, and therefore energy cost, for water year types. Dry years can result in groundwater levels dropping by several feet in some regions of the Central Valley, depending on local aquifer conditions. The CVHM or C2VSim models were not run for the alternatives. As such, depth to groundwater is held constant at the baseline levels under all water year types and alternatives.

4.4 Other Factors

Climate change effects are held constant in the analysis of the alternatives. The SWAP model has been linked to crop models, such as LAWS, to estimate the change in crop yield and crop evapotranspiration and, therefore, applied water requirements. Climate change effects on crop growth remain highly uncertain and are consequently held constant in the analysis.

Crop yields have been increasing for most crops due to technological innovations. Innovations like hybrid seeds, better chemicals and fertilizer, improved pest management, and irrigation and mechanical harvesting advances are some examples. The expected future rate of growth in crop yields remains a contentious topic among researchers. Consequently, yield changes due to technological innovations are held constant in the analysis of the alternatives. It is important to note that the SWAP model does allow for some minor yield response to changing market conditions. This effect is referred to as endogenous yield changes. The SWAP model includes full CES production functions for each crop and region, which allow for some endogenous yield change in response to changing market conditions, but there is no exogenous technological change included in the analysis.

The SWAP model allows for deficit irrigation of crops. Agricultural producers may choose to deficit irrigated crops and incur a loss in crop yield if the strategy maximizes net returns. Deficit irrigation typically is the result of water supply shortages and high water costs. The maximum level of deficit in the SWAP model for each crop is set at 95 percent of applied water needs for each crop and region.

4.5 NED Benefits Calculations

The basic guidelines for evaluating water development projects at the federal level are specified in the "Principles, Requirements, and Guidelines for Federal Investments in Water Resources" (PR&Gs; CEQ 2014). Under the PR&Gs, the federal objective for water contributions is to maximize the contribution to NED consistent with protection of the environment. In order to adhere to the PR&Gs and determine the contribution to NED, a series of adjustments to the SWAP model and data are necessary. Adjustments fall into two categories, pre- and post-processing. Pre-processing adjustments are made prior to optimization with the SWAP model and include adjustments to SWAP input data and exogenous projections of future costs and demands. Post-processing adjustments are applied to SWAP output and include adjustments to prices and costs. They are adjustments needed in order for the results to comply with PR&Gs and Reclamation guidelines for NED analysis. In particular, guidelines require that certain prices be used for valuing changes in physical inputs and outputs. They do not explicitly affect farmers' decisions, so they are applied after the SWAP optimization. Post-processing adjustments include interest rates, other supply costs, fallow land costs, normalized crop prices, consumer surplus, water costs, and management charges.

All of the NED adjustments follow the SWAP NED adjustments developed in consultation with Reclamation for the North of Delta Offstream Storage (NODOS) feasibility study. The data have been updated to reflect current conditions (e.g., Current Normalized Prices are updated), but the fundamental method is unchanged. This section provides an overview of the approach.

Pre-processing adjustments include changes to the data that occur before SWAP model optimization. This includes demand shifts, energy pumping costs, interest rate adjustment, and other factors as described earlier in this section. These adjustments are made prior to SWAP optimization and are made regardless of whether the project is being evaluated under NED guidelines.

Post-processing adjustments take place after the SWAP model optimization. These include:

1. The PR&Gs require that the federal discount rate be used for all interest and capital recovery calculations. The current federal discount rate (FY19) is 2.75 percent. A post-processing adjustment is applied to cost data components to adjust the interest rate to 2.75 percent.

2. Machinery capital recovery costs are removed from the NED analysis under all scenarios. Additional land coming into irrigated production (with the project versus without the project) would be quite small and is therefore unlikely to require additional machinery investment. By the same logic, buildings capital recovery costs are removed from the NED analysis under all scenarios.

3. Land rent and cash overhead and land capital recovery costs are removed from the NED analysis under all scenarios. The NED analysis is adjusted to remove land costs that are included within the SWAP data file because lands being brought into irrigated production are already considered a sunk investment. Sunk investments are irrelevant to determining the economic feasibility of new project investments.

4. Interest on operating capital and capital recovery charges for permanent crop establishment and for irrigation systems are adjusted using interest factors as noted above.

5. An annual maintenance cost of $41 per acre (in 2019 dollars) is used for the NED analysis to account for fallow land costs, as required by the PR&Gs.

6. Consumer surplus is the benefit (welfare gain) that consumers realize from being able to purchase crops at less than their maximum willingness to pay. Since the changes in water supply is small and crop prices are fixed, the change in consumer surplus is negligible and is excluded from the NED benefits calculations.

7. Surface water costs are excluded from the NED benefits calculation. In a NED benefit-cost analysis of a proposed project, the incremental investment and annual costs of the new water supply are accounted for on the cost side of the ledger, so including them as water costs within the benefits analysis would effectively be double-counting.

8. Reclamation guidelines for preparing NED analysis under the PR&Gs recommend including management costs at no less than six percent of variable costs. A six percent management charge is added to the variable production costs in the SWAP model.

9. The PR&Gs state that U.S. Department of Agriculture (USDA) Current Normalized Prices (CNP) must be used for benefits calculations when available. These prices have been adjusted by USDA to remove any federal subsidies because such subsidies represent an NED cost that must be accounted for in comparing project benefits and costs. For crop groups covered by USDA's CNP estimates, SWAP prices were converted to scaled CNP. For crop groups without available CNP, the SWAP-predicted prices are used. CNP reported in dollars per ton, are as follows: corn $120.36; cotton $1,413.07; dry beans $952.00; grains (wheat) $154.00; rice $312.80; and sugar beets $41.92.

Chapter 5 Description of Results

This section describes the SWAP model results for NAA and the alternatives. Changes in economic conditions in the Central Valley are summarized in terms of irrigated acreage, gross farm revenues, total income over expenses, groundwater use, groundwater cost, and estimated NED benefits. Water year types summarized in this section include average and dry conditions.

Tables 4 and 5 provide the SWAP model results for the average and dry water years, respectively. As shown, the total irrigated area is approximately 6.99 million acres under NAA in the average water year. Changes in the irrigated acres for the project alternatives are relatively modest and range from a reduction of 12,700 acres (Non-structural Alternative) to an increase of 3,000 acres (Dam Raise Alternative, CVP Only Storage Subalternative). For the alternatives that provide increased surface water deliveries, the change in irrigated acres is low because the change in surface water deliveries is offset by a corresponding change in groundwater pumping.

Changes in irrigated acres in the dry water year are generally higher across the project alternatives as the additional surface water is used to irrigate land that would otherwise have been fallowed. Total irrigated acres decline slightly for the Dam Raise Alternative, Investor Directed Storage Subalternative Configuration B and Subalternative Configuration D, and the Non-structural Alternative as the alternatives provide lower agricultural water supply than NAA in dry years. Overall, the change in irrigated acres in the dry year ranges from approximately -1,800 acres (Non-structural Alternative) to 3,800 acres (Dam Raise Alternative, Investor Directed Storage Subalternative Configuration C).

Total surface water use for NAA is 13.8 MAF in the average year. Total surface water use increases for all the alternatives. The largest increases in surface water use during the average year are associated with the Dam Raise Alternative, CVP Only Storage Subalternative at 34.6 TAF. The project alternatives provide more surface water during average year than the dry year. The change in surface water use during the dry year ranges from -6.7 TAF (Non-structural Alternative) to 4.9 TAF (Dam Raise Alternative, CVP Only Storage Subalternative).

NAA groundwater pumping totals approximately 8.1 MAF in the average year. As described above, groundwater use in the average water year tends to change inversely with changes in surface water use. For example, total groundwater use for alternative Dam Raise Alternative, CVP Only Storage Subalternative declines by 23.9 TAF while surface water use under the alternative increases by 34.6 TAF. Overall, groundwater pumping declines by between 2.5 TAF (Dam Raise Alternative, Investor Directed Storage Subalternative Configuration D) and 23.9 TAF (Dam Raise Alternative, CVP Only Storage Subalternative) in the average year.

In the dry year, NAA groundwater pumping is slightly lower than the average year at approximately 8.0 MAF. The decline in groundwater pumping is attributable to several Sacramento Valley SWAP regions with settlement contractors that receive higher surface water supplies during dry years relative to average years and therefore need to pump less groundwater to meet crop water

requirements. Overall, there is virtually no change in groundwater pumping for the project alternatives when compared to the NAA in the dry year.

Gross crop revenues experience little change from the NAA level of $29.4 billion in the average water year for most of the alternatives. The Non-structural Alternative results in a $15.5 million reduction in gross revenues due to the relatively large decline in surface water supply and the limits on groundwater pumping which do not allow agricultural producers to offset the lower surface water deliveries. The overall change ranges from -$15.5 million to $3.7 million. The change in gross revenue is small for most of the alternatives because the change in surface water deliveries for the project alternatives do not result in much change in the overall cropping pattern because the SWAP regions that experience an increase in surface water availability are at or near total acreage limits and therefore substitute the additional surface water with reduced groundwater pumping. In the dry year, gross crop revenues increase for those alternatives that provide increased surface water supply and decline for alternatives Dam Raise Alternative, Investor Directed Storage Subalternative Configuration B and Subalternative Configuration D, and the Non-structural Alternative which have reductions in surface water supply.

Income over expenses measures the difference between gross revenues and selected crop production costs. Production costs that are excluded from the NED analysis are described in Section 4.2. Groundwater costs are accounted for separately and are discussed below. As shown, income over expenses changes little from NAA with the total change ranging from -$5.7 million (Non-structural Alternative) to $1.5 million (Dam Raise Alternative, CVP Only Storage Subalternative). For the dry year, the change in income over expenses ranges from -$0.6 million (Non-structural Alternative) to $5.3 million (Dam Raise Alternative, CVP Only Storage Subalternative).

The effects of the project alternatives in the average water year are centered primary on groundwater use. As a result, groundwater pumping costs are impacted. Overall, groundwater pumping costs decline between $0.3 million (Non-structural Alternative) and $6.2 million (Dam Raise Alternative, CVP Only Storage Subalternative). In the dry year, groundwater pumping costs are unchanged from NAA as the SWAP regions affected by the project alternatives continue to pump the maximum allowed groundwater volume.

In the average year, NED benefits from the project alternatives range from -$5.9 million (Non-structural Alternative) to $12.4 million (Dam Raise Alternative, CVP Only Storage Subalternative). As previously described, the benefits are primarily derived from reduced groundwater pumping costs. During the dry year, the NED benefits result primarily from the change in income over expenses and range from -$0.7 million (Non-structural Alternative) to $2.5 million (Dam Raise Alternative, Investor Directed Storage Subalternative Configuration C).

Table 4. SWAP Model Results Summary, Average Water Year

Metric	NAA	Change from NAA					
		CVP-Only	CVP/SWP Split	Investor Directed Storage (Configuration A)	Investor Directed Storage (Configuration B)	Investor Directed Storage (Configuration C)	Investor Directed Storage (Configuration D)
Irrigated Acres (Thousands)	6,988.1	3.0	-0.5	2.4	0.3	1.2	0.1
Surface Water Use (TAF)	13,848.2	34.6	15.6	27.7	4.6	14.5	2.9
Groundwater Use (TAF)	8,062.0	-23.9	-17.1	-19.3	-3.7	-10.2	-2.5
Gross Revenue ($millions)	$29,740.4	$3.7	-$1.5	$2.9	$0.3	$1.4	$0.1
Income Over Expenses ($millions)	$16,860.7	$1.5	$0.3	$1.2	$0.1	$0.6	$0.1
Groundwater Costs ($millions)	$1,016.0	-$6.2	-$4.3	-$5.0	-$0.8	-$2.5	-$0.5
Estimated NED Benefits ($millions)	N/A	$7.7	$4.6	$6.1	$0.9	$3.1	$0.5

Table 5. SWAP Model Results Summary, Dry Water Year

Metric	NAA	Change from NAA					
		CVP-Only	CVP/SWP Split	Investor Directed Storage (Configuration A)	Investor Directed Storage (Configuration B)	Investor Directed Storage (Configuration C)	Investor Directed Storage (Configuration D)
Irrigated Acres (Thousands)	6,795.2	1.5	2.3	0.8	1.5	-1.5	3.8
Surface Water Use (TAF)	13,261.7	4.9	7.8	2.9	4.9	-3.3	11.3
Groundwater Use (TAF)	8,024.4	0.0	-0.1	0.0	0.0	0.0	0.0
Gross Revenue ($millions)	$29,445.1	$2.5	$6.0	$0.9	$2.5	-$3.9	$6.9
Income Over Expenses ($millions)	$16,792.8	$0.9	$2.2	$0.4	$0.9	-$1.2	$2.4
Groundwater Costs ($millions)	$1,013.2	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Estimated NED Benefits ($millions)	N/A	$1.0	$2.2	$0.4	$1.0	-$1.2	$2.5

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B.F. Sisk Dam Raise and Reservoir Expansion Project

Final Feasibility Report

Appendix B1: B.F. Sisk Dam Raise Design Report

BUREAU OF RECLAMATION

SAN LUIS & DELTA-MENDOTA WATER AUTHORITY

December 2020

BUREAU OF RECLAMATION

B. F. Sisk Dam Raise and Reservoir Expansion Project Draft Feasibility Design Report

Central Valley Project, California
Mid-Pacific Region



BUREAU OF RECLAMATION

December 2020

Mission Statements

The mission of the Department of the Interior is to conserve and manage the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provide scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honor the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Image: Aerial view, looking west, of B.F. Sisk Dam and San Luis Reservoir. Image courtesy of DWR.

B. F. Sisk Dam Raise and Reservoir Expansion Project Draft Feasibility Design Report

Central Valley Project, California
Mid-Pacific Region

— BUREAU OF —
RECLAMATION

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Mid-Pacific Region - Planning Division

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Attachment

Attachment A. B.F. Sisk Dam Increased Storage Alternatives, Appraisal Level Study: Technical Memorandum No. VB-86-68313-25
Attachment B. 2020 Cost Estimates

Acronyms and Abbreviations

AF	acre-feet
BA	Biological Assessment
BDCP	Bay-Delta Conservation Plan
BO	Biological Opinion
CALFED	CALFED Bay-Delta Program
CA	California Aqueduct
CAS	Corrective Action Study
CEQA	California Environmental Quality Act
COA	CVP/SWP Coordinated Operations Agreement
cfs	cubic-feet per second (ft3/s)
CVOO	Reclamation Central Valley Operations Office
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
D-1641	SWRCB Water Right Decision 1641
DMC	Delta-Mendota Canal
DWR	California Department of Water Resources
Delta	Sacramento-San Joaquin Delta
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ESA	Endangered Species Act
ft3/s	cubic feet per second
JPOD	Joint Point of Diversion
M&I	Municipal and Industrial
MAF	million acre-feet
mo	month
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
OCAP	Operations Criteria and Plan
OMR	Old and Middle River
Reclamation	The U.S. Bureau of Reclamation
RPA	reasonable and prudent alternatives
RWS	reservoir water surface
SLLPIP	San Luis Low Point Improvement Project
SWP	State Water Project
SWRCB	State Water Resource Control Board
TAF	thousand acre-feet
TM	Technical Memorandum
TSC	Reclamation's Technical Service Center
USFWS	U.S. Fish and Wildlife
yr	Year

Chapter 1 Executive Summary

The Bureau of Reclamation (Reclamation) developed this Feasibility Design Report to document studies to increase the storage capacity of San Luis Reservoir (behind B.F. Sisk Dam) to improve the reliability of Central Valley Project (CVP) and State Water Project (SWP) water supplies dependent upon San Luis Reservoir. Seismic risks under the dam and in the Delta, regulatory constraints to operating Delta export facilities, algae blooms at low water levels, and future climate change have and will reduce the reliability of CVP/SWP deliveries dependent upon the San Luis Reservoir.

Reclamation initiated feasibility studies of delivery reliability risks associated with algal blooms and low reservoir levels in 2001 with the San Luis Low Point Improvement Project (SLLPIP) feasibility study, authorized by P.L. 108-361. The SLLPIP Initial Alternatives Information Report identified raising B.F. Sisk (Sisk) Dam as one alternative to the low point problem; however, the alternative was eliminated from study after the Plan Formulation Report (PFR) because more cost-effective solutions seemed available at that time.

In 2006, as a response to studies that determined B.F. Sisk dam poses a potential risk of seismic failure, Reclamation also initiated a Safety of Dams Corrective Action Study (CAS) to determine a course of action to reduce the seismic risks at the dam. Alternatives being evaluated in the CAS include raising the dam and adding abutments, as well as restricting the water level in San Luis Reservoir.

Since then, Delta export facilities have been further restricted to protect threatened and endangered species in the Central Valley, and the State of California has initiated the Bay-Delta Conservation Plan to address the delivery reliability issues related to water exports from the Delta. This effort may or may not fully address delivery reliability issues related to San Luis Reservoir, and additional storage in San Luis Reservoir may be needed to further restore delivery reliability and system flexibility.

Modifications to the dam embankment and dike, spillway, intake towers, and access-bridge would be needed to increase storage capacity within San Luis Reservoir and reduce identified dam safety risks. These modifications have been found to be technically feasible to construct. Attachment A to this Report contains a series of technical memoranda which provided the basis for feasibility level conceptual designs, estimated field costs, and other considerations of the requirements to raise B.F. Sisk Dam which are presented in this report.

In order to generate feasibility level cost estimates for this study, a conceptual dam raise alternative was formulated that considered co-equal objectives of increasing storage and mitigating dam safety risks, while also minimizing impacts to existing facilities. The conceptual alternative consists of a raise of the reservoir water surface (RWS) by 10 feet and a corresponding raise of the dam crest by 20 feet, increasing reservoir capacity by approximately 130 TAF. This conceptual design included excavation of weaker foundation materials and addition of significant downstream stability berms in several areas around the dam embankment.

Total field costs were estimated to be $360 million to construct the conceptual design. The excavation and stability berms required for reducing dam safety risks account for approximately 67% of total field costs. Costs of design, design support, construction support and construction support activities are not included in the estimated field cost. The field cost estimates for this study do include estimates for mobilization, design and construction contingencies, and allowance for procurement strategies.

The maximum estimated benefit of increasing the capacity of San Luis Reservoir by 130 TAF (10 foot increase in the water surface elevation), under existing operations and regulations, is 43 TAF of additional average annual Delta exports. Additional studies indicate that, under current operations and regulations, benefits to CVP and SWP water supply and deliveries could potentially be realized with reservoir capacity increases up to 400 TAF (~30-feet RWS raise).

For example, a 400 TAF reservoir capacity increase could produce approximately 71 TAF of additional average annual Delta exports and deliveries under current operations and regulations. Based on the results of this report, additional in-depth studies exploring the opportunities for enlarging B.F. Sisk Dam to increase the capacity of San Luis Reservoir as a part of the San Luis Low Point Feasibility Study are warranted.

Further studies would be developed in coordination with Reclamation's Dam Safety Office, the State Department of Water Resources, the Santa Clara Valley Water District, and the San Luis & Delta-Mendota Water Authority, and other entities to ensure development of a feasible solution to the several risks to CVP and SWP water delivery reliability.

Based on the findings of this report, recommendations for further studies include:

1. Restore one or more San Luis Reservoir expansion alternatives to the San Luis Low Point Feasibility Studies to determine:
    a. Actions needed to correct identified dam safety risks
    b. Technical, environmental, economic, and financial feasibility of increasing south-of-Delta surface water storage capacity under a wide range of future conditions, including climate change and changes in Delta export and conveyance capacity
2. Address the following topics during the feasibility study process:
    a. Refine the area-capacity calculations for an expanded San Luis Reservoir
    b. Consider the need to upgrade the Gianelli pumping plant depending on the height of capacity increasing alternatives analyzed
    c. Opportunities to enhance recreation in the reservoir
    d. Upgrade/improve operational representation of San Luis Reservoir in the CALSIM-II and CalLite models
    e. Consider carryover operations with a larger reservoir to improve dry year delivery benefits
    f. Complete a constructability evaluation to provide a detailed analysis of possible construction phasing to reduce impacts to CVP and SWP operations during construction

g. Complete all necessary updates to geotechnical data and models

h. Evaluate operational changes for sharing Delta exports and export opportunities

3. Manage land uses within the potentially affected areas to avoid technical and logistical conflicts that may increase the cost of the dam safety and expansion projects

4. Develop a cost-share agreement with non-federal partners to fund the feasibility and environmental studies.

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Chapter 2 Introduction

The CVP/SWP, one of the Nation`s major water conservation developments, extends from California's Cascade Range in the north to the semi-arid but fertile plains along the Kern River in the south. The CVP/SWP was initially built primarily to protect the Central Valley from water supply shortages and flood damages, but the CVP/SWP also improves Sacramento River navigation, supplies municipal and industrial (M&I) water, generates electric power, conserves fish and wildlife, creates opportunities for recreation, and enhances regional water quality.

B.F. Sisk Dam and San Luis Reservoir are an integral part of the CVP/SWP system which is located on San Luis Creek approximately 12 miles west of Los Banos, California. The entire reservoir is within Merced County, California (Figure 1). San Luis Reservoir has 65 miles of shoreline and controls runoff from about 82 square miles. The dam is an off-stream water storage facility used to store supplemental water for irrigation and domestic water supply. Water is lifted from the O'Neill Forebay into the reservoir for storage by the Gianelli Pumping-Generating Plant, and then water is released back through the pump-generating plant for use and to generate electricity. The dam impounds approximately 2,040,500 AF at the maximum RWS elevation.

The dam was built by Reclamation beginning in February 1963 and was completed in 1967. Releases from the reservoir serve many purposes ranging from domestic supply to power generation to irrigation for both the CVP and SWP. While Reclamation owns the facilities, operations and maintenance (O&M) is jointly performed by the California Department of Water Resources (DWR) and Reclamation.

2.1 Purpose of the Feasibility Design Report

The purpose of this Feasibility Design Report is to document the results of an feasibility-level study to determine the nature of water and related resource problems and needs in the study area (section 2.4), formulate and assess preliminary management measures, determine the potential for federal interest, and recommend subsequent actions that may achieve the stated study objectives.

Specifically, this study was scoped to focus on evaluation of surface storage measures at San Luis Reservoir rather than demand reduction measures.

The scope of the Feasibility Design Report is consistent with the Reclamation Manual (USBR 2007), and other relevant federal water resources planning guidelines such as Principals and Requirements for Federal Investments in Water Resources (CEQ, 2013).

2.2 Need for the Feasibility Design Report

Reclamation has been working since 2001 on the San Luis Low Point Improvement Project (SLLPIP), which is investigating solutions to decreased water delivery reliability that occurs when San Luis Reservoir storage drops to a "low point," below 300 TAF. During low point times, Reclamation's San Felipe Unit (which draws water from San Luis Reservoir) can experience supply

interruptions due to low reservoir water levels relative to the San Felipe Division's intake within the reservoir. In 2008 the SLLPIP Initial Alternatives Information Report identified raising B.F. Sisk (Sisk) Dam as one alternative to the low point problem; however, the alternative was eliminated from study after the 2010 Plan Formulation Report (PFR) because more cost-effective solutions seemed viable at that time.

Concurrently, the Mid-Pacific Region continued to evaluate opportunities to reduce the water supply impact of the Central Valley Project Improvement Act (CVPIA), consistent with section 3408(j) Least Cost Yield Increase of CVPIA. Studies completed in 2005 and 2008 under this program (Reclamation 2005, 2008c) indicated that a combination of increased storage, both north and south of the Delta, along with improved Delta conveyance capacity would most efficiently reduce the water delivery impacts of CVPIA.

Additionally, in 2006, as a response to studies that determined Sisk dam poses a potential risk of seismic failure, Reclamation also initiated a Safety of Dams Corrective Action Study (CAS) to determine a course of action to reduce the seismic risks at the dam. Alternatives being evaluated in the CAS include raising the dam and adding abutments, as well as restricting the water level in San Luis Reservoir.

Based upon the earlier yield replacement studies, identified "low point" issues, and identified dam safety risks, the Planning Division embarked upon a feasibility study to develop a project that would both mitigate the dam safety issues and improve deliveries to the San Felipe Unit and CVP/SWP as a whole.

Around the same time that the region initiated the feasibility study, both CVP and SWP contractors began asking about expanding Sisk Dam while improving safety because they saw that additional south-of-Delta storage would be useful to better capture water supplies in the Delta at times when it would not be harmful to protected fish species.

2.3 Authorization for Feasibility Design Report

Reclamation is authorized to conduct General Planning Activities, such as this feasibility evaluation, by The Reclamation Act of June 17, 1902, (32 Stat. 388, 43 U.S.C. 391) and acts amendatory thereof and supplementary thereto.

The San Luis authorizing act, Public Law 86-488, 86th Congress, was signed into law on June 3, 1960.

2.4 Study Area

The San Luis Unit (Figure 1), a part of the combined CVP/SWP was authorized for construction in 1960. The principal purpose of the federal portion of the facilities is to furnish supplemental irrigation water supply to some 600,000 acres located in the western portion of Fresno, Kings, and Merced Counties. Deliveries from San Luis Reservoir also flow west out of the reservoir through Pacheco Pumping Plant and Conduit to the San Felipe Division of the CVP, which serves the SCVWD and the SBCWD. The San Felipe Division of the CVP provides supplemental irrigation to

63,500 acres of land, in addition to approximately 132 TAF of water annually for municipal and industrial use.

While Reclamation holds title to all San Luis Unit facilities, the majority of the facilities are operated as joint-use facilities, a combined effort of the federal and state governments, with 55 percent of the total costs contributed by the State of California and the remaining 45 percent by the United States.

The joint-use facilities are O`Neill Dam and Forebay, B.F. Sisk Dam, San Luis Reservoir, William R. Gianelli Pumping-Generating Plant, Dos Amigos Pumping Plant, Los Banos and Little Panoche Reservoirs, and San Luis Canal from O`Neill Forebay to Kettleman City, together with the necessary switchyard facilities.

The federal-only portion of the San Luis Unit includes the O`Neill Pumping Plant and Delta-Mendota Canal (DMC), Coalinga Canal, Pleasant Valley Pumping Plant, and the San Luis Drain. San Luis Reservoir serves as the major storage reservoir and O`Neill Forebay acts as an equalizing basin for the upper stage dual-purpose pumping-generating plant. Pumps located at the base of O`Neill Dam move water from the CVP DMC through an intake channel and discharge it into the O`Neill Forebay. The SWP California Aqueduct (CA) also flows directly into O`Neill Forebay. The pumping-generating units within the forebay lift the water and discharge it into the San Luis Reservoir. When not pumping, these units generate electric power by reversing flow through their turbines. Water for irrigation is released into the San Luis Canal and flows by gravity to Dos Amigos Pumping Plant where it is again lifted more than 100 feet to permit gravity flow to its terminus at Kettleman City. A state canal system continues to southern coastal areas. During irrigation months water from the CA flows through the O`Neill Forebay into the San Luis Canal instead of being pumped into the San Luis Reservoir. Two detention reservoirs, Los Banos and Little Panoche control cross drainage along the San Luis Canal. The reservoirs also provide recreation and flood control benefits.



Figure 1. Major facilities of the San Luis Unit and the feasibility study area.

Chapter 3 Problems and Opportunities

Water supply reliability problems associated with the CVP/SWP result from multiple factors that, in combination, have reduced the operational flexibility and delivery reliability of these water projects over time. Regulatory actions pursuant to the Endangered Species Act (ESA), CVPIA, and Clean Water Act, and implementation of the Reasonable and Prudent Alternatives (RPAs) from the 2008/2009 U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) Biological Opinions (BOs) have reduced the ability to export water supplies through the Delta export facilities. Demands within the CVP and SWP Service area developed when more water supplies were available and have increased while the supply availability has declined significantly.

Water resources problems related to San Luis Reservoir operations are described in the following sections.

3.1 Problems

Problems identified during this study fall into three main categories which reflect issues associated with water delivery reliability, operational flexibility, and climate change; each of which are discussed in further detail below.

3.1.1 Water Delivery Reliability

The term "water delivery reliability" can be defined as the annual amount of water that can be expected to be delivered with a certain frequency. Water delivery reliability is generally measured as a probability or likelihood that a contractor will receive a certain amount of water from the CVP/SWP in a particular year (DWR 2012).

Many factors combine to affect CVP/SWP water delivery reliability. These natural and human-created factors may include the availability of source water, regulatory restrictions on CVP/SWP operations, and the effects of climate change. Uncertainty also exists because of the potential for an emergency such as an earthquake striking in or near the Delta, which, if substantial enough, could interrupt CVP/SWP exports from the Delta and/or deliveries from south-of-Delta facilities such as San Luis Reservoir.

Previous reports have confirmed that there is a significant seismic risk to B.F. Sisk Dam due to the close proximity of several active faults (Reclamation 2013b). Failure of B.F. Sisk Dam would completely halt all deliveries from the San Luis Unit, severely impacting CVP and SWP water delivery reliability.

South-of-Delta agricultural water deliveries are becoming increasingly less reliable. During the past decade, initial annual allocations to south-of-Delta agricultural contractors have been as low as 0% of full contract supplies. Uncertainty in water supply makes it hard for farmers to plan their crops, obtain operating capitol, and make other important annual decisions related to their farming operations. Annual allocations of M&I, refuge, and settlement contractors' water deliveries have much higher reliability than agricultural allocations (Reclamation 2008b).

Additionally, Reclamation's San Felipe Unit contractors are faced with water delivery reliability risks due to the "low point" problem that is further defined in Section 4.4 of this report.

3.1.2 Operational Flexibility

The term "operational flexibility" can be defined as the ability to manage existing water supplies, consistent with the project authorizations and objectives, in an efficient manner while adapting to continuous changes in regulatory, physical, and hydrologic conditions. Physical limitations include capacity limits and maintenance requirements of the system.

Increased operational flexibility can result from the ability to transfer or convey water supplies among project features, draw from supplemental water supplies, and continuously manage operations among a matrix of integrated project facilities, among other things.

3.1.3 Climate Change

Future increases in air temperature, shifts in precipitation patterns, and sea level rise could affect California's water supply by changing how much water is available, when it is available, and how it is used. Expected impacts to the SWP and CVP include lower south-of-Delta exports, having less surplus water in reservoirs that can be used during shortages, pumping more groundwater to augment reductions in surface water supplies, and an increased risk that insufficient water availability could interrupt SWP and CVP operations.

A recent report by the California Climate Change Center (DWR 2009) used multiple climate projections to assess the future reliability of California's main water supply projects. Mid- century and end-of-the-century impacts were estimated for Delta exports, reservoir carryover storage, groundwater pumping, power supply, and the vulnerability of the CVP/SWP to operational interruptions. This study examined carryover storage for four major SWP and CVP water supply reservoirs: Lake Shasta, Trinity Lake, Lake Oroville, and Folsom Lake. The study concluded that reservoir carryover storage is expected to be reduced by 15%-19% by mid- century and 33%-38% at the end of the century.

These expected reductions in carryover storage reduce water supply reliability by reducing surplus storage that can be used in times of shortages. Additionally, annual Delta exports are expected to be reduced by approximately 7%-10% by mid-century and by 21%-25% at the end of the century. These impacts to carryover storage, water supply reliability, and Delta exports are likely to further reduce water deliveries south of the Delta.

3.2 Opportunities

3.2.1 Water Delivery Reliability

Regulatory restrictions on the CVP/SWP's Delta operations have been among the major factors affecting water delivery reliability (DWR 2012). Increased storage capacity at San Luis Reservoir could provide an opportunity to export more Delta water supplies when environmental and regulatory conditions allow, such as during the rainy season (December – March) when Delta exports are generally less restricted. These increased exports could improve CVP/SWP water supplies to support annual water allocations which in turn would equate to higher water delivery reliability for south-of-Delta contractors. Increasing the volume of water able to be stored in the

reservoir would also contribute to reducing the risk of delivery impacts to the San Felipe Unit due to the issues identified in the SLLPIP.

3.2.2 Operational Flexibility

Current CVP/SWP operational flexibility is partially constrained by limited south-of-Delta storage. As previously discussed, throughout the historic hydrologic record there are years when water quality and Delta conditions would allow exports from the Delta but Reclamation has nowhere to store additional water that could be exported. Increased storage at San Luis Reservoir would provide more operational flexibility to the CVP/SWP by enabling optimized export of Delta water when conditions allow. The ability to store these additional exports, when they are available, could contribute to increasing operational flexibility in the following ways:

- Increasing use of water available when not required for in-Delta and Delta outflow needs.
- Managing the timing of water availability to better match demand/water use (seasonally and year-to-year to meet drought needs)
- Providing emergency water supply
- Providing hydropower generation or flexible generation opportunities
- Adapting to loss of snowpack storage
- Supplementing local water supplies, conservation, reuse, and desalination

3.2.3 Ecosystem Restoration

Increased south-of-Delta water supplies, stored in San Luis reservoir, could potentially be delivered to south-of-Delta National Wildlife refuges as part of CVPIA Level 4 water delivery requirements.

3.3 Objectives

A planning objective is a statement of what an alternative plan should try to achieve. Based on the water resources problems and opportunities identified in sections 3.1 and 3.2, the following planning objectives were developed for this study:

- Increase storage capacity of San Luis Reservoir (water supply)
- Increase south-of-Delta deliveries by optimizing Delta export opportunities (operational flexibility and delivery reliability)
- Mitigate for identified seismic risks at B.F. Sisk Dam (dam safety)
- Reduce the frequency of San Luis Low Point events

3.4 Constraints

A constraint is a condition or restriction that limits the extent of a project or planning process and hinders the ability to achieve a particular objective. Several constraints to the stated objectives of this study have been identified, including the following:

3.4.1 Water Supply/Delta Exports

Water for additional storage south-of-Delta is constrained by an overall limited water supply and limited Delta exports under current operating agreements, permits, BOs, and other regulatory requirements. Access to the existing Delta water supply is limited, and is forecast to become more constrained in the future (DWR 2012).

3.4.2 Dam Safety

A series of studies and analyses culminating in the seismic risk analysis that was completed in 2006 determined that there is justification to take action to reduce risk to the downstream public in the vicinity of B.F. Sisk Dam. Consequently, Reclamation, with collaboration from DWR, initiated the Safety of Dams CAS to investigate and determine a course of action to mitigate risk. Reclamation initiated this study in 2011 to explore the possibility of developing a project that would both mitigate the dam safety risk and improve deliveries to the CVP/SWP.

3.4.3 CalSim-II Modeling

While the CalSim-II model is the most widely accepted model for analyzing CVP and SWP operations, it is a planning model only and does not forecast future operations or water deliveries. The model was created to look at large scale, system-wide, changes in the entire CVP and SWP on a monthly average time step. For this feasibility study, CalSim-II results are only valid as a comparison between operations with and without a proposed action and should not be construed as a forecast of future operations.

3.4.4 Gianelli Pumping Plant

There is an upper limit to the increase in the amount of hydraulic head (i.e. RWS raise) that the existing pumps can accommodate without significant reductions in efficiency or increases in operational risk. Further analysis should consider the potential need to upgrade the pumping plant, depending on the height of raise alternatives analyzed.

3.4.5 Regulatory Requirements

Ongoing reconsultation processes for the 2008 USFWS and 2009 NMFS BOs have resulted in some uncertainty in future CVP and SWP operational constraints. Section 4.5 of this report provides more detail on applicable regulatory requirements.

Operational assumptions for modeling and evaluation of potential benefits included in the feasibility study were derived from the:

- The Reclamation 2008 *Biological Assessment on the Continued Long-Term Operations of the CVP and SWP* (2008 OCAP BA) (Reclamation 2008a)
- The USFWS 2008 *Formal ESA Consultation on the Proposed Coordinated Operations of the CVP and SWP* (2008 USFWS BO) (USFWS 2008)
- The NMFS 2009 *BO and Conference Opinion on the Long-Term Operations of the CVP and SWP* (2009 NMFS BO) (NMFS 2009)
- Coordinated Operations Agreement (COA) between Reclamation and DWR for the CVP and SWP, as ratified by Congress (Reclamation and DWR 1986)

Chapter 4 Existing Conditions

This section is intended to provide some description and explanation of the existing facilities, features, and other components of B.F. Sisk Dam and its related structures which would need to be modified in order to construct a dam raise. General design and construction considerations are discussed in this section.

4.1 Facilities

4.1.1 Dam Embankment

B.F. Sisk Dam is a zoned earthfill structure that includes a wide central core (Zone1) with downstream drainage zones (Zones 2 and 4), a drainage blanket (Zones 2 and 4), and a toe drain. A typical section of the Dam is illustrated in Figure 2.

The upstream face of the dam is sloped at 3:1 horizontal to vertical (H:V) above elevation 400 and 8:1 H:V below elevation 400. The downstream face of the dam at the maximum section is sloped at 2:1 H:V above elevation 450, 2.5:1 H:V from elevation 450 to elevation 400, 6:1 H:V from elevation 400 to 290, and 2:1 H:V from elevation 290 to the downstream toe. The dam embankment has seven zones with the central zone consisting of low plasticity clay. The downstream face of the dam is covered by a 2-foot-thick rock blanket and the upstream face is covered by a 3-foot-thick layer of riprap. There is a saddle dike located along the north rim of the reservoir approximately 1,300 feet from the dam.

In September of 1981, four stability berms (three upstream and one downstream) were added as a result of an upstream slope failure caused by rapid drawdown.

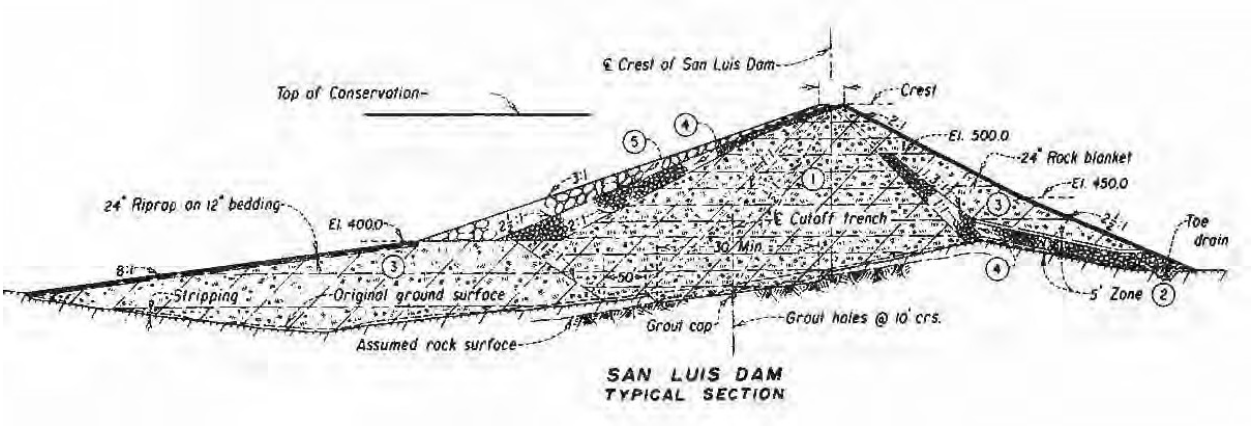


Figure 2. Typical Section of B.F. Sisk Dam



Figure 3. Close-up of B.F. Sisk Dam and Gianelli Pumping-Generating Plant

4.1.2 Gianelli Pumping-Generating Plant

The following paragraphs were taken from the Feasibility-Level Study of Static Stability for Increased Storage Technical Memorandum included as part of Attachment A to this report.

4.1.2.1 Gianelli Pumping-Generating Plant

The Gianelli Pumping-Generating Plant located at the left, northern, abutment of the dam (Figure 3) and serves as the outlet works for the dam. The outlet capacity of the plant is approximately 16,000 cubic-feet per second (cfs) with a full reservoir. The intakes to the penstocks are located near the left abutment of the dam and consist of a 284-foot-high structure containing four trashrack structures and four parallel 17.5-foot-diameter concrete tunnels/penstocks. The inlet to each tunnel is controlled by a roller-mounted emergency closure gate located in each trashrack structure. The tunnels are approximately 2,230 feet long with the last 1,180 feet of each tunnel containing a steel liner. The concrete tunnels/penstocks bifurcate to eight 11.5-foot diameter steel penstocks, with each steel penstock serving a pump-generator unit in the pump-generating plant. A 156-inch-diameter butterfly valve is located in each of the 11.5-foot-diameter steel penstocks just upstream from its respective pump-generator unit.

Each of the eight pump-generating units has a capacity of 63,000 horsepower as a motor, and 53,000 horsepower as a generator. Each unit features two-speed motor-generators by means of two rotors mounted on the same vertical shaft connected to Francis-type turbines. The lower motor operates at

150 revolutions per minute (rpm) and the upper motor operates at 120 rpm. The 150-rpm-motor is used for heads exceeding 190 feet while pumping and 227 feet while generating. In 1983, Units 1 and 5 were converted from 150 rpm to 156.5 rpm operation to increase efficiency at the higher head encountered when topping off the San Luis Reservoir.

4.1.3 Intake Towers / Trashrack Structures

Four separate trashrack structures, constructed on a common base and controlled by roller-mounted emergency closure gates, are provided at the reservoir end of the outlet tunnels and are joined to the tunnels by sections of conduit. The trashrack structures also serve as intake, discharge, and gate structures. Figure 4 is a profile view, looking north, of the trashrack structures, and their access bridge.



Figure 4. Outlet Works Intake Towers and Access Bridge

Each trashrack structure consists of a rectangular semi-bell mouth-shaped entrance joining a transition which changes from rectangular to a circular cross section. The entrance opening is a rectangle, 23.0 by 28.5 feet in size, and is vertical to permit seating of a 23.0- by 28.5-foot bulkhead gate. The centers of the entrance openings are at elevation 287.25 which is 38.75 feet below the minimum RWS elevation.

Each trashrack structure is provided with a 17.5- by 22.89-foot roller-mounted gate which operates in slots located 10 feet from the entrance opening. The roller-mounted gates provide emergency closure of the outlet works tunnels in the event of a failure of the penstocks or a malfunction of the butterfly valves installed near the pump turbine units. The emergency gate closure also permits dewatering of the tunnels for inspection, maintenance, and repair. The roller-mounted closure gates

are actuated by hydraulic hoists whose pistons are sufficiently long to close the gates with a single thrust. Each hoist is mounted on the top of the trashrack structure in the open position.

A single bulkhead gate is provided to be lowered over the entrance opening of any one of the trashrack structures to permit inspection, maintenance, and repair of the roller-mounted gate seats and guides. A gantry crane provides means of moving the bulkhead gate to a particular trashrack structure and in lowering and raising the gate.

4.1.4 Trashrack Structure Access Bridge

Vehicular and pedestrian access to the trashrack structures is provided by a 16-foot-wide bridge, about 1,060 feet long, which connects the crest of the dam with the left trashrack structure (Figure 4, Figure 5). The trashrack structures are connected by bridges which support the gantry crane.

4.1.5 Spillway

An uncontrolled concrete morning-glory-type spillway is located at the left abutment of the dam near station 139+00 (Figure 5). The full length of the spillway was excavated into bedrock. The upstream 350-foot section is a cut-and-cover conduit through the dam embankment and the left abutment. The remaining approximately 1000 feet to the stilling basin is an open chute. The design discharge capacity for the spillway is 1,030 cfs.



Figure 5. Overview of B.F. Sisk Inlet and Outlet Structures

4.2 Reservoir Area-Capacity

The Technical Record of Design and Construction (Reclamation 1974) indicates San Luis Reservoir has a surface area of 12,700 AF and an approximate capacity of 2,040,500 AF at the current maximum reservoir elevation (Figure 6).

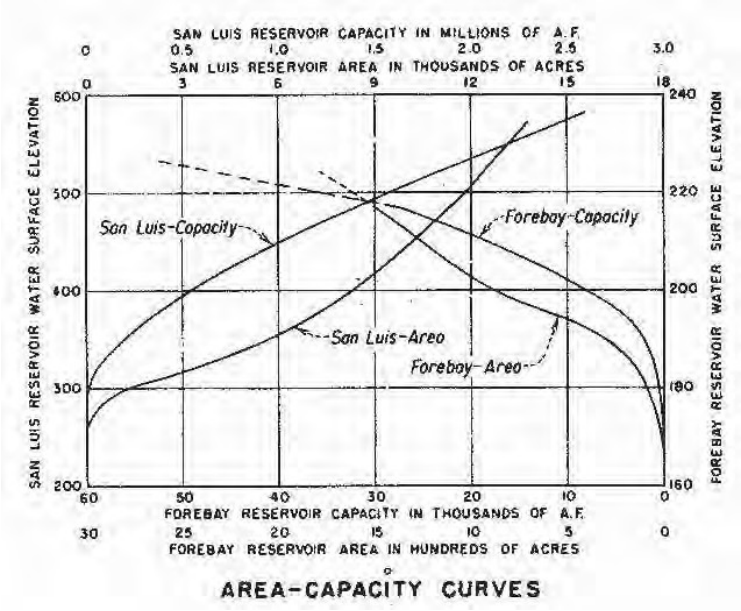


Figure 6. Area-Capacity Curves for San Luis Reservoir and O'Neill Forebay

This existing area capacity curve was calculated from a July 1960 aerial topographic survey. A contemporary topographic survey around the reservoir rim would be necessary for a more precise capacity increase calculation. As such, the reported increase in area capacity associated with a 10-foot reservoir raise is approximate. The existing area-capacity curve indicates total capacity of the reservoir with a 10-foot RWS raise would be approximately 2,226,500 AF, an increase of 131,500 AF. Extrapolating the surface area of 12,700 AF vertically 10 feet yields a capacity increase of 127,000 AF. For the purposes of this feasibility-level study, the increase in capacity associated with a 10-foot RWS raise is assumed to be approximately 130,000 AF.

4.3 Related Projects

The purpose of this section is to call attention to other known projects and project proposals which were considered for this feasibility-level investigation.

4.3.1 Safety of Dams Corrective Action Study, B.F. Sisk Dam

Studies have determined that B.F. Sisk dam poses a potential risk of seismic failure. As such, Reclamation's Safety of Dams office has initiated a Corrective Action Study (CAS) with DWR to determine a course of action to reduce the risk of dam failure. Current activities include the development of an EIS/EIR, geologic investigations, economic analysis, and preliminary engineering designs of various alternatives. The preliminary cross sections and dam raise designs described within this feasibility study have taken into account the dam safety issues that have been illuminated by the CAS.

The preliminary cost estimates completed for this study include costs for modifications that will be required to attain an appropriate static safety factor for the embankment. Dynamic (seismic) forces

were not evaluated as part of this feasibility study. Costs related to dam safety upgrades necessary under static conditions account for approximately one third of the overall costs of the dam raise.

4.3.2 Gianelli Pumping-Generating Plant Refurbishment Project

Increasing demands to run the pumping-generating plant units to meet changing operational needs has led to increased wear and tear of the units. The units operate throughout a wide range of reservoir elevations during a normal water delivery season. Currently, three major refurbishment projects are underway to restore the reliability of the Gianelli Pumping-Generating facility.

4.3.2.1 Motor-Generator Speed Conversion

The 8 units at Gianelli are unique in that a double motor-generator is mounted on each shaft. The lower motor-generator runs at 150 rpm and the upper runs at 120 rpm to improve efficiency and performance over the large range in head due to fluctuations in San Luis Reservoir. The 150 rpm rotors on Units 1 and 5 were converted to 156.5rpm in the mid-1980s to improve performance when "topping" off the reservoir. Two more units are scheduled for speed conversions as part of an extensive plan to rewind each of the motor-generators.

4.3.2.2 Pump-Turbines Refurbishment

Over the years, the pump/turbine casings have incurred significant metal loss from normal corrosion and cavitation. DWR has begun the process of a refurbishing all of the units.

4.3.2.3 Butterfly valves Refurbishment/Replacement

Each of the 8 units has a 156-inch butterfly valve and the units are paired into four common penstocks. When one butterfly valve fails, two units are affected. As of early 2013, one valve has been refurbished and was currently being installed back on Unit 5.

The projects listed above are currently in progress and are scheduled to be completed by 2026 at an estimated to cost $191.8M, of which the federal share is approximately $84.6M.

4.3.3 Proposed San Luis Reservoir Solar Project

The U.S. Department of Interior has established as a priority the development of renewable energy resources. As such, Reclamation has been collaborating with others to identify and implement renewable energy projects. To achieve that goal a multi-disciplinary team including the Bureau of Reclamation, California Department of Water Resources, and California State Parks and Recreation was recently formed to identify land use constraints associated with developing a utility-scale solar generation facility at B. F. Sisk Dam.

The solar project, as proposed, would be a ground based, tracker mounted solar facility located on land owned by Reclamation and located adjacent to the San Luis Reservoir and the O'Neill Forebay. Between twenty (20) and one hundred (100) megawatts of solar arrays in a multi- phased project would be installed at one or more locations in the area of the San Luis Unit.

4.3.4 San Luis Low Point Improvement Project

San Luis Reservoir is capable of receiving water from both the DMC and the CA, which enables the CVP and SWP to pump water into the reservoir during the wet season (October through March) and release water into the conveyance facilities during the dry season (April through September) when demands are higher. Deliveries from San Luis Reservoir also flow west through Pacheco

Pumping Plant and Conduit to the San Felipe Division of the CVP (Figure 1), which includes the SCVWD.

High temperatures and typically low reservoir levels during the summer months create conditions that foster algae growth in the surficial waters of San Luis Reservoir. When the RWS elevation approaches the elevation of the Pacheco Intakes, summer algal blooms cause water quality that is not suitable for municipal and industrial water users relying on existing water treatment facilities in Santa Clara County.

Typically, low point conditions occur when water levels in San Luis Reservoir reach an elevation of 369 feet above mean sea level or reservoir volume of approximately 300 TAF, when the water is approximately 35 feet above the top of the Lower Pacheco Intake. If water levels fall below 369 feet, the San Felipe Division's use of CVP supplies could be limited by algae-related water quality effects. San Luis Reservoir is the only delivery route for the San Felipe Division's CVP supplies authorized under their current CVP Water Service Contracts.

Reclamation, working with SCVWD, is exploring options to address the low point problem. The SLLPIP considers a Combination Alternative, Water Treatment Facility Upgrade Alternative, and a Bypass Alternative, to reduce the risk of "low point" water levels. These alternatives are being analyzed in a Draft Planning Study and Draft EIS/EIR. Reclamation and its consultant are working with SCVWD to refine the Combination Alternative as the locally preferred plan.

Measures contained in the alternative include:

- Routing CVP Water through the State's South Bay Aqueduct through an exchange of CVP and SWP water;
- Reoperation of Anderson Reservoir to provide additional local supplies;
- Blending San Luis Reservoir deliveries with those from Anderson Reservoir water to improve water quality for local consumptive uses;
- Development of new groundwater extraction capacity in the SCVWD service area; and
- Construction of a new groundwater recharge pond to provide adequate aquifer recharge.

Implementation of this project would provide operational flexibility of the San Luis Reservoir and improve reliability of water deliveries to CVP contractors.

4.4 Previous Studies

This section is intended to provide a brief description of previously completed studies that are related to the problems, opportunities, and objectives of this study.

4.4.1 CALFED Initial Surface Water Storage Screening, Integrated Storage Investigation

This report, published by CALFED (2000b), summarizes the initial screening for potential new surface water storage reservoirs to help meet the objectives of the CALFED Bay-Delta Program. CALFED began the initial screening with a list of fifty-two potential reservoir sites, including consideration of expansion of San Luis. Forty surface storage projects were removed during the initial screening for not significantly contributing to the CALFED multiple purpose objectives, including water supply, flood control, water quality, and ecosystem. The report is clear that those sites not retained for additional CALFED consideration would still be candidates for development by others for other purposes.

Enlarging of San Luis Reservoir was considered and eliminated from further analysis for apparent implementability conflicts. The CALFED program considered a dam raise of 40 feet in order to increase storage by 390 TAF. It was estimated that a total of 16 million cubic yards of material would have to be excavated to allow for the necessary extension of the drain and filter zones on the embankment. It was also hypothesized that the San Luis facility would need to be out of service for nearly 2 years in order to construct the raise. It was this potential long term shut down that rendered a Sisk dam raise not implementable and therefore screened out of further CALFED surface storage investigations. It was concluded that an enlargement of San Luis Reservoir in conjunction with a planned outage for another reason could be very attractive.

4.4.2 CALFED Surface Storage Program

The CALFED Final Programmatic Record of Decision (ROD) (CALFED 2000a) identified five surface storage projects that would contribute to the objectives of the program, including: North-of-the-Delta Off-stream Storage (NODOS) Investigation, Upper San Joaquin River Basin Storage Investigation (USJRBSI), Los Vaqueros Expansion (LVE) Investigation, Shasta Lake Water Resources Investigation (SLWRI), and In-Delta Storage Program (Figure 7). State participation in the In-Delta Storage Program was suspended in July 2006 when state funding was terminated and Reclamation did not receive authority to study the project.

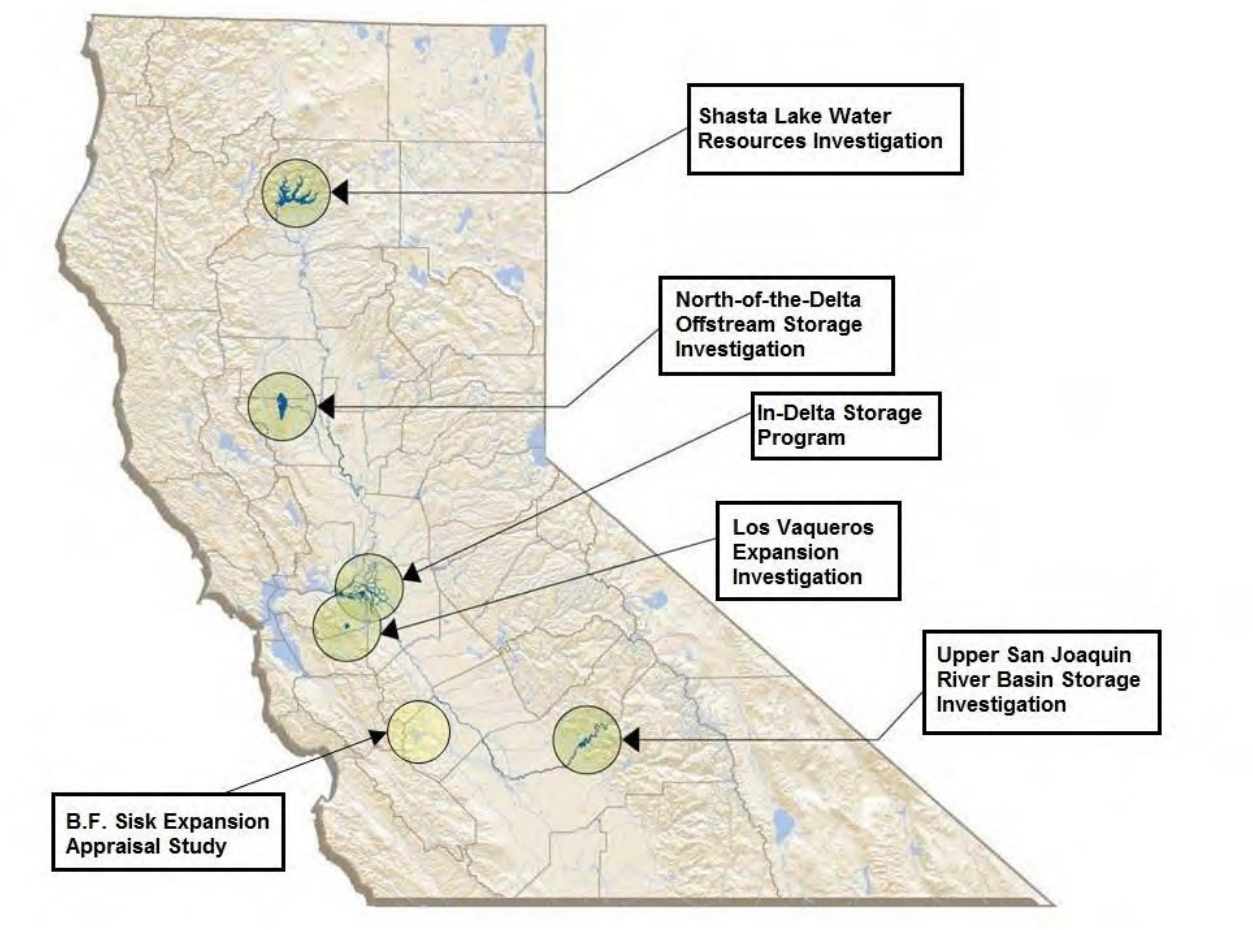


Figure 7. Locations of CALFED Surface Storage Investigations Relative to the Sisk Study Area[1].

The CALFED surface storage investigations are conceived to support multiple objectives that combine ecosystem restoration and water quality improvements with more traditional purposes of water supply reliability, hydropower, and flood protection. Since initiation of the surface storage investigations, the planning, biological, and regulatory conditions have changed significantly, including updated BOs for delta smelt and salmon, Delta export constraints, new state water legislation, and proposed operations contained in the BDCP. The investigations have been adapting to these changes and integrating new information into the feasibility studies and environmental review.

[1] This Feasibility Study is not a CALFED storage investigation, Figure 7 is for geographic reference only.

4.5 Influencing Contracts, Agreements, and Conditions

The following projects, contracts, agreements, and conditions have been considered as having the potential to influence the outcome of this feasibility study and/or being relevant to the conclusions and recommendations which will be included in this report.

4.5.1 State Water Resources Control Board Revised Water Right Decision 1641

The 1995 Bay-Delta Water Quality Control Plan (WQCP) contains current water quality objectives for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. SWRCB D-1641 (SWRCB 2000) and Water Right Order 2001-05 contain the current water right requirements to implement the 1995 WQCP. D-1641 incorporates water right settlement agreements between Reclamation and DWR and certain water users in the Delta and upstream watersheds regarding contributions of flows to meet water quality objectives. However, the SWRCB imposed terms and conditions on water rights held by Reclamation and DWR that require these two agencies, in some circumstances, to meet many of the water quality objectives established in the 1995 WQCP. D-1641 also authorizes the CVP and SWP to use joint points of diversion (JPOD) in the south Delta, and recognizes the CALFED Operations Coordination Group process for operational flexibility in applying or relaxing certain protective standards.

4.5.2 Joint Point of Diversion

The Joint Point of Diversion (JPOD) refers to the CVP/SWPs' shared use of each other's pumping facilities in the south Delta to export water from the Delta. The CVP and SWP have historically coordinated use of Delta export pumping facilities to assist with deliveries and to aid each other during times of facility failures. In 1978, by agreement with DWR, and with authorization from the SWRCB, the CVP began using the SWP Banks Pumping Plant for replacement pumping (195 TAF per year) for lost capacity at Jones Pumping Plant because of striped bass export restrictions in SWRCB Water Right Decision 1485. In 1986, Reclamation and DWR formally agreed that "either party may make use of its facilities available to the other party for export and conveyance of water by written agreement" and that the SWP would pump CVP water to make up for striped bass protection measures (USBR and DWR 1986).

4.5.3 Coordinated Operations Agreement

Reclamation and the DWR operate their respective facilities in accordance with the Agreement between the United States and the State of California for Coordinated Operation of the Central Valley Project and the State Water Project executed in 1986 (Coordinated Operations Agreement, hereinafter referred to as COA). The COA defines the project facilities and their water supplies, sets forth procedures for coordinating operations, and identifies formulas for sharing joint responsibilities for meeting Delta standards and other legal uses of water. COA further identifies how unstored flow is shared, sets up a framework for exchange of water and services between the projects, and provides for periodic review of the agreement.

Implementation of the COA principles has evolved since 1986, as changes have occurred to CVP and SWP facilities, operating criteria, and overall physical and regulatory environment. For example, updated water quality and flow standards adopted by the State Water Resource Control Board (SWRCB), CVPIA, and Endangered Species Act (ESA) responsibilities have affected both CVP and SWP operations. The 1986, COA incorporated the SWRCB Water Right Decision 1485 (D-1485) provisions regarding Delta salinity, outflow, and export restrictions. D-1485 included

implementation provisions for the Bay-Delta Water Quality Control Plan (WQCP) that was current at the time, but has since been updated with Water Right Decision 1641 (D-1641). COA envisioned and provided a methodology to incorporate future regulatory changes, such as Delta salinity requirements, but did not explicitly envision or address sharing of export restrictions. D-1641 and the 2008 U.S. Fish and Wildlife Service (USFWS) Biological Opinion (BO) and 2009 National Marine Fisheries Service (NMFS) BO included various export restrictions not explicitly addressed in the 1986 COA. However, the available export capacity as a result of these export restrictions was shared between the CVP and the SWP in absence of a formal update to the COA.

In 2018, Reclamation and DWR amended four key elements of the COA to address changes since the COA was signed: (1) in-basin uses, (2) export restrictions, (3) CVP use of Banks Pumping Plant up to 195,000 acre-feet per year (AFY), and (4) periodic review. The COA sharing percentages for meeting Sacramento Valley in-basin uses now vary from 80 percent responsibility of the United States and 20 percent responsibility of the state of California in wet year types to 60 percent responsibility of the United States and 40 percent responsibility of the state of California in critical year types. In a dry or critical year following two dry or critical years, the United States and state of California will meet to discuss additional changes to the percentage sharing of responsibility to meet in-basin uses. When exports are constrained and the Delta is in balanced conditions, Reclamation may pump up to 65 percent of the allowable total exports with DWR pumping the remaining capacity. In excess conditions, these percentages change to 60/40. The COA defines balanced conditions as periods when it is agreed that releases from upstream reservoirs plus unregulated flow approximately equal the water supply needed to meet Sacramento Valley in-basin uses, plus exports. The COA defines excess conditions as periods when it is agreed that releases from upstream reservoirs plus unregulated flow exceed Sacramento Valley in-basin uses, plus exports.

4.5.4 Biological Opinions on Long-term Operation of the Central Valley Project and State Water Project

On October 21, 2019, USFWS and NOAA Fisheries released biological opinions on the effects of coordinated long-term operations of the CVP and SWP (USFWS 2019; NOAA Fisheries 2019). In the 2019 biological opinion, USFWS concluded that continued long-term operations of the CVP and SWP are "not likely to jeopardize" the continued existence of delta smelt and its critical habitat (USFWS 2019).

Similar to the USFWS biological opinion on delta smelt, NOAA Fisheries concluded that continued long-term operations of the CVP and SWP are "not likely to jeopardize" continued existence of Sacramento River winter run Chinook salmon, Central Valley spring run Chinook salmon, Central Valley steelhead, and the southern Distinct Population Segment of North American green sturgeon or destroy or adversely modify their designated or proposed critical habitat (NOAA Fisheries 2019).

On November 21, 2019, the California Natural Resources Agency announced litigation challenging the 2019 USFWS and NOAA Fisheries Biological Opinions and the "not likely to jeopardize" determinations.

The ROD for the Reinitiation of Consultation on the Coordinated Long-Term Modified Operations of the CVP and SWP was released on February 19, 2020.

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Chapter 5 Management Measures

The purpose of this section is to provide a brief discussion of the process to develop management measures to achieve study objectives. The sections to follow briefly describe a range of dam raise concepts and management measures identified during the feasibility study. A management measure is a feature or activity that can be implemented at a specific geographic site to address one or more planning objectives. Measures are the building blocks of which alternative plans are made. Measures become more specific and better defined as planning progresses (IWR 1996).

5.1 Non-Structural Measures

Non-Structural measures could potentially contribute to meeting the objectives of this study. The Safety of Dams CAS completed preliminary evaluations of some of the non-structural alternatives discussed below (Reclamation 2013b). The following non-structural measures were identified. The evaluation results for these and other non-structural and structural measures that were identified are presented in Appendix A of the B.F. Sisk Dam Raise and Reservoir Expansion Project Environmental Impact Report/Supplemental Environmental Impact Statement (SLDMWA and Reclamation 2020).

5.1.1 Reservoir Restrictions / Increased Freeboard

Dam safety risks could potentially be reduced by lowering the reservoir level such that even if the dam were to experience a large crest settlement, a breach leading to failure would not occur. Since B.F. Sisk is an off-stream storage facility, a reservoir restriction is feasibly obtained by not filling (pumping into) the reservoir. This measure would consist only of a change in operations, so it is considered non-structural.

Based on seismic deformation estimates (Reclamation 2013b) a permanent restriction of at least 50 feet would be required to reduce the risk to within current Reclamation Public Protection Guidelines. This would require a substantial reallocation and reduction of project water deliveries and would significantly reduce the amount of power which can be generated.

5.1.2 Demand Reduction / Water Use Efficiency

As a means to reduce demands on existing supplies, existing Reclamation water reuse and water use efficiency programs could be further implemented to ease demands on the San Luis Reservoir. A water reuse project is a project that reclaims and reuses municipal, industrial, domestic, or agricultural wastewater and naturally impaired groundwater and/or surface waters. Reclaimed water can be used for a variety of purposes such as environmental restoration, fish and wildlife, groundwater recharge, municipal, domestic, industrial, agricultural, power generation, or recreation.

Reclamation's Water Use Efficiency Program offers grant opportunities for water conservation and water use efficiency projects. The goal of the program is to accelerate the implementation of cost-effective actions that provide water management benefits through conservation. Water use efficiency implementation is intrinsically linked to other benefits such as water quality, water supply reliability, and in stream flows (Reclamation 2013a).

5.1.3 Changes in Operations

Further studies could evaluate operational changes at San Luis Reservoir that may improve water delivery reliability, such as adding a carryover storage component.

5.1.4 Groundwater Storage

Further studies could evaluate potential use of groundwater storage opportunities throughout the Central Valley. Groundwater storage could be evaluated for use in conjunction with or as an alternative to more surface water.

5.1.5 Pumping Capacity Restrictions

Non-structural evaluations could consider the benefits and impacts of increased Delta pumping limits during less sensitive times of the year for fish and water quality.

5.2 Structural Measures

Structural measures refer to features that require construction or assembly on-site. Structural measures could potentially contribute to meeting the objectives of this study. The structural measures are identified and described below.

5.2.1 Downstream Stability Berms

B.F. Sisk Dam is founded on four different geologic units: Panoche Formation (rock), Tulare Formation, Slopewash, and Patterson Alluvium. Previous studies have shown that the undrained strength of the Slopewash and the liquefied strength of the Patterson Alluvium, triggered by seismic loading, result in significant deformations (crest settlement) of the dam at those locations. These dynamically unstable areas can be stabilized with the use of berms located at the downstream toe of the dam and keyed into high strength foundation material.

The berms are constructed by first excavating overburden foundation soils down to either the dense basal gravel layer or bedrock beneath the berm footprint. During this excavation, the rock blanket or slope protection is also removed to the top elevation of the berm. Next, the existing toe drain is removed by excavation. These two operations would expose the existing blanket drain and surrounding filter materials in the downstream face of the dam. Above the blanket drain, the existing Zone 3 shell would be exposed. After completion of the excavations, backfill would be placed and compacted. Incorporated into the primary backfill material is an extension of the blanket drain that connects to a new toe drain constructed at the toe of the berm. The final step is to place slope protection on the downstream face of the berm.

5.2.2 Downstream Crack Filters

Crest settlement in response to a seismic event can result in two types of failure: dam overtopping and post-earthquake erosion through cracks caused by shaking or settlement. The stability berm and crest raise measures primarily address the overtopping issue. The cracking issue is addressed by a filter being incorporated into the crest raise geometry and added to the upper part of the downstream face of the dam. Significant seismic deformations typically produce cracking of the embankment near the crest. Deformation cracking for embankments on liquefiable foundations is typically limited to depths of about 10 to 25% of the embankment height based on historical

performance records of embankment dams. The primary function of the downstream filter zones is to provide a filter to mitigate the potential for internal erosion through post-seismic crest cracks.

5.2.3 Various Crest / Embankment Raises

Crest raise measures include raising the height of the dam to increase the amount of available freeboard and to provide space for additional reservoir storage capacity. Crest raises of various heights could be studied in order to balance needs for additional freeboard and additional storage space. The conceptual structural designs analyzed for this feasibility study built upon existing designs and concepts that were developed as part of a CAS.

Three crest raise methodologies were conceptualized during the CAS that were also evaluated for the feasibility study. The following two concepts were eliminated from further consideration due to the lack of erosion control measures that were shown to cause significant cracking of the dam crest in the event of a large earthquake:

- Steepened upstream and downstream slopes utilizing either a reinforced earth section or soil cement for the upstream and downstream slope faces; and,

- Vertical upstream and downstream slopes using a mechanically stabilized earth (MSE) wall section

A third conceptual design was carried forward in the CAS and is similar to the conceptual design that was developed for the feasibility study.

5.2.4 Alternative Dam Sites

Further studies could consider alternative dam sites within or adjacent to the San Luis Reservoir.

5.3 Alternatives

Alternatives consist of a set of one or more management measures functioning together to address one or more planning objectives.

Alternatives can consist of structural and/or non-structural measures and also always include a no action alternative in order to describe "future without" conditions. In order to get a feasibility level cost estimate a conceptual dam raise alternative needed to be formulated as a basis for material quantities and construction methods to be estimated. The sections below discuss the no action and a conceptual dam raise alternative which were developed during technical studies completed during the feasibility process.

5.3.1 No Action Alternative

Defining likely without-project conditions (the No Action Alternative) is an important step in federal water resources planning. The without-project conditions aid in accurately defining water resources problems and needs. The without-project conditions serve as a baseline against which alternatives can be evaluated to determine their effectiveness, and to identify resulting impacts. In defining the without-project conditions, changes in parameters are taken into account such as projections related to population, land uses, and new local and regional water resources and programs related to local and regional water resources. Normally only currently adopted projections

and/or projects that are either under construction or authorized and funded, would be included in the without-project conditions.

5.3.2 Conceptual Dam Raise Alternative

The embankment raise concept developed for this study includes two structural components; a crest raise, and downstream stability berms. Both of these components have been included in the feasibility-level studies to maintain consistency with the B.F. Sisk Dam Safety of Dams Modification Project. The crest raise component is required to accommodate the additional volume of water and some degree of increased freeboard and the downstream stability berms are necessary to increase static and dynamic stability of the embankment to the appropriate safety factor. In order to raise B.F. Sisk Dam, corresponding modifications to the dam embankment, dike, spillway, intake towers, and access-bridge would be needed.

In this study, a conceptual dam raise alternative was identified based on balancing the need for additional storage while minimizing impacts to existing facilities. This concept was also developed in a way to limit impacts to project costs by limiting the number and types of facilities affected by potential dam expansion construction.

In order to develop feasibility level field cost estimates a conceptual alternative needed to be formulated. The conceptual alternative evaluated for this feasibility study included a 10-foot RWS raise in conjunction with a 20-foot embankment raise.

Figure 8 is a graphic summary and typical section of the proposed modification alternative.

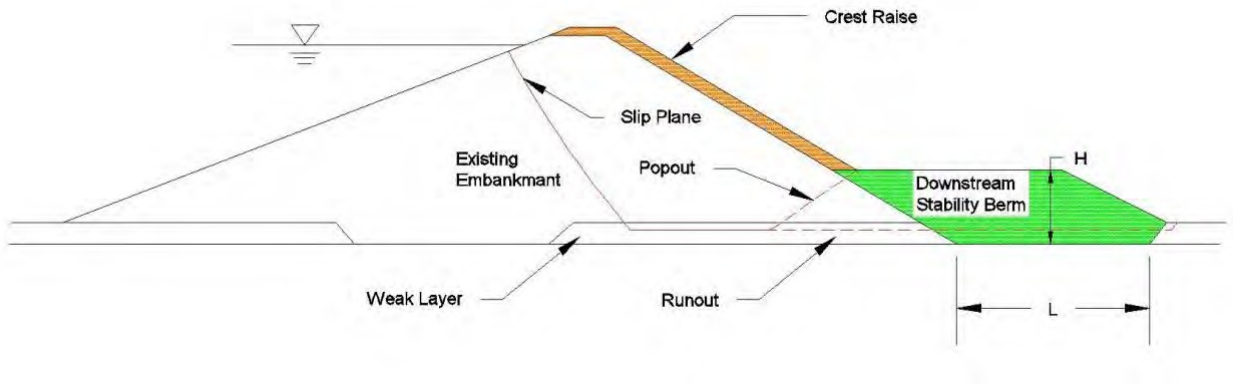


Figure 8. Typical Section of the Conceptual Modification Alternative

5.3.2.1 Construction Considerations

The scope of the proposed modifications will likely require multi-year phasing of the work and thorough coordination between construction contractors. Construction sequencing will be required to allow some of the outlet works intake towers to remain operational while other towers undergo demolition and reconstruction. Due to the location of the intake towers within the reservoir, the limited access, and the desire to maintain water storage during construction, use of a barge will likely be required for demolition and construction of the intake towers.

Construction sequencing will be required for excavation, demolition, and reconstruction of the spillway to ensure the RWS is well below the level of the modifications. Construction will impact several recreation areas around the reservoir.

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Chapter 6 Considerations for Structural Modifications

The sections below summarize the structural modifications that would be needed to implement the conceptual alternative as described in the previous section (5.3.2).

6.1 Intake Towers/Trashrack Structures

In order to increase the San Luis Reservoir water surface by 10 feet, the existing intake towers would need to be raised a corresponding 10 feet. To accomplish this, the top 16.25 feet of the existing towers would be demolished. The intake tower walls would be extended vertically using forms and cast-in-place concrete. The intake tower operating platform with support corbels would be reconstructed as originally designed.

Prior to demolition of the top of the intake towers, all existing equipment including the roller gate, hoist stem extension, gantry crane, and bulkhead gate would be removed. This equipment would be re-installed after extension of the intake towers is completed.

6.2 Trashrack Structure Access Bridge

The current access bridge deck elevation is at the same elevation as the crest of the dam and the top of the intake tower/trashrack structures. The bridge span would be removed and replaced with a similar-type superstructure at an appropriately raised elevation. The new bridge deck elevation would vary between the intake towers and the abutment. The existing bridge piers would be extended vertically and the new bridge would be founded on the extended piers.

An analysis of the feasibility of raising this access bridge has been carried out and has determined that raising the access bridge is technically feasible. The cost of raising the bridge has been estimated to be on the order of $11,000,000. Technical Memorandum BFS-8140-STY- 2013-1 and cost estimates have been included in Attachment A of this report

6.3 Spillway

The morning glory spillway is located approximately 100 feet upstream of the centerline of the dam near station 139+00, and the access bridge for the intake towers intersects the crest at approximately station 140+50, as shown on Figure 5. The upper 22 feet of the spillway would be demolished. The spillway would then be raised 10 feet. Excavation of the upstream face of the dam would be necessary to expose the top 22 feet of the spillway. The embankment section would be reconstructed after modifications to the spillway structure were completed. Modifications to the spillway may also involve covering part of the open chute to accommodate the new fill and/or overlay.

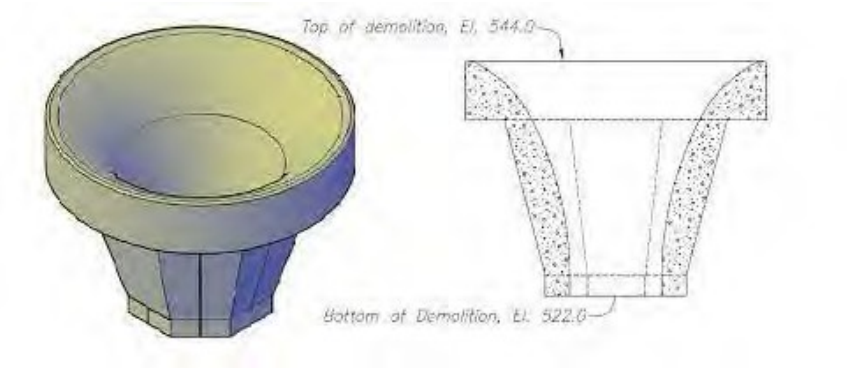


Figure 9. Approximate Limits of Spillway Demolition

Modifications to the spillway will be required if the dam is raised. The spillway modification will most likely be limited to cutting away the existing upstream opening (Figure 9), raising the spillway, and replacing the spillway opening.

Chapter 7 Cost Estimates

Feasibility-level field cost estimates were made for the conceptual design of a 10-foot RWS raise in conjunction with the 20-foot dam raise. Only construction costs are presented here; that is, no contract, design, or remediation costs, or time escalations are included. The contingency includes 15 percent to cover costs for current "unlisted" items and 25 percent to reflect the uncertainty in the appraisal-level quantities. Detailed appraisal level estimate worksheets are included in Attachment A. Two estimates were made in an attempt to bracket the uncertainty associated with the potential variability of the dam foundation. The worksheets include costs for two different berm sizes for differing strength assumptions, therefore total costs were reported as a range. For the sake of this feasibility design study, the high end of the appraisal-level cost estimates presented in Attachment A were updated to January 2020 price level. The updated feasibility-level cost estimates are presented in Attachment B. Further development and value analysis of designs and cost estimates could potentially find significant cost savings, however at this level of design many construction variables are undefined so contingencies are high and cost estimates are very conservative.

For further details on field cost estimates, fill quantities estimated, and other cost estimation considerations please refer to Attachment A of this report.

The values presented in Table 1 are field cost estimates made at the feasibility level for the most probable cost estimate and, as such, should not be used for as a definitive indicator of total project costs. Table 2 presents values under the probable low-cost estimate and similar to the most probable estimate should not be used for as a definitive indicator of total project costs. The estimates only include costs for construction and do not include associated costs for design, investigations, project coordination, contract administration, construction management, environmental studies, mitigation, operation and maintenance costs, etc.

Contingencies are considered funds to be used after construction starts and not for design changes during project planning. The purpose of contingencies is to identify funds to pay contractors for overruns on quantities, changed site conditions, change orders, etc. As per the Reclamation Cost Estimating Handbook (Reclamation 1989), feasibility-level estimates should have 15± percent added for contingencies. Based on the current level of design data, geologic information, and general knowledge of the conditions at the various sites, the contingency line item was set at 15± percent of the contract cost for all features. The contingency line item is a rounded value which may cause the dollar value to deviate from the actual percentage shown.

It should be noted that the estimated cost for the crest raise and dam/dike modifications, including the downstream berms needed for static stability, is greater than 90 percent of the field costs. Modifications to the structures account for less than 10 percent of the field costs.

Table 1. Summary of Design Level Field Cost Estimates – Most Probable

Feature	Cost	% Total Cost
Civil/Structural*	$1,202,616.00	0.5%
Structural Modifications	$41,760,224.50	16.5%
Crest Raise*	$123,906,297.00	49%
Dikes	$85,851,470.00	34%
Subtotal	$252,720,607.50	100%
Total Estimated Field Costs	$492,020,607.50**	

Notes:
* Shared features with B.F. Sisk Dam Safety of Dams (SOD) Modification Project
**Total estimated field costs include mobilization (~5%), design contingencies (~15%), construction contingencies (~15%), cost indexing (January 2020), and escalation to Notice to Proceed and mid-point construction (January 2028). See Attachment B for detailed cost estimate worksheets.

Table 2. Summary of Design Level Field Cost Estimates –Probable Low-Cost

Feature	Cost	% Total Cost
Civil/Structural*	$1,182,080.67	0.5%
Structural Modifications	$41,123,632.00	19.5%
Crest Raise*	$109,298,633.33	52%
Dikes	$59,100,963.33	28%
Subtotal	$210,705,309.33	100%
Total Estimated Field Costs	$405,377,104.00**	

Notes:
* Shared features with B.F. Sisk Dam Safety of Dams (SOD) Modification Project
**Total estimated field costs include mobilization (~5%), design contingencies (~15%), construction contingencies (~15%), cost indexing (January 2020), and escalation to Notice to Proceed and mid-point construction (January 2028). See Attachment B for detailed cost estimate worksheets.

Chapter 8 References

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B.F. Sisk Dam Raise and Reservoir Expansion Project San Luis Reservoir Expansion Final Feasibility Design Report

Attachment A
B.F. Sisk Dam Increased Storage Alternatives, Appraisal Level Study: Technical Memorandum No. VB-86-68313-25

ATTACHMENT A

Technical Memorandum No. VB-86-68313-25

B.F. Sisk Dam Increased Storage Alternatives, Appraisal Level Study

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RECLAMATION

Managing Water in the West

Technical Memorandum No. VB-86-68313-25

B.F. Sisk Dam – Increased Storage Alternatives, Appraisal-Level Study

Central Valley Project, California
Mid-Pacific Region



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

April 2013

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo (courtesy of DWR) – Aerial photograph of B.F. Sisk Dam and San Luis Reservoir

Technical Memorandum No. VB-86-68313-25

B.F. Sisk Dam – Increased Storage Alternatives, Appraisal-Level Study

Central Valley Project, California
Mid-Pacific Region

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

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Technical Memorandum No. VB-86-68313-23

B.F. Sisk Dam – Increased Storage Alternatives, Appraisal-Level Study

Central Valley Project, California
Mid-Pacific Region

P.E.
Author: Tonya Hart, P.E.
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Civil Engineer, Geotechnical Engineering Group 3, 86-68313

Randall Kuzniakowski
Peer Review: Randy Kuzniakowski, P.E.
Civil Engineer, Geotechnical Engineering Group 4, 86-68314

4/5/2013
Date

REVISIONS					
Date	Description	Prepared	Checked	Technical Approval	Peer Review

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Acronyms and Abbreviations

AF	acre-feet
APS	allowance for procurement strategies
bcy	bank cubic yards
BOR	Bureau of Reclamation
CAS	Corrective Action Study
CFR	Comprehensive Facility Review
CMP	Corrugated Metal Pipe
CRB	Consultant Review Board
CY	cubic yards
DWR	California Department of Water Resources
FLAC	Fast Lagrangian Analysis of Continua
FS	factor of safety
ft^2	square foot (feet)
ft^3	cubic foot (feet)
GVS	Great Valley Sequence
IE	Issue Evaluation
km	kilometer(s)
MPRO	Mid-Pacific Regional Office
MSE	Mechanically Stabilized Earth
NVS	North Valley Section
PMP	Project Management Plan
RA	Risk Analysis
RRA	Risk Reduction Analysis
Reclamation	Bureau of Reclamation
RWS	reservoir water surface
SOD	Safety of Dams
SPT	standard penetration test
SVS	South Valley Section
TM	Technical Memorandum
TSC	Technical Service Center
URS	URS Group, Inc.

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Exhibit D – TM BFS-8110-STY-2012-1
Exhibit E – TM BFS-8140-STY-2013-1

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Exhibit A

Cost Estimate Worksheets – Option A

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FEATURE:
B.F. Sisk Dam Modification
Appraisal Level Study
20-foot Dam Raise
Middle Estimated Drained Strength Parameters
Option A
Geotechnical (86-68313)

PROJECT:
Central Valley Project, Madera County, California

WOID:	A176F	**ESTIMATE LEVEL:**	Appraisal
REGION:	MP	**UNIT PRICE LEVEL:**	Oct-12

FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[Copy of 001 Summary BF Sisk - Drained.xlsx]Sht 1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		The cost estimate sheets from B.F. Sisk Dam Appraisal-Level Construction Considerations					
		(TM VB-8313-9; May 2010) were used to establish quantities for preparing this cost estimate. The borrow					
		areas, construction methods, and environmental considerations presented in TM VB-8313-9 are					
		assumed to be the same for this Appraisal-Level study. Additionally, information presented in					
		B.F. Sisk Dam Appraisal-Level Study of Static Stability for Increased Storage report (TM VB-86-68313-22;					
		December 2012) should be reviewed.					
		NOTES:					
		1) Quantities were calculated at specific sections (e.g. stations 37+00, 65+00, 86+00, 107+00 and 147+20)					
		and the dike during this Appraisal-Level study. Quantities at stations 169+00 and 180+00 were taken					
		from VB-8313-9 and were not recalculated during this study. The quantities indicated at each station					
		were assumed to be representative of the location (e.g. station 37+00 represents total quantities					
		between stations 0+00 and 56+00).					
		2) Raise includes removal of 10 feet of the existing crest for penetration into existing Zone 1 core					
		(6 inches of gravel surfacing plus Zone 4, Zone 5 (riprap), and Zone 1).					
		3) Costs associated with escalation to NTP, and non-contract costs are not					
		included; mobilization and allowance for procurement strategies costs are included.					
		4) There is a Corrective Action Study (CAS) underway to address risks of dam failure during a major					
		earthquake. This appraisal-level study evaluated increased storage in San Luis Reservoir based solely					
		on static stability conditions using post-earthquake soil strength parameters. These estimates were					
		prepared to provide a general order-of-magnitude-type cost. This study is not meant to be a					
		stand-alone study, rather it should be reviewed during the CAS.					

QUANTITIES		PRICES	
BY Tonya Hart, P.E.	**CHECKED** Tuti Tierney	**BY** Greg Akins	**CHECKED** 1/25/2013
DATE PREPARED 12/21/12	**PEER REVIEW / DATE** Randy Kuzniakowski	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE: B.F. Sisk Dam Modification Appraisal Level Study 20-foot Dam Raise Only, No D/S Berm Middle Estimated Drained Strength Parameters **Geotechnical (86-68313)**	**PROJECT:** Central Valley Project, Madera County, California
	WOID: A176F **ESTIMATE LEVEL:** Appraisal
	REGION: MP **UNIT PRICE LEVEL:** Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Sht 4A

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		The quantities on this sheet apply to the following locations. Sections for these locations were not					
		analyzed in Slope/W for static stability. However, because the embankment is founded directly					
		on bedrock (i.e. potentially liquefiable foundation materials were removed during construction),					
		no downstream berm is needed.					
		Stations 0+00 to 31+00					
		Stations 46+00 to 56+00					
		Stations 114+00 to 139+00					
		Stations 149+00 to 165+00					
		Stations 173+00 to 176+00					
		Stations 183+00 to 185+00					
	1	**Excavation, Common**	**86-68313**	**304,000**	**yd3**	**$4.50**	**$1,368,000.00**
	2	**Zone 1: Selected clay, sand, and gravel**	**86-68313**	**195,000**	**yd3**	**$18.00**	**$3,510,000.00**
		compacted by tamping rollers to 6-inch lifts					
		(Assume Borrow Area 6 is sole borrow					
		source for Zone 1 material and is rippable					
		with dozer and processing is required)					
	3	**Processed sand & gravel**	**86-68313**	**646,000**	**yd3**	**$55.00**	**$35,530,000.00**
		compacted by vibratory smooth drum rollers in 12-inch					
		to 24-inch lifts (for D/S filter zones & U/S riprap					
		bedding and crack stopper zones) (Assume Basalt Hill is					
		sole borrow source for sand & gravel which must be					
		drilled/blasted and processed)					
	4	**Misc. Fill**	**86-68313**	**2,170,000**	**yd3**	**$9.30**	**$20,181,000.00**
		(Assume Borrow Area 6 is sole borrow					
		source material which is rippable					
		with dozer and minimal processing required)					
		SUBTOTAL THIS SHEET					**$60,589,000.00**

QUANTITIES		PRICES	
BY Tonya Hart, P.E.	**CHECKED** Tuti Tierney	**BY** Greg Akins	**CHECKED** 1/25/2013
DATE PREPARED 12/21/12	**PEER REVIEW / DATE** Randy Kuzniakowski	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE: B.F. Sisk Dam Modification Appraisal Level Study 20-foot Dam Raise Middle Estimated Drained Strength Parameters Geotechnical (86-68313)	**PROJECT:** Central Valley Project, Madera County, California **WOID:** A176F **ESTIMATE LEVEL:** Appraisal **REGION:** MP **UNIT PRICE LEVEL:** Oct-12 **FILE:** U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Summary: Stations 37+00 thru 180+00 below					
	5	**Excavation, Common**		507,000	yd3	$4.50	$2,281,500.00
	6	**Filter**		1,414,000	yd3	$55.00	$77,770,000.00
		compacted by vibratory smooth drum rollers in 12-inch					
		to 24-inch lifts (for D/S filter zones & U/S riprap					
		bedding and crack stopper zones) (Assume Basalt Hill is					
		sole borrow source for sand & gravel which must be					
		drilled/blasted and processed)					
	7	**Misc. Fill**		4,475,000	yd3	$9.30	$41,617,500.00
		(Assume Borrow Area 6 is sole borrow source material which					
		is rippable with dozer and minimal processing required)					
Sta	37+00						
		Excavation, Common	86-68313	53,000	yd3		Included above
		Filter	86-68313	210,000	yd3		Included above
		Misc. Fill	86-68313	427,000	yd3		Included above
Sta	65+00						
		Excavation, Common	86-68313	147,000	yd3		Included above
		Filter	86-68313	107,000	yd3		Included above
		Misc. Fill	86-68313	669,000	yd3		Included above
Sta	86+00						
		Excavation, Common	86-68313	131,000	yd3		Included above
		Filter	86-68313	276,000	yd3		Included above
		Misc. Fill	86-68313	1,368,000	yd3		Included above
Sta	107+00						
		Excavation, Common	86-68313	90,000	yd3		Included above
		Filter	86-68313	530,000	yd3		Included above
		Misc. Fill	86-68313	1,085,000	yd3		Included above
Sta	147+20	Excavation, Common	86-68313	35,000	yd3		Included above
		Filter	86-68313	239,000	yd3		Included above
		Misc. Fill	86-68313	561,000	yd3		Included above
		SUBTOTAL THIS SHEET					$121,669,000.00

QUANTITIES		PRICES	
BY Tonya Hart, P.E.	**CHECKED** Tuti Tierney	**BY** Greg Akins	**CHECKED** 3/20/13
DATE PREPARED 12/21/12	**PEER REVIEW / DATE** Randy Kuzniakowski	**DATE PREPARED** 1/25/2013 - revised 3/20/13	**PEER REVIEW / DATE** 3/22/13

FEATURE: B.F. Sisk Dam Modification Appraisal Level Study 20-foot Dam Raise "Best" Drained Strength Parameters **Geotechnical (86-68313)**	**PROJECT:** Central Valley Project, Madera County, California
	WOID: A176F **ESTIMATE LEVEL:** Appraisal
	REGION: MP **UNIT PRICE LEVEL:** Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Sht 4A

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
Sta	169+00						
		Excavation, Common	86-68313	14,000	yd3		Included above
		Filter	86-68313	20,000	yd3		Included above
		Misc. Fill	86-68313	230,000	yd3		Included above
Sta	180+00						Included above
		Excavation, Common	86-68313	37,000	yd3		Included above
		Filter	86-68313	32,000	yd3		Included above
		Misc. Fill	86-68313	135,000	yd3		
		Dike					
	8	**Excavation, Common**	**86-68313**	**5,000**	**yd3**	**$4.50**	**$22,500.00**
	9	**Filter**	**86-68313**	**8,000**	**yd3**	**$55.00**	**$440,000.00**
		compacted by vibratory smooth drum rollers in 12-inch					
		to 24-inch lifts (for D/S filter zones & U/S riprap					
		bedding and crack stopper zones) (Assume Basalt Hill is					
		sole borrow source for sand & gravel which must be					
		drilled/blasted and processed)					
	10	**Misc. Fill**	**86-68313**	**15,000**	**yd3**	**$9.30**	**$139,500.00**
		(Assume Borrow Area 6 is sole borrow source material which					
		is rippable with dozer and minimal processing required)					
		SUBTOTAL THIS SHEET					**$602,000.00**

QUANTITIES		PRICES	
BY Tonya Hart, P.E.	**CHECKED** Tuti Tierney	**BY** Greg Akins	**CHECKED** 1/28/2013
DATE PREPARED 12/21/12	**PEER REVIEW / DATE** Randy Kuzniakowski	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE:	PROJECT:
B.F. Sisk Dam Static Dam Raise Cost Estimate Outlet Works Intake Towers Middle Estimated Drained Strength Parameters	Central Valley Project, Madera County, California
	WOID: AF743 — ESTIMATE LEVEL: Appraisal
	REGION: MP — UNIT PRICE LEVEL: Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		GENERAL SITEWORK					
		Assume the reservoir is low enough for					
		work to commence, and all equipment is					
		removed from the top of the intake towers					
		MOBILIZATION	86-68130	1	LS	Included on summary sheet	
		Assume a barge is mobilized for the work					
		INTAKE TOWERS					
	11	**Full depth saw cut**	**86-68130**	**520**	**LF**	**$240.00**	**$124,800.00**
		depth of cut varies from 2' to 3'					
	12	**Remove and dispose of top of intake towers**	**86-68130**	**1,200**	**yd3**	**$540.00**	**$648,000.00**
		quantity includes removal of the top 14 - 16					
		feet of 4 intake towers as well as gantry					
		crane slabs between towers					
	13	**Furnish, form, and place reinforced concrete**	**86-68130**	**1,700**	**yd3**	**$1,500.00**	**$2,550,000.00**
		4,500psi @ 28 days					
	14	**Cementitious Materials**	**86-68130**	**510**	**tons**	**$200.00**	**$102,000.00**
		assumed to be 600lbs/yd3					
	15	**Furnish and place concrete reinforcement**	**86-68130**	**255,000**	**lbs**	**$1.50**	**$382,500.00**
		assumes 150lbs/yd3					
	16	**Drill and grout anchor bars**	**86-68130**	**2,100**	**ea**	**$130.00**	**$273,000.00**
		assume #9 bars and 2" dia holes					
		5425 ft of linear drilling (31" per hole)					
		bars included in concrete reinforcement					
		line item					
		SUBTOTAL THIS SHEET					**$4,080,300.00**

QUANTITIES		PRICES	
BY Michael Shepherd	CHECKED Jason Schneider, P.E.	BY Greg Akins	CHECKED 01/28/2013
DATE PREPARED 11/15/12	PEER REVIEW / DATE Jason Schneider, P.E.	DATE PREPARED 01/25/13	PEER REVIEW / DATE 1/28/13

FEATURE:	PROJECT:
B.F. Sisk Dam Static Raise Cost Estimate Morning Glory Spillway Middle Estimated Drained Strength Parameters	Central Valley Project, Madera County, California
	WOID: AF743 — ESTIMATE LEVEL: Appraisal
	REGION: MP — UNIT PRICE LEVEL: Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		GENERAL SITEWORK					
		Assume the reservoir is low enough for					
		work to commence					
		MOBILIZATION	86-68130	1	LS	Included on summary sheet	
		Assume the excavation and demolition					
		equipment is on site (from the intake tower					
		work)					
		SPILLWAY					
	17	**Full depth saw cut**	86-68130	48	LF	$200.00	$9,600.00
		depth of cut 2'-6"					
	18	**Excavation of upstream embankment**	86-68130	1,950	yd3	$27.00	$52,650.00
		Includes compacted embankment, rip rap					
		bedding, and rip rap					
	19	**Remove and dispose of top of Spillway**	86-68130	180	yd3	$600.00	$108,000.00
		quantity includes removal of the top 22ft					
	20	**Furnish, form, and place reinforced concrete**	86-68130	220	yd3	$1,400.00	$308,000.00
		4500psi @ 28 days					
	21	**Furnish and place concrete reinforcement**	86-68130	33,000	lbs	$1.50	$49,500.00
		assume 150lbs/yd3					
	22	**Cementitious Materials**	86-68130	66	tons	$200.00	$13,200.00
		600 lbs/yd3					
	23	**Drill and grout anchor bars**	86-68130	80	ea	$130.00	$10,400.00
		assume # 11 bars and 2.5" dia holes 255					
		feet of linear drilling (38" per hole) bars					
		included in concrete reinforcement line item					
		SUBTOTAL THIS SHEET					$551,350.00

QUANTITIES		PRICES	
BY Michael Shepherd	**CHECKED** Jason Schneider, P.E.	**BY** Greg Akins	**CHECKED** 1/28/2013
DATE PREPARED 11/15/12	**PEER REVIEW / DATE** Jason Schneider, P.E.	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE:
B.F. Sisk Dam
Static Raise Cost Estimate
Morning Glory Spillway
Middle Estimated Drained Strength Parameters

PROJECT:
Central Valley Project, Madera County, California

WOID:	AF743	**ESTIMATE LEVEL:**	Appraisal
REGION:	MP	**UNIT PRICE LEVEL:**	Oct-12
FILE:	U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16		

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		SPILLWAY					
	24	**Place compacted embankment**	86-68130	1,950	yd3	$20.00	$39,000.00
		Includes compacted embankment, rip rap					
		bedding, and rip rap					
		SUBTOTAL THIS SHEET					$39,000.00

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Michael Shepherd	Jason Schneider, P.E.	Greg Akins	01/28/2013
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
11/15/12	Jason Schneider, P.E.	01/25/13	1/28/13

FEATURE: BF Sisk (formerly San Luis) Dam Appraisal Level Study 20 - foot dam raise Intake Tower Access Bridge Middle Estimated Drained Strength Parameters	**PROJECT:** Central Valley Project, Madera County, California **WOID:** A176F **ESTIMATE LEVEL:** Appraisal **REGION:** MP **UNIT PRICE LEVEL:** Oct-12 **FILE:** U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16

PLANT ACCOU	PAY ITEM	DESC	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	25	**Removal & Disposal of Existing Bridge**	86-68140	1	ls	$1,150,000.00	$1,150,000.00
		The existing dam will be raised 20 feet. Since it would be very difficult to raise & reuse the existing bridge superstructure (six spans), it will be removed & replaced with a new bridge. The existing bridge superstructure consists of two steel plate girders (considered fracture critical) supporting a reinforced concrete deck Reservoir will not be dewatered, so demolition must consider barg access & handling / dispostal of structural steel coated with lead paint. To estimate the amount of materials to be removed, the existing bridge superstructure quantities are estimated to be:					
		Reinforced concrete = 400 cy					
		Structural steel = 640,000 lbs					
	26	**Concrete (4,500 psi @ 28 days)**	86-68140	1,030	yd^3	$1,400.00	$1,442,000.00
		Concrete volume is based on 3 quantities:					
		1. Pier caps extended vertically 12 ft.=170 cy					
		2. Superstructure deck = 700 cy					
		3. Abutment @ dam = 150 cy					
	27	**Cementatious Material (6 sacks/cy)**	86-68140	290	tons	$200.00	$58,000.00
	28	**Reinforcing Steel**	86-68140	260,000	lbs	$1.50	$390,000.00
		Specified minimum yield strength = 60 ksi					
	29	**Structural Steel (bridge superstructure)**	86-68140	2,500,000	lbs	$3.00	$7,500,000.00
		Structural steel girders conforming to ASTM A709 Grade 50W (Fy 50 ksi, weathering). See attached drawing for bridge cross sectior					
	30	**Bridge Guardrail (California ST-10)**	86-68140	2,370	lf	$220.00	$521,400.00
		See attached Caltrans Standard Plans B11-68, B11-69 & B11-70 f rail details					
	31	**Backfill behind/around abutment**	86-68140	170.0	yd^3	$20.00	$3,400.00
	32	**Compacted backfill behind/around abutment**	86-68140	170.0	yd3	$20.00	$3,400.00
		SUBTOTAL THIS SHEET					$11,068,200.00

ANTITIES 3400

BY Jesus G. Romero, PE	**CHECKED** Joseph M. Gemperline, PE	**BY** Greg Akins	**CHECKED** 01/28/2013
DATE PREPARED 12/07/12	**PEER REVIEW / DATE** Roman M. Koltuniuk, PE	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE:
BF Sisk (formerly San Luis) Dam
Appraisal Level Study
20 - foot dam raise
Intake Tower Access Bridge
Middle Estimated Drained Strength Parameters

PROJECT:
Central Valley Project, Madera County, California

WOID:	A176F	**ESTIMATE LEVEL:**	Appraisal
REGION:	MP	**UNIT PRICE LEVEL:**	Oct-12

FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16

PLANT ACCOU	PAY ITEM	DESC	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	33	**Epoxy grouted anchors into existing caps**	86-68140	400	ea	$50.00	$20,000.00
		1in diameter Hilti Adhesive anchor: HIT_HY 150 MAX-SD+HAS. Grouted anchors are spaced at 1'-0" (16 x 5 grid), 80 per pier cap.					
	34	**Bearing Pads**	86-68140	18	ea	$1,500.00	$27,000.00
		Preformed fabric bearing pads at piers. Size of pads are estimate to be 5" thick x 2'-0" wide by 1'-9" long. Total number of pads = 18					
	35	**Bridge Joint Seals at Expansion Joints**	86-68140	60	lf	$200.00	$12,000.00
		Elastomeric expansion device equalt to General Tire Co. Transflex Model 1300 or to Watson Bowman & Associates Waboflex-SR Model SR 13 for full width of bridge.		20	lf		
		2 ½" by 2 ¾" Preformed Compression Joint Seals at tower & at abutment.		40	lf		
		SUBTOTAL THIS SHEET					$59,000.00

QUANTITIES

BY	CHECKED
Jesus G. Romero, PE	Joseph M. Gemperline, PE
DATE PREPARED	**PEER REVIEW / DATE**
12/07/12	Roman M. Koltuniuk, PE

PRICES

BY	CHECKED
Greg Akins	01/28/2013
DATE PREPARED	**PEER REVIEW / DATE**
01/25/13	1/28/13

FEATURE: B. F. Sisk Dam Modification Roller Gate re-location and Stem Extension Middle Estimated Drained Strength Parameters	**PROJECT:** Central Valley Project, Madera County, California
	WOID: — **ESTIMATE LEVEL:** Appraisal
	REGION: MP **UNIT PRICE LEVEL:** Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	36	**Site Survey (Pre-Rehab)**	86-68420	1	LS	$12,000.00	$12,000.00
		(assess general conditions and take					
		measurements as needed)					
		NOTE: The following quantities are for work on					
		one roller gate, hoist, & associated equipment					
		Total work is for four gates.					
	37	**Shut down and lock out unit associated with**	86-68420	1	LS	$5,000.00	$5,000.00
		gate to be removed					
	38	**Remove hydraulic piping to hoist**	86-68420	1	EA	$9,500.00	$9,500.00
		Crew: 1 supervisor, 1 mechanic					
		Shut valves to hoist					
		Drain oil from piping (15 gallons, 1 Crew HR)					
		Disconnect piping and plug ends (1 Crew HR)					
		Remove piping to hoist 150# (3 Crew HR)					
	39	**Remove Hydraulic Power Unit (8 Crew HR)**	86-68420	1	EA	$14,500.00	$14,500.00
		Disconnect electrical					
		Remove and store indorrs					
		Raise Roller Gate					
		Crew: 1 supervisor, 2 mechanics, 1 laborer					
	40	**Raise/lock gateby Gov't force (1 Crew HR)**	86-68420	1	LS	$3,500.00	$3,500.00
		Assume contractor assists gov't forces					
	41	**Remove hoist (18 Crew HR)**	86-68420	1	LS	$21,000.00	$21,000.00
	42	**Remove intermediate stems (12 Crew HR)**	86-68420	1	LS	$26,000.00	$26,000.00
	43	**Remove gate (10 Crew HR)**	86-68420	1	LS	$31,000.00	$31,000.00
		SUBTOTAL THIS SHEET	1				$122,500.00

QUANTITIES		PRICES	
BY D.L. Read	**CHECKED** D.M. Drake	**BY** Greg Akins	**CHECKED** 1/29/2013
DATE PREPARED 12/10//2012	**PEER REVIEW / DATE** DM Drake	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:	PROJECT:
B. F. Sisk Dam Modification Roller Gate re-location and Stem Extension Middle Estimated Drained Strength Parameters	Central Valley Project, Madera County, California
	WOID: / ESTIMATE LEVEL: Appraisal
	REGION: MP / UNIT PRICE LEVEL: Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Install Embedded metalwork					
	44	**Furnish and install embedded gate guides**	86-68420	1,875	LB	$13.00	$24,375.00
		Install Roller Gate					
		Crew: 1 supervisor, 2 mechanics, 1 laborer					
	45	**Install gate (10 Crew HR)**	86-68420	1	LS	$36,000.00	$36,000.00
	46	**Install intermediate stems (12 Crew HR)**	86-68420	1	LS	$30,000.00	$30,000.00
	47	**Furnish and install one new intermediate stem**	86-68420	1	LS	$140,000.00	$140,000.00
		(steel - 1,475 # each, 12 Crew HR)					
	48	**Install hoist (18 Crew HR)**	86-68420	1	LS	$50,000.00	$50,000.00
	49	**Install hoist (18 Crew HR)**	86-68420	1	LS	$42,000.00	$42,000.00
		SUBTOTAL THIS SHEET	2				$322,375.00

QUANTITIES		PRICES	
BY D.L. Read	CHECKED D.M. Drake	BY Greg Akins	CHECKED 01/28/2013
DATE PREPARED 12/10//2012	PEER REVIEW / DATE D. M. Drake	DATE PREPARED 01/25/13	PEER REVIEW / DATE 1/28/13

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
B. F. Sisk Dam Modification
Roller Gate re-location and Stem Extension
Middle Estimated Drained Strength Parameters

PROJECT:
Central Va Central Valley, California
California

WOID: | **ESTIMATE LEVEL:** Appraisal

REGION: MP | **UNIT PRICE LEVEL:** Oct-12

FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Install Hydraulic Controls					
		Crew: 1 supervisor, 1 mechanic, 1 laborer					
	50	**Install Hydraulic Power Unit (6 Crew HR)**	86-68420	1	LS	$23,000.00	$23,000.00
	51	**Connect piping (16 Crew HR)**	86-68420	1	LS	$21,000.00	$21,000.00
	52	**Electrically connect HPU, power, & control board**	86-68420	1	LS	$18,000.00	$18,000.00
		1 electician (10 HR)					
	53	**Fill and vent system (6 Crew HR)**	86-68420	1	LS	$15,000.00	$15,000.00
	54	**Test system:**		1	LS	$19,000.00	$19,000.00
	55	**Pressure test (6 Crew HR)**	86-68420	1	LS	$12,000.00	$12,000.00
	56	**Leak test Cylinder (6 Crew HR)**	86-68420	1	LS	$12,000.00	$12,000.00
	57	**Operational test (6 Crew HR)**	86-68420	1	LS	$12,000.00	$12,000.00
		SUBTOTAL THIS SHEET	3				$132,000.00

QUANTITIES		PRICES	
BY D.L. Read	**CHECKED** D.M. Drake	**BY** Greg Akins	**CHECKED** 1/28/2013
DATE PREPARED 12/10//2012	**PEER REVIEW / DATE** D.M. Drake	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE: B.F. Sisk Raise Appraisal Study Intake Tower Modifications Mechanical Equipment Group 86-68410 Most Probable Estimate Middle Estimated Drained Strength Parameters	**PROJECT:** Central Valley Project, Madera County, California **WOID:** A176F **ESTIMATE LEVEL:** Appraisal **REGION:** MP **UNIT PRICE LEVEL:** Oct-12 **FILE:** U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		GANTRY CRANE:					
	58	**Remove and dispose exist crane rails**	86-68410	19,200	lbs.	$0.75	$14,400.00
		All parts are structural steel					
		- 85# ASCE rails, 600 feet, 16,040 lbs.					
		- 585 Rail clips, 293 lbs.					
		- 290 Bearing plates, 1,600 lbs.					
		- 320 - ¾" Dia. x 12" machine bolts, 640 lbs.					
		- 300 - ¾" Dia. x 10" welded studs, 600 lbs.					
	59	**Furnish and install new crane rails**	86-68410	19,200	lbs.	$9.00	$172,800.00
		Structural steel, coated					
		- 85# ASCE rails, 600 feet, 16,040 lbs.					
		- 585 Rail clips, 293 lbs.					
		- 290 Bearing plates, 1,600 lbs.					
		- 320 - ¾" Dia. x 12" machine bolts, 640 lbs.					
		- 300 - ¾" Dia. x 10" welded studs, 600 lbs.					
	60	**Rerope the hoist and provide a new drums to**	86-68410	1	LS	$120,000.00	$120,000.00
		accommodate the additional 10"-0" of height					
		- 1-inch Dia. 6x37 IWRC, galvanized, extra		1,300	ft.		
		improved plow steel (XIP)					
		- Two new drums, cast steel, coated,		3,090	lbs.		
		9'-4" long, 24" dia., 1,545 lbs. ea.					
		Assume:					
		- Rope is 4 part					
		SUBTOTAL THIS SHEET					$307,200.00

QUANTITIES		PRICES	
BY R. Stephen	**CHECKED** A. Ritt	**BY** Greg Akins	**CHECKED** 01/28/2013
DATE PREPARED 12/17/12	**PEER REVIEW / DATE** D. Hulse	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** SHEET _14 _ OF _16 _

FEATURE: B.F. Sisk Raise Appraisal Study Intake Tower Modifications Mechanical Equipment Group 86-68410 Most Probable Estimate Middle Estimated Drained Strength Parameters	**PROJECT:** Central Valley Project, Madera County, California
	WOID: A176F **ESTIMATE LEVEL:** Appraisal
	REGION: MP **UNIT PRICE LEVEL:** Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		GANTRY CRANE:					
	61	**Remove, store and reinstall gantry crane**	**86-68410**	**1**	**L.S.**	**$250,000.00**	**$250,000.00**
		after modifications to the intake towers are					
		completed					
		- Gantry crane will have to be disassembled					
		due to width of access bridge					
		- Crane dead weight is 176,000 lbs.					
		- Crane is approx. 40'-0" tall, 40'-0" wide,					
		and 38'-0" long.					
		Assume:					
		- Crane is stored onsite					
		- Crane is fully functional					
		- No modernization is required					
		- Removal and reinstallazation will require					
		the use of a mobile crane, ~20T					
		SUBTOTAL THIS SHEET					**$250,000.00**

QUANTITIES		PRICES	
BY R. Stephen	**CHECKED** A. Ritt	**BY** Greg Akins	**CHECKED** 01/28/2013
DATE PREPARED 12/17/12	**PEER REVIEW / DATE** D. Hulse	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE:	PROJECT:
B.F. Sisk Raise Appraisal Study Intake Tower Modifications Mechanical Equipment Group 86-68410 Most Probable Estimate Middle Estimated Drained Strength Parameters	Central Valley Project, Madera County, California WOID: A176F — ESTIMATE LEVEL: Appraisal REGION: MP — UNIT PRICE LEVEL: Oct-12 FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		BULKHEAD GATE:					
	62	**Remove and reinstall bulkhead gates,**	86-68410	1	L.S.	$500,000.00	$500,000.00
		lifting frame and storage arms.					
		- (2) Top bulkhead gates, 75,000 lbs. ea.,					
		approx. 24'-6" wide x 15'-0" tall					
		- (2) Bottom bulkhead gates, 73,000 lbs. ea.,					
		approx. 24'-6" wide x 14'-6" tall					
		- Bulkhead gates are stored in the top of the					
		guides of the intake towers.					
		- Lifting frame, 12,000 lbs., 26'-0" x 16'-6"					
		- (8) Storage arms, 1,200 lbs. ea., fastened					
		to concrete deck by anchor bolts, on top					
		of a grout pad.					
	63	**Remove and dispose existing bulkhead guides**	86-68410	20,000	lbs.	$0.75	$15,000.00
		- Embedded in concrete					
		- Eight at 2,500 lbs. ea., 10'-0" long					
	64	**Furnish and install new bulkhead guides**	86-68410	40,000	lbs.	$9.00	$360,000.00
		- Structural steel, coated, embedded					
		- Eight at 5,000 lbs. ea., 20'-0" long					
		SUBTOTAL THIS SHEET					$875,000.00

QUANTITIES		PRICES	
BY R. Stephen	CHECKED A. Ritt	BY Greg Akins	CHECKED 1/28/2013
DATE PREPARED 111/29/2012	PEER REVIEW / DATE D. Hulse	DATE PREPARED 01/25/13	PEER REVIEW / DATE 1/28/13

FEATURE:	PROJECT:			
B.F. Sisk Dam Modification Appraisal Level Study 20-foot Dam Raise Middle Estimated Drained Strength Parameters Option A	Central Valley Project, Madera County, California			
	WOID: A176F	ESTIMATE LEVEL:	Appraisal	
	REGION: MP	UNIT PRICE LEVEL:	Oct-12	
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[001 Summary BF Sisk - Drained.xlsx]Summary 16			

PLANT ACCOUNT	PAY ITEM	DESCRIPTION					AMOUNT
		Subtotal Sheet 2 of 16					**$60,589,000.00**
		Subtotal Sheet 3 of 16					**$121,669,000.00**
		Subtotal Sheet 4 of 16					**$602,000.00**
		Subtotal Sheet 5 of 16					**$4,080,300.00**
		Subtotal Sheet 6 of 16					**$551,350.00**
		Subtotal Sheet 7 of 16					**$39,000.00**
		Subtotal Sheet 8 of 16					**$11,068,200.00**
		Subtotal Sheet 9 of 16					**$59,000.00**
		Subtotal Sheet 10 of 16					**$122,500.00**
		Subtotal Sheet 11 of 16					**$322,375.00**
		Subtotal Sheet 12 of 16					**$132,000.00**
		Subtotal Sheet 13 of 16					**$307,200.00**
		Subtotal Sheet 14 of 16					**$250,000.00**
		Subtotal Sheet 15 of 16					**$875,000.00**
		Subtotal					**$200,666,925.00**
		Mobilization	5%	+/-			$10,000,000.00
		Subtotal with Mobilization					**$210,666,925.00**
		Contract Cost Allowances (Sum of):	18%	+/-			$39,333,075.00
		Design Contingencies,15% (+/-)					
		APS, 3% (+/-). Type of procurement:Request for Proposal					
		CONTRACT COST					**$250,000,000.00**
		Construction Contingencies	25%	+/-			$60,000,000.00
		FIELD COST (Unit Price Level Oct 2012)					**$310,000,000.00**
		Non-Contract Costs		**To be determined by the appropriate responsible offic**			
		Escalation to Notice to Proceed (NTP)		**To be determined by the appropriate responsible offic**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible offic**			
		Ref.: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03.					

QUANTITIES		PRICES	
BY See Estimate Sheets	**CHECKED** See Estimate Sheets	**BY** Greg Akins	**CHECKED** 3/20/13
DATE PREPARED	**PEER REVIEW / DATE** See Estimate Sheets	**DATE PREPARED** 1/25/2013 - revised 3/20/13	**PEER REVIEW / DATE** 3/22/13

Exhibit B

Cost Estimate Worksheets – Option B

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FEATURE: B.F. Sisk Dam Modification Appraisal Level Study 20-foot Dam Raise Middle Estimated Undrained Strength Parameters Option B Geotechnical (86-68313)	**PROJECT:** Central Valley Project, Madera County, California
	WOID: A176F **ESTIMATE LEVEL:** Appraisal
	REGION: MP **UNIT PRICE LEVEL:** Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Sht 1

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		The cost estimate sheets from B.F. Sisk Dam Appraisal-Level Construction Considerations					
		(TM VB-8313-9; May 2010) were used to establish quantities for preparing this cost estimate. The borrow					
		areas, construction methods, and environmental considerations presented in TM VB-8313-9 are					
		assumed to be the same for this Appraisal-Level study. Additionally, information presented in					
		B.F. Sisk Dam Appraisal-Level Study of Static Stability for Increased Storage report (TM VB-86-68313-22;					
		December 2012) should be reviewed.					
		NOTES:					
		1) Quantities were calculated at specific sections (e.g. stations 37+00, 65+00, 86+00, 107+00 and 147+20)					
		and the dike during this Appraisal-Level study. Quantities at stations 169+00 and 180+00 were taken					
		from VB-8313-9 and were not recalculated during this study. The quantities indicated at each station					
		were assumed to be representative of the location (e.g. station 37+00 represents total quantities					
		between stations 0+00 and 56+00).					
		2) Raise includes removal of 10 feet of the existing crest for penetration into existing Zone 1 core					
		(6 inches of gravel surfacing plus Zone 4, Zone 5 (riprap), and Zone 1).					
		3) Costs associated with escalation to NTP, and non-contract costs are not					
		included; mobilization and allowance for procurement strategies costs are included.					
		4) There is a Corrective Action Study (CAS) underway to address risks of dam failure during a major					
		earthquake. This appraisal-level study evaluated increased storage in San Luis Reservoir based solely					
		on static stability conditions using post-earthquake soil strength parameters. These estimates were					
		prepared to provide a general order-of-magnitude-type cost. This study is not meant to be a					
		stand-alone study, rather it should be reviewed during the CAS.					

QUANTITIES		PRICES	
BY Tonya Hart, P.E.	**CHECKED** Tuti Tierney	**BY** Greg Akins	**CHECKED** 1/28/2013
DATE PREPARED 12/21/12	**PEER REVIEW / DATE** Randy Kuzniakowski	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE: B.F. Sisk Dam Modification Appraisal Level Study 20-foot Dam Raise Only, No D/S Berm Middle Estimated Undrained Strength Parameters Geotechnical (86-68313)	**PROJECT:** Central Valley Project, Madera County, California
	WOID: A176F **ESTIMATE LEVEL:** Appraisal
	REGION: MP **UNIT PRICE LEVEL:** Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		The quantities on this sheet apply to the following locations. Sections for these locations were not					
		analyzed in Slope/W for static stability. However, because the embankment is founded directly					
		on bedrock (i.e. potentially liquefiable foundation materials were removed during construction),					
		no downstream berm is needed.					
		Stations 0+00 to 31+00					
		Stations 46+00 to 56+00					
		Stations 114+00 to 139+00					
		Stations 149+00 to 165+00					
		Stations 173+00 to 176+00					
		Stations 183+00 to 185+00					
	1	**Excavation, Common**	**86-68313**	**304,000**	**yd3**	**$4.50**	**$1,368,000.00**
	2	**Zone 1: Selected clay, sand, and gravel**	**86-68313**	**195,000**	**yd3**	**$18.00**	**$3,510,000.00**
		compacted by tamping rollers to 6-inch lifts					
		(Assume Borrow Area 6 is sole borrow					
		source for Zone 1 material which is rippable					
		with dozer and processing is required)					
	3	**Processed sand & gravel compacted by**	**86-68313**	**646,000**	**yd3**	**$55.00**	**$35,530,000.00**
		vibratory smooth drum rollers in 12-inch to					
		24-inch lifts (for D/S filter zones & U/S riprap					
		bedding and crack stopper zones)					
		(Assume Basalt Hill is sole borrow					
		source for sand & gravel which must be drilled/					
		blasted and processed)					
	4	**Misc. Fill**	**86-68313**	**2,170,000**	**yd3**	**$9.30**	**$20,181,000.00**
		(Assume Borrow Area 6 is sole borrow					
		source for Zone 1 material which is rippable					
		with dozer and minimal processing is required)					
		SUBTOTAL THIS SHEET					**$60,589,000.00**

QUANTITIES		PRICES	
BY Tonya Hart, P.E.	**CHECKED** Tuti Tierney	**BY** Greg Akins	**CHECKED** 1/28/2013
DATE PREPARED 12/21/12	**PEER REVIEW / DATE** Randy Kuzniakowski	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE:
B.F. Sisk Dam Modification
Appraisal Level Study
20-foot Dam Raise
"Best" Undrained Strength Parameters
Geotechnical (86-68313)

PROJECT:
Central Valley Project, Madera County, California

WOID:	**A176F**	**ESTIMATE LEVEL:**	**Appraisal**
REGION:	**MP**	**UNIT PRICE LEVEL:**	**Oct-12**

FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Sht 3B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Summary Station 37+00 to 180+00					
	5	**Excavation, Common**		**1,177,000**	**yd3**	**$4.50**	**$5,296,500.00**
	6	**Filter**		**1,763,000**	**yd3**	**$55.00**	**$96,965,000.00**
		compacted by vibratory smooth drum rollers in 12-inch					
		to 24-inch lifts (for D/S filter zones & U/S riprap					
		bedding and crack stopper zones) (Assume Basalt Hill is					
		sole borrow source for sand & gravel which must be					
		drilled/blasted and processed)					
	7	**Misc. Fill**		**5,688,000**	**yd3**	**$9.30**	**$52,898,400.00**
		(Assume Borrow Area 6 is sole borrow source material which					
		is rippable with dozer and minimal processing is required)					
Sta	37+00						
	10	Excavation, Common	86-68313	260,000	yd3		Included above
	20	Filter	86-68313	274,000	yd3		Included above
	30	Misc. Fill	86-68313	738,000	yd3		Included above
Sta	65+00						
	10	Excavation, Common	86-68313	466,000	yd3		Included above
	20	Filter	86-68313	312,000	yd3		Included above
	30	Misc. Fill	86-68313	1,196,000	yd3		Included above
Sta	86+00						
	10	Excavation, Common	86-68313	131,000	yd3		Included above
	20	Filter	86-68313	276,000	yd3		Included above
	30	Misc. Fill	86-68313	1,368,000	yd3		Included above
Sta	107+00						
	10	Excavation, Common	86-68313	90,000	yd3		Included above
	20	Filter	86-68313	530,000	yd3		Included above
	30	Misc. Fill	86-68313	1,085,000	yd3		Included above
Sta	147+20						
	10	Excavation, Common	86-68313	179,000	yd3		Included above
	20	Filter	86-68313	319,000	yd3		Included above
	30	Misc. Fill	**86-68313**	936,000	yd3		**Included above**
		SUBTOTAL THIS SHEET					**$155,159,900.00**

QUANTITIES		**PRICES**	
BY Tonya Hart, P.E.	**CHECKED** Tuti Tierney	**BY** Greg Akins	**CHECKED** 3/20/13
DATE PREPARED 12/21/12	**PEER REVIEW / DATE** Randy Kuzniakowski	**DATE PREPARED** 1/25/2013 - revised 3/20/13	**PEER REVIEW / DATE** 3/22/13

FEATURE: B.F. Sisk Dam Modification Appraisal Level Study 20-foot Dam Raise "Best" Undrained Strength Parameters Geotechnical (86-68313)	**PROJECT:** Central Valley Project, Madera County, California
	WOID: A176F **ESTIMATE LEVEL:** Appraisal
	REGION: MP **UNIT PRICE LEVEL:** Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
Sta	169+00						
	10	Excavation, Common	86-68313	14,000	yd3		Included above
	20	Filter	86-68313	20,000	yd3		Included above
	30	Misc. Fill	86-68313	230,000	yd3		Included above
Sta	180+00						
	10	Excavation, Common	86-68313	37,000	yd3		Included above
	20	Filter	86-68313	32,000	yd3		Included above
	30	Misc. Fill	86-68313	135,000	yd3		Included above
		Dike					
	8	**Excavation, Common**	**86-68313**	**5,000**	**yd3**	**$4.50**	**$22,500.00**
	9	**Filter**	**86-68313**	**8,000**	**yd3**	**$55.00**	**$440,000.00**
		compacted by vibratory smooth drum rollers in 12-inch					
		to 24-inch lifts (for D/S filter zones & U/S riprap					
		bedding and crack stopper zones) (Assume Basalt Hill is					
		sole borrow source for sand & gravel which must be					
		drilled/blasted and processed)					
	10	**Misc. Fill**	**86-68313**	**15,000**	**yd3**	**$9.30**	**$139,500.00**
		(Assume Borrow Area 6 is sole borrow source material which					
		is rippable with dozer and minimal processing is required)					
		SUBTOTAL THIS SHEET					**$602,000.00**

QUANTITIES		PRICES	
BY Tonya Hart, P.E.	**CHECKED** Tuti Tierney	**BY** Greg Akins	**CHECKED** 01/28/2013
DATE PREPARED 12/21/12	**PEER REVIEW / DATE** Randy Kuzniakowski	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE:
B.F. Sisk Dam
Static Dam Raise Cost Estimate
Outlet Works
Intake Towers
Middle Estimated Undrained Strength Parameters

PROJECT:
Central Valley Project, Madera County, California

WOID: AF743 **ESTIMATE LEVEL:** Appraisal
REGION: MP **UNIT PRICE LEVEL:** Oct-12
FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		GENERAL SITEWORK					
		Assume the reservoir is low enough for					
		work to commence, and all equipment is					
		removed from the top of the intake towers					
		MOBILIZATION	86-68130	1	LS	Included on summary sheet	
		Assume a barge is mobilized for the work					
		INTAKE TOWERS					
	11	**Full depth saw cut**	**86-68130**	**520**	**LF**	**$240.00**	**$124,800.00**
		depth of cut varies from 2' to 3'					
	12	**Remove and dispose of top of intake towers**	**86-68130**	**1,200**	**yd3**	**$540.00**	**$648,000.00**
		quantity includes removal of the top 14 - 16					
		feet of 4 intake towers as well as gantry					
		crane slabs between towers					
	13	**Furnish, form, and place reinforced concrete**	**86-68130**	**1,700**	**yd3**	**$1,500.00**	**$2,550,000.00**
		4,500psi @ 28 days					
	14	**Cementitious Materials**	**86-68130**	**510**	**tons**	**$200.00**	**$102,000.00**
		assumed to be 600lbs/yd3					
	15	**Furnish and place concrete reinforcement**	**86-68130**	**255,000**	**lbs**	**$1.50**	**$382,500.00**
		assumes 150lbs/yd3					
	16	**Drill and grout anchor bars**	**86-68130**	**2,100**	**ea**	**$130.00**	**$273,000.00**
		assume #9 bars and 2" dia holes					
		5425 ft of linear drilling (31" per hole)					
		bars included in concrete reinforcement					
		line item					
		SUBTOTAL THIS SHEET					**$4,080,300.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Michael Shepherd	Jason Schneider, P.E.	Greg Akins	01/28/2013
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
11/15/12	Jason Schneider, P.E.	01/25/13	1/28/13

FEATURE:	PROJECT:	
B.F. Sisk Dam Static Raise Cost Estimate Morning Glory Spillway Middle Estimated Undrained Strength Parameters	Central Valley Project, Madera County, California	
	WOID: AF743	ESTIMATE LEVEL: Appraisal
	REGION: MP	UNIT PRICE LEVEL: Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16	

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		GENERAL SITEWORK					
		Assume the reservoir is low enough for					
		work to commence					
		MOBILIZATION	86-68130	1	LS	Included on summary sheet	
		Assume the excavation and demolition					
		equipment is on site (from the intake tower					
		work)					
		SPILLWAY					
	17	**Full depth saw cut**	86-68130	48	LF	$200.00	$9,600.00
		depth of cut 2'-6"					
	18	**Excavation of upstream embankment**	86-68130	1,950	yd3	$27.00	$52,650.00
		Includes compacted embankment, rip rap					
		bedding, and rip rap					
	19	**Remove and dispose of top of Spillway**	86-68130	180	yd3	$600.00	$108,000.00
		quantity includes removal of the top 22ft					
	20	**Furnish, form, and place reinforced concrete**	86-68130	220	yd3	$1,400.00	$308,000.00
		4500psi @ 28 days					
	21	**Furnish and place concrete reinforcement**	86-68130	33,000	lbs	$1.50	$49,500.00
		assume 150lbs/yd3					
	22	**Cementitious Materials**	86-68130	66	tons	$200.00	$13,200.00
		600 lbs/yd3					
	23	**Drill and grout anchor bars**	86-68130	80	ea	$130.00	$10,400.00
		assume # 11 bars and 2.5" dia holes 255					
		feet of linear drilling (38" per hole) bars					
		included in concrete reinforcement line item					
		SUBTOTAL THIS SHEET					$551,350.00

QUANTITIES		PRICES	
BY Michael Shepherd	CHECKED Jason Schneider, P.E.	BY Greg Akins	CHECKED 01/28/2013
DATE PREPARED 11/15/12	PEER REVIEW / DATE Jason Schneider, P.E.	DATE PREPARED 01/25/13	PEER REVIEW / DATE 1/28/13

FEATURE:
B.F. Sisk Dam
Static Raise Cost Estimate
Morning Glory Spillway
Middle Estimated Undrained Strength Parameters

PROJECT:
Central Valley Project, Madera County, California

WOID:	**AF743**	**ESTIMATE LEVEL:**	**Appraisal**
REGION:	**MP**	**UNIT PRICE LEVEL:**	**Oct-12**

FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		SPILLWAY					
	24	**Place compacted embankment**	**86-68130**	**1,950**	**yd3**	**$20.00**	**$39,000.00**
		Includes compacted embankment, rip rap					
		bedding, and rip rap					
		SUBTOTAL THIS SHEET					**$39,000.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Michael Shepherd	Jason Schneider, P.E.	Greg Akins	01/28/2013
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
11/15/12	Jason Schneider, P.E.	01/25/13	1/28/13

FEATURE:	PROJECT:
BF Sisk (formerly San Luis) Dam Appraisal Level Study 20 - foot dam raise Intake Tower Access Bridge Middle Estimated Undrained Strength Parameters	Central Valley Project, Madera County, California WOID: A176F ESTIMATE LEVEL: Appraisal REGION: MP UNIT PRICE LEVEL: Oct-12 FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESC	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	25	**Removal & Disposal of Existing Bridge**	86-68140	1	ls	$1,150,000.00	$1,150,000.00
		The existing dam will be raised 20 feet. Since it would be very difficult to raise & reuse the existing bridge superstructure (six spans), it will be removed & replaced with a new bridge. The existing bridge superstructure consists of two steel plate girders (considered fracture critical) supporting a reinforced concrete deck Reservoir will not be dewatered, so demolition must consider barg access & handling / dispostal of structural steel coated with lead paint. To estimate the amount of materials to be removed, the existing bridge superstructure quantities are estimated to be:					
		Reinforced concrete = 400 cy					
		Structural steel = 640,000 lbs					
	26	**Concrete (4,500 psi @ 28 days)**	86-68140	1,030	yd^3	$1,400.00	$1,442,000.00
		Concrete volume is based on 3 quantities:					
		1. Pier caps extended vertically 12 ft.=170 cy					
		2. Superstructure deck = 700 cy					
		3. Abutment @ dam = 150 cy					
	27	**Cementatious Material (6 sacks/cy)**	86-68140	290	tons	$200.00	$58,000.00
	28	**Reinforcing Steel**	86-68140	260,000	lbs	$1.50	$390,000.00
		Specified minimum yield strength = 60 ksi					
	29	**Structural Steel (bridge superstructure)**	86-68140	2,500,000	lbs	$3.00	$7,500,000.00
		Structural steel girders conforming to ASTM A709 Grade 50W (Fy 50 ksi, weathering). See attached drawing for bridge cross sectior					
	30	**Bridge Guardrail (California ST-10)**	86-68140	2,370	lf	$220.00	$521,400.00
		See attached Caltrans Standard Plans B11-68, B11-69 & B11-70 f rail details					
	31	**Backfill behind/around abutment**	86-68140	170.0	yd^3	$20.00	$3,400.00
	32	**Compacted backfill behind/around abutment**	86-68140	170.0	yd3	$20.00	$3,400.00
		SUBTOTAL THIS SHEET					$11,068,200.00

ANTITIES 3400

BY	CHECKED	BY	CHECKED
Jesus G. Romero, PE	Joseph M. Gemperline, PE	Greg Akins	01/28/2013
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
12/07/12	Roman M. Koltuniuk, PE	01/25/13	1/28/13

FEATURE:
BF Sisk (formerly San Luis) Dam
Appraisal Level Study
20 - foot dam raise
Intake Tower Access Bridge
Middle Estimated Undrained Strength Parameters

PROJECT:
Central Valley Project, Madera County, California

WOID:	A176F	**ESTIMATE LEVEL:**	Appraisal
REGION:	MP	**UNIT PRICE LEVEL:**	Oct-12

FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOU	PAY ITEM	DESC	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	33	**Epoxy grouted anchors into existing caps**	86-68140	400	ea	$50.00	$20,000.00
		1in diameter Hilti Adhesive anchor: HIT_HY 150 MAX-SD+HAS. Grouted anchors are spaced at 1'-0" (16 x 5 grid), 80 per pier cap.					
	34	**Bearing Pads**	86-68140	18	ea	$1,500.00	$27,000.00
		Preformed fabric bearing pads at piers. Size of pads are estimate to be 5" thick x 2'-0" wide by 1'-9" long. Total number of pads = 18					
	35	**Bridge Joint Seals at Expansion Joints**	86-68140	60	lf	$200.00	$12,000.00
		Elastomeric expansion device equalt to General Tire Co. Transflex Model 1300 or to Watson Bowman & Associates Waboflex-SR Model SR 13 for full width of bridge.		20	lf		
		2 ½" by 2 ¾" Preformed Compression Joint Seals at tower & at abutment.		40	lf		
		SUBTOTAL THIS SHEET					$59,000.00

QUANTITIES

BY	CHECKED
Jesus G. Romero, PE	Joseph M. Gemperline, PE
DATE PREPARED	**PEER REVIEW / DATE**
12/07/12	Roman M. Koltuniuk, PE

PRICES

BY	CHECKED
Greg Akins	01/28/2013
DATE PREPARED	**PEER REVIEW / DATE**
01/25/13	1/28/13

FEATURE:
B. F. Sisk Dam Modification
Roller Gate re-location and Stem Extension
Middle Estimated Undrained Strength Parameters

PROJECT:
Central Valley Project, Madera County, California

WOID: | **ESTIMATE LEVEL:** Appraisal
REGION: MP | **UNIT PRICE LEVEL:** Oct-12
FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	36	**Site Survey (Pre-Rehab)**	86-68420	1	LS	$12,000.00	$12,000.00
		(assess general conditions and take					
		measurements as needed)					
		NOTE: The following quantities are for work on					
		one roller gate, hoist, & associated equipment					
		Total work is for four gates.					
	37	**Shut down and lock out unit associated with**	86-68420	1	LS	$5,000.00	$5,000.00
		gate to be removed					
	38	**Remove hydraulic piping to hoist**	86-68420	1	EA	$9,500.00	$9,500.00
		Crew: 1 supervisor, 1 mechanic					
		Shut valves to hoist					
		Drain oil from piping (15 gallons, 1 Crew HR)					
		Disconnect piping and plug ends (1 Crew HR)					
		Remove piping to hoist 150# (3 Crew HR)					
	39	**Remove Hydraulic Power Unit (8 Crew HR)**	86-68420	1	EA	$14,500.00	$14,500.00
		Disconnect electrical					
		Remove and store indorrs					
		Raise Roller Gate					
		Crew: 1 supervisor, 2 mechanics, 1 laborer					
	40	**Raise/lock gateby Gov't force (1 Crew HR)**	86-68420	1	LS	$3,500.00	$3,500.00
		Assume contractor assists gov't forces					
	41	**Remove hoist (18 Crew HR)**	86-68420	1	LS	$21,000.00	$21,000.00
	42	**Remove intermediate stems (12 Crew HR)**	86-68420	1	LS	$26,000.00	$26,000.00
	43	**Remove gate (10 Crew HR)**	86-68420	1	LS	$31,000.00	$31,000.00
		SUBTOTAL THIS SHEET	1				$122,500.00

QUANTITIES		**PRICES**	
BY D.L. Read	**CHECKED** D.M. Drake	**BY** Greg Akins	**CHECKED** 1/28/2013
DATE PREPARED 12/10//2012	**PEER REVIEW / DATE** D M Drake	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE:
B. F. Sisk Dam Modification
Roller Gate re-location and Stem Extension
Middle Estimated Undrained Strength Parameters

PROJECT:
Central Valley Project, Madera County, California

WOID: | **ESTIMATE LEVEL:** Appraisal
REGION: MP | **UNIT PRICE LEVEL:** Oct-12
FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Install Embedded metalwork					
	44	**Furnish and install embedded gate guides**	86-68420	1,875	LB	$13.00	$24,375.00
		Install Roller Gate					
		Crew: 1 supervisor, 2 mechanics, 1 laborer					
	45	**Install gate (10 Crew HR)**	86-68420	1	LS	$36,000.00	$36,000.00
	46	**Install intermediate stems (12 Crew HR)**	86-68420	1	LS	$30,000.00	$30,000.00
	47	**Furnish and install one new intermediate stem**	86-68420	1	LS	$140,000.00	$140,000.00
		(steel - 1,475 # each, 12 Crew HR)					
	48	**Install hoist (18 Crew HR)**	86-68420	1	LS	$50,000.00	$50,000.00
	49	**Install hoist (18 Crew HR)**	86-68420	1	LS	$42,000.00	$42,000.00
		SUBTOTAL THIS SHEET	2				$322,375.00

QUANTITIES		PRICES	
BY D.L. Read	**CHECKED** D.M. Drake	**BY** Greg Akins	**CHECKED** 1/28/2013
DATE PREPARED 12/10//2012	**PEER REVIEW / DATE** D M Drake	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE:
B. F. Sisk Dam Modification
Roller Gate re-location and Stem Extension
Middle Estimated Undrained Strength Parameters

PROJECT:
Central Va Central Valley, California
California

WOID: | **ESTIMATE LEVEL:** Appraisal
REGION: MP | **UNIT PRICE LEVEL:** Oct-12
FILE: U:\2012 Projects\BF

PCNT ACQU	PAY ITEM	DESC	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Install Hydraulic Controls					
		Crew: 1 supervisor, 1 mechanic, 1 laborer					
	50	**Install Hydraulic Power Unit (6 Crew HR)**	86-68420	1	LS	$23,000.00	$23,000.00
	51	**Connect piping (16 Crew HR)**	86-68420	1	LS	$21,000.00	$21,000.00
	52	**Electrically connect HPU, power, & control board**	86-68420	1	LS	$18,000.00	$18,000.00
		1 electician (10 HR)					
	53	**Fill and vent system (6 Crew HR)**	86-68420	1	LS	$15,000.00	$15,000.00
	54	**Test system:**		1	LS	$19,000.00	$19,000.00
	55	**Pressure test (6 Crew HR)**	86-68420	1	LS	$12,000.00	$12,000.00
	56	**Leak test Cylinder (6 Crew HR)**	86-68420	1	LS	$12,000.00	$12,000.00
	57	**Operational test (6 Crew HR)**	86-68420	1	LS	$12,000.00	$12,000.00
		SUBTOTAL THIS SHEET	3				$132,000.00

QUANTITIES

BY	CHECKED
D.L. Read	D.M. Drake
DATE PREPARED 12/10//2012	**PEER REVIEW / DATE** D M Drake

PRICES

BY	CHECKED
Greg Akins	1/28/2013
DATE PREPARED 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE:

B.F. Sisk Raise Appraisal Study
Intake Tower Modifications
Mechanical Equipment Group 86-68410
Most Probable Estimate
Middle Estimated Undrained Strength Parameters

PROJECT: Central Valley Project, Madera County, California

WOID:	A176F	**ESTIMATE LEVEL:**	Appraisal
REGION:	MP	**UNIT PRICE LEVEL:**	Oct-12

FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		GANTRY CRANE:					
	58	**Remove and dispose exist crane rails**	86-68410	19,200	lbs.	$0.75	$14,400.00
		All parts are structural steel					
		- 85# ASCE rails, 600 feet, 16,040 lbs.					
		- 585 Rail clips, 293 lbs.					
		- 290 Bearing plates, 1,600 lbs.					
		- 320 - ¾" Dia. x 12" machine bolts, 640 lbs.					
		- 300 - ¾" Dia. x 10" welded studs, 600 lbs.					
	59	**Furnish and install new crane rails**	86-68410	19,200	lbs.	$9.00	$172,800.00
		Structural steel, coated					
		- 85# ASCE rails, 600 feet, 16,040 lbs.					
		- 585 Rail clips, 293 lbs.					
		- 290 Bearing plates, 1,600 lbs.					
		- 320 - ¾" Dia. x 12" machine bolts, 640 lbs.					
		- 300 - ¾" Dia. x 10" welded studs, 600 lbs.					
	60	**Rerope the hoist and provide a new drums to**	86-68410	1	LS	$120,000.00	$120,000.00
		accommodate the additional 10"-0" of height					
		- 1-inch Dia. 6x37 IWRC, galvanized, extra		1,300	ft.		
		improved plow steel (XIP)					
		- Two new drums, cast steel, coated,		3,090	lbs.		
		9'-4" long, 24" dia., 1,545 lbs. ea.					
		Assume:					
		- Rope is 4 part					
		SUBTOTAL THIS SHEET					$307,200.00

QUANTITIES		**PRICES**	
BY R. Stephen	**CHECKED** A. Ritt	**BY** Greg Akins	**CHECKED** 01/28/2013
DATE PREPARED 12/17/12	**PEER REVIEW / DATE** D. Hulse	**DATE PREPARED** 01/25/13	**PEER REVIEW / DATE** 1/28/13

FEATURE:	PROJECT:
B.F. Sisk Raise Appraisal Study Intake Tower Modifications Mechanical Equipment Group 86-68410 Most Probable Estimate Middle Estimated Undrained Strength Parameters	Central Valley Project, Madera County, California
	WOID: A176F — ESTIMATE LEVEL: Appraisal
	REGION: MP — UNIT PRICE LEVEL: Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		GANTRY CRANE:					
	61	**Remove, store and reinstall gantry crane**	86-68410	1	L.S.	$250,000.00	$250,000.00
		after modifications to the intake towers are					
		completed					
		- Gantry crane will have to be disassembled					
		due to width of access bridge					
		- Crane dead weight is 176,000 lbs.					
		- Crane is approx. 40'-0" tall, 40'-0" wide,					
		and 38'-0" long.					
		Assume:					
		- Crane is stored onsite					
		- Crane is fully functional					
		- No modernization is required					
		- Removal and reinstallazation will require					
		the use of a mobile crane, ~20T					
		SUBTOTAL THIS SHEET					$250,000.00

QUANTITIES		PRICES	
BY R. Stephen	CHECKED A. Ritt	BY Greg Akins	CHECKED 01/28/2013
DATE PREPARED 12/17/12	PEER REVIEW / DATE D. Hulse	DATE PREPARED 01/25/13	PEER REVIEW / DATE 1/28/13

FEATURE:	PROJECT:
B.F. Sisk Raise Appraisal Study Intake Tower Modifications Mechanical Equipment Group 86-68410 Most Probable Estimate Middle Estimated Undrained Strength Parameters	Central Valley Project, Madera County, California WOID: A176F ESTIMATE LEVEL: Appraisal REGION: MP UNIT PRICE LEVEL: Oct-12 FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Summary 16

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		BULKHEAD GATE:					
	62	**Remove and reinstall bulkhead gates, lifting**	86-68410	1	L.S.	$500,000.00	$500,000.00
		frame and storage arms.					
		- (2) Top bulkhead gates, 75,000 lbs. ea.,					
		approx. 24'-6" wide x 15'-0" tall					
		- (2) Bottom bulkhead gates, 73,000 lbs. ea.,					
		approx. 24'-6" wide x 14'-6" tall					
		- Bulkhead gates are stored in the top of the					
		guides of the intake towers.					
		- Lifting frame, 12,000 lbs., 26'-0" x 16'-6"					
		- (8) Storage arms, 1,200 lbs. ea., fastened					
		to concrete deck by anchor bolts, on top					
		of a grout pad.					
	63	**Remove and dispose existing bulkhead guides**	86-68410	20,000	lbs.	$0.75	$15,000.00
		- Embedded in concrete					
		- Eight at 2,500 lbs. ea., 10'-0" long					
	64	**Furnish and install new bulkhead guides**	86-68410	40,000	lbs.	$9.00	$360,000.00
		- Structural steel, coated, embedded					
		- Eight at 5,000 lbs. ea., 20'-0" long					
		SUBTOTAL THIS SHEET					$875,000.00

QUANTITIES		PRICES	
BY R. Stephen	CHECKED A. Ritt	BY Greg Akins	CHECKED 1/28/2013
DATE PREPARED 111/29/2012	PEER REVIEW / DATE D. Hulse	DATE PREPARED 01/25/13	PEER REVIEW / DATE 1/28/13

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** SHEET _16 _ OF _16 _

FEATURE:	PROJECT:	
B.F. Sisk Dam Modification Appraisal Level Study 20-foot Dam Raise Middle Estimated Undrained Strength Parameters Option B	Central Valley Project, Madera County, California	
	WOID: A176F	ESTIMATE LEVEL: Appraisal
	REGION: MP	UNIT PRICE LEVEL: Oct-12
	FILE: U:\2012 Projects\BF Sisk\002 Completed Sheets\[002 Summary BF Sisk - Undrained.xlsx]Sht 3B	

PLANT ACCOUNT	PAY ITEM	DESCRIPTION					AMOUNT
		Subtotal Sheet 2 of 16					**$60,589,000.00**
		Subtotal Sheet 3 of 16					**$155,159,900.00**
		Subtotal Sheet 4 of 16					**$602,000.00**
		Subtotal Sheet 5 of 16					**$4,080,300.00**
		Subtotal Sheet 6 of 16					**$551,350.00**
		Subtotal Sheet 7 of 16					**$39,000.00**
		Subtotal Sheet 8 of 16					**$11,068,200.00**
		Subtotal Sheet 9 of 16					**$59,000.00**
		Subtotal Sheet 10 of 16					**$122,500.00**
		Subtotal Sheet 11 of 16					**$322,375.00**
		Subtotal Sheet 12 of 16					**$132,000.00**
		Subtotal Sheet 13 of 16					**$307,200.00**
		Subtotal Sheet 14 of 16					**$250,000.00**
		Subtotal Sheet 15 of 16					**$875,000.00**
		Subtotal					**$234,157,825.00**
		Mobilization	5%	+/-			$11,500,000.00
		Subtotal with Mobilization					**$245,657,825.00**
		Contract Cost Allowances (Sum of):	18%	+/-			$44,342,175.00
		Design Contingencies,15% (+/-)					
		APS, 3% (+/-). Type of procurement:Request for Proposal					
		CONTRACT COST					**$290,000,000.00**
		Construction Contingencies	25%	+/-			$70,000,000.00
		FIELD COST (Unit Price Level Oct 2012)					**$360,000,000.00**
		Non-Contract Costs		**To be determined by the appropriate responsible offic**			
		Escalation to Notice to Proceed (NTP)		**To be determined by the appropriate responsible offic**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible offic**			
		Ref.: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03.					

QUANTITIES		PRICES	
BY See Estimate Sheets	**CHECKED** See Estimate Sheets	**BY** Greg Akins	**CHECKED** 3/20/13
DATE PREPARED	**PEER REVIEW / DATE** See Estimate Sheets	**DATE PREPARED** 1/25/2013 - revised 3/20/13	**PEER REVIEW / DATE** 3/22/13

Exhibit C

TM VB-86-68313-22

Appraisal-Level Study of Static Stability for Increased Storage

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RECLAMATION

Managing Water in the West

Technical Memorandum No. VB-86-68313-22

Appraisal-Level Study of Static Stability for Increased Storage

B.F. Sisk Dam
Central Valley Project, California
Mid-Pacific Region



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

January 2013

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo – Aerial photograph of B.F. Sisk Dam and San Luis Reservoir.

Technical Memorandum No. VB-86-68313-22

Appraisal-Level Study of Static Stability for Increased Storage

B.F. Sisk Dam
Central Valley Project, California
Mid-Pacific Region

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

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Technical Memorandum No. VB-86-68313-22

Appraisal-Level Study of Static Stability for Increased Storage

B.F. Sisk Dam
Central Valley Project, California
Mid-Pacific Region

P.E.

Prepared: Tonya Hart, P.E.
Geotechnical Engineer, Geotechnical Engineering Group 3, 86-68313

Tuti H Tierney P. E.

Checked: Tuti Tierney, P.E.
Civil Engineer, Geotechnical Engineering Group 3, 86-68313

Randall Kuzniakowski

Peer Review: Randall Kuzniakowski, P.E.
Civil Engineer, Geotechnical Engineering Group 4, 86-68314

1/28/13
Date

REVISIONS					
Date	Description	Prepared	Checked	Technical approval	Peer review

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Acronyms and Abbreviations

BOR	Bureau of Reclamation
CAS	Corrective Action Study
CFR	Comprehensive Facility Review
CRB	Consultant Review Board
DWR	Department of Water Resources
FLAC	Fast Lagrangian Analysis of Continua
FS	factor of safety
ft^2	square foot (feet)
ft^3	cubic foot (feet)
GVS	Great Valley Sequence
IE	Issue Evaluation
km	kilometer(s)
MPRO	Mid-Pacific Regional Office
MSE	Mechanically Stabilized Earth
NVS	North Valley Section
PMP	Project Management Plan
RA	Risk Analysis
Reclamation	Bureau of Reclamation
RWS	reservoir water surface
SOD	Safety of Dams
SPT	Standard Penetration Test
SVS	South Valley Section
TM	Technical Memorandum
URS	URS Group, Inc.

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B Results of Static Stability Analyses

Exhibit D

TM BFS-8110-STY-2012-1

Analysis of Spillway, and Outlet Works Towers and Conduit, and Gianelli Pumping-Generating Plant

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RECLAMATION

Managing Water in the West

Technical Memorandum No. BFS-8110-STY-2012-1

B.F. Sisk Dam
Analysis of Spillway, and Outlet Works Towers and Conduit, and Gianelli Pumping –Generating Plant

Central Valley Project, California
Mid-Pacific Region



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

December 2012

Mission Statements

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BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Structural Analysis Group, 86-68110

Technical Memorandum No. BFS-8110-STY-2012-1

B.F. Sisk Dam - Analysis of Spillway, and Outlet Works Towers and Conduit, and Gianelli Pumping – Generating Plant

B.F. Sisk Dam
Central Valley Project, California
Mid Pacific Region

Prepared: Michael A Shepherd
Civil Engineer, Structural Analysis Group 86-68110

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Civil Engineer, Waterways and Concrete Dams Group 86-68130

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Civil Engineer, Waterways and Concrete Dams Group 86-68130

1/26/2013
Date

REVISIONS					
Date	Description	Prepared	Checked	Technical Approval	Peer Review

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Exhibit E

TM BFS-8140-STY-2013-1

Analysis of Trashrack Structure Access Bridge

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RECLAMATION

Managing Water in the West

Technical Memorandum No. BFS-8140-STY-2013-1

B.F. Sisk Dam - Analysis of Trashrack Structure Access Bridge

Central Valley Project, California
Mid-Pacific Region



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

March 2013

Mission Statements

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B.F. Sisk Dam - Analysis of Trashrack Structure Access Bridge

Central Valley Project, California
Mid-Pacific Region

For further information regarding this Technical Memorandum, contact:

Jesus Romero
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jromero@usbr.gov

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Water Conveyance Group, 86-68140

Technical Memorandum No. BFS-8140-STY-2013-1

B.F.Sisk Dam - Analysis of Trashrack Structure Access Bridge

Central Valley Project, California
Mid-Pacific Region

P.E.

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Civil Engineer, Water Conveyance Group, 86-68140

P.E.

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Civil Engineer, Water Conveyance Group, 86-68313

P.E.

Peer Review: Roman Koltuniuk, P.E.
Supervisory Civil Engineer, Structural Analysis Group, 86-68110

3/8/2013
Date

REVISIONS					
Date	Description	Prepared	Checked	Technical approval	Peer review

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B.F. Sisk Dam Raise and Reservoir Expansion Project
San Luis Reservoir Expansion
Draft Feasibility Design Report

Attachment B 2020 Cost Estimates

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

230-kV Circuits Re-Alignment to HV Power Cables Study
Civil/Structural (86-68120)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
UNIT PRICE LEVEL: July 2016
INDEXTED TO: Jan 2020
FILE: C:\Users\carthur\Desktop\Contracts_052819\BF Sisk\Raise\Feasibility Study\Cost Estimate\[B.F.SiskDamRaise_QEW's_R2_Hwy152removed_092120_Rounded.xlsx]Miscellaneous (3 of 3)

PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			CIVIL/STRUCTURAL					
	1	Shared	**Remove and Salvage of Transmission**	86-68120	1	ls	$28,670.00	$28,670.00
			Towers (C4-T3 and C3-T3) and Leg Extensions					
			(Transmission towers consists of prismatic					
			steel lattice structures up to 155'-6" tall, cast					
			in place concrete footings with drilled and					
			grouted anchor bars)					
			(2 - steel weight = 28,000 lb ea.)					
			(8 - concrete foundations @ 13.2 yd3 ea.)					
			(8 - Common excavations @ 35 yd3 ea.)					
	2	Shared	**Structural Excavation for Switchyard**	86-68120	77	yd3	$115.00	$8,820.00
			Foundations (Rock)					
			(Assume 1/4:1 cut slope)					
			(Assume rock must be blasted)					
			(4 - Take Off Structure Foundations @ 57.2 yd3 ea.)					
	3	Shared	**Structural Excavation for Switchyard**	86-68120	1	ls	$8,000.00	$8,000.00
			Foundations (Common)					
			(Assume 1:1 cut slope)					
			(Assume stockpiling and reuse of gravel					
			surfacing, and backfill)					
			4 - Take Off Structure Foundations					
			Gravel @ 30.7 yd3 ea. (8-in thick)					
			Common excavation @ 232.5 yd3 ea.					
			12 - Pothead Structure Foundations					
			Gravel @ 6.5 yd3 ea. (8-in thick)					
			Common excavation @ 19.4 yd3 ea.					
			SUBTOTAL THIS SHEET					**$45,490.00**

QUANTITIES		**PRICES**	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED 05/15/20	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

230-kV Circuits Re-Alignment to HV Power Cables Study
Civil/Structural (86-68120)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			CIVIL/STRUCTURAL					
	4	Shared	**Structural Excavation for Precast Concrete**	86-68120	1	ls	$3,330.00	$3,330.00
			Non-Vehicular Cable Trench (Common)					
			(Assume 1:1 cut slope)					
			(Assume stockpiling and reuse of gravel surfacing)					
			Gravel @ 245.1 yd3 (8-in thick)					
			Common excavation @ 324.4 yd3					
	5	Shared	**Saw cut Asphalt**	86-68120	370	lin ft	$4.20	$1,554.00
	6	Shared	**Structural Excavation for Precast Concrete**	86-68120	1	ls	$1,870.00	$1,870.00
			Non-Vehicular Cable Trench (Asphalt Road)					
			(Assume 1:1 cut slope in asphalt and common					
			material, assume stock piling of crushed					
			rockbase)					
			Asphalt @ 48.8 yd3 (2-in thick)					
			Crushed Rock @ 139.4 yd3 (6-in thick)					
			Common excavation @ 252.7 yd3					
	7	Shared	**Structural Excavation for Precast Concrete**	86-68120	1	ls	$210.00	$210.00
			Vehicular Cable Trench (Common)					
			(Assume 1:1 cut slope					
			Assume stockpiling and reuse of gravel surfacing)					
			Gravel @ 7.5 yd3 (8-in thick)					
			Common excavation @ 11.9 yd3					
	8	Shared	**Haul and Dispose of Excavated Rock**	86-68120	77	yd3	$17.50	$1,340.00
			(4 - Take Off Structure Foundations @ 57.2 yd3)					
			(Assume 20 mile disposal site)					
			SUBTOTAL THIS SHEET					**$8,304.00**

QUANTITIES		**PRICES**	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED 05/15/20	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

230-kV Circuits Re-Alignment to HV Power Cables Study
Civil/Structural (86-68120)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
REGION: MP
ESTIMATE LEVEL: Feasibility
UNIT PRICE LEVEL: July 2016
INDEXTED TO: Jan 2020

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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			CIVIL/STRUCTURAL					
	9	Shared	**Haul and Dispose of Gravel Surfacing**	86-68120	37	yd3	$17.50	$640.00
			(4 - Take Off Structure Foundations @ 1.2 yd3 ea.)					
			(12 - Pothead Structure Foundations @ 1.1 yd3 ea.)					
			(Non-Vehicular Cable Trench @ 88.8 yd3)					
			(Vehicular Crossing Cable Trench @ 3 yd3)					
			(Assume 20 mile disposal site)					
	10	Shared	**Haul and Dispose of Common Excavation**	86-68120	233	yd3	$17.50	$4,080.00
			(4 - Take Off Structure Foundations @ 31.5 yd3 ea.)					
			(12 - Pothead Structure Foundations @ 3.9 yd3 ea.)					
			(Non-Vehicular Cable Trench Excavation @ 449.6 yd3)					
			(Vehicular Crossing Cable Trench Excavation @ 11.9 yd3)					
			(2 - Transmission Tower Foundations @ 35 yd3 ea.)					
			(Assume 20 mile disposal site)					
	11	Shared	**Haul and Dispose Asphalt Surfacing**	86-68120	16	yd3	$81.00	$1,323.00
			(Assume 2" of asphalt surfacing)					
			(Assume 20 mile disposal site)					
	12	Shared	**Haul and Dispose of Crushed Rock Base**	86-68120	17	yd3	$17.50	$303.00
			(Assume 20 mile disposal site)					
	13	Shared	**Precast Concrete Cable Trench**	86-68120	1	ls	$616,670.00	$616,670.00
			24" wide one piece cable trench: 2550 lin ft					
			(Trenwa, Pedestrian Base & Concrete Lid,					
			BP2415-120 & LP24-30)					
			24" HS-20 wide HS-20 vehicular crossing = 40 lin ft					
			(Trenwa, Road Crossing HS-20 & Steel Lid,					
			BHS2416-120 & LHS24-24)					
			SUBTOTAL THIS SHEET					**$623,016.00**

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
Casey Arthur			
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
05/15/20			

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

230-kV Circuits Re-Alignment to HV Power Cables Study
Civil/Structural (86-68120)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
REGION: MP
ESTIMATE LEVEL: Feasibility
UNIT PRICE LEVEL: July 2016
INDEXTED TO: Jan 2020
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			CIVIL/STRUCTURAL					
	14	Shared	**Reuse, Place, and Compact Stockpiled**	86-68120	367	yd3	$9.80	$3,590.00
			Backfill Material					
			(4 - Take Off Structure Foundations @ 31.9 yd3 ea.)					
			(4 - Take Off Structure Foundations @ 200.9 yd3 ea.)					
			(12 - Pothead Structure Foundations @ 15.5 yd3 ea)					
	15	Shared	**Furnish, Install, Place, and Compact Sand**	86-68120	87	yd3	$90.00	$7,800.00
			Backfill					
			(2550 lin ft Non-Vehicular Cable Vault = 256 yd3)					
			(40 lin ft Vehicular Crossing Cable Vault = 6 yd3)					
	16	Shared	**Reuse, Place, and Compact Stockpiled**	86-68120	117	yd3	$9.80	$1,140.00
			Gravel Surfacing					
			(4 - Take Off Structure Foundations @ 29.5 yd3)					
			(12 - Pothead Structure Foundations @ 5.4 yd3)					
			(1440 lin ft Non-Vehicular Cable Vault = 156 yd3)					
			(40 lin ft Vehicular Crossing Cable Vault = 9 yd3)					
	17	Shared	**Furnish, Install, Place, and Compact**	86-68120	45	yd3	$88.00	$3,960.00
			Sand Subase Material					
			(2550 lin ft Non-Vehicular Cable Vault = 131.6 yd3)					
			(40 lin ft Vehicular Crossing Cable Vault = 2.3 yd3)					
	18	Shared	**Reuse, Place, and Compact 6" Rockbase**	86-68120	29	yd3	$9.80	$287.00
	19	Shared	**Place 2" Hot Mix Asphalt Surfacing**	86-68120	193	yd2	$22.00	$4,253.00
			(Surface: 555 lin ft x 14.4 lin ft)					
	20	Shared	**Place 2" Loose Sand in Cable Trenches**	86-68120	11	yd3	$87.00	$957.00
			(2590 lin ft of cable trenches)					
			SUBTOTAL THIS SHEET					**$21,987.00**

QUANTITIES		**PRICES**	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED 05/15/20	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

230-kV Circuits Re-Alignment to HV Power Cables Study
Civil/Structural (86-68120)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			CIVIL/STRUCTURAL					
	21	Shared	**Cast-in-place concrete for Switchyard**	86-68120	107	yd3	$780.00	$83,200.00
			Foundations					
			(Assume f'c = 4,500 psi)					
			(8 - Take Off Structure Foundations = 34 yd3)					
			(12 - Pothead Structure Foundations @ 3.6 yd3)					
	22	Shared	**Furinsh and Handle Cementitious Materials**	86-68120	98	ton		Included in Item 21
			for Switchyard Foundations					
			(Assume 0.306 ton/yd3)					
	23	Shared	**Furnish and Place Reinforcing Bars**	86-68120	17,667	lb	$2.30	$40,633.00
			(Assume 165 lb/yd3)					
	24	Shared	**Switchyard Steel Structures**	86-68120	32,333	lb	$11.50	$371,833.00
			(4 - Take Off Structures @ 19,950 lb)					
			(12 - Pothead Structures = 1,420 lb)					
	25	Shared	**Chainlink Fence**	86-68120	73	lin ft	$78.00	$5,720.00
			(7' Chainlink Fence w/ 6' of Fabric and 1' of					
			Three-strand Barbed Wire at Top)					
			(Assume 2 man gate access gates)					
	26	Shared	**Drilling and Grouting Anchor Bars for**	86-68120	1	ls	$2,433.33	$2,433.00
			Switchyard Foundations					
			(4 Foundations)					
			#8 Rebar: 534 lb (10 bars @ 5'-0" ea.)					
			Grout: 0.25 yd3					
			Drill 2-1/2" Dia. Holes: 200 lin ft					
			SUBTOTAL THIS SHEET					**$503,819.00**

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
Casey Arthur			
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
05/15/20			

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Spillway, Conduit and Outlet Works Modification with retaining wall for Geotechnical needs

PROJECT:
BF SISK - Dam Raise

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION:
UNIT PRICE LEVEL: July 2016
INDEXTED TO: Jan 2020
FILE: C:\Users\carthur\Desktop\Contracts_052819\BF Sisk\Raise\Feasibility Study\Cost Estimate\[B.F.SiskDamRaise_QEW's_R2_Hwy152removed_092120_Rounded.xlsx]Miscellaneous (3 of 3)

PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			SPILLWAY CREST STRUCTURE					
	27		**Excavation Crest Structure**		1	LS	$105,000.00	$105,000.00
			Riprap - Remove and Stockpile		7,900	yd3		Included in Item 27
			Zone 1 and compacted Backfill		1,600	yd3		Included in Item 27
			- Remove and dispose (basalt hill)					
			Bedding - Remove and dispose(basalt hill)		4,000	yd3		Included in Item 27
	28		**Remove Existing Crest Structure**		1	LS	$11,500.00	$11,500.00
			Note: may require platforms for inside the					
			structure concrete work.					
			Demolition of existing concrete in the intake		180	yd3		Included in Item 28
			and chute section downstream of dam					
			assume crushed and dispose basalt hill					
			Sawcut inside and outside		92	ft		Included in Item 28
			circumfrence 2-inch deep					
			Reinforcing steel (disposed off site after		31,000	lbs		Included in Item 28
			Crushing concrete)					
	29		**New Reinforced Concrete - Crest Str.**		240	yd3	$360.00	$86,400.00
			Assume 4500psi concrete					
			Including intake and new pipe section					
	30		**Reinforcement for New Concrete - Crest Str.**		40,800	lbs	$2.30	$93,840.00
			assume 60ksi steel					
	31		**Cementious Materials - Crest Str.**		73	tons		Included in Item 29
			assume 610 lb/yd3 for 4500psi concrete					
			20% pozzolan					
			SUBTOTAL THIS SHEET					**$296,740.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Casey Arthur			
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
05/15/20			

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
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Most Probable Values

Spillway, Conduit and Outlet Works Modification
with retaining wall for Geotechnical needs

PROJECT:
BF SISK - Dam Raise

WOID: **A999F** **ESTIMATE LEVEL:** **Feasibility**
REGION: **UNIT PRICE LEVEL:** **July 2016**
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	32		**Rebuild Compacted Backfill, Riprap, Bedding, and**		1	LS	$890,000.00	$890,000.00
			Zone 1 Material at Spillway crest					
			Riprap - Reused Material (assume 15% loss)		6,700	yd3		Included in Item 32
			New Material required		1,200	yd3		Included in Item 32
			Zone 1 Material - New Material		20,700	yd3		Included in Item 32
			Bedding - New Material		4,000	yd3		Included in Item 32
			Specially Compacted Backfill -					
			New Material Required		160	yd3		Included in Item 32
			SPILLWAY CHUTE CONDUIT					
	33		**Excavaton - Chute**		680	yd3	$8.90	$6,052.00
	34		**Remove Existing Chute**		270	yd3	$360.00	$97,200.00
			Demo existing concrete, assume crush and dispose basalt hill					
			Reinforcing steel, dispose off site after crushing concrete		46,000	lbs		Included in Item 34
			Sawcut 2" inside and outside perimeters Conduit and chute sections		154	ft		Included in Item 34
	35		**New Reinforced Concrete Conduit**		790	yd3	$650.00	$513,500.00
			Assume 4500psi concrete					
	36		**Reinforcement for new Concrete Conduit**		135,000	lbs	$2.30	$310,500.00
			assume 60ksi steel					
	37		**Cementitious Material - Concrete Conduit**		240	tons		Included in Item 35
			assume 610 lb/yd3 for 4500psi concrete 20% pozzolan					
	38		**Specially Compacted Backfill - Concrete Conduit**		1,700	yd3	$88.00	$149,600.00
			SUBTOTAL THIS SHEET					**$1,966,852.00**

QUANTITIES		**PRICES**	
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
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Most Probable Values

Spillway, Conduit and Outlet Works Modification
with retaining wall for Geotechnical needs

PROJECT:
BF SISK - Dam Raise

WOID: A999F
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UNIT PRICE LEVEL: July 2016
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			OUTLET WORKS MODIFICATION					
			Note: Concrete work for outlet works					
			will require placing platforms inside and					
			outside and require barges to haul in					
			equipment and remove material					
			as needed.					
	39		**Remove Existing Outlet Structure**		1	LS	$1,100,000.00	$1,100,000.00
			down 14' from top of concrete					
			Demo existing concrete, assume crush and					
			dispose basalt hill		1,250	yd3		Included in Item 34
			Sawcut inside and out 2" around perimeter		1,048	ft		Included in Item 34
			Reinforcing steel, dispose off site after		210,000	lbs		Included in Item 34
			crushing concrete					
	40		**Remove & Dispose Crain Rail Girders and Struts**		65,000	lbs	$1.00	$65,000.00
			Weight shown on 805-D-1800					
			Calculated for 8150					
			May contain heavy metal coatings					
	41		**Embedded Misc Metalwork**		37,500	lbs	$14.00	$525,000.00
			Remove and Dispose, may contain heavy					
			metal coatings					
			Handrails		16,500	lbs		Included in Item 41
			Grating		21,000	lbs		Included in Item 41
			Calculated for 8120					
	42		**New Concrete - Modified Outlet Works**		1,720	yd3	$650.00	$1,118,000.00
			Assume 4500psi concrete					
	43		**Reinforcement for Modified Outlet Works**		293,000	lbs	$2.30	$673,900.00
			assume 60ksi steel					
	44		**Cementitious Material - Concrete Conduit**		525	tons		Included in Item 42
			assume 610 lb/yd3 for 4500psi concrete					
			20% pozzolan					
			SUBTOTAL THIS SHEET					**$3,481,900.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Casey Arthur			
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05/15/20			

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Spillway, Conduit and Outlet Works Modification
with retaining wall for Geotechnical needs

PROJECT:
BF SISK - Dam Raise

WOID: **A999F** **ESTIMATE LEVEL:** **Feasibility**
REGION: **UNIT PRICE LEVEL:** **July 2016**
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			OUTLET WORKS MODIFICATION - Cont'd					
	45		**Furnish and Install Crane Rail Girders and Struts**		65,000	lbs	$11.50	$747,500.00
			Assume same taken out put back new					
	46		**Furnish and Install Misc Metalwork**		37,500	lbs	$11.50	$431,250.00
			Handrails		16,500	lbs		Included in Item 46
			Grating		21,000	lbs		Included in Item 46
			Assume same taken out put back new					
			RETAINING WALL FOR GEOTECH NEEDS					
	47		**New Concrete - Transmisson Tower Wall**		475	yd3	$640.00	$304,000.00
			Assume 4500psi concrete					
	48		**Reinforcement for Transmission Tower Wall**		81,000	lbs	$2.30	$186,300.00
			assume 60ksi steel					
	49		**Cementitious Material - Concrete Conduit**		145	tons		Included in Item 48
			assume 610 lb/yd3 for 4500psi concrete					
			20% pozzolan					
			SUBTOTAL THIS SHEET					**$1,669,050.00**

QUANTITIES		PRICES	
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

TRASHRACK STRUCTURE ACCESS BRIDGE

Most Probable
Civil Structures Group (86-68150)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
UNIT PRICE LEVEL: July 2016
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	50		**Removal & Disposal of Existing Bridge**	86-68150	1	LS	$1,150,000.00	$1,150,000.00
			As part of the San Luis Dam Reservoir Expansion, the existing dam crest will be raised 22 feet resulting in a normal maximum W.S. El. 554.0 (10 feet higher than existing normal W.S. El.). This requires the removal of the existing bridge superstructure, which is a composite section consisting of two steel plate girders and reinforced concrete deck. Since the existing piers are so deep (Piers 1 & 2 are 228 feet 150 feet tall, respectively), bridge construction will be facilitated when the existing reservoir is near the current Normal reservoir W.S. El. 544.0. After the bridge is removed, the existing piers will be extended up ~10 feet. Existing structural steel is painted (likely lead based paint). The existing abutment will also be removed. The following quantities of materials is to be removed.					
			1. Structural steel = 580,000 lbs					
			2. Reinforced concrete (bridge deck) = 400 cy					
			3. Reinforced concrete (abutment) = 150 cy					
			4. Surface area of structural steel requiring the removal of lead based paint = 250,000 sf					
			5. Earth removal @ abutment = 2750 cy					
	51		**Cast-in-Place Concrete (4,500 psi)**	86-68150	920	YD^3	$2,600.00	$2,392,000.00
			Cast-in place concrete is based on 3 items:					
			1. Pier caps extended ~10 feet = 140 cy					
			2. New bridge superstructure = 630 cy					
			3. New bridge abutment = 150 cy					
	52		**Cementatious Materials (6.5 sacks/cy)**	86-68150	281	TONS		
	53		**Furnish & Install 60 ksi reinforcement**	86-68150	220,000	LB	$2.30	$506,000.00
			Bridge deck @ 250 lb/cy = 160,000 lb					
			Piers & abutment @ 200 lb/cy = 60,000 lb					
			SUBTOTAL THIS SHEET					**$4,048,000.00**

QUANTITIES		PRICES	
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FEATURE:
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Most Probable Values

TRASHRACK STRUCTURE ACCESS BRIDGE

Most Probable
Civil Structures Group (86-68150)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
REGION: MP
ESTIMATE LEVEL: Feasibility
UNIT PRICE LEVEL: July 2016
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	54		**Furnish & Install Structural Steel**	86-68150	1,750,000	LB	$11.50	$20,125,000.00
			Structural steel girders conforming to ASTM A709 Grade 50w (F_y = 50 ksi, weathering).					
	55		**Bridge Guardrail (California ST-10)**	86-68150	2,200	LF	$290.00	$638,000.00
			See attached Caltrans Standard Plans B11-68, B11-69 & B11-70 for details					
	56		**Structural Excavation @ abutment**	86-68150	675	CY	$8.90	$6,007.50
	57		**Backfill about structures**	86-68150	550	CY	$12.00	$6,600.00
	58		**Compacted backfill about structures**	86-68150	550	CY	$12.00	$6,600.00
	59		**Furnish & Install Epoxy Grouted Anchors**	86-68150	400	EA	$185.00	$74,000.00
			Pier extension requires 1-inch diameter Hilti Adhesive Anchors (HIT_HY 150 MAX-SD+HAS). Grouted anchors spaced at 1'-0" (16 x 5 grid), 80 per pier cap.					
	60		**Elastomeric Bearing Pads**	86-68150	24	EA	$1,150.00	$27,600.00
			Steel reinforced, 60 Durometer Hardness. 16" x 20" x 7" (L x W x T) @ supports					
	61		**Bridge Joint Seals at Expansion Joints**	86-68150	60	LF	$52,000.00	$3,120,000.00
			At Pier 5:					
			Elastomeric expansion device equal to General Tire Co. Transflex Model 1300 or Watson Bowman & Associates Waboblex-SR Model SR 13 for full width of bridge		20	LF		Included in Item 61
			At Trashrack Structure & Abutment:					
			2 $^{1}/_{2}$" by 2 $^{3}/_{4}$" Preformed Compression Joint Seals		40	LF		Included in Item 61
			SUBTOTAL THIS SHEET					**$24,003,807.50**

QUANTITIES		PRICES	
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Gantry Crane

Group (86-68410)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
REGION: MP
ESTIMATE LEVEL: Feasibility
UNIT PRICE LEVEL: July 2016
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			GANTRY CRANE:					
	62		**Remove and dispose exist crane rails**	86-68410	19,500	lbs.	$1.55	$30,225.00
			All parts are structural steel					
			- 85# ASCE rails, 600 feet, 16,040 lbs.					
			- 585 Rail clips, 468 lbs.					
			- 290 Bearing plates, 1,600 lbs.					
			- 320 - ¾" Dia. x 12" machine bolts, 640 lbs.					
			- 300 - ¾" Dia. x 10" welded studs, 600 lbs.					
	63		**Furnish and install new crane rails**	86-68410	19,200	lbs.	$8.50	$163,200.00
			Structural steel, coated					
			- 85# ASCE rails, 600 feet, 16,040 lbs.					
			- 585 Rail clips, 468 lbs.					
			- 290 Bearing plates, 1,600 lbs.					
			- 320 - ¾" Dia. x 12" machine bolts, 640 lbs.					
			- 300 - ¾" Dia. x 10" welded studs, 600 lbs.					
	64		**Remove and dispose existing 50-ton gantry**	86-68410	15,000	lbs.	$1.75	$26,250.00
			crane trolley, including drums and wire rope					
			- Approx. size: 15'-0" long x 15'-0"wide x					
			5'-0" high					
			- 2,500-feet of 1-inch Dia. 6x37 IWRC, gal-					
			vanized, extra improved plow steel (XIP)					
	65		**Provide new 50-ton gantry crane trolley to**	86-68410	15,000	lbs.	$6.90	$103,500.00
			accommodate the additional 10"-0" of height					
			- Approx. size: 15'-0" long x 15'-0"wide x					
			5'-0" high					
			- 2,600-feet of 1-inch Dia. 6x37 IWRC, gal-					
			vanized, extra improved plow steel (XIP)					
			SUBTOTAL THIS SHEET					**$323,175.00**

QUANTITIES		**PRICES**	
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Casey Arthur			
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05/15/20			

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Gantry Crane

Group (86-68410)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			GANTRY CRANE:					
	66		**Remove, store and reinstall gantry crane after**	86-68410	1	L.S.	$250,000.00	$250,000.00
			modifications to the intake towers are					
			completed.					
			- Gantry crane will have to be disassembled					
			due to width of access bridge					
			- Crane dead weight is 177,000 lbs.					
			- Crane is approx. 40'-0" tall, 40'-0" wide,					
			and 38'-0" long.					
			Assume:					
			- Crane is stored onsite					
			- Crane is fully functional					
			- No modernization is required					
			- Removal and reinstallazation will require					
			the use of a mobile crane, ~20T					
			SUBTOTAL THIS SHEET					**$250,000.00**

QUANTITIES		PRICES	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Bulkhead Gate

Group (86-68410)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			BULKHEAD GATES:					
	67		**Remove and reinstall bulkhead gates, lifting**	86-68410	1	LS	$27,000.00	$27,000.00
			frame and storage arms.					
			- (1) Top bulkhead gate section, 75,000 lbs.,					
			approx. 24'-6" wide x 15'-0" tall					
			- (1) Bottom bulkhead gate sect., 73,000 lbs,					
			approx. 24'-6" wide x 14'-6" tall					
			- (1) Lifting frame, 12,000 lbs., 26'-0" x 16'-6"					
			- Bulkhead gate sections and lifting frame					
			are stored in the top of the guides of the					
			intake towers.					
			- (8) Storage arms, 1,200 lbs. ea., fastened					
			to concrete deck by anchor bolts, on top					
			of a grout pad.					
	68		**Coatings and repair**		160	LF	$21,000.00	$3,360,000.00
			- Top and bottom bulkhead gate sections:					
			- Sand blast all surfaces					
			- Remove, dispose and replace neoprene					
			music note seals, 80 ft each					
			- Lifting frame					
			- Spot repair coating (assume 5% of total					
			surface area)					
	69		**Remove and dispose existing bulkhead guides**	86-68410	20,000	lbs.	$1.50	$30,000.00
			- Embedded in concrete					
			- Eight at 2,500 lbs. ea., 10'-0" long					
	70		**Furnish and install new bulkhead guides**	86-68410	60,000	lbs.	$11.50	$690,000.00
			- Structural steel, coated, embedded					
			- Eight at 7,500 lbs. ea., 30'-0" long					
			SUBTOTAL THIS SHEET					**$4,107,000.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Casey Arthur			
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05/15/20			

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Bulkhead Gate

Group (86-68410)

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
UNIT PRICE LEVEL: July 2016
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			BULKHEAD GATES:					
	71		**Furnish and install bulkhead gates, welded**		163,000	lbs	$9.90	$1,613,700.00
			structural steel, coated					
			- (1) Top bulkhead gate section, 83,000 lbs.,					
			- (1) Bottom bulkhead gate sect., 80,000 lbs					
			SUBTOTAL THIS SHEET					**$1,613,700.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Casey Arthur			
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
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Most Probable Values

Roller Gate re-location and Stem Extension

86-68420

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	72		**Site Survey (Pre-Rehab) assess general**	86-68420	1	LS	$33,000.00	$33,000.00
			conditions and take measurements as needed					
			NOTE: The following quantities are for work on one roller gate, hoist, & associated equipment Total work is for four gates.					
	73		**Raise/lock gate by Gov't force**	86-68420	1	LS	$21,000.00	$21,000.00
	74		**Shut down and lock out unit associated with**	86-68420	1	LS	$2,700.00	$2,700.00
			gate to be removed by Gov't force					
	75		**Remove hydraulic piping to hoist**	86-68420	1	LS	$11,500.00	$11,500.00
			Crew: 1 supervisor, 1 mechanic					
			Shut valves to hoist					
			Drain oil from piping (15 gallons, 1 Crew HR)					
			Disconnect piping and plug ends (1 Crew HR)					
			Remove piping to hoist 150# (3 Crew HR)					
	76		**Remove Hydraulic Power Unit (8 Crew HR)**	86-68420	1	LS	$18,500.00	$18,500.00
			Disconnect electrical					
			Remove and store indoors					
			Remove Roller Gate					
			Crew: 1 supervisor, 2 mechanics, 1 laborer					
			Use existing gantry crane to place on flatbed					
	77		**Remove hoist (18 Crew HR)**	86-68420	1	LS	$48,000.00	$48,000.00
	78		**Remove intermediate stems (12 Crew HR)**	86-68420	1	LS	$32,000.00	$32,000.00
	79		**Remove gate (12 Crew HR)**	86-68420	1	LS	$27,000.00	$27,000.00
			Transport gate to staging area					
			Jack or lift off of flatbed onto cribbing 75Tons					
			SUBTOTAL THIS SHEET	1				**$193,700.00**

QUANTITIES		PRICES	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED 05/15/20	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Roller Gate re-location and Stem Extension

86-68420

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
UNIT PRICE LEVEL: July 2016
INDEXTED TO: Jan 2020
FILE: C:\Users\carthur\Desktop\Contracts_052819\BF Sisk\Raise\Feasibility Study\Cost Estimate\[B.F.SiskDamRaise_QEW's_R2_Hwy152removed_092120_Rounded.xlsx]Miscellaneous (3 of 3)

PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			Install Embedded metalwork					
			Crew: 1 supervisor, 2 mechanics, 1 laborer					
	80		**Furnish and install embedded gate guides**	86-68420	1,875	LB	$14.00	$26,250.00
			(16 Crew HR)					
			Install Roller Gate					
			Crew: 1 supervisor, 2 mechanics, 1 laborer					
	81		**Pressure wash gate for inspection**	86-68420	1	LS	$11,000.00	$11,000.00
			Inspect seals, wheels, and paint					
			Spot paint rust areas (3 SF)					
			Inspect and test roller chains and ways					
			(18 Crew HR)					
	82		**Install gate (12 Crew HR)**	86-68420	1	LS	$53,000.00	$53,000.00
			Lift or jack off of cribbing onto flatbed 75Tons					
			Transport to gantry crane					
	83		**Install intermediate stems (12 Crew HR)**	86-68420	1	LS	$27,000.00	$27,000.00
	84		**Furnish and install one new intermediate stem**	86-68420	1	LS	$70,000.00	$70,000.00
			(steel - 1,475 # each, 12 Crew HR)					
	85		**Install hoist (18 Crew HR)**	86-68420	1	LS	$33,000.00	$33,000.00
	86		**Install hoist (18 Crew HR)**	86-68420	1	LS	$33,000.00	$33,000.00
			SUBTOTAL THIS SHEET	**2**				**$253,250.00**

QUANTITIES		**PRICES**	
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Roller Gate re-location and Stem Extension

86-68420

PROJECT:
Central Valley Project, Madera County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			Install Hydraulic Controls					
			Crew: 1 supervisor, 1 mechanic, 1 laborer					
	87		**Install Hydraulic Power Unit (6 Crew HR)**	86-68420	1	LS	$33,000.00	$33,000.00
	88		**Connect piping (16 Crew HR)**	86-68420	1	LS	$20,000.00	$20,000.00
	89		**Electrically connect HPU, power, & control boa**	86-68420	1	LS	$2,800.00	$2,800.00
			1 electician (10 HR)					
	90		**Fill and vent system (6 Crew HR)**	86-68420	1	LS	$4,000.00	$4,000.00
			Test system:					
	91		**Pressure test (6 Crew HR)**	86-68420	1	LS	$4,000.00	$4,000.00
	92		**Leak test Cylinder (6 Crew HR)**	86-68420	1	LS	$4,000.00	$4,000.00
	93		**Operational test (6 Crew HR)**	86-68420	1	LS	$4,000.00	$4,000.00
			SUBTOTAL THIS SHEET					**$71,800.00**

QUANTITIES		PRICES	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

230-kV Circuits Re-Alignment to HV Power Cables
Study
Electrical (8430)

PROJECT:
Central Valley
West San Joaquin Division, San Luis Unit

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
UNIT PRICE LEVEL: July 2016
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
			Part 1 - Furnish and Install (F&I):					
8430	94	Shared	**High Voltage Power Cable**	F&I	3,000	ln ft	$16.50	$49,500.00
8430	95	Shared	**High Voltage Cable Potheads**	F&I	4	ea	$4,900.00	$19,600.00
8430	96	Shared	**High Voltage Surge Arresters**	F&I	4	ea	$14,000.00	$56,000.00
8430	97	Shared	**Cable Trench for HV Power Cables**	F&I	1,000	ln ft	$59.00	$59,000.00
8430	98	Shared	**954 kcmil ACSR (Cardinal)**	F&I	333	ln ft	$11.50	$3,833.00
8430	99	Shared	**Insulator Assemblies**	F&I	8	ea	$1,900.00	$15,200.00
8430	100	Shared	**3/8-in 7-strand wire**	F&I	167	ln ft	$6.40	$1,067.00
8430	101	Shared	**500 kcmil bare stranded copper (ground) cable**	F&I	2,333	ln ft	$15.50	$36,167.00
			Part 2 - Remove and Dispose (R&D):					
8430	102	Shared	**954 kcmil ACSR (Cardinal)**	R&D	5,200	ln ft	$1.50	$7,800.00
8430	103	Shared	**3/8-in 7-strand wire**	R&D	2,400	ln ft	$1.50	$3,600.00
8430	104	Shared	**Insulator Assemblies**	R&D	18	ea	$100.00	$1,800.00
			Part 3 - Modify					
			Items under Part 2 could possibly be re-used for	Mod				
			items E1.5 thru 7					
			List as a savings but don't total					
			See 'Details' sheets for detailed item descriptions					
			SUBTOTAL THIS SHEET					**$253,567.00**

QUANTITIES		PRICES	
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Main Embankment Modifications (Most Probable)

(86-68313)

PROJECT:
Central Valley Project, Merced County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
UNIT PRICE LEVEL: July 2016
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		GENERAL NOTES:					
		The quantity estimates for this San Luis					
		Reservoir Expansion Feasibility Level Study					
		rely considerably on the quantity estimate					
		worksheets developed by URS as part of the					
		concurrent Safety of Dams Corrective Action					
		Study for B.F. Sisk Dam. Where URS is cited					
		on the subsequent sheets, refer to URS					
		Technical Memorandum No. VB-R14PD00522-30,					
		dated January 2016 for additional details. Unless					
		otherwise stated, assume details presented in the					
		URS TM apply to the quantity estimates in these					
		worksheets.					
		SUBTOTAL THIS SHEET					

QUANTITIES		**PRICES**	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED 05/15/20	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Main Embankment Modifications (Most Probable)

(86-68313)

PROJECT:
Central Valley Project, Merced County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	105	Shared	**Dewatering**		1	L.S.	$933,333.33	$933,330.00
			See URS Appendix B, Alt. 7, Pay Item 1					
	106	Shared	**Demolition**		1	L.S.	$35,000.00	$35,000.00
			See URS Appendix B, Alt. 7, Pay Item 2					
	107	Shared	**Stripping & Stockpiling Topsoil**		398	ac	$6,200.00	$2,467,600.00
			Stripping of Abutments, Existing Ground Beyond					
			Toe of Dam, Borrow Area 6, Construction Use					
			& Stockpiling Areas; Assume 12-inch depth of					
			Topsoil; No Clearing & Grubbing Req'd; Average					
			2-mile one-way haul to Borrow Area 6					
	108	Shared	**Stripping & Stockpiling Rock Blanket**		247,800	cy	$9.00	$2,230,200.00
			See URS Appendix B, Alt. 7, Pay Item 4					
	109	Shared	**Stripping & Stockpiling Zone 4 & 5**		45,467	cy	$8.70	$395,560.00
			See URS Appendix B, Alt. 7, Pay Item 5					
	110	Shared	**Unclassified Excavation**		613,667	cy	$6.30	$3,866,100.00
			Excavation below berms; No dam face					
			excavation required					
	111		**Zone 1A**	WCO	90,000	cy	$9.50	$855,000.00
			Excavate from Borrow Area 6					
			No processing required					
			2-mile one-way haul to dam					
			Placed in 8-inch loose lifts					
			Compacted by tamping sheepsfoot rollers					
	112		**Zone 4**	WCO	40,000	cy	$14.00	$560,000.00
			Upstream Bedding sourced from Basalt Hill;					
			Minus 8-inch rock fragments; processing					
			required; 2-mile one-way haul to dam; placed					
			in 12-inch lifts; compacted by crawler tractor					
			SUBTOTAL THIS SHEET					**$11,342,790.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Casey Arthur			
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Main Embankment Modifications (Most Probable)

(86-68313)

PROJECT:
Central Valley Project, Merced County, California

WOID: A999F **ESTIMATE LEVEL:** Feasibility
REGION: MP **UNIT PRICE LEVEL:** July 2016
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	113		**Zone 5 (Riprap)**	WCO	33,000	cy	$105.00	$3,465,000.00
			8-inch plus to 36-inch nominal dia. rock					
			Assume all 8-inch plus to 18-inch minus					
			material sourced from Basalt Hill (comprising					
			30 percernt of total Riprap volume); all rock					
			greater than 18-inch diameter sourced					
			from Commercial Source (comprising 70					
			percent of total Riprap volume)					
	114		**Zone 6**	WCO	441,000	cy	$62.00	$27,342,000.00
			Filter Sand & Gravel for Blanket Drain & Toe					
			Drain from Commercial Source (Assume haul is 50%					
			local & 50% long distance); Place in 18-inch loose					
			lifts; Compact by vibratory smooth drum roller					
	115		**Zone 7**	WCO	140,000	cy	$30.00	$4,200,000.00
			Drain gravel and cobbles from Basalt Hill;					
			Processing required; 2-mile one-way haul to					
			dam; Placed in 24-inch loose lifts; Compacted					
			by vibratory smooth drum roller					
	116		**Zone 8**	WCO	4,800,000	cy	$11.00	$52,800,000.00
			Miscellaneous Fill from Borrow Area 6 and					
			8-inch minus rock from Basalt Hill; Minimal					
			Processing required; 2-mile one-way haul to					
			dam; Placed in 12-inch loose lifts; Compacted					
			by tamping sheepsfoot rollers					
	117		**Zone 9A**	WCO	173,000	cy	$62.00	$10,726,000.00
			Filter Sand for Crackstopper from local					
			Commercial Source; Placed in 12-inch loose lifts;					
			Compacted by vibratory smooth drum roller					
	118		**Zone 9B**	WCO	155,000	cy	$32.00	$4,960,000.00
			Drain Gravel for Crackstopper from Basalt Hill;					
			Processing required; 2-mile one-way haul to					
			dam; Placed in 12-inch loose lifts; Compacted					
			by vibratory smooth drum roller					
			SUBTOTAL THIS SHEET					**$103,493,000.00**

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
Casey Arthur			
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Main Embankment Modifications (Most Probable)

(86-68313)

PROJECT:
Central Valley Project, Merced County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	119	Shared	**Rock Blanket Fill Placement from Stockpile/Borrow**		228,967	cy	$12.50	$2,862,080.00
			From Stockpile - 371,700 cy					
			No processing required; 2-mile one-way					
			haul to dam; Placed in 24-inch loose lifts;					
			No compaction requirement					
			From Basalt Hill - Remaining cubic yards					
			Processing required; 2-mile one-way					
			haul to dam; Placed in 24-inch loose lifts;					
			No compaction requirement					
	120	Shared	**Instrumentation**		1	L.S.	$1,666,666.67	$1,666,670.00
			See URS Appendix B, Alt. 7, Pay Item 19 and					
			Phase 2 Feasibility Corrective Action Study					
			Instrumentation Quantity Estimate					
			Worksheets					
	121	Shared	**Reclamation of Disturbed Areas**		374	ac	$7,100.00	$2,657,770.00
			Includes:					
			Borrow Area 6, Construction Use Areas,					
			Stockpiling Areas, Dikes, Boat Launch					
			Areas					
			See URS Appendix B, Alt. 7, Pay Item 20					
	122	Shared	**Asphalt**		38,333	sy	$29.00	$1,111,670.00
			Dam Crest, 20 ft Wide, Assume 4-inch thick					
			42,700 sy					
			From Sta. -4+00 to Sta. 188+00					
			Assume 1-ft-wide gravel shoulder each side					
			CA State Parks Roadways and Parking Areas					
			16,700 sy, Assume 4-inch thick					
			6,000 lin. feet of 25-ft-wide roadway					
			Assume 1-ft-wide gravel shoulder each					
			side					
			55,600 sy parking lots, Assume 4-inch thick					
			SUBTOTAL THIS SHEET					**$8,298,190.00**

QUANTITIES		**PRICES**	
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
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Miscellaneous Modifications (Most Probable)

(86-68313)

PROJECT:
Central Valley Project, Merced County, California

WOID: A999F
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		GENERAL NOTE:					
		The haul route distances for the various dikes					
		around San Luis Reservoir vary. The following					
		distances are approximate one-way haul on					
		Highway 152 from Borrow Area 6 to each dike.					
		West Dike (Pacheco Pumping Plant) - 15 to 16 miles					
		East Dike (just north of BF Sisk Dam) - 3.5 miles					
		Hwy 152 Dikes at Cottonwood Bay - 12 to 13 miles					
		Misc. Dikes (adj. to Hwy 152 on east side of					
		San Luis Reservoir) - 5 to 6 miles					
		SUBTOTAL THIS SHEET					**$0.00**

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Miscellaneous Modifications (Most Probable)

(86-68313)

PROJECT:
Central Valley Project, Merced County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
UNIT PRICE LEVEL: July 2016
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	123		**South Boat Ramp Extension**		200	ft	$700.00	$140,000.00
			Extend Boat Ramp in kind to Elevation 576 ft					
	124		**Pacheco Boat Ramp Extension**		2,000	ft	$700.00	$1,400,000.00
			Extend Boat Ramp in kind to Elevation 576 ft					
	125		**East Dike Zone 8**		500	cy	$37.00	$18,500.00
			22 ft U/S Raise; From Borrow Area 6					
	126		**East Dike Zone 6 - 22-ft U/S Raise**		200	cy	$79.00	$15,800.00
			Filter Sand from Commercial Source (Assume					
			haul is 50% local & 50% long distance)					
	127		**East Dike Zone 1A**		10,700	cy	$12.00	$128,400.00
			22 ft U/S Raise; From Borrow Area 6					
	128		**East Dike Zone 4**		3,200	cy	$46.00	$147,200.00
			22 ft U/S Raise; From Basalt Hill					
	129		**East Dike Zone 5 (Riprap)**		4,000	cy	$115.00	$460,000.00
			8-inch plus to 36-inch nominal dia. rock					
			Assume 30% of volume from Basalt Hill &					
			70% of volume from Commercial Source)					
	130		**West Dike Zone 8**		30,600	cy	$48.00	$1,468,800.00
			Misc. Material from Borrow Area 6					
	131		**West Dike Zone 6**		24,300	cy	$65.00	$1,579,500.00
			Filter Sand from Commercial Source (Assume					
			haul is 50% local & 50% long distance)					
	132		**West Dike Zone 7**		21,600	cy	$52.00	$1,123,200.00
			Drain gravel and cobbles from Basalt Hill					
	133		**West Dike Zone 1A**		182,500	cy	$32.00	$5,840,000.00
			From Borrow Area 6					
	134		**West Dike Zone 4**		24,100	cy	$56.00	$1,349,600.00
			Upstream Bedding sourced from Basalt Hill					
	135		**West Dike Zone 5 (Riprap)**		24,100	cy	$130.00	$3,133,000.00
			8-inch plus to 36-inch nominal dia. rock					
			Assume 30% of volume from Basalt Hill &					
			70% of volume from Commercial Source)					
			SUBTOTAL THIS SHEET					**$16,804,000.00**

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
Casey Arthur			
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FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Miscellaneous Modifications (Most Probable)

(86-68313)

PROJECT:
Central Valley Project, Merced County, California

WOID: A999F **ESTIMATE LEVEL:** Feasibility
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PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	136		**Misc. Dikes Zone 8; From Borrow Area 6**		61,200	cy	$44.00	$2,692,800.00
	137		**Misc. Dikes Zone 6**		48,600	cy	$64.00	$3,110,400.00
			Filter Sand from Commercial Source (Assume					
			haul is 50% local & 50% long distance)					
	138		**Misc. Dikes Zone 7**		43,200	cy	$42.00	$1,814,400.00
			Drain gravel and cobbles from Basalt Hill					
	139		**Misc. Dikes Zone 1A**		365,000	cy	$11.50	$4,197,500.00
			From Borrow Area 6					
	140		**Misc. Dikes Zone 4**		48,200	cy	$46.00	$2,217,200.00
			Upstream Bedding sourced from Basalt Hill					
	141		**Misc. Dikes Zone 5**		48,200	cy	$105.00	$5,061,000.00
			8-inch plus to 36-inch nominal dia. rock					
			Assume 30% of volume from Basalt Hill &					
			70% of volume from Commercial Source)					
	142		**Hwy 152 Dikes at Cottonwood Bay:**	**Addressed as part of Highway 152 Design Cost Estimate**				
			New embankments upstream & downstream					
			of Hwy 152 at Cottonwood Bay. Assume					
			approx. 2,000 linear foot length on north (D/S)					
			side of hwy and approx. 3,000 linear foot					
			length on south (U/S) side of hwy. Include					
			developing construction access from hwy &					
			traffic barriers to separate hwy traffic from					
			construction. Placement and compaction					
			requirements are unchanged from zones					
			within main embankment.					
			Zone 1A (from Borrow Area 6)		388,000	cy		Included in item 142
			Zone 4 (from Basalt Hill)		53,000	cy		Included in item 142
			Zone 5 (50% from Basalt Hill & 50%		53,000	cy		Included in item 142
			from Commercial Source)					
			Zone 6 (from local Commercial Source)		53,000	cy		Included in item 142
			Zone 7 (from Basalt Hill)		46,000	cy		Included in item 142
			Zone 8 (from Borrow Area 6)		66,000	cy		Included in item 142
			SUBTOTAL THIS SHEET					**$19,093,300.00**

QUANTITIES		**PRICES**	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED 05/15/20	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Toe Drains (Most Probable)

(86-68313)

PROJECT:
Central Valley Project, Merced County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
UNIT PRICE LEVEL: July 2016
INDEXTED TO: Jan 2020
FILE: C:\Users\carthur\Desktop\Contracts_052819\BF Sisk\Raise\Feasibility Study\Cost Estimate\[B.F.SiskDamRaise_QEW's_R2_Hwy152removed_092120_Rounded.xlsx]Miscellaneous (3 of 3)

PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	143	Shared	**Removal and disposal of existing 8-inch-diameter**		2,600	ft	$155.00	$403,000.00
			sewer pipe toe drain					
			Assume pipe can be disposed of in landfill					
	144	Shared	**Removal and disposal of existing 15-inch-dia.**		200	ft	$160.00	$32,000.00
			asbestos bonded perforated, G.M.P. toe drain					
			Assume disposal in hazardous waste landfill					
	145	Shared	**Excavation and stockpiling of existing crushed**		3,267	cy	$17.50	$57,170.00
			rock and graded sand surrounding pipe - total					
			excavated length is 14,000 feet					
			Assume can be reused as Zone 8 material					
	146	Shared	**Installation of new 15-inch-dia. perforated HDPE**		1,500	ft	$82.00	$123,000.00
			SDR 15 pipe					
	147	Shared	**installation of new 8-inch-dia. perforated HDPE**		4,333	ft	$69.00	$299,000.00
			SDR 15 pipe					
	148	Shared	**Installation of precast concrete manholes**		6	ea.	$20,000.00	$120,000.00
			Manholes will serve as inspection wells to					
			facilitate monitoring of new toe drains.					
			Assume average depth of 30feet.					
			SUBTOTAL THIS SHEET					**$1,034,170.00**

QUANTITIES		**PRICES**	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED 05/15/20	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**

FEATURE:
B.F. Sisk Dam Raise and Reservoir Expansion Project
10 ft RWS raise, Additional 10-ft Crest Raise, D/S Stability Berms
Most Probable Values

Estimator Added Items

PROJECT:
Central Valley Project, Merced County, California

WOID: A999F
ESTIMATE LEVEL: Feasibility
REGION: MP
UNIT PRICE LEVEL: July 2016
INDEXTED TO: Jan 2020
FILE: C:\Users\carthur\Desktop\Contracts_052819\BF Sisk\Raise\Feasibility Study\Cost Estimate\[B.F.SiskDamRaise_QEW's_R2_Hwy152removed_092120_Rounded.xlsx]Miscellaneous (3 of 3)

PLANT ACCOUNT	PAY ITEM	SHARED SOD ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	149		**Tower Crane**		1	LS	$12,000,000.00	$12,000,000.00
			Crane will be set-up on Outlet Structure					
			Tower 3. Towers 1,2 and 4 will be raised					
			and the crane will be moved from Tower 3					
			to Tower 4. Tower 3 will then be raised.					
	150		**Intake Tower/Pier Support**		1	LS	$7,600,000.00	$7,600,000.00
			The floating barge will be loaded at the Pacheco					
			Loading Dock and tugged to the Outlet Structure					
			This items includes the price of tug boats, a barge,					
			stair tower and a crane.					
	151	Shared	**Site Security and Fencing**		1	LS	$1,400,000.00	$1,400,000.00
			The high trafficed area will need to have additional					
			site security and fencing around the equipment and construction site.					
			A more detailed plan of fencing and security will be					
			necessary as the scope of the project progresses.					
	152	Shared	**Haul Road Construction**		8	Miles	$240,000.00	$1,920,000.00
	153	Shared	**Eroision Control**		1	LS	$4,000,000.00	$4,000,000.00
			SUBTOTAL THIS SHEET					**$26,920,000.00**

QUANTITIES		PRICES	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED 05/15/20	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**

FEATURE: Field Cost Summary Sheet

Summary Sheet

PROJECT: Central Valley Project, Merced County, California

WOID: A999F **ESTIMATE LEVEL:** Feasibility

REGION: MP **UNIT PRICE LEVEL:** July 2016

INDEXTED TO: Jan 2020

FILE: C:\Users\carthur\Desktop\Contracts_052819\BF Sisk\Raise\Feasibility Study\Cost Estimate\[B.F.SiskDamRaise_QEW's_R2_Hwy152removed_092120_Rounded.xlsx]Miscellaneous (3 of 3)

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Sheet 1					$45,490.00
		Sheet 2					$8,304.00
		Sheet 3					$623,016.00
		Sheet 4					$21,987.00
		Sheet 5					$503,819.00
		Sheet 6					$296,740.00
		Sheet 7					$1,966,852.00
		Sheet 8					$3,481,900.00
		Sheet 9					$1,669,050.00
		Sheet 10					$4,048,000.00
		Sheet 11					$24,003,807.50
		Sheet 12					$323,175.00
		Sheet 13					$250,000.00
		Sheet 14					$4,107,000.00
		Sheet 15					$1,613,700.00
		Sheet 16					$193,700.00
		Sheet 17					$253,250.00
		Sheet 18					$71,800.00
		Sheet 19					$253,567.00
		Sheet 20					$0.00
		SUBTOTAL THIS SHEET					**$43,735,157.50**

QUANTITIES		PRICES	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED 05/15/20	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**

FEATURE: Field Cost Summary Sheet	**PROJECT:** Central Valley Project, Merced County, California
	WOID: A999F **ESTIMATE LEVEL:** Feasibility
	REGION: MP **UNIT PRICE LEVEL:** July 2016 **INDEXTED TO:** Jan 2020
	FILE: C:\Users\carthur\Desktop\Contracts_052819\BF Sisk\Raise\Feasibility Study\Cost Estimate\[B.F.SiskDamRaise_QEW's_R2_Hwy152removed_092120_Rounded.xlsx]Miscellaneous (3 of 3)

Summary Sheet

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal (from previous sheets)					$43,735,157.50
		Sheet 21					$11,342,790.00
		Sheet 22					$103,493,000.00
		Sheet 23					$8,298,190.00
		Sheet 24					$0.00
		Sheet 25					$16,804,000.00
		Sheet 26					$19,093,300.00
		Sheet 27					$1,034,170.00
		Sheet 28					$26,920,000.00
							$0.00
		Subtotal					**$230,720,610.00**
		Cost Indexing from Unit Price Level (July 2016) to Current (Jan 2020)					
		Earth Dam Constuction Cost Trends	1.11				**$255,977,010.00**
		Mobilization	5%	+/-			$12,800,000.00
		Subtotal with Mobilization					**$268,777,010.00**
		Contract Cost Allowances (Sum of):	18%	+/-			$48,400,000.00
		Design Contingencies, 15% (+/-)					
		APS, 3 % (+/-). Type of procurement: Request for Proposal					
		CONTRACT COST					**$317,177,010.00**
		Construction Contingencies	20%	+/-			$63,500,000.00
		FIELD COST (Unit Price Level Jul 2021)					**$380,677,010.00**
		Escalation to Notice to Proceed (NTP), from Current Price Level (Jan 2020) to NTP (July 2026)					$87,000,000.00
		at	3.5%	per year for	6.50	years	
							$467,677,010.00
		Escalation to Mid-Point Construction, from NTPl (July 2026) to Mid-Point (Jan 2028)					$24,600,000.00
		at	3.5%	per year for	1.50	years	
		FIELD COST (with Indexing, Escalation to NTP & mid-point Construction, Price Level jan 2028)					**$492,277,010.00**
		Non-Contract Costs		**To be determined by the appropriate responsible office**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible office**			
		Ref.: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03.					

QUANTITIES		PRICES	
BY Casey Arthur	**CHECKED**	**BY**	**CHECKED**
DATE PREPARED 05/15/20	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**

B.F. Sisk Dam Raise and Reservoir Expansion Project

Final Feasibility Report

Appendix B2: State Route 152 Modifications Design Report

BUREAU OF RECLAMATION

SAN LUIS & DELTA-MENDOTA WATER AUTHORITY

December 2020

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Feasibility Design Report – SR 152 Modifications

B.F. Sisk Dam Raise and Reservoir Expansion Project, California
California Great Basin Region

Prepared under the direction of:

Robert Fosse, CA Registered Civil Engineer No. 44724
Stephen L. Whiteside
E. Onur Tastan

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Attachment C Calculations
Attachment D Cost Estimate
Attachment E Construction Schedule

Chapter 1 Introduction and Project Overview

1.1 Introduction

This report summarizes the feasibility-level design of the proposed modifications at the State Route (SR) 152 crossing of Cottonwood Bay. These modifications are a necessary component of the larger B.F. Sisk Dam Raise and Reservoir Expansion Project under development by the U.S. Department of the Interior (DOI), Bureau of Reclamation (Reclamation), and the San Luis & Delta-Mendota Water Authority (SLDMWA). Reclamation is evaluating this project as a connected action to the B.F. Sisk Dam Safety of Dams (SOD) Modification Project to create additional project benefits by increasing storage within San Luis Reservoir. SLDMWA is the lead state agency for the Feasibility Report and Environmental Impact Report (EIR) pursuant to the California Environmental Quality Act (CEQA) and Reclamation is the lead federal agency for the Feasibility Report and Supplemental Environmental Impact Statement (SEIS), pursuant to the National Environmental Policy Act (NEPA). The overall Feasibility Report effort will be developed consistent with the Reclamation Manual Directives and Standards (FAC TRMR-95) *Developing Additional Project Benefits in Conjunction with a Safety of Dams Modification Project* (2019) (2019 Directives and Standards).

1.2 B.F. Sisk Dam

B.F. Sisk Dam was constructed to create the off-stream San Luis Reservoir, which provides supplemental storage capacity for the Central Valley Project (CVP) and State Water Project (SWP). Currently, San Luis Reservoir provides 2,027,840 acre-feet of water storage for the CVP and SWP. The water stored in the reservoir is managed for federal (45 percent) and state (55 percent) uses as part of the CVP and SWP, respectively. Typically, during the winter and early spring, water conveyed from the Delta in the Delta-Mendota Canal (DMC) (a CVP facility) and California Aqueduct (an SWP facility) is lifted from O'Neill Forebay into San Luis Reservoir for storage using the pump-turbines in the Gianelli Pumping-Generating Plant (see **Figure 1-1**). Later in the year, when CVP and SWP demands increase, water is released from San Luis Reservoir through O'Neill Forebay and is conveyed via the DMC or the San Luis Canal/California Aqueduct for use by water users (Reclamation 2019). As water is released back through the Gianelli Pumping-Generating Plant, the plant generates hydropower, which is used to offset the energy demand of the project operations. Water is also diverted from the west side of San Luis Reservoir at the Pacheco Pumping Plant to supply water to two CVP contractors—the Santa Clara Valley Water District (Valley Water) and the San Benito County Water District (SBCWD) (Reclamation 2019). In addition to storing and supplying water, San Luis Reservoir provides recreation opportunities.

The B.F. Sisk Dam SOD Modification Project is a federal project that has the potential to influence water supply conditions in San Luis Reservoir. In 2006, Reclamation completed a risk analysis of B.F. Sisk Dam that concluded there is justification to take action to reduce risk to the downstream

public from a potential severe earthquake. Consequently, Reclamation, in coordination with the California Department of Water Resources (DWR), completed a corrective action study in December 2019. The Crest Raise Alternative, one of the alternatives evaluated in the study that would reduce the dam safety risk, was selected to be implemented. Raising the crest elevation 12 feet would increase the distance between the water surface and the dam crest (freeboard) to prevent reservoir overtopping and failure in the event of dam deformation from a seismic event. The Crest Raise Alternative does not provide for any additional storage.

The Reclamation Safety of Dams Act of November 2, 1978 (SOD Act) (43 U.S.C. §506 et seq.), was amended by P.L. 114-113 to include authority for Reclamation to develop additional project benefits in conjunction with an SOD modification. Pursuant to Section 5.B. of the SOD Act, as amended, Reclamation must determine that additional project benefits are necessary and in the interest of the United States prior to developing any additional project benefits, consistent with Reclamation law. Furthermore, it must be determined that the development of additional project benefits will not negatively impact the SOD Modification Project.

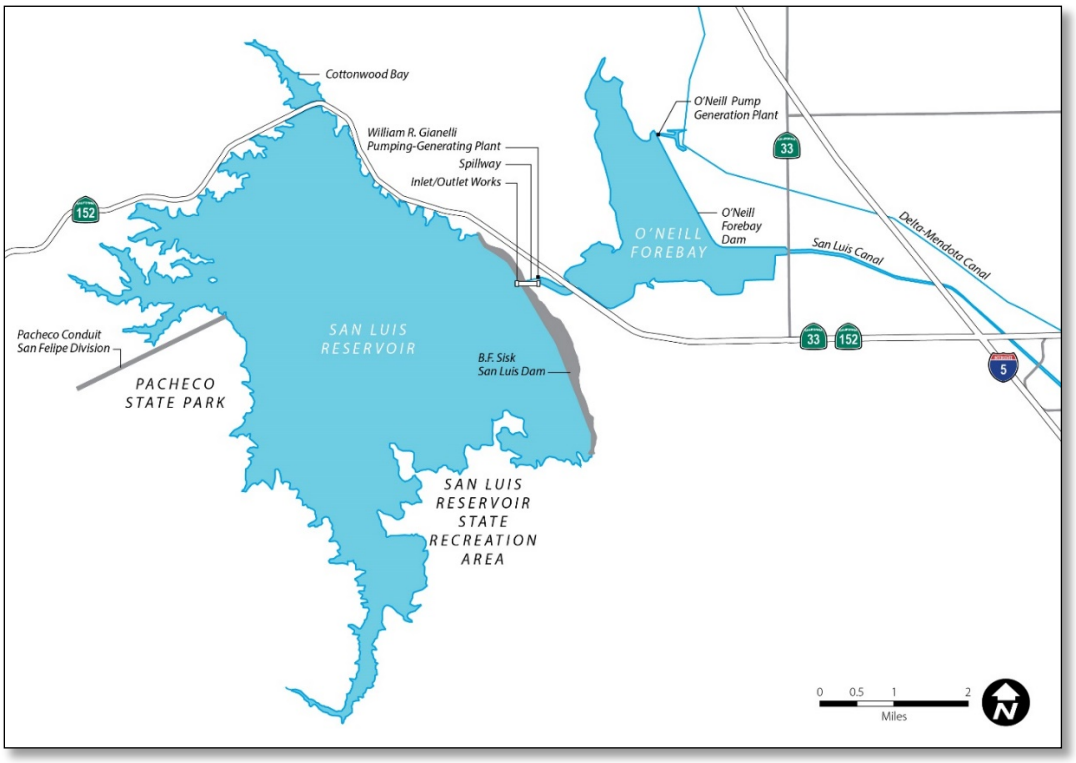


Figure 1-1. San Luis Reservoir and Associated Facilities

1.3 B.F. Sisk Dam Raise and Reservoir Expansion Project

As a connected action to the B.F. Sisk SOD Modification Project, Reclamation and SLDMWA seek to evaluate an increase in storage capacity of the San Luis Reservoir. The increased storage capacity would be achieved by an additional 10-foot raise of the B.F. Sisk Dam embankment across the entire dam crest above the level proposed for dam safety purposes. This additional 10 feet of dam

embankment could add approximately 130,000 acre-feet (AF) of water storage to San Luis Reservoir. SLDMWA, in coordination with Reclamation, is conducting a feasibility study to evaluate the Proposed Action and a potential cost-share in accordance with the Reclamation SOD Act, and the Water Infrastructure Improvements for the Nation (WIIN) Act (P.L. 114-322) §4007.

In support of a previous project, the San Luis Low Point Improvement Project (SLLPIP) Feasibility Study, Reclamation's Technical Services Center (TSC) initiated work on feasibility-level designs for the modifications required at B.F. Sisk Dam and the dike that protects the Pacheco Pumping Plant on the west side of the reservoir at high storage elevations. In support of this San Luis Reservoir Expansion Project Feasibility Study, the TSC will be finalizing those feasibility-level designs and cost estimates.

During this preliminary design work, the TSC noted potential impacts to SR 152 along the northern edge of the reservoir. Specifically, the potential need for modifications to those roadway sections and embankments to protect them against higher storage levels, as indicated in **Figure 1-2.**

The reservoir capacity expansion would raise the reservoir high-water level 10 feet to 554 feet. Raising the maximum surface elevation to 554 feet impacts SR 152 at two locations northwest of B.F. Sisk Dam, as shown in Figure 1-2. The location indicated as Levee is an embankment that is approximately 1900-feet-long and more than 100-feet-high at the center.

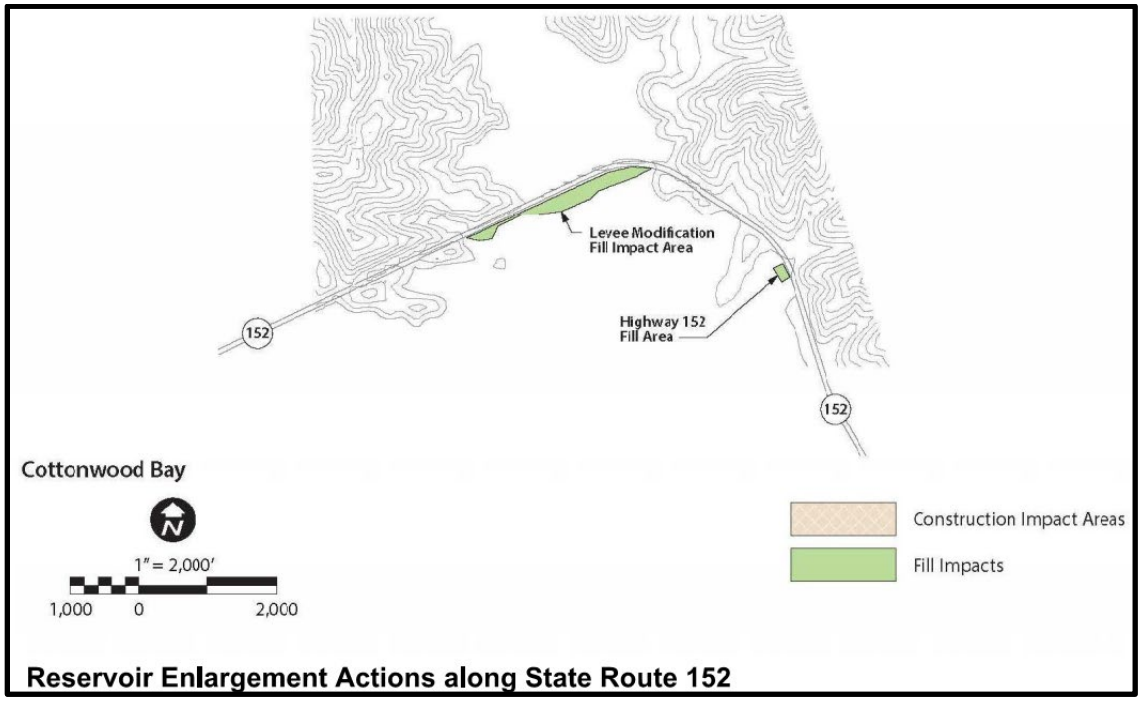


Figure 1-2. Reservoir Enlargement Actions along SR 152

1.4 Purpose of the Feasibility Design Report

This Feasibility Design Report presents the information developed to support a feasibility-level design and cost estimate for necessary modifications to SR 152 potentially impacted by the increased maximum reservoir storage elevation in the area near Cottonwood Bay. This Feasibility Design Report includes a description of the existing facilities and a description of proposed geotechnical, civil, and structural improvements included in the Alternative. It also includes information related to construction of, operation and maintenance of, and costs associated with the proposed improvements.

Chapter 2 Existing Conditions

2.1 Project Location Overview

B.F. Sisk Dam, also known as San Luis Dam, forms San Luis Reservoir, which is located between Los Banos and Gilroy, California, along Pacheco Pass in Merced County. Although the dam was constructed and is owned by Reclamation, the DWR operates the facilities, and the California Department of Parks and Recreation manages the recreational resources associated with San Luis Reservoir. San Luis Reservoir serves as an off-stream reservoir for Reclamation's CVP and DWR's SWP. B.F. Sisk Dam is an earth-filled gravity embankment dam with a crest height of 382 feet and an overall length of approximately 3.5 miles. Completed in 1967, San Luis Reservoir is the largest off-stream reservoir in the United States, with a capacity of 2,041,000 AF.

2.2 Overview of Existing Roadway

SR 152 is a state highway that runs east from near the middle of California SR 1 in Watsonville to SR 99 in the southeast part of Merced County. Its western portion (which is also known as Pacheco Pass Road and Pacheco Pass Highway) provides access to and from Interstate 5 toward Southern California for motorists in or near Gilroy, San Jose and the rest of Silicon Valley.

In the vicinity of San Luis Reservoir, SR 152 is a four-lane divided expressway that descends down toward the east from the Pacheco Pass summit, along the northern and eastern shore of the reservoir. The route then passes between the San Luis Dam and the O'Neill Forebay at the eastern base of the dam.

A portion of SR 152 at the northern edge of the reservoir crosses Cottonwood Creek with a fill embankment that creates Cottonwood Bay to the north.

2.3 Available Caltrans As-Builts

Caltrans provided construction as-built drawings from 1975 that contain roadway plan and elevation profiles, cross sections, and details (Attachment A). At this time, there are no other data available regarding site excavation, grading, or site-specific subsurface data, including the characterization of the embankment fill material.

A review of the available Caltrans construction as-built drawings indicates that the existing SR 152 roadway elevation at the top of the fill embankment ranges from approximately Elevation (El)555 to El 560. The existing embankment has 2 Horizontal : 1 Vertical (2H:1V) slopes on both sides with rock riprap and filter (permeable granular material) layers.

The embankment is bisected by two reinforced concrete pipe (RCP) culverts, a 24-inch-diameter Class 3 RCP at El430 feet and a 60-inch-diameter Class 4 RCP at El 450, hydraulically connecting Cottonwood Bay and Cottonwood Creek with San Luis Reservoir to maintain the water levels at the same elevation. The culverts also have reinforced concrete debris rack structures with steel grates at each end.

2.4 Geology, Seismicity, and Soils

California is divided into 11 defined geologic regions, called geomorphic provinces. The San Luis Reservoir and Cottonwood Bay are near the boundary of the Great Valley (San Joaquin Valley portion) and the Coast Ranges geomorphic provinces (CGS 2002a).

The boundary between these two provinces is roughly marked by the Ortigalita fault and the O'Neill fault system that pass underneath and to the south of the San Luis Reservoir and O'Neill Forebay (Jennings and Bryant 2010; USGS 2011). The Ortigalita fault separates bedrock units of the upper Cretaceous marine and Plio-Pleistocene nonmarine and the recent overlying fan and basin deposits of the Great Valley (located to the east of the fault) from the upper Jurassic/lower Cretaceous Franciscan Complex bedrock units that make up the Diablo Range portion of the Coast Ranges Province (located to the west of the fault) (Dibblee 1975, Rogers 1966). These and other geologic units in the San Luis Reservoir region are described in more detail below. Faults and other potential geologic hazards in the region are described in more detail in Section 2.4.2.

The San Luis Reservoir State Recreation Area Resource Management Plan/General Plan Environmental Impact Assessment/Environmental Impact Report (EIS/EIR) describes the four geologic formations in the area around San Luis Reservoir. These include:

1. **Franciscan Formation:** This formation is along the entire western side and southern tip of the reservoir's shoreline. This rock formation is the oldest in western Merced County and is composed of a thick assemblage of sedimentary, igneous, and metamorphic rocks. The sedimentary rocks consist of sandstone, shale, chert, and small amounts of conglomerate.
2. **Panoche Formation:** This formation is along most of the eastern shore of the San Luis Reservoir with some intrusion of the Plio-Pleistocene nonmarine and fan deposits of the Great Central Valley. The formation consists of arenaceous shale and thinly bedded sandstone, approximately 25,000-feet-thick. The sedimentary sequence of the formation consists of lenses of coarse-grained conglomerate of boulders, cobbles, and pebbles of porphyritic and granite rock.
3. **Tulare Formation:** This formation is mainly on the shore of O'Neill Forebay and adjacent to the forebay dam. The formation varies in depth from 8 to 42 feet and overlies all of the older formations. In addition, the central portion of the B.F. Sisk Dam is founded in the Tulare formation. The formation is approximately 150-feet-thick below the maximum section of the B.F. Sisk Dam. The Tulare formation consists of nonmarine gravel, sand, and silt, and is derived from rocks from the Franciscan formation. Stream terraces are also found in this formation. Briggs (1953 as cited in Herd 1979) also noted a dark-gray- to light-gray-colored diatomaceous clay in the O'Neill Forebay area.

4. **Tertiary Volcanic Formation:** This formation is along the eastern and western shores of San Luis Reservoir and occurs in small scattered deposits. Volcanic rocks are interspersed with andesite (pink and gray), rhyolite (white to gray), and limonite (dark gray to black basalt). There is a remnant basalt flow at Basalt Hill just south of the Basalt Use Area. The hill is thought to have been the vent from which the basalt extruded. Fan deposits occur principally on the eastern shore of O'Neill Forebay. Recent alluvium conceals all older formations along the western side of the San Joaquin Valley.

2.4.1 Soils

This section describes the soil associations and properties of soils in the vicinity of the San Luis Reservoir.

There are several soil associations that occur around the San Luis Reservoir. The Resource Management Plan/General Plan for the San Luis Reservoir SRA describes that Denverton, Kettleman, and Altamont clay associations occupy 2,650 acres of the lands surrounding the reservoir (Bureau of Reclamation [Reclamation], and California Department of Parks and Recreation [CDPR] 2013). Rough stony land is the second most common soil type in the reservoir area, occupying approximately 2,000 acres mostly on the western side of the reservoir.

Other minor soil associations include the Rincon-Pleasanton association comprised of Pleasanton gravelly sandy loam, Los Banos clay loams, Rincon clay, and Rincon loam; Altamont-Kettleman loam to the northeast shore of O'Neill Forebay; Sobrante, Vallecitos, and Contra Costa loams; Herdlyn clay loam and Solano silt loam; Herdlyn clay loam on the southern and eastern shores of O'Neill Forebay; and Sorrento, Mocho, and Esparto loams in scattered areas at the reservoir (Reclamation and CDPR 2013).

The reservoir area Resource Management Plan/General Plan also indicates that the majority of developed lands in the vicinity of the reservoir, including most recreation areas, have slight or moderate erosion potential. Many of the undeveloped areas along the western, northern, and southern shorelines are categorized as having severe erosion hazard.

2.4.2 Geologic Hazards

San Luis Reservoir is in a seismically active area and is close to several faults and fault systems. The Ortigalita fault passes under the reservoir in two locations—one is along the western shore of the reservoir crossing over Lone Oak Bay to the east and the other runs from Cottonwood Bay close to the eastern shore of the reservoir on the eastern side of Basalt Hill (Reclamation and CDPR 2013 and USGS 2011). A detailed geologic study to characterize all the potential seismic sources[1] in the area of B.F. Sisk and O'Neill Forebay Dams was conducted by Reclamation in 1999 and 2000. That study identified nine faults as being potentially significant sources of seismic shaking, including:

- Strike-slip faults of the Ortigalita and San Andreas faults

[1] CGS describes seismic sources (faults) as (1) Active, which describe historical and Holocene faults with displacements within the past 11,000 years; (2) Potentially Active, which describes faults with evidence of displacements during the Quaternary (the past 1.6 million years); (3) Inactive, which are pre-Quaternary age. Seismic events and displacements may still take place along an inactive fault; however, the chances of that happening are considered low.

- West-dipping, bedding-plane, reverse faults within the Great Valley Sequence
- West-dipping, blind thrust faults along the uplift margin of the Diablo Range (Reclamation 2009)

Located in the eastern part of the San Andreas Fault system, the Ortigalita Fault in the vicinity of the reservoir has two sections—the Los Banos Valley section and the Cottonwood Arm section (roughly corresponding to the locations described above [USGS 2011 and Bryant and Cluett 2000a]). The Los Banos Valley section is in Merced County. Bryant and Cluett (2000b) do not report any recent (historic) earthquakes and the most recent prehistoric deformation (defined as the most recent prehistoric surface rupturing or surface deforming earthquake) was the latest Quaternary (approximately 15,000 years ago). The Cottonwood Arm section is in Merced and Stanislaus Counties. There are no records of recent earthquake activity along this section of the Ortigalita fault zone. The most recent prehistoric deformation was approximately 15,000 years ago (Bryant and Cluett 2000a).

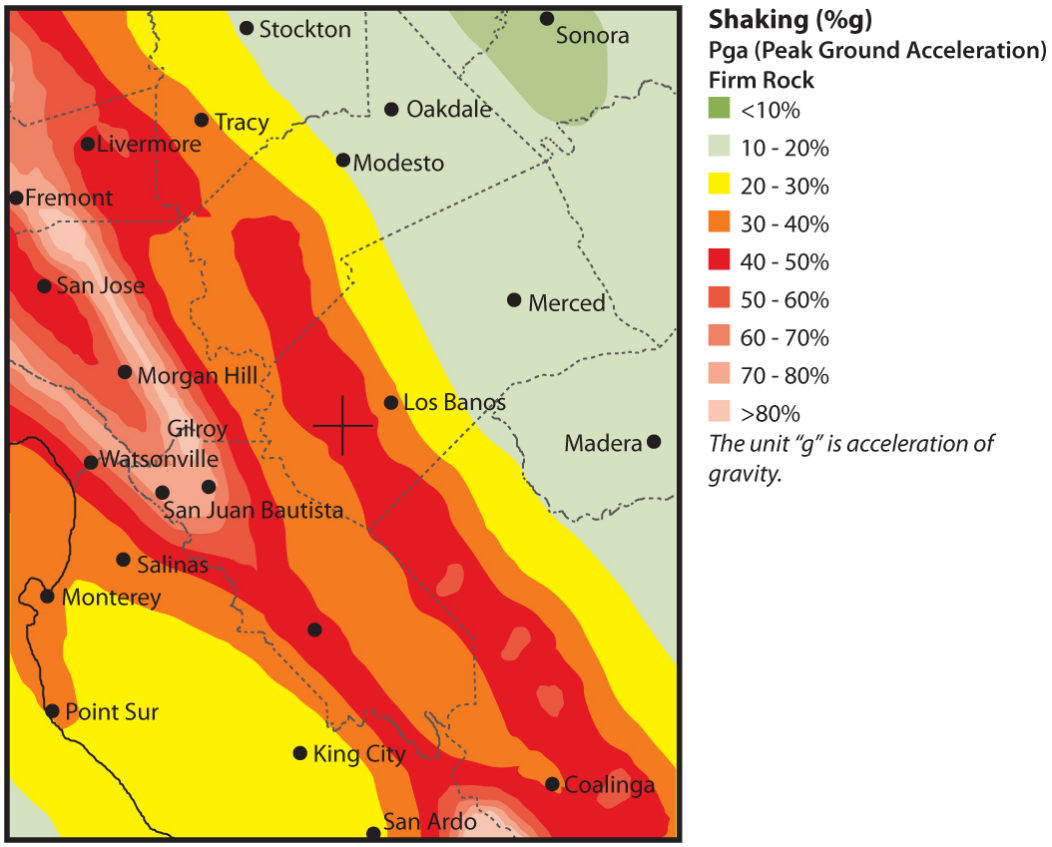
The O'Neill Fault System runs south and east of O'Neill Forebay and south of San Luis Reservoir (USGS 2011). The most recent prehistoric deformation at this fault system was approximately 130,000 years ago (USGS 2011).

The Calaveras and San Andreas faults are 23 and 28 miles away, respectively (Reclamation and CDPR 2013). These faults can cause earthquakes at or near San Luis Reservoir, given that fault offsets can take place along either single- or multiple-fault planes. During a seismic event, secondary fault rupture and displacements can take place on neighboring faults that have been previously considered less than active.

The CGS publishes maps of the probabilistic seismic hazards in the state. **Figure 2-1** shows the probabilistic seismic ground shaking in Merced County near San Luis Reservoir, where the peak ground acceleration in firm rock in the area of the reservoir is approximately 0.4 g ("g" is the acceleration of gravity). As illustrated in the figure, in the case of an earthquake, the western part of Merced County would be subject to higher ground shaking than the eastern part of the county. This peak acceleration has a 10 percent probability of being exceeded in 50 years, corresponding to the return period of 475 years.

The 2007 Working Group on California Earthquake Probabilities developed earthquake rupture forecasts to predict the likelihood of a magnitude 5 or greater earthquake occurring in the next 30 years (USGS, DOC, and CGS 2008).

Table 2-1 summarizes the group's findings relative to Type A faults (defined as faults known to be active) in the area of analysis.



Source: CGS 2012a.

Figure 2-1. Site peak ground acceleration – Merced County

Table 2-1. 30-Year Probability of 6.7-Magnitude Events on Type A Faults

Fault	Mean Probability
South San Andreas	59%
Calaveras	7%

Source: USGS and CGS 2008

Based on the information available from the USGS, The Ortigalita Fault Zone's Ortigalita-Cottonwood Arm Section (**Figure 2-2**) traverses through the SR 152 embankment foundation.

For the return period of 975 years, the seismicity at the SR 152 embankment section is high with the peak ground acceleration (PGA) of 0.77 g calculated with the Caltrans ARS 3.0.1 tool. The reported PGA is obtained from probabilistic methods, and the deterministic approach is no longer supported by the Caltrans' ARS tool.



Figure 2-2. Location of the fault traversing through the SR 152 Embankment

Landslides are common within the Coast Ranges, specifically the west side of Merced County because of steep slopes, unstable terrain, and proximity to earthquake faults (Merced County 2013). As mapped by the county, the eastern portion of San Luis Reservoir, including O'Neill Forebay, is in a low potential landslide zone, while the western portion of the reservoir is in a medium potential landslide zone (Merced County 2013).

There are no reported asbestos occurrences, former asbestos mines, or former asbestos prospects mapped in Merced County.

Chapter 3 Proposed Improvements

3.1 B.F. Sisk Dam Modifications

B.F. Sisk Dam was constructed to create the off-stream San Luis Reservoir that provides supplemental storage capacity for the CVP and SWP. With the modifications to Sisk Dam, as described in Chapter 1, the San Luis Reservoir Expansion Alternative would be completed by placing additional fill material on the dam embankment to raise the dam crest to increase storage capacity. The expanded capacity in San Luis Reservoir would be shared with 45 percent assigned to the CVP and 55 percent assigned to the SWP. This split is consistent with the existing storage capacity allotment in San Luis Reservoir.

The Dam Raise Alternative would build on the physical modifications proposed in the B.F. Sisk SOD Modification Project to raise the dam crest an additional 10 feet to a new crest elevation of 576 feet. This additional 10 feet in embankment height would support a new water surface elevation of 554 feet and an additional 130 thousand-acre-feet (TAF) in storage capacity. In addition to the 10 feet in new embankment height added by the reservoir expansion, the existing intake towers and access bridge would need to be raised to match the height of the new dam crest.

As part of this alternative, the dam crest would be raised by adding additional embankment material, stability berms, and downstream crack filters. With increased reservoir surface elevations, modifications would also be made at multiple locations along SR 152 to prevent inundation of the roadway when the enlarged reservoir is filled to capacity, modifications to the Dinosaur Point Boat Launch and Goosehead Point Boat Launch would be made to increase the ramps' operating elevation by 10 feet, and the crest of an existing berm developed during construction of the Pacheco Pumping Plant would be raised to protect the plant against high storage levels.

3.2 SR 152 Embankment at Cottonwood Bay Modifications

As noted above, during preliminary design work for the Sisk Dam modifications, the TSC noted potential impacts to SR 152 along the northern edge of the reservoir. Specifically, the potential need for modifications to those roadway sections and embankments to protect them against higher storage levels, as indicated in Figure 1-2.

The reservoir capacity expansion would raise the reservoir high-water level 10 feet to El 554. Raising the reservoir elevation to El 554 impacts SR 152 at two locations northwest of B.F. Sisk Dam, as shown in Figure 1-2. The location indicated as Levee is an embankment that is approximately 1,900-feet-long and is higher than 100 feet at the center (hereafter referred to as SR 152 Embankment).

If the reservoir maximum surface elevation were raised to El 554, the roadway surface would be only 1 foot above the proposed high-water level, and there would not be enough freeboard to protect against wave action.

Modifications to the SR 152 Embankment are evaluated as part of this Feasibility Design Report.

3.3 SR 152 East Overlook Modifications

There is an overlook area (referred to as East Overlook Area) consisting of a parking lot built on a slope to the east of the Cottonwood Bay embankment where there is a need for additional modifications to the reservoir slope protection from higher storage levels. This area lies adjacent to the western edge of SR 152 and a small turnout parking area. The elevation of the roadway does not need to be modified to raise the freeboard. Additional fill and rock slope protection is required on the eastern slope of the reservoir to protect against wave action from the higher reservoir levels. Modifications to this area are also part of this Feasibility Design Report.

Chapter 4 Detailed Design Considerations

This chapter identifies considerations for the project, which are described in detail in Section 4.4 Engineering Analyses.

4.1 Design Requirements

The following is a summary of the design requirements

- **Sufficient freeboard**

  The existing SR 152 embankment riprap rock slope protection on the slope of the embankment extends up to a minimum of 5 feet above the current high-water level at El 544 feet. The proposed embankment alternatives and modifications will need to evaluate the rock slope protection requirements above the proposed high-water level of El 554 feet, including protecting against wave action.

- **Static and seismic stability**

  Slope stability of the existing and proposed embankment slopes will be evaluated for both static and seismic (pseudo-static conditions).

- **Maintain culverts**

  The existing 24- and 66-inch-diameter RCP culverts connecting Cottonwood Bay and San Luis Reservoir will need to be maintained and extended for the proposed embankment slope modifications.

- **Filter zones for riprap**

  The existing embankment slopes have pervious material filter zones between the embankment fill and the riprap rock slope protection that extend up to the current high-water level of El 544 feet. The proposed embankment modifications will evaluate the required extension of the filter level for the proposed high-water level of El 554 feet. Filter layers will also serve as bedding layer for the riprap.

- **Caltrans design requirements**

  The proposed embankment geometry highway elevation, slope, and curve radius will need to be designed in conformity with the current version of the Caltrans Highway Design Manual and other traffic requirements.

4.2 Data Collection

The following background data, reports, and plans were evaluated during preparation of this report.

- **Caltrans**

  As discussed above, Caltrans provided construction as-built drawings from 1975 that contain roadway plan and elevation profiles, cross sections, and details. At the time of this report, Caltrans has not provided additional information on the embankment, including previous geotechnical explorations, analyses, and characterization of the embankment structural fill material.

- **Reclamation**

  Reclamation provided several background reports for the project vicinity, including:

  - Draft Alternatives Report for the B.F. Sisk Dam Corrective Action Study, Environmental Impact Statement/Environmental Impact Report (April 2017)
  - B.F. Sisk Dam Safety of Dams Modification Project, Draft Environmental Impact Statement/Environmental Impact Report (April 2019)
  - B.F. Sisk Dam Safety of Dams Modification Project, Final Environmental Impact Statement/Environmental Impact Report (August 2019)
  - San Luis Low-Point Improvement Project Feasibility Report (August 2017)
  - Reclamation Manual, Design Data Collection Guidelines, Chapter 3 – Feasibility Designs (September 2007)

- **Geologic Data**

  There are many available geologic maps and reports for the project vicinity posted online by the California Geologic Survey (CGS) Department of Conservation, United States Geological Survey (USGS), and other websites.

- **Drone Survey**

  A Drone-based survey was conducted on February 12, 2020 for the areas of interest and is discussed further in Section 4.2.1.

4.2.1 Drone Topographic Survey and Civil Design

A drone-based survey was conducted on February 12, 2020 for the areas of interest. The survey was conducted using a Phantom 4 RTK drone and D-RTK 2 base station in conjunction with Propeller Aeropoints placed throughout the flight area.

As the drone is flown, it collects real-time error-correcting information from the base station, which is geotagging each image. The drone data are first processed with just the image data and then those results are reprocessed using the data captured by the Aeropoints as ground control points around the site to improve the coordinate location and further tighten up the results.

The extent of the drone imagery for the embankment area is shown in **Figure 4-1.** Drone survey also covered the East Overlook Area. Contours outside this area, and below the water level, were generated using historical maps and Google Earth imagery. Conducting comprehensive topographic surveying is recommended for the next phases of the design. The surveying should also include bathymetric surveys that map the bottom elevation of the reservoir at a maximum grid size of 10 feet.



Figure 4-1. Area of drone imagery for the surveying of the embankment area

4.3 Alternatives Development and Evaluation

Four alternatives (**Table 4-1**) were considered to provide a stable embankment when subjected to the reservoir water level raise. Based on the results of the wave runup and freeboard analyses, it was determined that the embankment crest needed to be raised approximately 10 feet to El 565. The following four alternatives were considered:

1. Alternative 1: Place additional fill material to raise the embankment crest elevation approximately 10 feet without changing the width of the roadway. The slopes would be flattened to 3H:1V using riprap on both sides to increase seismic stability (**Figure 4-2**).
2. Alternative 2: Install wave protection walls on both sides of the roadway at the existing elevation of the embankment. For seismic stability, a riprap buttress would be placed at the toes of the embankment slopes (**Figure 4-3**). The roadway surface be raised 2 feet above the proposed high-water level to approximately El 557.
3. Alternative 3: Construct a new roadway embankment against the Cottonwood Bay side of the existing roadway embankment.
4. Alternative 4: Construct a new roadway embankment against the San Luis Reservoir side of the existing roadway embankment.

Table 4-1 summarizes the advantages, disadvantages, and approaches to reduce issues for each of the alternatives.

Three representative cross-sections are provided in Attachment B, and as Sheets C-3 and as C-3A, for Alternatives 1 and 2, respectively.

Table 4-1. Considered Alternatives for Raising the SR 152 Embankment

Description	Advantages	Disadvantages	How to Address Issues
Alternative 1 • Flatten embankment slopes to 3H:1V using riprap placed or dumped underwater. Riprap construction would be performed from the water. • Raise embankment crest to provide enough freeboard. • Roadway would be shut down in two stages.	• Cofferdam is not needed.	• Highway needs to be shut down in two stages to raise the embankment.	
	• Existing riprap is left in place.	• Placing additional riprap underwater.	• Considered feasible, should confirm with a contractor. Consider using barge for lake side and barge and conveyor for bay side.
	• Riprap volume less than Alternatives 3 and 4.	• Need to extend culverts and debris guard and outlets using underwater construction.	• Underwater construction including divers on lake side. Possibly can do it in the dry on bay side if culverts are temporarily plugged.
	• Can keep highway in operation until raising embankment crest.	• Large volume, availability, and cost of riprap.	• Use smaller riprap for the body of the rockfill and larger riprap on slope surface for wave action protection.
	• May be able to use a barge for access and construction.		
Alternative 2 • Add wave protection walls on both sides of existing roadway. • Wave protection walls to provide enough freeboard. Bayside wall could be lower height because of much less wave action. • Raise grade between walls to provide grade	• Less earthwork than other alternatives.	• Design would need details at entrance and exit to floodwall section.	
	• If wave protection walls are damaged during earthquake, they could be repaired.	• Roadway would need to be shut down in two stages.	• Wave runup analyses for a vertical floodwall need to be performed to determine the required wall height at the bay side.
	• Although wave protection walls restrict viewing, that may be better	• Placing additional riprap underwater.	• Consider using barge for lake side and barge and conveyor for bay side.

Description	Advantages	Disadvantages	How to Address Issues
at least 3 feet above high-water level. • Extend filter layer and riprap to top of slope. • Riprap buttresses likely needed for seismic stability.	for safety. Also, they serve as guard rails.		
	• Load on walls would be relatively small, only affected by wave action, and inverted concrete T-walls may be appropriate.	• Need to extend culverts and debris guard and outlets.	• Underwater construction, including divers on lake side. Possibly can do it in the dry on bay side if culverts are temporarily plugged.
	• May be able to use a barge for access and construction.		
Alternative 3 • Construct new roadway embankment on Cottonwood Bay side of existing roadway. • Bayside slope of new embankment would be 3H:1V. • New embankment crest elevation to provide enough freeboard. • New embankment crest would have four-lane roadway.	• Will likely need to shut down roadway for shorter period than for Alternatives 1 and 2.	• Would need significant excavation into hillsides on bay side.	
	• No work needed on lake side if slope can be kept at 2H:1V.	• Need a larger volume of material than for Alternatives 1 and 2.	
	• Only need to extend culverts on one side.	• Access is difficult to bay side.	
	• Can construct in the dry if culverts can be blocked off.	• Significant land acquisition required.	
Alternative 4 • Construct new roadway embankment on lake side of existing roadway. • Lakeside slope of new embankment would be 3H:1V. • New embankment crest elevation to provide enough freeboard.	• Do not need to shut down highway.	• Need a larger volume of material than for Alternatives 1 and 2.	
	• No work needed on Cottonwood Bay side if slope can be kept at 2H:1V.	• Would need a cofferdam to construct in the dry so the roadway would be underlain by compacted fill, not riprap.	
	• Do not need to cut into hillside on bay side.	• Roadway alignment issues. Will need to cut into hill at east end.	

Description	Advantages	Disadvantages	How to Address Issues
• New embankment crest would have four-lane roadway.	• Only need to extend culverts on one side.		
	• May be able to use a barge for access and construction.		

Based on the results of the evaluation, it was concluded that Alternatives 1 and 2 be considered for additional evaluation.

4.4 Engineering Analyses

4.4.1 Embankment Slope Stability Analyses

For the proposed two alternatives, slope-stability analyses were performed in accordance with Caltrans and FHWA guidance using the software package SLOPE/W (Version 9.0.4) produced by Geo-Slope International. The Morgenstern-Price limit equilibrium method was used to balance both force and moment components in the slope-stability models.

All relevant calculation files mentioned in this section are included in Attachment C.

The embankment cross section at the deepest section of the valley was selected as the reference section for stability analyses, where the base of the embankment is at El 424. Chapter 2 provides a detailed description of the existing site conditions, and Figures 4-2 and 4-3 illustrate the embankment configuration for Alternatives 1 and 2, respectively.

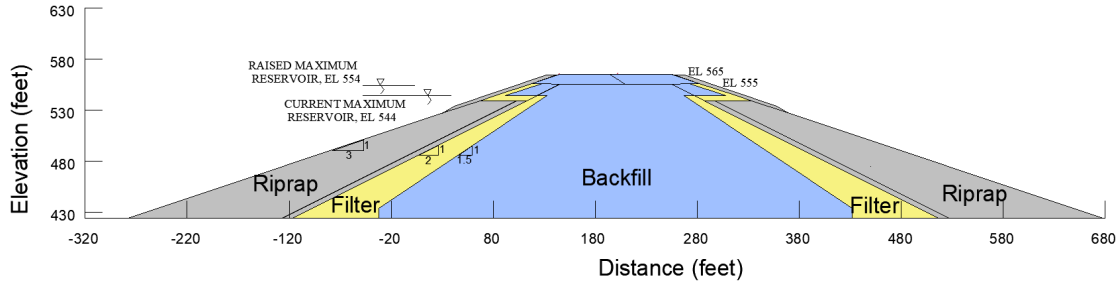


Figure 4-2. Analyzed geometry for Alternative 1

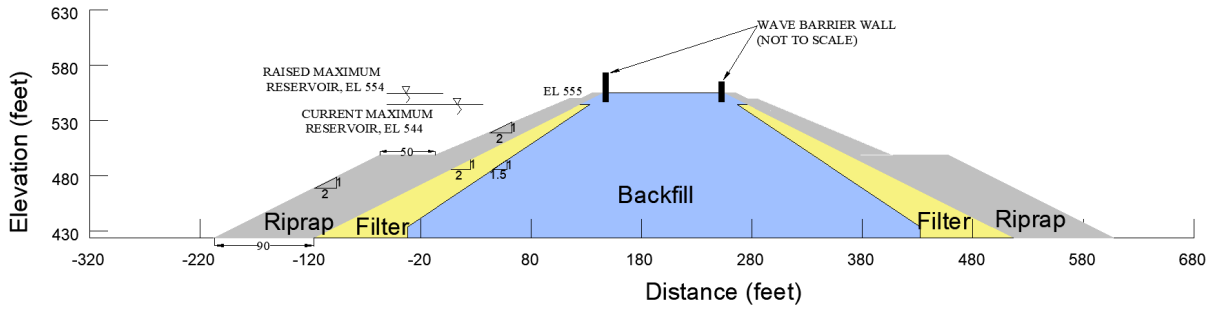


Figure 4-3. Analyzed geometry for Alternative 2

It is assumed that the existing embankment was constructed in accordance with Caltrans specifications; therefore, the strength parameters for the embankment backfill, filter material, and riprap were selected based on recommendations within the Caltrans geotechnical manual and the FHWA Geotechnical Engineering Circular No. 5 (Loehr et al. 2016).

Based on visual observations at the site, the embankment is assumed to be founded on bedrock or weathered rock; thus, the slope-stability analyses focused primarily on stability within the embankment section. **Table 4-2** summarizes the selected soil unit weights and strengths.

Table 4-2. Summary of Assumed Strength Parameters

Soil Designation	Unit Weight (pcf)	Friction Angle (°)	Cohesion (psf)
Riprap	140	45	0
Embankment Backfill	130	35	0
Filter Material	110	34	0
Foundation Material	120	38	0

Notes: pcf= pound-force per cubic foot, psf=pounds per square foot

Between the two alternatives being considered, Alternative 1 would raise the existing crest elevation low point from El 555 to El 565 and flatten the side slopes from 2 Horizontal : 1 Vertical (2H:1V) to a 3H:1V slope. The additional slope material would predominantly consist of riprap with additional filter material near the top of the embankment. The analyzed configuration for Alternative 1 is shown in Figure 4-2.

Alternative 2 would maintain the current crest elevation (El 555), add a 90-foot-wide riprap buttress from the toe of the slopes to an elevation of El 499, add riprap reinforcement to the upper portion of the embankment ranging from 40-feet-wide to 10-feet-wide, incorporate a wall at both sides of the crest to accommodate the additional freeboard requirements, and add an additional 2 feet of fill under the pavement to ensure the surface of the pavement is at least 3 feet above the highest water level.

Alternative 2 would also introduce a 50-foot-wide bench at El 499 and a 10-feet-wide bench at El 550. The design slopes for the lower buttress and the upper reinforcement would be 2H:1V and

2.4H:1V, respectively. All the additional material would consist of riprap for this alternative. Analyzed configuration for Alternative 2 is shown in Figure 4-3.

The design's high-water level and low-water level were modeled at El 554 and El 424, respectively, for Alternatives 1 and 2. The design's high-water level represents the proposed increased capacity of the San Luis Reservoir, and the design's low-water level represents a dry embankment.

Five design scenarios were evaluated for each proposed embankment alternative: long-term stability for both high-water and low-water conditions, seismic stability for both high-water and low-water conditions, and a rapid drawdown condition. The seismic stability analyses were performed using pseudo-static analysis, limit equilibrium methods, and a horizontal seismic coefficient, k_h=0.2 (based on the Caltrans Geotechnical Manual guidelines). The rapid drawdown analyses assumed a drawdown rate of 2 feet/day, which corresponds to the allowable controlled water release rate for the B.F. Sisk Dam. A summary of the slope-stability results is provided in **Table 4-3.**

Table 4-3. Summary of Slope-Stability Results

Design Condition	Estimated Factors of Safety		
	Required	Alternative 1	Alternative 2
Long-Term, Low-Water	1.5	2.1	1.9
Long-Term, High-Water	1.5	2.3	2.1
Seismic, Low-Water	1.1	1.3	1.2
Seismic, High-Water	1.1	1.0	1.0
Rapid Drawdown	1.1	2.1	1.8

The seismic slope stability governs the side slope geometry and, therefore, the quantity of the riprap for both design alternatives. The geometry was designed such that the factor of safety for the seismic design load case is between 1.0 and 1.1 for both Alternatives. The design also assumed relatively conservative parameters for the embankment material and foundation material. As such, with field investigation and refined analyses during later phases of the design, the established geometry at the feasibility level is expected to be representative of the final design geometry.

4.4.2 Embankment Seepage Analyses

Seepage is not a concern for the embankment because both sides of the embankment are hydraulically connected via two culverts at the base. However, a transient seepage analysis was conducted for reservoir elevation drawdown at a rate of 2 feet/day. Slope stability is not a concern at this drawdown rate for either Alternative (see results in Table 4-3).

Additional seepage analyses may be necessary at later stages of the design for the condition where the culverts are blocked off during construction, and there is a head difference between the northern and southern sides of the embankment.

4.4.3 Wave Runup Analyses and Freeboard Requirements

Wave runup and wind setup were calculated in accordance with Chapter 6 of Reclamation's *Design Standards No. 13 – Embankment Dams* manual to estimate the minimum freeboard requirements at the SR 152 embankment location. Because the reservoir stage is likely to maintain high-water elevations

for extended periods, the minimum freeboard was calculated for and applied to the proposed maximum reservoir stage of El 554.

Design wind velocities were estimated based on the peak wind velocity measurements from the local LBN station near the toe of the B.F. Sisk Dam (http://cdec.water.ca.gov/cdecstation2/?sta=LBN), where the measurements date back to 2003.

The determined wind velocities represent peak gusts measured on land, so they need to be converted to sustained wind velocities over water.

The methods presented in USACE engineering manual *EM 1110-2-1100 Coastal Engineering Manual* were used to convert peak gust wind velocities to sustained (1-hour) wind velocities over water.

In accordance with the method identified in the design standards, the fetch was calculated by constructing nine radials from the center of the embankment to the opposite shoreline. Each radial was separated by 3 degrees, and the fetch length was determined to be the arithmetic mean of all nine radials.

The sustained wind velocities and the fetch were used to calculate the fetch-limited significant wave height, H_s, which is defined as the average of the highest one-third of the waves in a wave field. Depending on the design criteria and the approach angle of the wave field, the significant wave height needs to be adjusted to a design wave height. Because overtopping of the embankment will not be allowed, the significant wave height must be increased to a design wave height that corresponds to the highest one-percent of waves. Assuming the wave height distribution can be described using a Rayleigh distribution, 1.67 is used as the design wave height conversion factor to convert the significant wave height to the one-percent design wave height (Chapter 6 of Reclamation's *Design Standards No. 13 – Embankment Dams*).

The angle of incidence between the embankment and the wave front will influence the design wave height as well. For this design, the calculated fetch was perpendicular to the embankment; therefore, no reduction factor is applied.

The design wave height corresponds to an open-water wave height. If a deep-water wave reaches a sloping embankment without major modifications in characteristics, the wave will break on the embankment and run up the slope to a height governed by the angle of the slope, the roughness and permeability of the embankment surface, and the wave characteristics. Wave runup is defined as the vertical difference between the maximum elevation to which the water will rush up the slope and the stillwater elevation. The wave runup was calculated using the design wave height, a surf similarity factor, curve fitting factors, and four reduction factors. The surf similarity factor, which compares the embankment slope angle and the steepness of the incident wave, was used to determine the appropriate curve fitting factors for the runup calculation. The reduction factors were used to adjust the runup calculation for the following: slope surface roughness, the presence or lack of a berm, the influence of shallow-water conditions, and the incidence angle for the incoming wave.

Wind blowing over a water surface introduces a shear force on the surface of the water in the direction of the wind. This force results in a rise in the water elevation on the windward shore and a fall in the water elevation on the opposite shore. The rise in the direction of the wind is called setup, and it is a function of the wind velocity, the fetch distance, and the average water depth along the

length of the fetch. The wind velocity and fetch were described above, and the average depth was estimated at 50 feet.

The minimum freeboard requirements need to account for both the runup and the setup components of the wave action. Therefore, the freeboard is calculated as the sum of the runup and setup. The freeboard calculation indicates that 10 feet of freeboard is adequate to protect against wind-generated waves.

This analysis does not consider the settlement of the embankment due to a seismic event because there are no subsurface data available for the fill and foundation materials of the embankment. Based on a review of the available geologic maps and Caltrans construction as-built plans, and the inspection of road cuts and rock outcrops in the vicinity, it is assumed that the foundation material is weathered bedrock. Therefore, the settlement potential is expected to be controlled by the settlement within the embankment.

A geotechnical investigation and seismic deformation analysis will be needed for final design.

Potential seismic seiche-related wave action is considered to require less freeboard than wind-generated wave action. The freeboard requirement governs the crest elevation for Alternative 1, and the wall height for Alternative 2. Note, the Cottonwood Bay side does not require walls as high as the Lakeside requires because it has much smaller waves.

Wave runup is also considered for the East Overlook Area. The minimum freeboard requirements for the wave runup are provided for Alternatives 1 and 2 for the SR 152 Embankment, and the East Overlook Area in **Table 4-4.**

Table 4-4. Summary of Minimum Freeboard and Riprap Gradation Requirements

Design Slope	Minimum Freeboard (feet)	Mean Rock Diameter (inches)	Minimum Riprap Thickness (feet)	Recommended Caltrans Rock Gradation Class Per Section 72
Alternative 1 – Southern Embankment Slope	4.0	11	1.9	Class III
Alternative 2 – Southern Embankment Slope	5.0	12	2.0	Class III
Alternative 1 – Northern Embankment Slope	1.5	5	0.8	Class II
Alternative 2 – Northern Embankment Slope	1.9	5.5	0.9	Class II
East Overlook Area	2.1	9	1.5	Class II

4.4.4 Riprap Design Requirements

The minimum riprap thickness and gradation requirements were calculated in accordance with Chapter 7 of Reclamation's *Design Standards No. 13 – Embankment Dams* manual in conjunction with the freeboard analyses presented in Section 4.4.3. The fetch-limited significant wave height determined (as previously described) was used to estimate the design wave height. For riprap design, the significant wave height was converted to the 10-percent wave height, i.e., only 10 percent of the waves in the wave field are larger. Assuming the wave height distribution can be described using a

Rayleigh distribution, 1.27 is used as the riprap design wave height conversion factor to convert the significant wave height to the 10-percent design wave height.

The 10-percent wave height, the unit weight of the riprap (assumed to be 160 pcf), and the specific gravity of the riprap (assumed to be 2.65) were used to estimate the mean rock weight required to resist the wave forces on the embankment. Using the volume, weight, and diameter relationships presented in the design standards, the mean rock weight was converted to a mean rock volume and a mean rock diameter. In accordance with the design standards, the minimum riprap thickness is the equivalent of two mean rock diameters.

The riprap calculations indicate that, of the four cases considered and shown in Table 4-3, the largest mean rock diameter is 12 inches or greater (mean weight of 150 pounds or greater) is sufficient to limit damage to the embankment. The corresponding minimum riprap thickness of 2.8 feet is required for riprap stability. The mean diameter and minimum thicknesses for other cases are provided in Table 4-3.

4.4.5 Ortigalita Fault Displacement and Slope Deformation Analyses

For the fault displacement potential, based on simplified calculations for the strike-slip fault, an average displacement of 3 to 4 feet is estimated for an earthquake with Moment Magnitude (M_w)=7 for the Ortigalita Fault parameters. Based on the USBR Design Standards No. 13, the thickness of the sandy filter layer should be wide enough to accommodate such displacements. From this perspective, the provided filter thickness of 10 feet is adequate for both Alternatives.

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Chapter 5 Construction

This section describes construction staging, sequencing, schedule, and environmental impacts.

5.1 Borrow Areas

Required borrow materials for the project are planned to be sourced from two local borrow sites—Basalt Hill and Borrow Area 6 (**Figure 5-1**). The Basalt Hill Borrow area was used to support construction of the original B.F. Sisk Dam and is planned to be used to supply materials that include gravel size (filter material) and crushed rock size (riprap). These materials would be produced on-site by blasting and crushing source material present at Basalt Hill. Borrow Area 6 would supply material for the structural fill to be used as embankment fill.

Source for the riprap material is assumed to be 100 percent from the Basalt Hill quarry. The cost of mining the Basalt Hill quarry is included in the construction activities. Source for the embankment material is assumed to be Borrow Site 6, which is about 7 miles from the SR 152 site.

The potential haul routes to transport materials from Basalt Hill Borrow area include barging across the reservoir and utilizing existing haul roads and SR 152. It is anticipated that the structural fill and filter material may be transported via trucks using SR 152. The riprap material will be transported by barge and tugboats. As mentioned in Chapter 4, the riprap size for the southern end of the embankment is large—having a mean diameter of 12–17 inches. These large-size riprap materials are anticipated to be transported using barges through the reservoir.

It is understood that Caltrans would like to limit truck traffic on SR 152. As a result, the cost estimate is based on transporting riprap by barge. Additional discussion with Caltrans is needed to determine if they would allow truck traffic and what measures they would require. One option is to transport materials at night. Utilizing two separate transportation routes would reduce the risk to the project schedule.

5.2 Construction Staging

As discussed above, there are two alternative estimates for consideration. Alternative 1 is to raise the SR 152 embankment by 10 vertical lineal feet, which includes adding approximately 804,000 cubic yards (cy) of riprap for slope protection, 102,000 cy of embankment, 4,600 lineal feet of asphalt cement (A/C) pavement, 480 lineal feet of submerged RCP pipe, and 3,400 lineal feet of storm drain pipe.

About one-half mile southeast from the site, the East Overlook parking area will need additional14,000 sf pavement and approximately 1,500 cy of riprap for slope protection.

Another 12 miles south, the existing two-mile dirt road from the Basalt Hill Quarry will be developed and made suitable for truck hauls from the quarry to the docking area stockpile. The docking area will be filled with grouted riprap where a 500-ton-per-hour conveyor system will be installed to load riprap and filter material on barges. Tugboats will transport the 60-foot by 120-foot aggregate barges 5 miles north to the SR 152 site where barges with crawler cranes and clamshell bucket attachments will feed barge-mounted conveyor hoppers.

The existing riprap slope for the lake side of SR 152 will be widened using conveyor systems mounted on barges and land-based excavators with thumb attachments. A marine diving crew will ensure riprap placement meets quality compliance. The riprap material for the bayside slope will be transported using a 350-ton-per-hour fixed-conveyor system that will span the width of SR 152 without intermediate supports. The bayside slope protection will be widened using one 250-ton-per-hour telestacker-type mobile conveyor system and excavators with thumb attachments after dewatering a portion of the bay side. Dewatering of the bay side will be facilitated by plugging both the 24-inch and 66-inch existing submerged RCP pipes. There will be four 100-ton crawler crane barges, four 150-ton-per-hour telestacker-type mobile conveyor barges, and eight 1000-ton aggregate barges. All barges will be assembled on-site at the Basalt Hill docking area with a combination of 40×10×7-foot and 20×10×7-foot floats, ramps, and cleats.

Alternative 2 is similar to Alternative 1, except that the SR 152 embankment would be raised by 1 vertical lineal foot, which includes adding approximately 513,000 cy of riprap for slope protection, 3,500 cy of embankment, and 2,700 cy of concrete for the construction of wave protection walls. Concrete batch plants are approximately 20 miles from the SR 152 site.

Equipment in the staging areas would include trailers, equipment to be used, and stockpiled materials. The staging area is expected to be at the western end of the highway embankment on the lake side for work on the embankment and at the eastern end of the embankment for work on the Cottonwood Bay side.

Details and extends of the staging areas will be established in final design. Proposed borrow and staging areas for B.F. Sisk Dam Raise and Reservoir Expansion Project are shown in Figure 5-1.

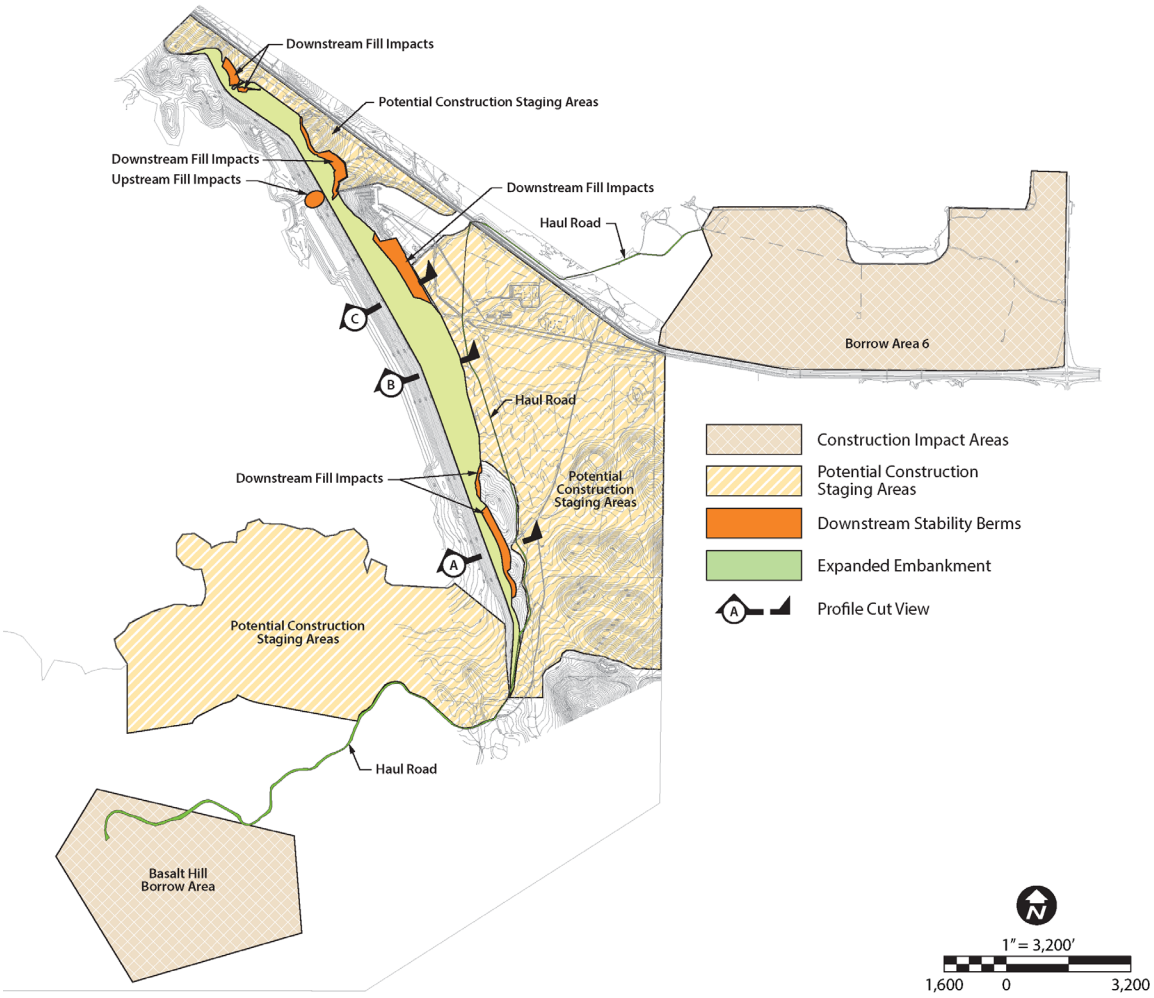


Figure 5-1. Reservoir expansion construction and staging areas

5.3 Construction Sequencing

The general sequence of construction will be as follows:

- Contractor will receive notice to proceed (NTP); after which the Contractor will mobilize to the site and begin procuring subs, preparing submittals, and surveying the site
- Mining, processing, and stockpiling at Basalt Hill quarry
- Basalt Hill aggregate road for truck haul
- Rough excavation and site grading
- Barge and conveyor system assembly
- Stockpile riprap and fill materials
- Construction of the new embankment modifications
- Construction of the new roadway pavement sections and/or concrete T-wall type; site wave protection walls only apply to Alternative 2

5.4 Schedule

Recreational activities would be suspended for safety reasons during the entire construction schedule at Basalt Point. Recreational use for boating on the reservoir would be supported through the use of the boat launch at Dinosaur Point, but would be limited to areas away from B.F. Sisk Dam for the full construction schedule.

Construction is expected to last approximately 22 to 24 months for Alternative 1 and approximately 16 to 18 months for Alternative 2. The construction duration is based on an approximate 75 to 130 workers on-site. Work would be performed from 6:00 a.m. to 6:00 p.m., five days per week, 12 months per year. A smaller crew of 10 to 20 people would be active at the site from 6:00 p.m. to 6:00 a.m. to perform equipment maintenance, repair activities, crushing operations at Basalt Hill, and borrow operations in Borrow Area 6. It is assumed, for the purpose of this Feasibility Design Report, that construction would start in summer of 2022.

5.5 Environmental Impacts During Construction

The following environmental impacts are anticipated during construction:

- Construction footprint (site plan), total acreage of disturbed ground:
  - Lakeside and Cottonwood Creek Dam Area is approximately 1,500,000 square feet (sf) (plan view)
  - Cottonwood Creek Dam Area Laydown measures approximately 1 acre
  - Basalt Hill Dock Area (for loading and storage) measures approximately 1 acre
  - Trucking route from Basalt Hill to Dock Area is 1.8 miles
- Types and amount of construction equipment (e.g., bulldozers, excavators, graders)
  - 16 barges total:
    - 8 aggregate barges
    - 4 conveyor barges (four telestackers, one on each barge)
    - 4 crane barges (four 100-ton tower cranes, one on each barge)
  - For a complete list of equipment for each Alternative, see the Equipment Recap pdfs in Attachment D.
- Total number of truck trips to/from site (e.g., construction worker(s) arrival/departure, equipment and/or material delivery, hauling demolition material to landfill).
  - Alternative 1: approximately 15,000 truck trips
  - Alternative 2: approximately 9,000 truck trips
- Hours of operation during construction: The current estimate assumes one 10-hour shift per day. The EIR and SEIS will assume two 10-hour shifts to provide coverage for any contractor requests to help meet the schedule, if necessary.
- Demolition materials are assumed to be nonhazardous.
- Existing asphalt pavement roadway demolition is approximately 7,500 cy
- On-site material (soil) disposal sites include the Merced County Regional Waste Authority Hwy 59 Landfill, located approximately 60 miles one way.

Chapter 6 Project Cost Estimate

The following describes the process used to develop the Opinion of Probable Construction Cost (OPCC) summarized as a table in Attachment D. The estimate was generated using the procedures generally described in Reclamation's Cost Estimating Handbook dated 1989, as modified by the following Reclamation Directives and Standards:

- Cost Estimating (FAC 09-01)
- Construction Cost Estimates and Project Cost Estimates (FAC 09-02)
- Construction costs for Alternatives 1 and 2 were developed without considering potential overlap of activities for Sisk Dam improvements, such as development and operation of Basalt Hill. Coordination of these two projects is recommended and expected, which will likely reduce the costs reported herein.

6.1 Construction Cost

The cost estimates for Alternatives 1 and 2 were prepared based on the contents of this report in combination with the engineering design drawings contained in Attachment A. The basis for this estimate is an OPCC, which is often used in determining costs for municipal and other public construction projects, from which the Reclamation-defined "Unit Price" for major items was developed. Based on the information available, the OPCC developed is considered a Class 4 Estimate, as recognized by the Association for the Advancement of Cost Engineering International (AACE International).

A deterministic method for quantification of scope and assembly of costs was used to include sufficient detail in the drawings. Quantity takeoff was performed and transcribed into individual line item entries based on historical cost data for pricing and productivity. The historical cost archive is maintained primarily in the Sage Timberline Office Estimating application. This estimating system consists of a custom database (over 130,000 items) with assemblies that group items into definable cost systems and a spreadsheet to display results grouped according to a user-defined Work Breakdown Structure (WBS). Scope items, where the level of project definition is conceptual in nature, were parametrically estimated utilizing cost data from similar projects in scope and size and adjusted to suit the specific requirements for the alternatives.

Labor costs were adjusted in the OPCC according to the project location based on published prevailing wage rates, R.S. Means Location Adjustments, and payroll tax information. The rates used were computed into averages that were based on a mixture of resources required for a given crew. Multiple crews were utilized in the costs, as required for the different disciplines and activities involved in the work. Detailed line items throughout the OPCC were calculated using a production rate that was established through a combination of estimating guides, historical data, and specific experience with the disciplines and trades required to perform the work. Estimating guides that are

utilized in the estimate include the Richardson Cost Data, RSMeans, Mechanical Contractors Association of America (MCAA), and National Electrical Contractors Association (NECA).

Material pricing, which is maintained in the database, is compiled and calculated per quoted pricing, vendor updates, and multipliers on published list pricing. Pricing used in the OPCC was reviewed by the estimators and adjusted based on the most current information available, as retained from recent bids on competitively priced projects.

Construction equipment costs are regularly updated according to the Rental Rate Blue Book, published by EquipmentWatch and approved by the Federal Highway Administration (FHWA). Cost for construction equipment is stored as an hourly rate that is then computed into averages based on a mixture of types of equipment required for a given crew. Multiple crews are utilized in the cost in the same manner as labor crews, with most crews containing both labor and equipment resources and having total amounts displayed in different cost categories. Individual line items are calculated using a production rate that is established through a combination of estimating guides, historical data, and specific experience with the disciplines and trades required to perform the work.

Each alternative was developed with inputs and reviews by CDM Smith's project manager and estimator assigned to current dam and levee projects with riprap slope protection. Once these were developed, the estimate was further reviewed (for constructability, equipment selection, and production rates) by a civil general contractor familiar with riprap production and installation in quantities similar in scope to this project.

The total most probable project cost for each of the Alternatives is as follows:

- **Feasibility Study Alternative 1** → $383.0 M (raise embankment by 10 feet)
- **Feasibility Study Alternative 2** → $256.0 M (raise embankment by 2 feet and construct wave protection walls)

Based on AACE Estimate Class 4: 1–5 percent Project Definition and Feasibility Study (with a low range of –15 to –30 percent and a high range of +20 to +50 percent), the total project cost ranges are as follows:

- **Feasibility Study Alternative 1** → $268 M to $575 M (raise embankment by 10 feet)
- **Feasibility Study Alternative 2** → $179 M to $384 M (raise embankment by 2 feet and construct wave protection walls)

Construction durations are as follows:

- **Alternative 1** → 22–24 months
- **Alternative 2** → 16–18 months

These estimates do not include the design phase and preconstruction activities, but do include the following adjustments and markups:

- Labor cost OT adjustments for working five 10-hour single shifts per week
- 25-percent markup for all subcontractors

These estimates also include the following indirect costs:

- 10 percent for general conditions
- 0.4 percent for building permits
- 8.75 percent for sales tax
- 0.25 percent for builder's risk insurance
- 2 percent for insurance
- 1 percent for bonds
- 10 percent for contractor total overhead and profit
- 25 percent for contingency
- 8 percent for escalation (4 percent per year)

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Chapter 7 Additional Studies Recommended for Final Design

The CDM Smith team anticipates the need to continue coordination with Caltrans on proposed modifications to the SR 152 embankment. The CDM Smith team will follow the requirements of the Caltrans Project Development Procedures Manual to complete the Project Approval/ Environmental Document (PAED) phase of work, including the preparation of the Project Report in accordance with Appendix K of the Caltrans Project Development Procedures Manual (Caltrans 2016). The Caltrans PAED phase may also include multiple special studies, such as traffic, cultural resources, and stormwater, to support the project approval.

The following studies are recommended or required to complete final design:

7.1 Surveying

Additional surveying activities recommended for final design include the following:

- Field surveying will be required for final design to verify and locate existing surface features, ground surface elevations and grades, as well as the location of existing utilities at the proposed construction area.
- Culverts should be inspected by divers using camera systems to evaluate the existing condition of the culverts and decide if repairs are necessary.
- Potholing of existing buried utilities to verify depth and location is recommended where required.
- Bathymetric surveys to develop reservoir bottom elevation mapping on both sides of the embankment. The measurement grid spacing should be less than 10 feet.
- Topographic surveying of the Basalt Hill Area will be required.

7.2 Additional Investigations During Final Design

Additional investigations recommended for final design include the following:

- Geotechnical investigations, including soil material and strength testing primarily along the crest of the embankment. A few borings should be drilled near the toe of the embankment on both sides. Borings should reach as deep as one embankment height below the foundation elevation. If rock is encountered at shallower depths, the boring may be terminated after coring for at least 20 feet and encountering rock with a rock quality designation (RQD) of at least 80 percent. Geotechnical laboratory tests should be performed on embankment and foundation samples, including index tests, shear strength and stiffness test, hydraulic conductivity tests, and unconfined compression tests on rock cores. Laboratory tests should

also be performed on borrow samples. Geotechnical drilling should also be conducted at the Basalt Hill to determine the depth of the rock that could be mined.

- Field reconnaissance is recommended to determine the exact location of the Ortigalita fault near the embankment location. Geophysical studies may be necessary if the fault trace is not visible on the ground surface.

7.3 Permits

This document only addresses design issues related to construction of the proposed facilities; however, permitting and coordination with other agencies will be critical for successful completion of this project. The B.F. Sisk Dam Raise and Reservoir Expansion Project Feasibility Report includes additional information on required project permitting and the proposed approach for securing those permits.

7.4 Studies

The list of additional studies recommended for final design include both additional field studies and additional review of information potentially available upon request from local entities as well as detailed engineering studies utilizing field investigation and laboratory test results. Additional studies should include but are not limited to:

- Seepage and slope-stability analyses
- Detailed freeboard calculations with site-specific wind speeds and wind directions
- Seismic stability and settlement analyses, preferably based on finite difference or finite element models
- Liquefaction triggering and settlement analyses
- Fault assessment and deformation potential calculation

Chapter 8 References

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B.F. Sisk Dam Raise and Reservoir Expansion Project
Feasibility Design Report- SR 152 Modifications

Attachment A As-Builts Engineering Design Drawings

D.P.R. DIV. NO.	STATE	F.A. PROJECT No.	SHEET NO.	TOTAL SHEETS
7	CALIF.		1	134

DIST.	COUNTY	ROUTE	SECTION	POST MILE	POST MILE
X	SCL/Mer	32	G-A	8	12.1+

INDEX OF SHEETS

Sheet No. 1 Title Sheet
" " 2-3 Typical Cross Sections
" " 4 Paving Details
" " 5 Working Area
" " 6-40 Plan and Profile
" " 41-42 Miscellaneous Details
" " 43-70 Miscellaneous Drainage Details
" " 71-90 Structure List
" " 91-93 Construction Notes
" " 94-118 Construction Details
" " 119-121 Roadside Sign Plans
" " 1-202 Cross Sections
" " 1-10 Mass Diagram

BRIDGE PLANS

Sheet No. 1-13 San Luis Dam Forebay Bridge - Br. No. 39-145 R/L

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

AS BUILT
10-063814

PLANS FOR CONSTRUCTION ON
STATE HIGHWAY

In Santa Clara and Merced Counties
between 1.0 mile west of Santa Clara-Merced County Line and
1.8 miles west of Route 121, about 15 miles west of Los Banos

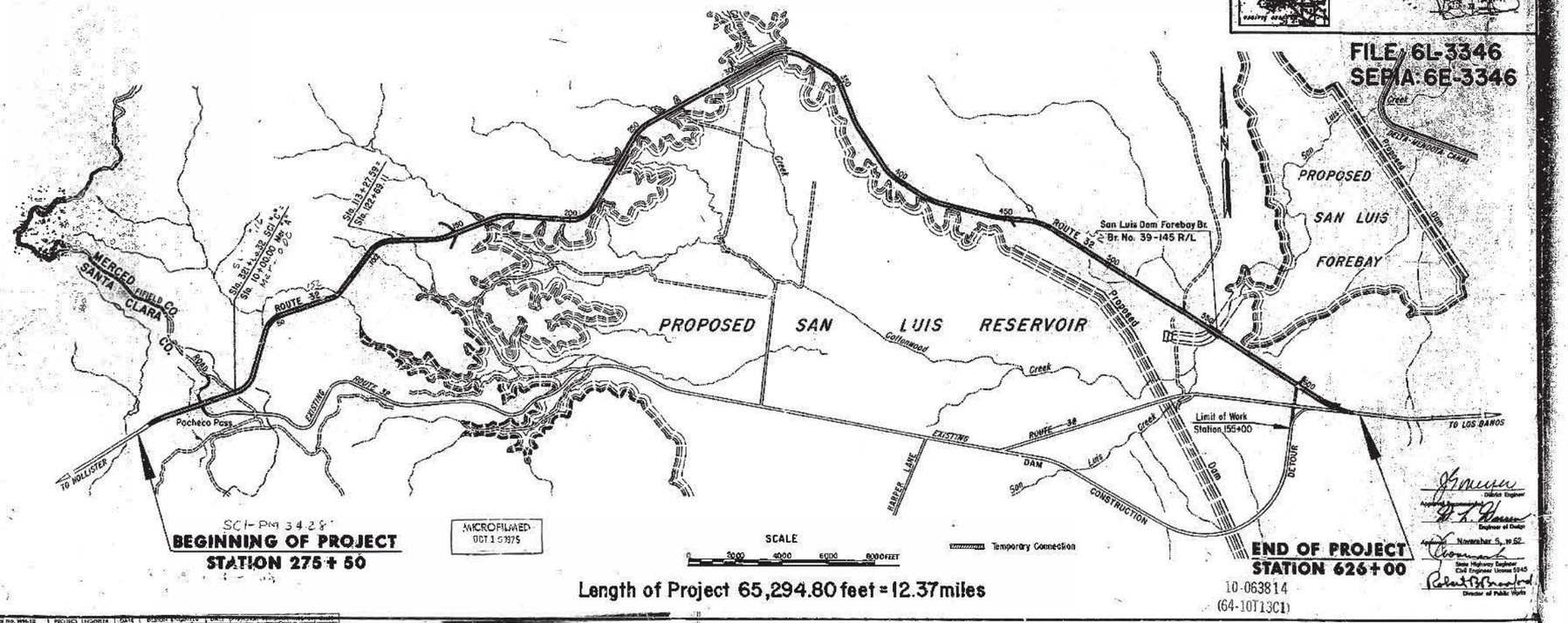
(being the detail plans of a portion of the route for the State highway adopted by the California Highway Commission August 31, 1960 and declared a

FREEWAY

by resolution of the California Highway Commission August 31, 1960)

STATE OF CALIFORNIA KEY MAP

FILE 6L-3346
SERIA 6E-3346



SCl-Pm 34.28
BEGINNING OF PROJECT
STATION 275+50

END OF PROJECT
STATION 626+00

Length of Project 65,294.80 feet = 12.37 miles

MICROFILMED OCT 16 1975

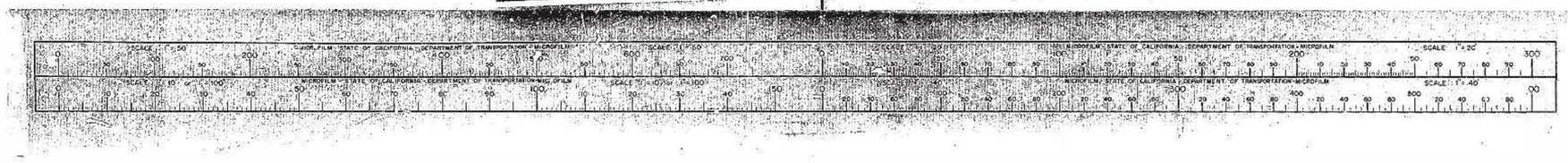
10-063814
(64-10T13C1)

PROJECT ENGINEER	DATE	DESIGN ENGINEER	DATE
Materials Engr.		Bridge Design Engr.	

AS BUILT PLANS
Contract No. 10-063814
Date Completed —
Document No. 00023032

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

10/16/75 Dale M. Anderson Micrographic Supervisor



D.P.R. NO.	STATE	FEDERAL PROJECT NO.		SHEET NO.	TOTAL SHEETS
7	CALIF.			17	134

DIST.	COUNTY	ROUTE	SEC.	SHEET NO.	TOTAL SHEETS
X	MER	32	A	17	121

Dist. Eng. Dist. X

Approved November 5, 1962

Engr. Los Banos License No. 7603

NOTE: Fence to Follow R/W Except Where Shown

220,322.221N 1,814,327.174E

CHD-5 Elev. 886.312'

Type WM Freeway Fence

220,383.577N 1,814,795.960E

220,857.099N 1,815,259.706E

R/W

Conform Line

221,171.152N 1,816,114.605E

FL 430.0'

FL 450.0'

For Complete R/W and Accurate Access Data, See R/W Record Maps at District Office.

End A.C. Dike

Metal Beam Guard Rail

A.C. Spillway

GCP DI. FL 550.0'

18'x64' R.C.P.

GF 553.5'

N 64°41' E 6207.294'

310

320

330

Grate 555.2'

GCP DI. FL 553.0'

18'x60' R.C.P.

FL 549.2

FL 549.0'

N 220,687.154 E 1,814,245.276

N 220,881.893 E 1,815,334.446

N 220,801.669 E 1,816,147.504

NOTE: See Drainage Detail For Debris Barrier Design.

220,713.162 N. 1,815,913.626 E.

66" RCP

53'

58'

360'

B.C.

Sta. 44+51.25

Service Road Barrier

219,938.905N 1,814,574.441E

219,693.105N 1,814,418.843E

FL 423.64

FL 450.0'

220,387.738N 1,816,067.557E

220,036.933N 1,815,913.064E

220,610.457N 1,816,631.332E

R = 1350'
Δ = 59°45'
T = 775.50'
L = 1407.83'

48F-793 Elev. 432.881'

NOTE: Fence to Follow R/W Except Where Shown

N 220,737.214 E 1,817,067.524

660 620 580 540 500 460 420 380

Prof.le Grade

-0.151 %

+1.153 %

1000' V.C.

1200' V.C.

Ground Line

557.10 555.30 B.V.C. 555.28 555.22 555.23 555.26 555.34 555.44 555.58 555.74 555.95 556.18 556.45 556.74 557.06 557.45 557.84 558.27 558.74 559.23 559.76 560.32 E.V.C. 567.24 B.V.C. 567.76 568.31 568.79 569.23 569.65 570.01 570.33 570.64

Scale: 1" = 100'

Cu. Exc. Yds. Emb.	79,307	83,670	2,091,498	701,455
Sta.	6 7 8 9 300	1 2 3 4 5 6 7 8 9 310	1 2 3 4 5 6 7 8 9 320	1 2 3 4 5 6

AS BUILT PLANS
Contract No. 10-063814
Date Completed —
Document No. 00003038

MICROFILMED 06/11/1975

17

PROJECT ENGINEER	DATE	DESIGN ENGINEER	DATE	APPROVAL RECOMMENDED BY	DATE
Ted Mastenbrook	8/62	L. R. Bond	8/1962	Irvine Bastian	8/62

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

DATE 10/15/75 SIGNATURE Della Meadows TITLE Microfilm Supervisor

MICROFILM – STATE OF CALIFORNIA – DEPARTMENT OF TRANSPORTATION – MICROFILM

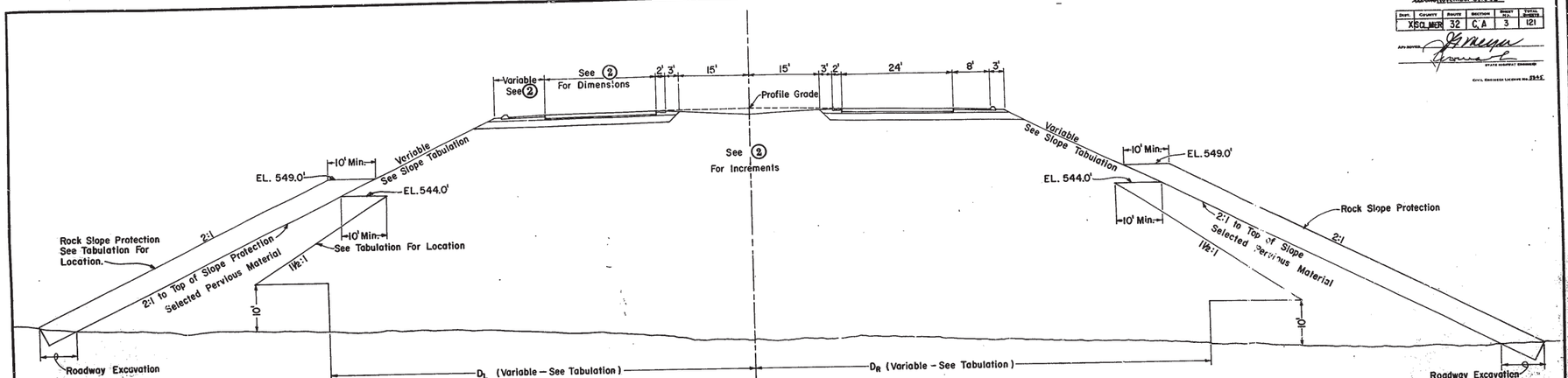
L.P.A. DIST. No.	STATE	FEDERAL PROJECT No.	SHEET No.	TOTAL SHEETS
7	CALIF.		3	134

November 5, 1962

DIST.	COUNTY	ROUTE	SECTION	SHEET NO.	TOTAL SHEETS
X-SCL-MER		32	C, A	3	121

APPROVED: J. A. Meyer
STATE HIGHWAY ENGINEER

CIVIL ENGINEER LICENSE No. 7935



ROCK SLOPE PROTECTION LEFT

Station	to	Station
161+50		163+30
232+20		234+53
263+50		266+10
271+75		272+95
292+95		294+85
303+80		324+10
425+05		427+20

SELECTED PERVIOUS MATERIAL LEFT

Station	to	Station
293+08		294+70
304+00		323+50

D_L TABULATION

Station	to	Station	D_L
293+08		293+40	82' to 98'
293+40		294+70	98' to 77'
304+00		310+00	65' to 175'
310+00		312+00	175'
312+00		323+50	175' to 100'

D_R TABULATION

Station	to	Station	D_R
233+60		234+20	171' to 180'
234+20		256+20	180'
265+50		266+35	135'
266+35		271+80	135' to 115'
293+90		296+00	68' to 110'
296+00		297+00	110'
297+00		298+00	110' to 80'
301+30		304+00	64' to 95'
304+00		307+80	95' to 175'
307+80		312+00	175'
312+00		323+00	175' to 73'
426+30		430+00	130'

SELECTED PERVIOUS MATERIAL RIGHT

Station	to	Station
233+00		236+20
265+50		271+80
293+90		298+00
301+30		323+00
426+30		430+00

ROCK SLOPE PROTECTION RIGHT

Station	to	Station
163+90		168+20
209+50		210+70
232+90		236+90
265+00		272+60
293+80		299+20
300+35		323+20
348+20		349+35
363+40		367+40
383+90		385+15
387+85		391+30
395+90		397+50
412+40		417+80
425+50		431+05
438+35		439+35

CUT SLOPES LEFT

Station	to	Station	to	Slope
281+50	S.CL.-32-C	293+50	S.CL.-32-C	1:1
293+50	S.CL.-32-C	316+00	S.CL.-32-C	1½:1
316+00	S.CL.-32-C	129+00	MER-32-A	1:1
129+00		171+50		1½:1
171+50		208+00		1:1
208+00		239+00		1½:1
239+00		260+00		1:1
260+00		403+00		1½:1
403+00		410+00		1:1
410+00		623+00		2:1

CUT SLOPES RIGHT

Station	to	Station	to	Slope
281+50	S.CL.-32-C	320+00	S.CL.-32-C	1½:1
320+00	S.CL.-32-C	38+00	MER.-32-A	1:1
38+00		65+00		¾:1
65+00		128+00		1:1
128+00		180+50		1½:1
180+50		207+50		1:1
207+50		216+00		2:1
216+00		239+00		1½:1
239+00		259+50		1:1
259+50		335+00		1½:1
335+00		349+00		2:1
349+00		398+00		1½:1
398+00		410+00		1:1
410+00		623+00		2:1

FILL SLOPES

Station	to	Station	to	Slope
281+50	S.CL.-32-C	305+25	S.CL.-32-C	2:1
305+25	S.CL.-32-C	293+00	MER-32-A	1½:1
293+00		623+00		2:1

BENCHES LEFT

Station	to	Station	to	Y_0	Y_3	Y_6
19+00	MER-32-A	30+50	MER-32-A	50		
84+50		101+50		40	80	80
108+50		128+00		40	80	
137+00		144+00		50		
180+00		189+00		40	80	
213+00		217+50		50		
220+00		229+00		50		
240+00		245+50		50		
249+00		260+00		50		
275+00		292+50		50	80	
325+00		334+00		50	50	
352+50		361+00		50	50	
367+50		381+00		50	50	
397+00		403+00		50	50	

BENCHES RIGHT

Station	to	Station	to	Y_0	Y_3
22+50	MER-32-A	66+00	MER-32-A	50	
85+00		101+00		40	80
123+00		128+00		40	
138+00		146+00		50	
181+00		186+00		40	80
198+00		206+00		50	
220+00		226+00		50	
250+00		259+00		50	
274+00		293+50		50	
324+50		334+00		50	

4 EMBANKMENT DETAILS

Scale: 1" = 10'

8" P.M.P. UNDERDRAIN & PERMEABLE MATERIAL IN TRENCH

Station	Side
12+00	Rt.
12+00	Lt.
63+00	Rt. & Lt.
92+00	Rt. & Lt.
108+50	Rt. & Lt.
137+50	Rt. & Lt.
193+00	Rt. & Lt.
219+50	Rt. & Lt.
248+50	Rt. & Lt.
274+00	Rt. & Lt.
36+00	
58+50	
71+50	
101+50	
128+50	
151+50	
188+00	
229+00	
260+50	
293+50	

PERMEABLE MATERIAL BLANKET

Station	to	Station
12+00		30+00
63+00		71+50
92+00		101+50
108+50		128+50
219+50		229+00
248+50		260+50
274+00		293+50

NOTE:
Dimensions Are Subject to Tolerences Specified in The Standard Specifications.
Standard Superelevation to be Applied Except 5% Max. Superelevation on Truck Climbing Lanes.

CLASS 2 AGGREGATE SUBBASE

Station	to	Stations	to	Depth
281+50	S.CL.-32-C	231+00	S.CL.-32-C	1.17'
231+00	S.CL.-32-C	207+75	MER-32-A	1.00'
207+75		228+75		2.00'
228+75		280+00		1.00'
280+00		338+80		3.00'
338+80		588+00		1.00'
588+00		617+74		2.00'

W. L. Pearson
Engineer of Design
Civil Engineer License No. 7033

D. H. Willis
ASSISTANT STATE HIGHWAY ENGINEER

MICROFILMED OCT 1 5 1975

AS BUILT PLANS
Contract No. 10-063814
Date Completed —
Document No. 00003038

(X-SCl, Mer-32-C,A)
TYPICAL CROSS-SECTIONS

AS BUILT 10-063814 LE-3396

7786

AGENCY ENGINEER	DATE	DESIGN ENGINEER	DATE	APPROVAL RECOMMENDED BY	DATE
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

DATE 10/6/75 SIGNED [signature] TITLE Microfilm Supervisor

MICROFILM - STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION - MICROFILM

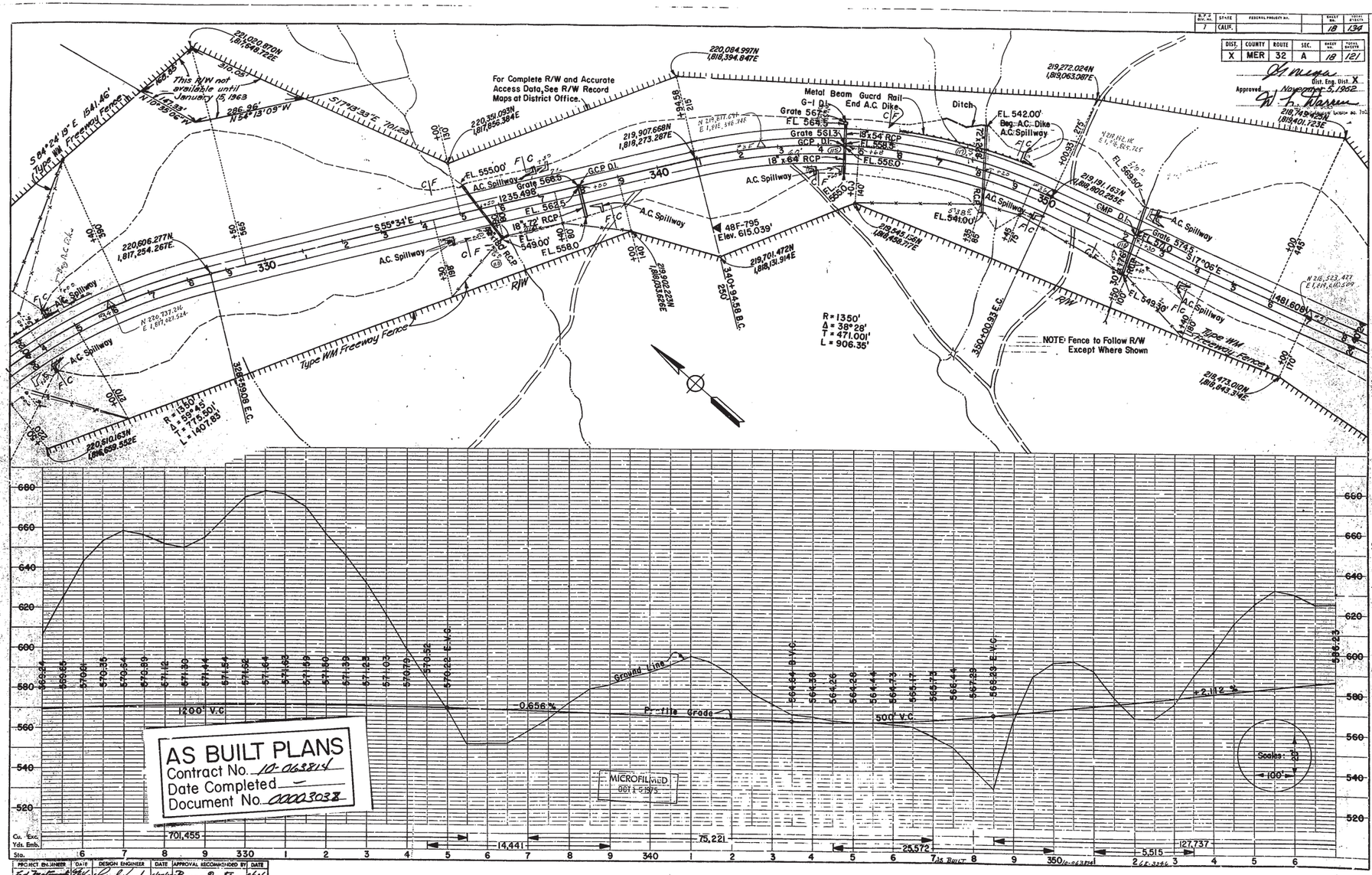
B.P.R. Div. No.	STATE	FEDERAL PROJECT No.	SHEET NO.	TOTAL SHEETS
7	CALIF.		18	134

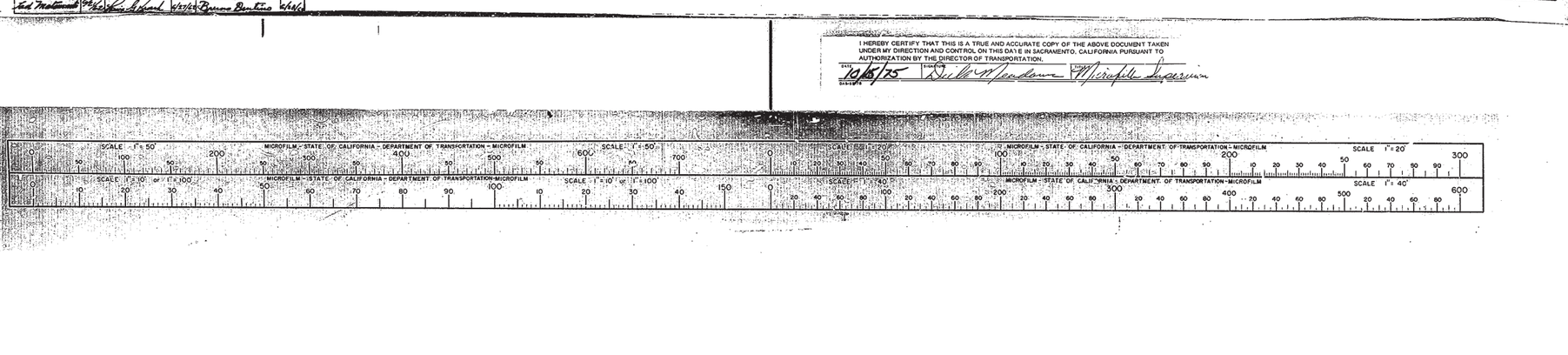
DIST.	COUNTY	ROUTE	SEC.	SHEET NO.	TOTAL SHEETS
X	MER	32	A	18	121

Dist. Eng. Dist. X

Approved November 5, 1962

218,745.425N
1,815,401.235E





AS BUILT PLANS
Contract No. 10-063814
Date Completed —
Document No. 00003038

MICROFILMED
OCT 1 5 1975

18

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DATE 10/15/75 SIGNATURE

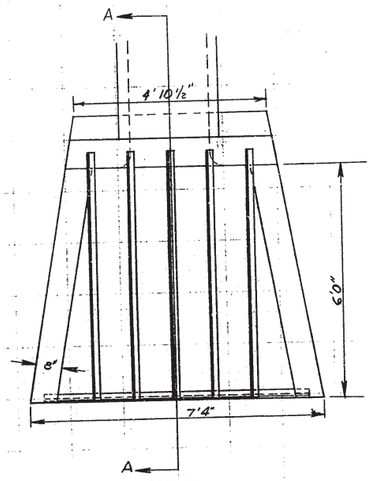
DIST.	COUNTY	ROUTE	SECTION	SHEET NO.	TOTAL SHEETS
X	MER	32	A	68	121

DIST.	STATE	FEDERAL PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
7	CALIF.			68	134

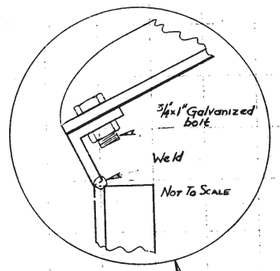
APPROVED November 5, 1962

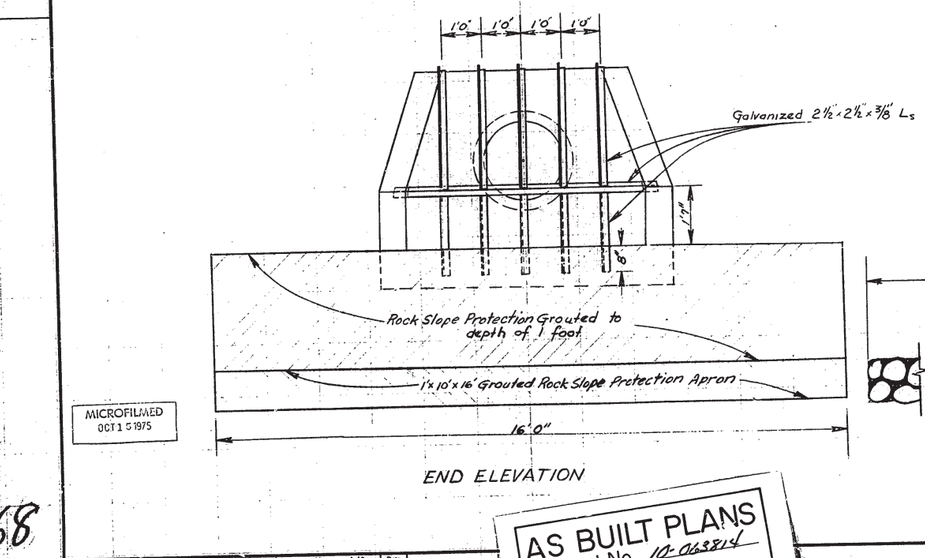
DISTRICT ENGINEER

Engineer in Charge
Civil Engineer License No. 7688

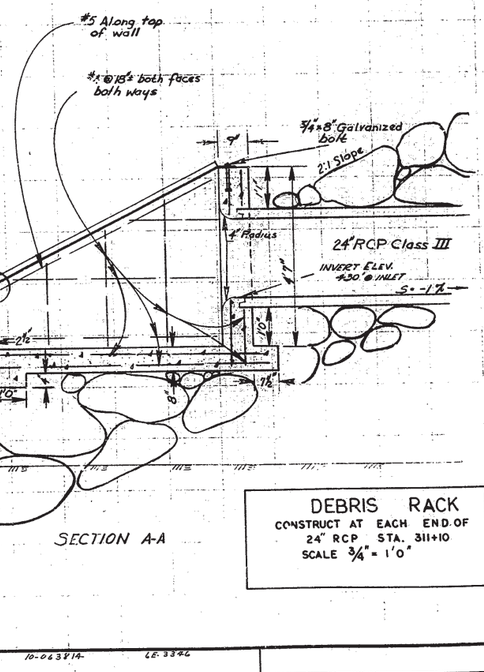


PLAN





END ELEVATION



SECTION A-A

DEBRIS RACK
CONSTRUCT AT EACH END OF 24" RCP STA. 311+10
SCALE 3/4" = 1'0"

MICROFILMED
OCT 1 5 1975

Project Engineer	Date	Design Engineer	Date	Approval Recommended By	Date
Ted Matthews	4/14/62	Lewis L. Hardy	4/21/62	Bruno Deutsch	4/26/62

AS BUILT PLANS
Contract No. 10-063814
Date Completed —
Document No. 00003032

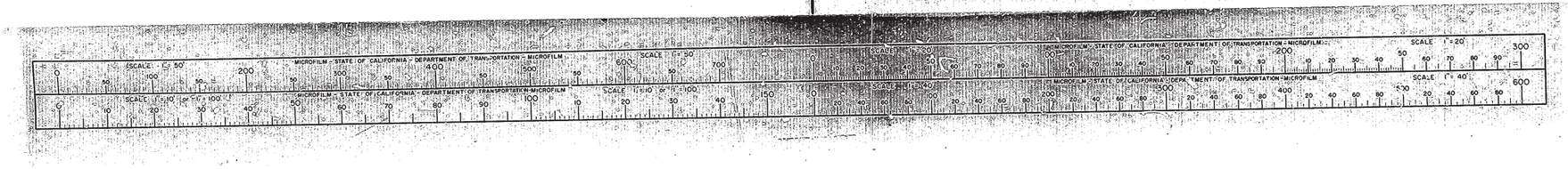
AS BUILT	10-063V14-	LE 3346

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

DATE 10/15/75 TRANSCRIBED BY Wells Henderson COMPARED BY Microfilm Supervisor

68

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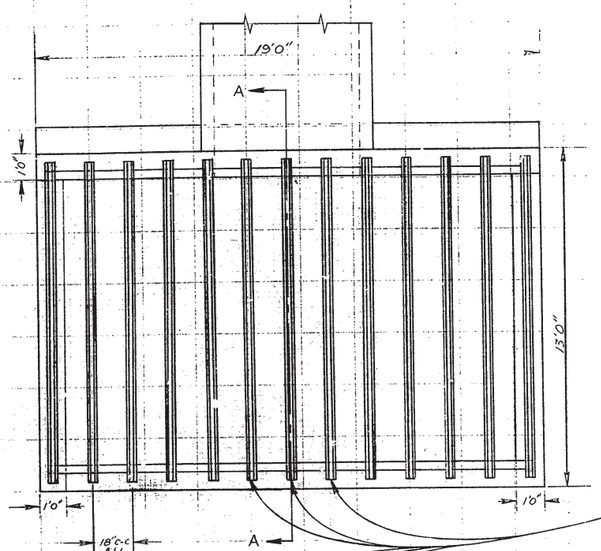
DIST.	COUNTY	ROUTE	SECTION	SHEET NO.	TOTAL SHEETS
7	CALIF.			59	134
X	MER	32	A	59	181

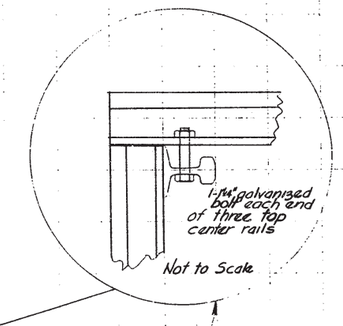
APPROVED: November 5, 1962

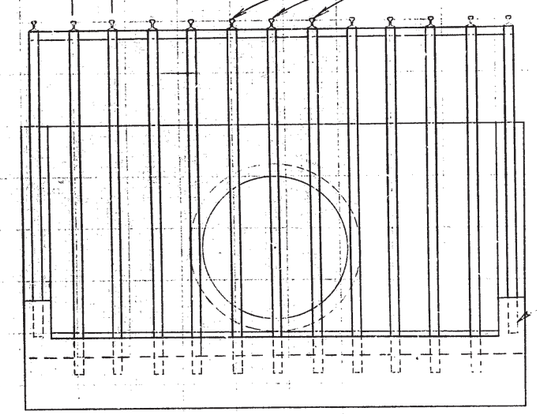
DISTRICT ENGINEER

ASSISTANT CHIEF ENGINEER (BRIDGES) SACRAMENTO, CALIFORNIA

PLAN



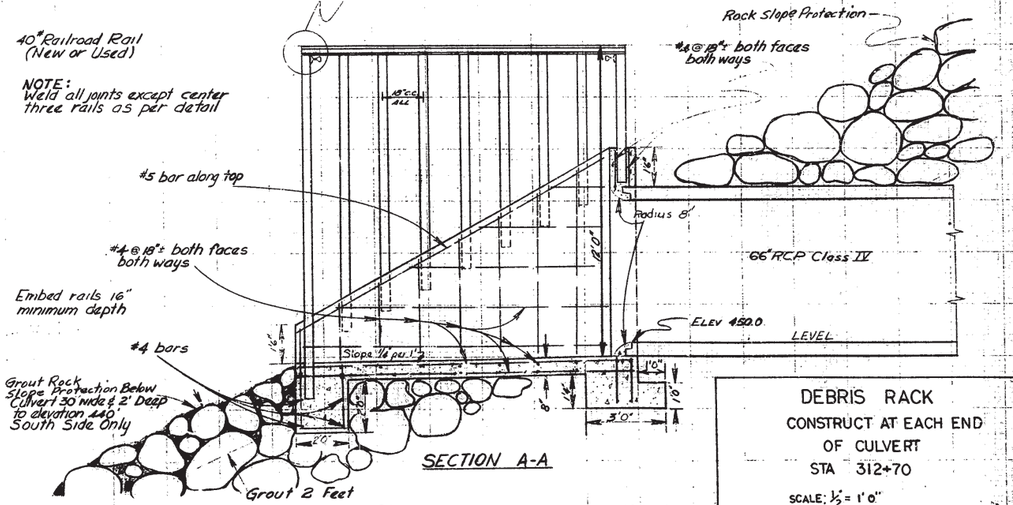




END ELEVATION

40" Railroad Rail (New or Used)

NOTE:
Weld all joints except center three rails as per detail



SECTION A-A

DEBRIS RACK
CONSTRUCT AT EACH END OF CULVERT
STA 312+70
SCALE: ½" = 1'0"

AS BUILT PLANS
Contract No. 10-063814
Date Completed —
Document No. 0000303232

AS BUILT 10-063814 1F-3306

Project Engineer	Date	Design Engineer	Date	Approved Recommended By	Date
Fred Testaverde	9/62	Kenneth J. Kassel / Victor Bruno	9/62	Director	11/62

MICROFILMED
OCT 1 5 1975

69

PHOTOGRAPHIC PRINT ON 100% RAG PAPER CLOTH

PRINTED ON 100% RAG PAPER CLOTH

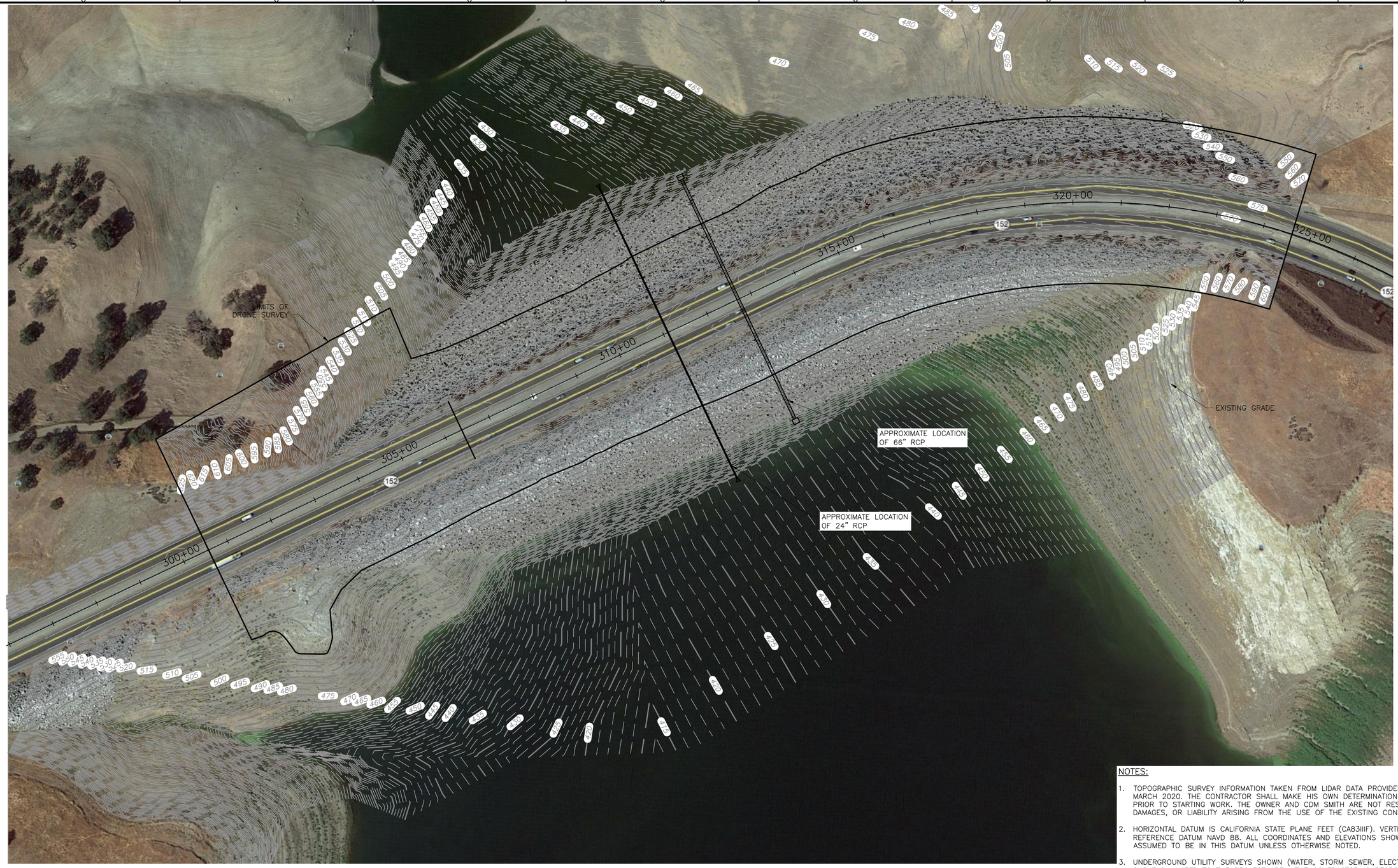
I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

DATE 10/15/75 SIGNATURE W. M. Maclaren TITLE Microfilm Supervisor

MICROFILM – STATE OF CALIFORNIA – DEPARTMENT OF TRANSPORTATION – MICROFILM

B.F. Sisk Dam Raise and Reservoir Expansion Project
Feasibility Design Report- SR 152 Modifications

Attachment B- Feasibility-Level Design Drawings



PLAN
1" = 100'

NOTES:

1. TOPOGRAPHIC SURVEY INFORMATION TAKEN FROM LIDAR DATA PROVIDED BY CDM SMITH AND DATED MARCH 2020. THE CONTRACTOR SHALL MAKE HIS OWN DETERMINATION OF EXISTING CONDITIONS PRIOR TO STARTING WORK. THE OWNER AND CDM SMITH ARE NOT RESPONSIBLE FOR CLAIMS, DAMAGES, OR LIABILITY ARISING FROM THE USE OF THE EXISTING CONDITIONS SHOWN.
2. HORIZONTAL DATUM IS CALIFORNIA STATE PLANE FEET (CA83IIIF). VERTICAL INFORMATION REFERENCE DATUM NAVD 88. ALL COORDINATES AND ELEVATIONS SHOWN ON THESE PLANS ARE ASSUMED TO BE IN THIS DATUM UNLESS OTHERWISE NOTED.
3. UNDERGROUND UTILITY SURVEYS SHOWN (WATER, STORM SEWER, ELECTRIC) WERE ONLY PARTIAL SURVEYS, LIMITED TO THE PROJECT AREA. THE CONTRACTOR IS RESPONSIBLE FOR IDENTIFYING AND LOCATING ALL UTILITIES PRIOR TO THE START OF WORK. ALL UTILITIES THAT ARE NOT INTENDED TO BE DEMOLISHED SHALL BE PROTECTED THROUGHOUT THE PROJECT. ANY DAMAGED UTILITIES SHALL BE REPAIRED OR REPLACED AT THE CONTRACTORS EXPENSE.
4. EXISTING CONTOURS SHOWN INCLUDES AREAS OUTSIDE OF DRONE SURVEY. CONTOURS OUTSIDE OF SURVEY AREA ARE APPROXIMATE AND ARE FOR DISCUSSION PURPOSES ONLY.

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: E.O. TASTAN
DRAWN BY: K. RYAN
SHEET CHK'D BY: S. WHITESIDE
CROSS CHK'D BY: R. FOSSE
APPROVED BY: E.O. TASTAN
DATE: JUNE 2020

CDM Smith
2295 Gateway Oaks Drive, Suite 250
Sacramento, CA 95833 | Tel: (916) 576-7497

LOS BANOS, CALIFORNIA

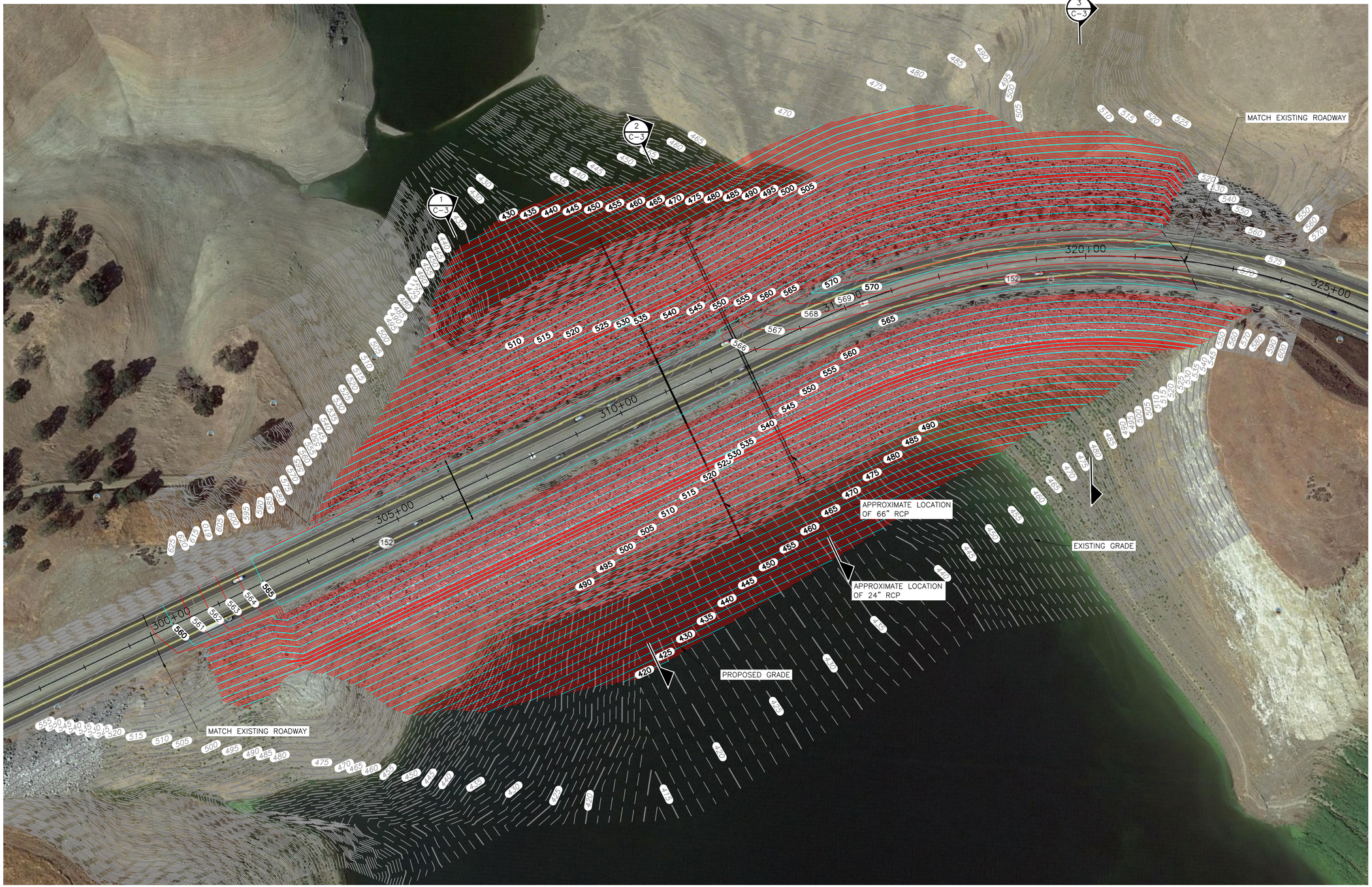
SISK DAM RAISE FEASIBILITY

HIGHWAY 152 EMBANKMENT EXISTING CONDITIONS PLAN

PROJECT NO. 141064-242990
FILE NAME: C001EXPL.DWG
SHEET NO.
C-1

PRELIMINARY DRAWINGS - NOT FOR CONSTRUCTION

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PLAN
1" = 100'

VOLUME SUMMARY	
MATERIAL	VOLUME (CY)
CLASS II RIPRAP	647,150
CLASS III RIPRAP	157,306
EMBANKMENT	102,160
FILTER	56,088

NOTE:

1. QUANTITIES REPORTED ARE AS PLACED VOLUMES.

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: E.O. TASTAN
DRAWN BY: K. RYAN
SHEET CHK'D BY: S. WHITESIDE
CROSS CHK'D BY: R. FOSSE
APPROVED BY: E.O. TASTAN
DATE: JUNE 2020

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Sacramento, CA 95833 | Tel: (916) 576-7497

LOS BANOS, CALIFORNIA

SISK DAM RAISE FEASIBILITY

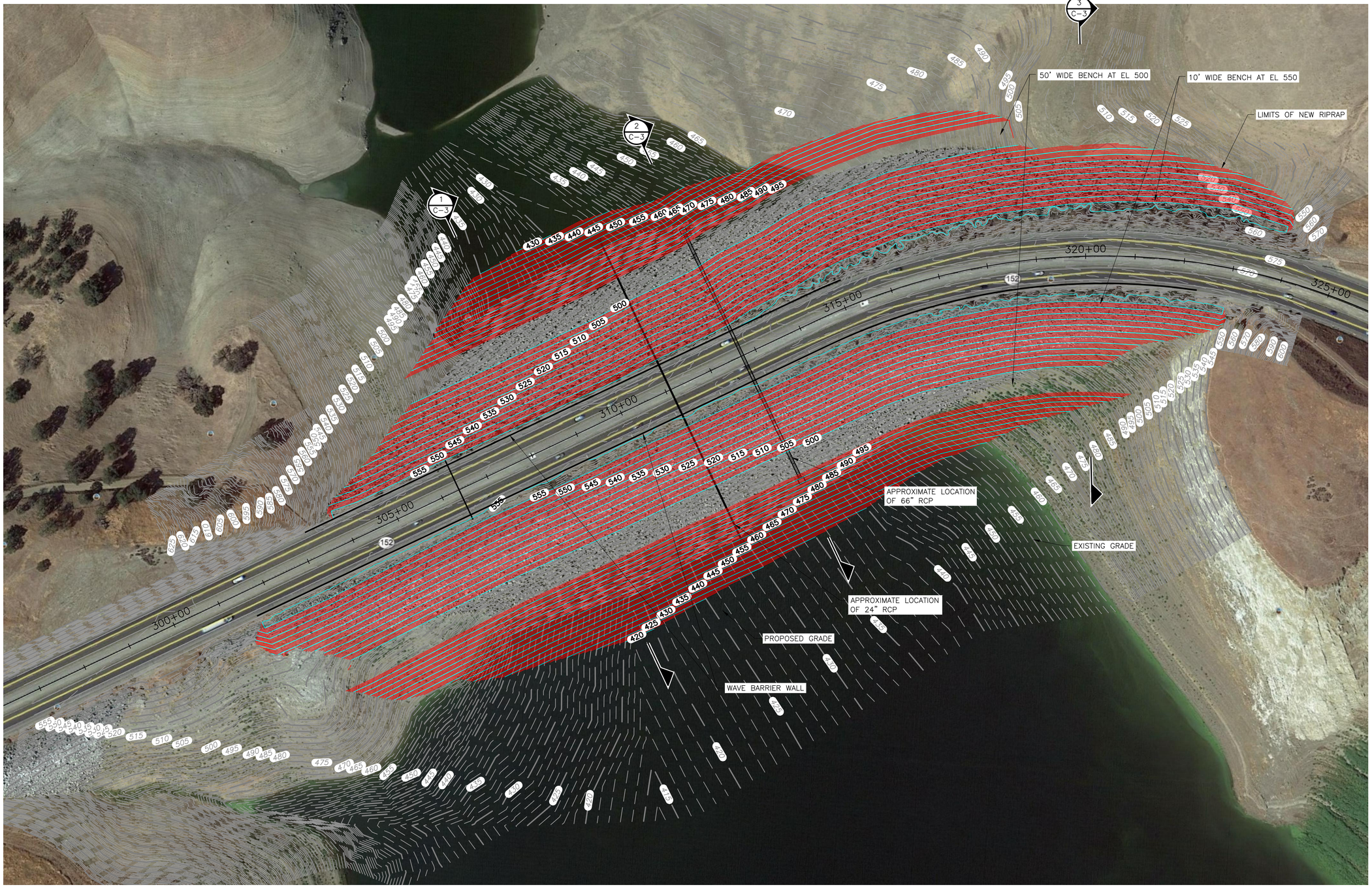
HIGHWAY 152 EMBANKMENT PROPOSED SITE AND GRADING PLAN ALTERNATIVE 1

PROJECT NO. 141064-242990
FILE NAME: C002STPL.DWG

SHEET NO.
C-2

PRELIMINARY DRAWINGS - NOT FOR CONSTRUCTION

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PLAN
1" = 100'

N

1" = 100'
50 0 100

VOLUME SUMMARY	
MATERIAL	VOLUME (CY)
CLASS II RIPRAP	381,332
CLASS III RIPRAP	131,300
EMBANKMENT	3,468

NOTE:

1. QUANTITIES REPORTED ARE AS PLACED VOLUMES.

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: E.O. TASTAN
DRAWN BY: K. RYAN
SHEET CHK'D BY: S. WHITESIDE
CROSS CHK'D BY: R. FOSSE
APPROVED BY: E.O. TASTAN
DATE: JUNE 2020

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Sacramento, CA 95833 | Tel: (916) 576-7497

LOS BANOS, CALIFORNIA

SISK DAM RAISE FEASIBILITY

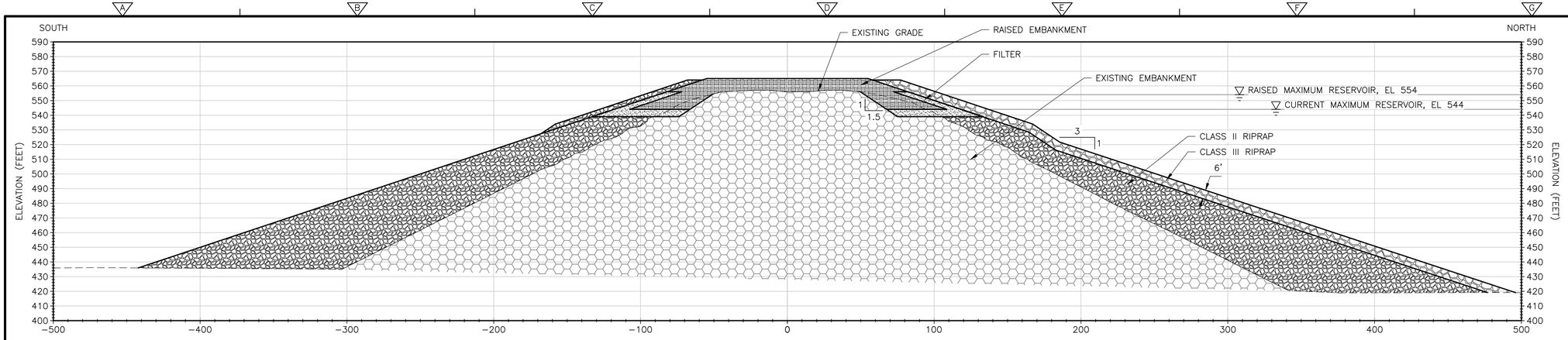
HIGHWAY 152 EMBANKMENT PROPOSED SITE AND GRADING PLAN ALTERNATIVE 2

PROJECT NO. 141064-242990
FILE NAME: C002STPL-A.DWG

SHEET NO.
C-2A

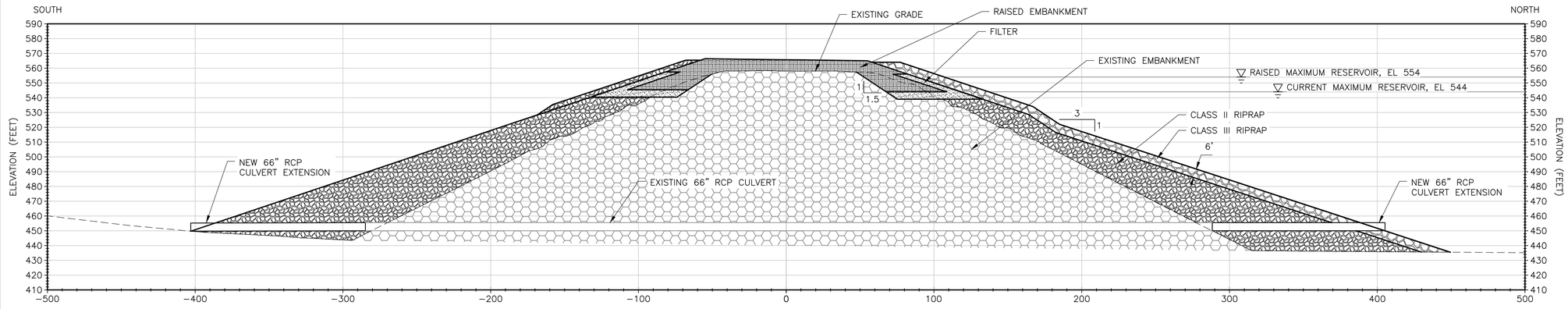
PRELIMINARY DRAWINGS - NOT FOR CONSTRUCTION

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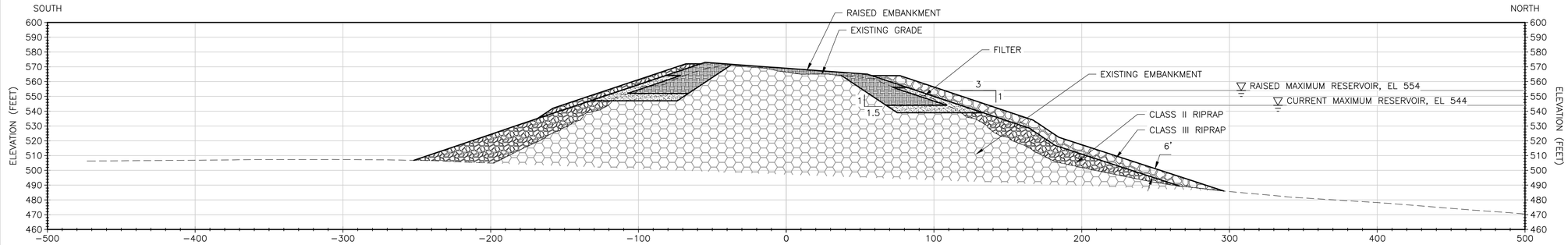
STATION 308+50

SECTION 1
1"=40'
C-2



STATION 312+71

SECTION 2
1"=40'
C-2



STATION 320+00

SECTION 3
1"=40'
C-2

1" = 40'
20 0 40

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: E.O. TASTAN
DRAWN BY: K. RYAN
SHEET CHK'D BY: S. WHITESIDE
CROSS CHK'D BY: R. FOSSE
APPROVED BY: E.O. TASTAN
DATE: JUNE 2020

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Sacramento, CA 95833 | Tel: (916) 576-7497

LOS BANOS, CALIFORNIA

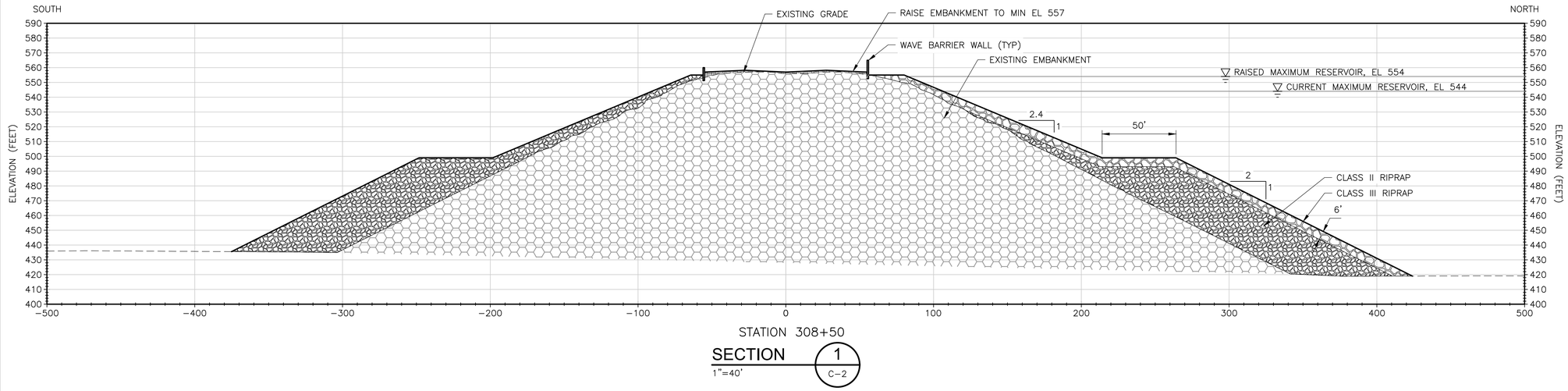
SISK DAM RAISE FEASIBILITY

HIGHWAY 152 EMBANKMENT CROSS SECTIONS ALTERNATIVE 1

PROJECT NO. 141064-242990
C003SCTN_1_8557_68DFB554.DWG
SHEET NO.
C-3

PRELIMINARY DRAWINGS - NOT FOR CONSTRUCTION

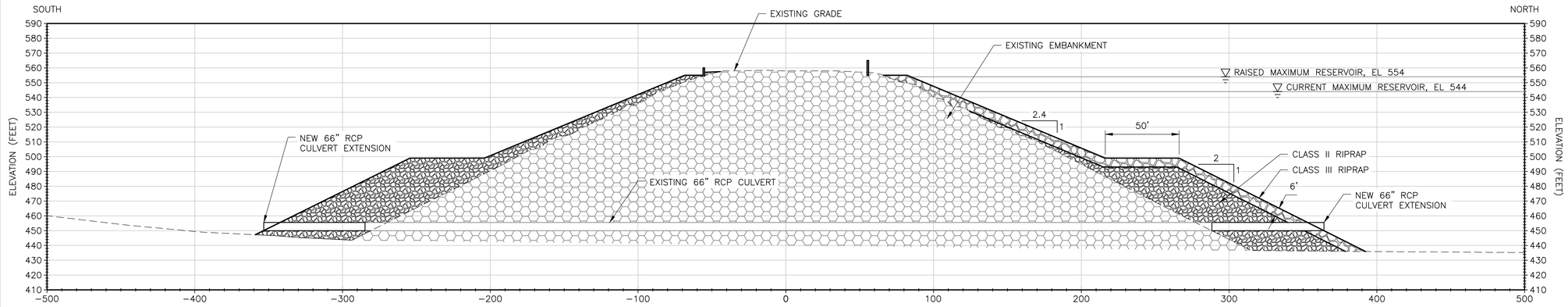
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STATION 308+50

SECTION 1 (C-2)

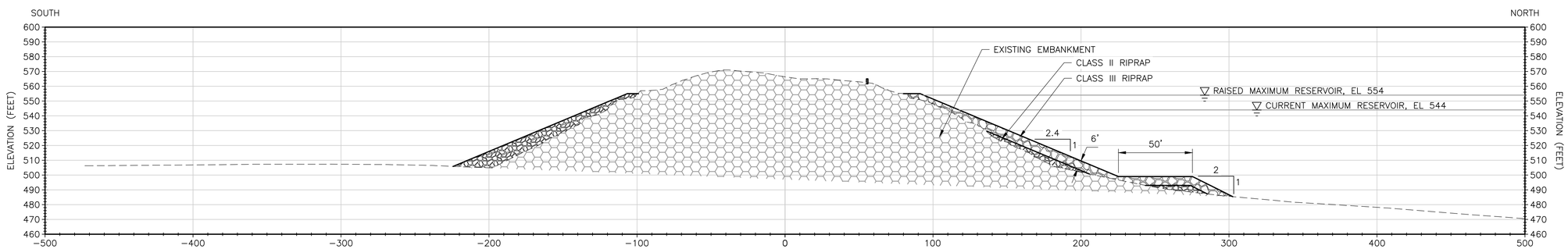
1"=40'



STATION 312+71

SECTION 2 (C-2)

1"=40'



STATION 320+00

SECTION 3 (C-2)

1"=40'

1" = 40'

20 0 40

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REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: E.O. TASTAN
DRAWN BY: K. RYAN
SHEET CHK'D BY: S. WHITESIDE
CROSS CHK'D BY: R. FOSSE
APPROVED BY: E.O. TASTAN
DATE: JUNE 2020

CDM Smith
2295 Gateway Oaks Drive, Suite 250
Sacramento, CA 95833 | Tel: (916) 576-7497

LOS BANOS, CALIFORNIA

SISK DAM RAISE FEASIBILITY

HIGHWAY 152 EMBANKMENT CROSS SECTIONS ALTERNATIVE 2

PROJECT NO. 141064-242990
FILE NAME: C003SCTN-A.DWG

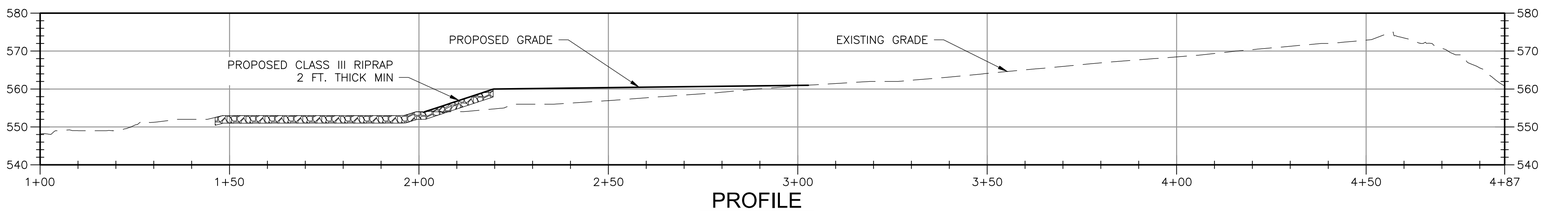
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C-3A

PRELIMINARY DRAWINGS - NOT FOR CONSTRUCTION

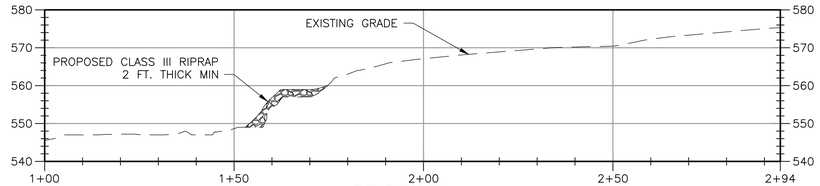


1" = 40'
20 0 40

PLAN
1" = 40'



PROFILE
1" = 20'H 1" = 20'V



PROFILE
1" = 20'H 1" = 20'V

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: E.O. TASTAN
DRAWN BY: K. RYAN
SHEET CHK'D BY: S. WHITESIDE
CROSS CHK'D BY: R. FOSSE
APPROVED BY: E.O. TASTAN
DATE: JUNE 2020

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LOS BANOS, CALIFORNIA

SISK DAM RAISE FEASIBILITY

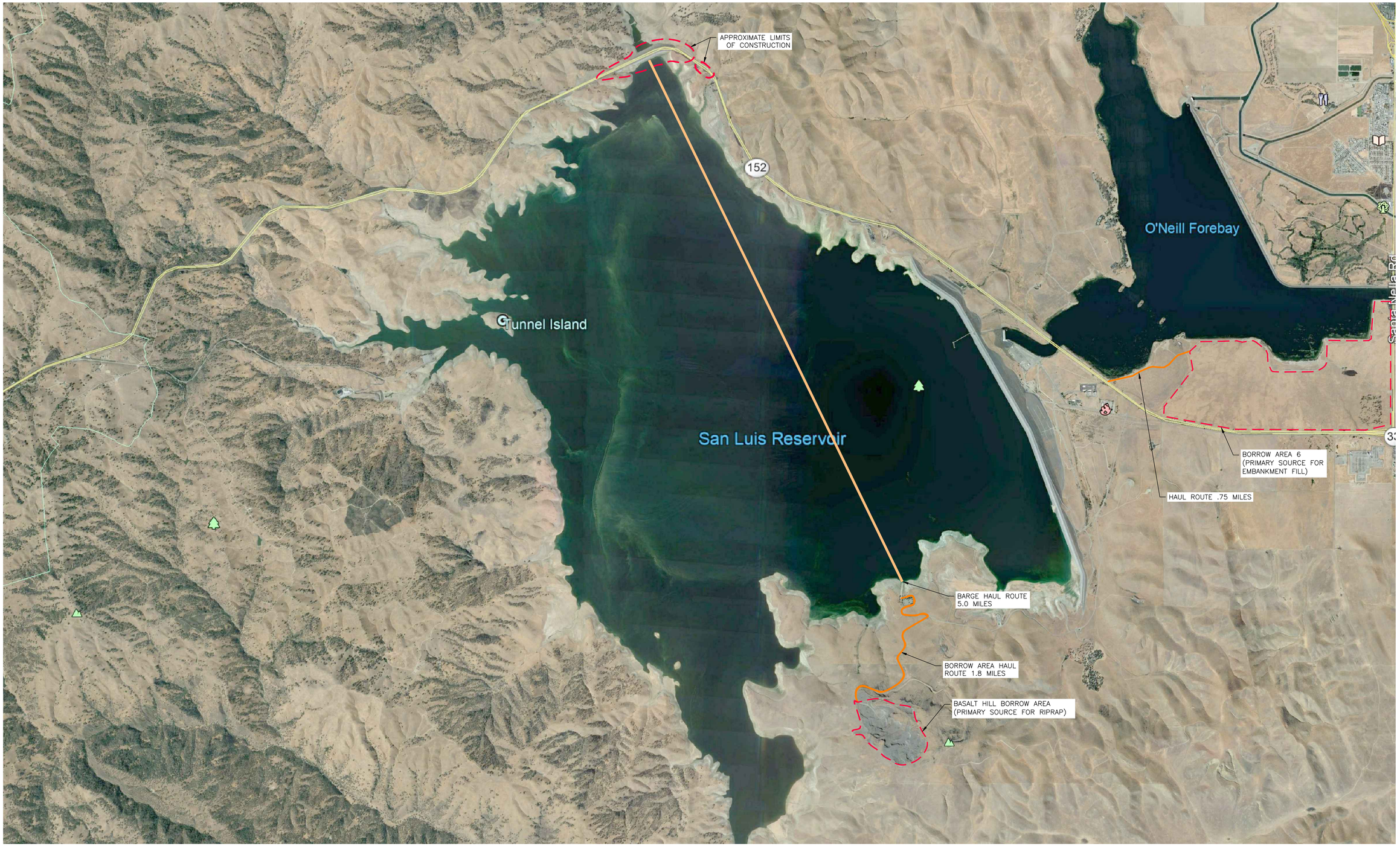
EAST OVERLOOK
PROPOSED SITE AND GRADING PLAN

PROJECT NO. 141064-242990
FILE NAME: C004STPL.DWG

SHEET NO.
C-4

PRELIMINARY DRAWINGS - NOT FOR CONSTRUCTION

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PLAN
NTS

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: E.O. TASTAN
DRAWN BY: K. RYAN
SHEET CHK'D BY: S. WHITESIDE
CROSS CHK'D BY: R. FOSSE
APPROVED BY: E.O. TASTAN
DATE: JUNE 2020

CDM Smith
2295 Gateway Oaks Drive, Suite 250
Sacramento, CA 95833 | Tel: (916) 576-7497

LOS BANOS, CALIFORNIA

SISK DAM RAISE FEASIBILITY

PROPOSED BORROW AREA LOCATION PLAN

PROJECT NO. 141064-242990
FILE NAME: C005STPL.DWG

SHEET NO.
C-5

PRELIMINARY DRAWINGS - NOT FOR CONSTRUCTION

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B.F. Sisk Dam Raise and Reservoir Expansion Project
Feasibility Design Report- SR 152 Modifications

Attachment C Calculations

Client:	**San Luis & Delta-Mendota Water Authority**	Calculated by: KNA	Date: 01-May-20
Project:	**B.F. Sisk Dam Raise Project**	Checked by: EOT	Date: 04-May-20
Detail:	**Modifications to SR 152 - Slope Stability**	Reviewed by: --	Date: --
Project #:	**141064-242990**		

Purpose: Perform global stability analyses for the modified SR 152 embankment design. Evaluate two design alternatives for the following design conditions: Long-term stability for low-water and high-water design levels, Seismic stability for low-water and high water design levels, and rapid drawdown

Procedure: Selected the deepest cross-section of the valley to represent the critical cross-section for global stability design. The selected section has a base elevation of 424 feet. Design alternative 1 modeled the crest at an elevation of 565 feet and utilized a 3H:1V slope. Design alternative 2 modeled the crest at an elevation of 555 feet and utilized a buttress reinforcement with a 2H:1V slope. A bench was modeled at an elevation of 500 feet.

Based on visual observations at the site, the emankment is assumed to lie directly on bedrock or weathered rock. Therefore, the global stability analyses focused primarily on stability within the embankment section.

The existing embankment was constructed to Caltrans compaction specifications. The strength parameters for the embankment backfill, filter material, and Riprap sections of the embankment were selected based on recommendations within the Caltrans geotechnical manual and the FHWA Geotechnical Engineering Circular No. 5 (Loehr, et al., 2016). See **Table 1** for the selected design soil

Table 1: Summary of Soil Strength Parameters

Soil Designation	Unit Weight (pcf)	Friction Angle, ϕ' (°)	Cohesion (psf)
Riprap	140	45	0
Embankment Backfill	130	35	0
Filter Material	110	34	0
Foundation Material	120	38	0

Utilized the GeoStudio 2018 software suite to perform the global stability analyses using the Morgenstern-Price method. Seep/W was used to perform the hydraulic analyses for the rapid drawdown stability analyses, and Slope/W was used to perform limit equilibrium and pseudostatic stability analyses.

The drawdown rate for the rapid drawdown stability analyses was selected as 2 feet per day to model the operational limit for the reservoir.

The seismic coefficient, k_h = 0.2 g, was selected based on the Caltran's geotechnical manual design

Conclusions: The stability analyses indicate that the proposed embankment design will satisfy the minimum factor of safety requirements for each design condition. See **Table 2**, below, for a summary of the analysis results. The output files for each design condition are attached.

Table 2: Summary of Slope Stability Results

Design Condition	Required Factor of Safety	Estimated Factor of Safety	
		Alternative 1	Alternative 2
Long-Term, Low Water	1.5	2.12	1.91
Long-Term, High Water	1.5	2.32	2.12
Seismic, Low Water	1.1	1.27	1.17
Seismic, High Water	1.0	1.02	1.00
Rapid Drawdown	1.1	2.12	1.78

Client:	**San Luis & Delta-Mendota Water Authority**	Calculated by: KNA	Date: 01-May-20
Project:	**B.F. Sisk Dam Raise Project**	Checked by: EOT	Date: 04-May-20
Detail:	**Modifications to SR 152 - Slope Stability**	Reviewed by: --	Date: --
Project #:	**141064-242990**		

References:

1. *Caltrans Geotechnical Manual - Embankments*, December 2014.
2. Loehr, J.E., Lutenegger, A., Rosenblad, B., and Boeckmann, A. (2016*), FHWA NHI-16-072, Geotechnical Site Characterization*, Geotechnical Engineering Circular No. 5, November 2016.
3. Das, Braja M. (2007), *Principles of Foundation Engineering*, Sixth Edition.
4. Holtz and Kovacs (1981), *An Introduction to Geotechnical Engineering*.
5. McCarthy, David F. (1998), *Essentials of Soil Mechanics and Foundations: Basic Geotechnics*, Fifth Edition.

Attachments:

Sixteen (16) GeoStudio output files:
- Three (3) Seep/W output files for Alternative 1,
- Five (5) Slope/W outpput files for Alternative 1,
- Three (3) Seep/W output files for Alternative 2, and
- Five (5) Slope/W outpput files for Alternative 2.

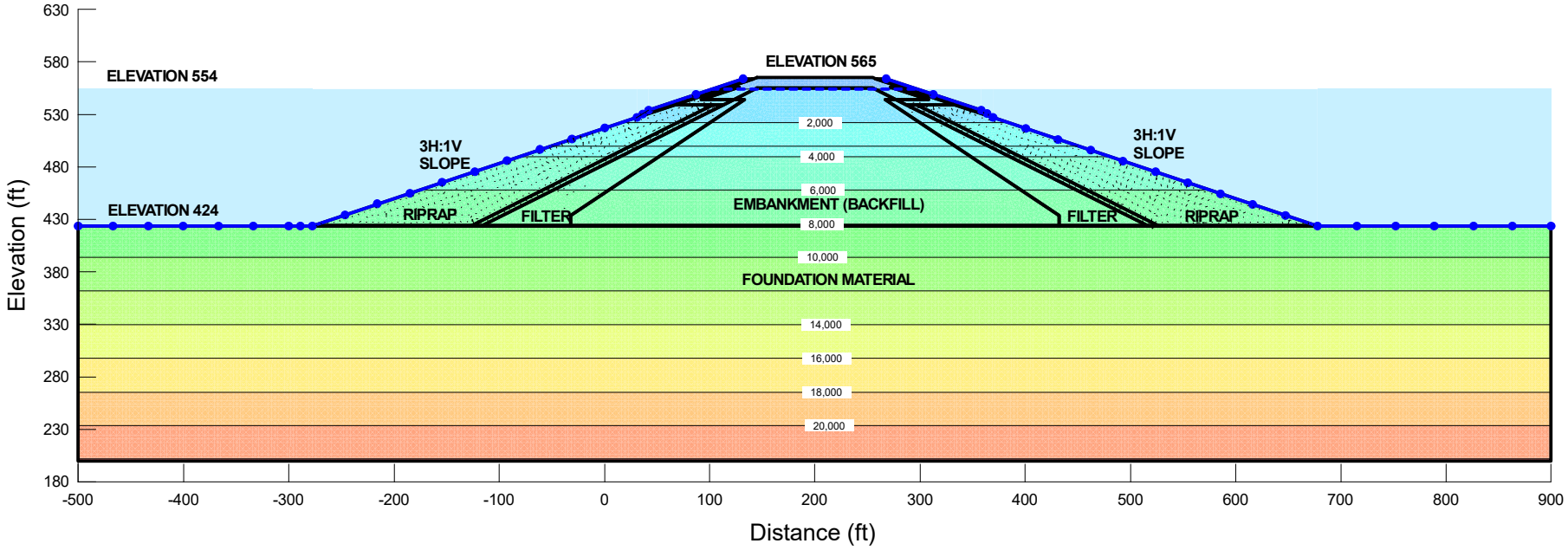
Design Alternative No. 1

Client: San Luis & Delta-Mendota Water Authority **Raised Crest with 3H:1V Slope**
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 1.1 Modified Steady State (El. 554)
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Steady-State

Color	Name	Model	Sat Kx (ft/sec)	Volumetric Water Content	Vol. WC. Function	K-Function
	Embankment	Saturated / Unsaturated			Silty Clay	Silty Clay Conductivity
	Filter	Saturated / Unsaturated			Sand	Sand Conductivity
	Foundation	Saturated Only	3e-07	0.4		
	Riprap	Saturated / Unsaturated			Gravel	Gravel Conductivity



Prepared By: Applegate, Kermit
Date: 05/21/2020

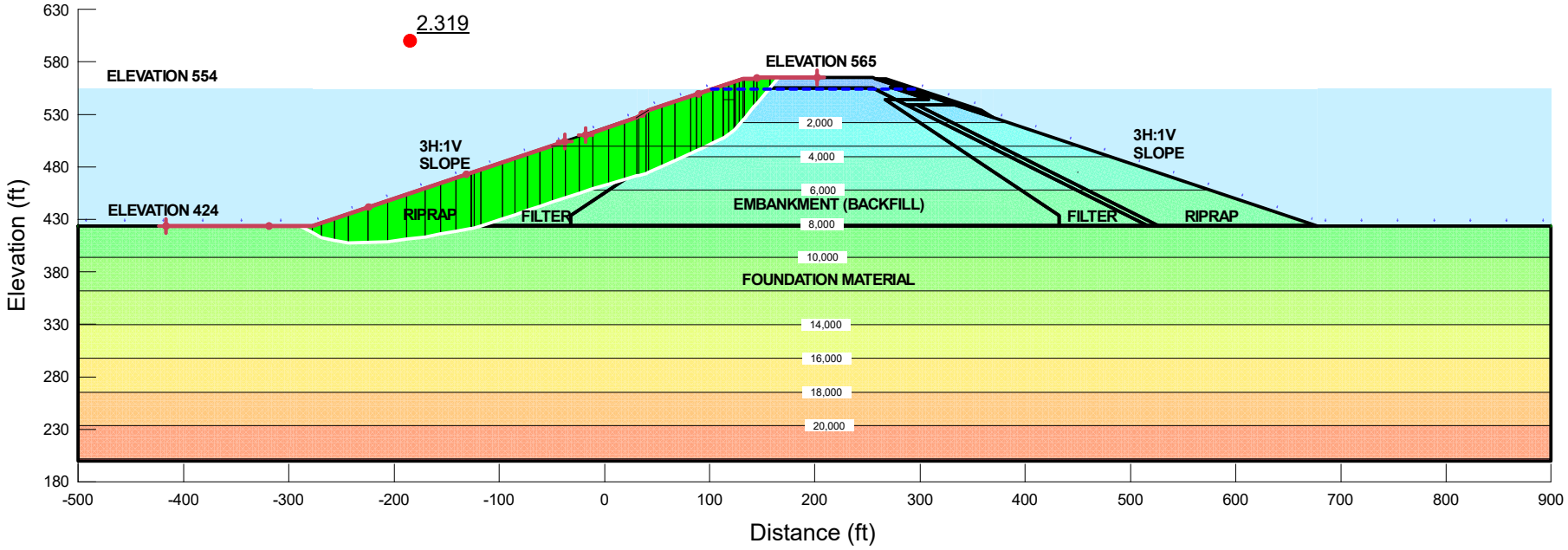
Design Alternative No. 1

Client: San Luis & Delta-Mendota Water Authority **Raised Crest with 3H:1V Slope**
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 1.1.1 Modified Steady State Static Stability
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment	Mohr-Coulomb	130	0	35
	Filter	Mohr-Coulomb	110	0	34
	Foundation	Mohr-Coulomb	120	0	38
	Riprap	Mohr-Coulomb	140	0	45



Prepared By: Applegate, Kermit
Date: 05/21/2020

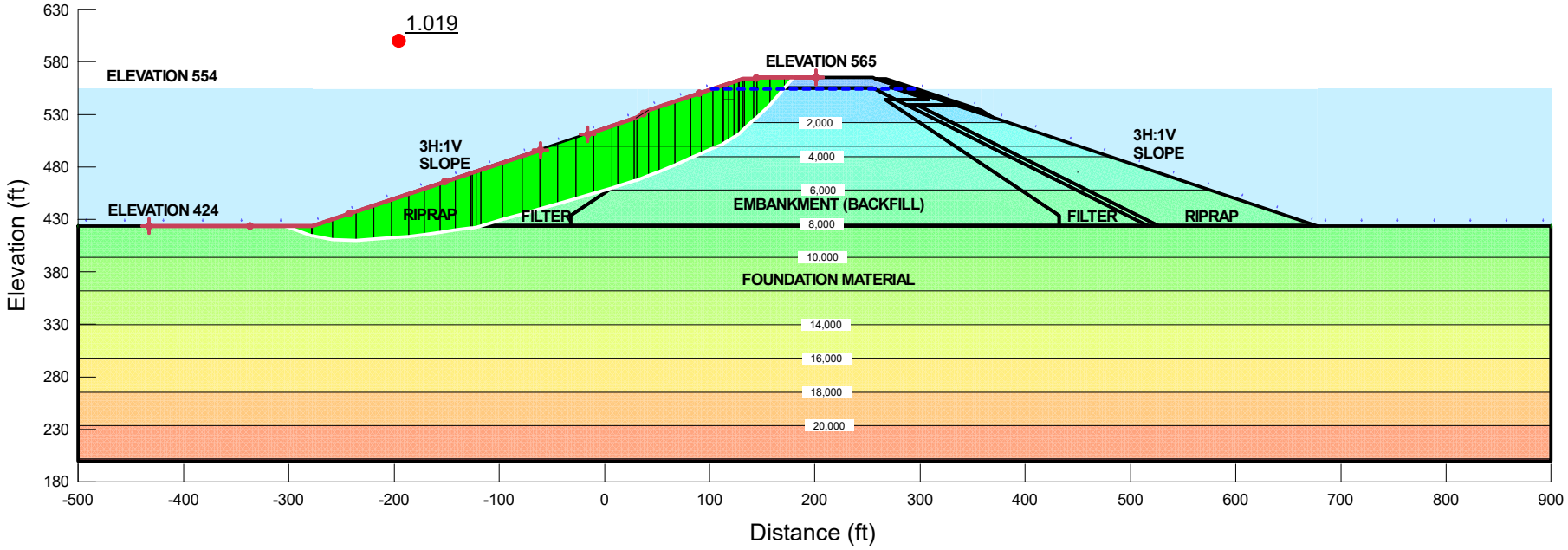
Design Alternative No. 1

Client: San Luis & Delta-Mendota Water Authority **Raised Crest with 3H:1V Slope**
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 1.1.2 Modified Steady State Pseudo-Static Stability
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0.2

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment	Mohr-Coulomb	130	0	35
	Filter	Mohr-Coulomb	110	0	34
	Foundation	Mohr-Coulomb	120	0	38
	Riprap	Mohr-Coulomb	140	0	45



Prepared By: Applegate, Kermit
Date: 05/21/2020

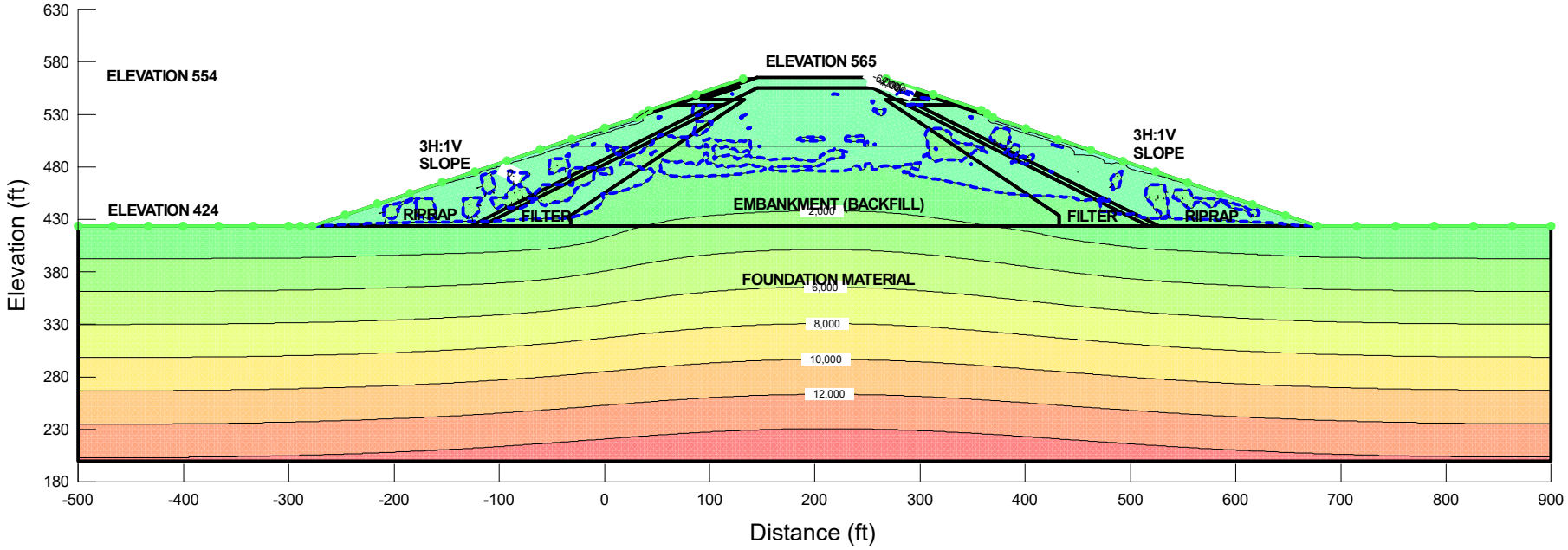
Design Alternative No. 1

Client: San Luis & Delta-Mendota Water Authority **Raised Crest with 3H:1V Slope**
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 1.2 Modified Transient State - Drawdown at 2 ft/day
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Transient

Color	Name	Model	Sat Kx (ft/sec)	Volumetric Water Content	Vol. WC. Function	K-Function
	Embankment	Saturated / Unsaturated			Silty Clay	Silty Clay Conductivity
	Filter	Saturated / Unsaturated			Sand	Sand Conductivity
	Foundation	Saturated Only	3e-07	0.4		
	Riprap	Saturated / Unsaturated			Gravel	Gravel Conductivity



Prepared By: Applegate, Kermit
Date: 05/21/2020

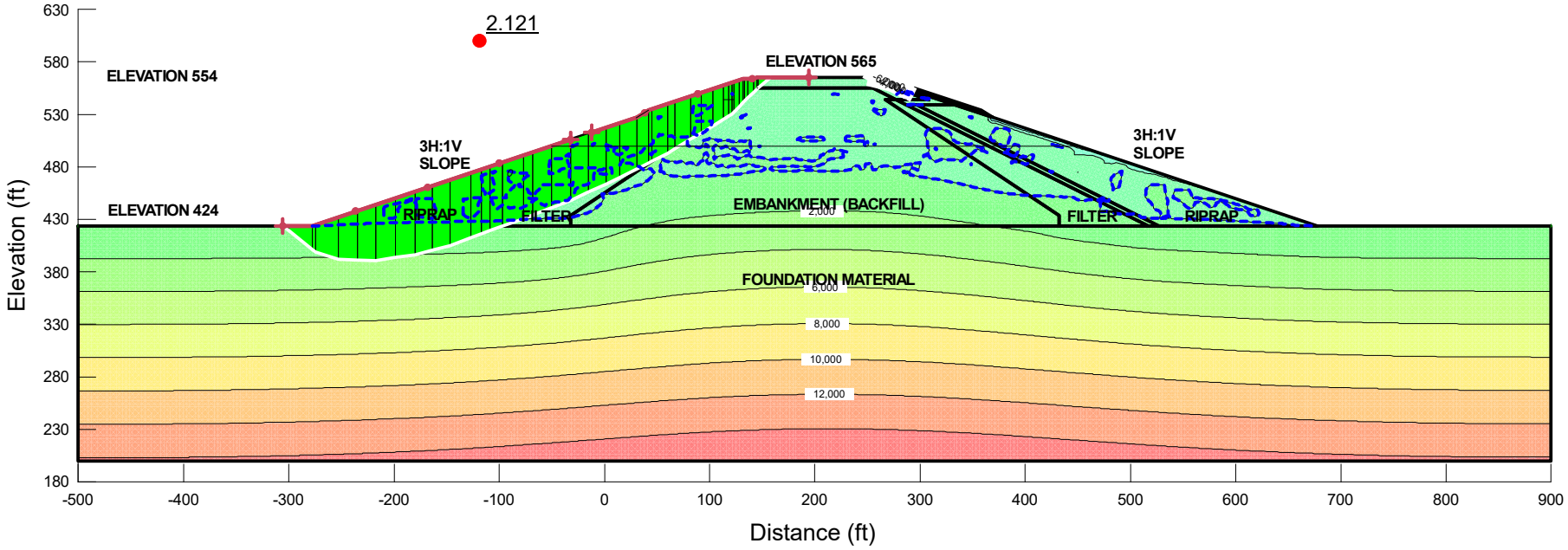
Design Alternative No. 1

Client: San Luis & Delta-Mendota Water Authority **Raised Crest with 3H:1V Slope**
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 1.2.1 Drawdown Stability (2 ft/day)
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment	Mohr-Coulomb	130	0	35
	Filter	Mohr-Coulomb	110	0	34
	Foundation	Mohr-Coulomb	120	0	38
	Riprap	Mohr-Coulomb	140	0	45



Prepared By: Applegate, Kermit
Date: 05/21/2020

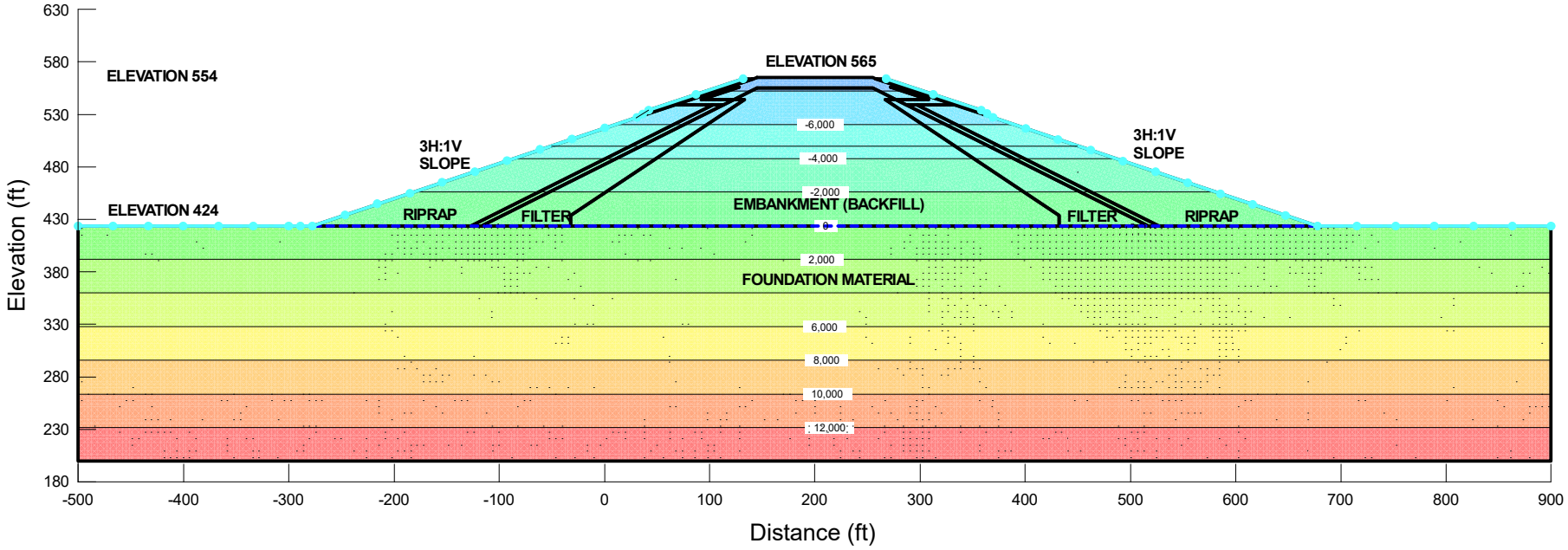
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Client: San Luis & Delta-Mendota Water Authority **Raised Crest with 3H:1V Slope**
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 1.3 Low-Water Steady State (El. 424)
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Steady-State

Color	Name	Model	Sat Kx (ft/sec)	Volumetric Water Content	Vol. WC. Function	K-Function
	Embankment	Saturated / Unsaturated			Silty Clay	Silty Clay Conductivity
	Filter	Saturated / Unsaturated			Sand	Sand Conductivity
	Foundation	Saturated Only	3e-07	0.4		
	Riprap	Saturated / Unsaturated			Gravel	Gravel Conductivity



Prepared By: Applegate, Kermit
Date: 05/21/2020

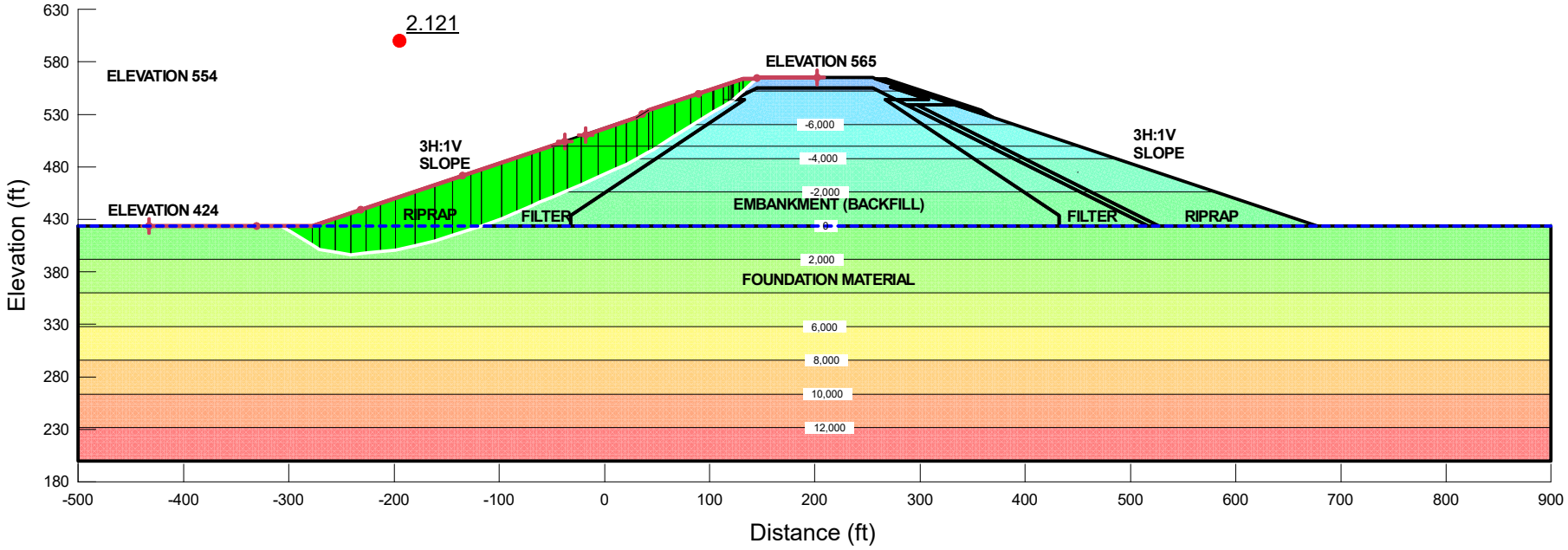
Design Alternative No. 1

Client: San Luis & Delta-Mendota Water Authority **Raised Crest with 3H:1V Slope**
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 1.3.1 Low-Water Steady State Static Stability
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment	Mohr-Coulomb	130	0	35
	Filter	Mohr-Coulomb	110	0	34
	Foundation	Mohr-Coulomb	120	0	38
	Riprap	Mohr-Coulomb	140	0	45



Prepared By: Applegate, Kermit
Date: 05/21/2020

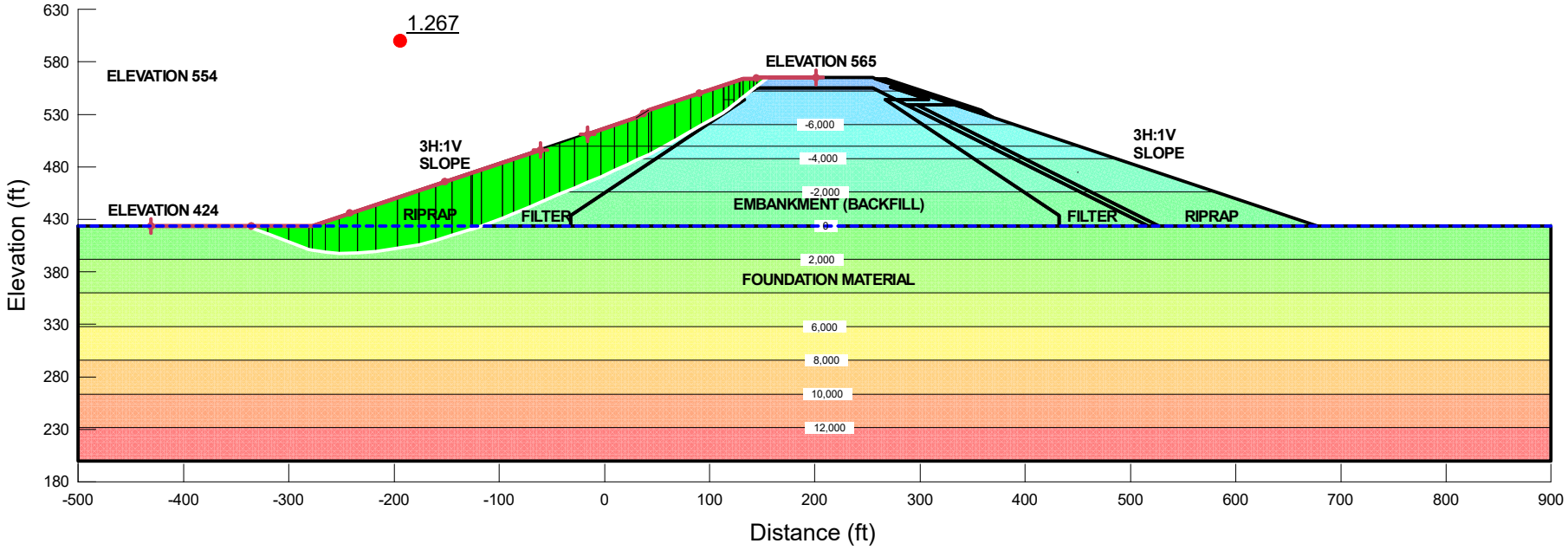
Design Alternative No. 1

Client: San Luis & Delta-Mendota Water Authority **Raised Crest with 3H:1V Slope**
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 1.3.2 Low-Water Steady State Pseudo-Static Stability
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0.2

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment	Mohr-Coulomb	130	0	35
	Filter	Mohr-Coulomb	110	0	34
	Foundation	Mohr-Coulomb	120	0	38
	Riprap	Mohr-Coulomb	140	0	45



Prepared By: Applegate, Kermit
Date: 05/21/2020

Design Alternative No. 2

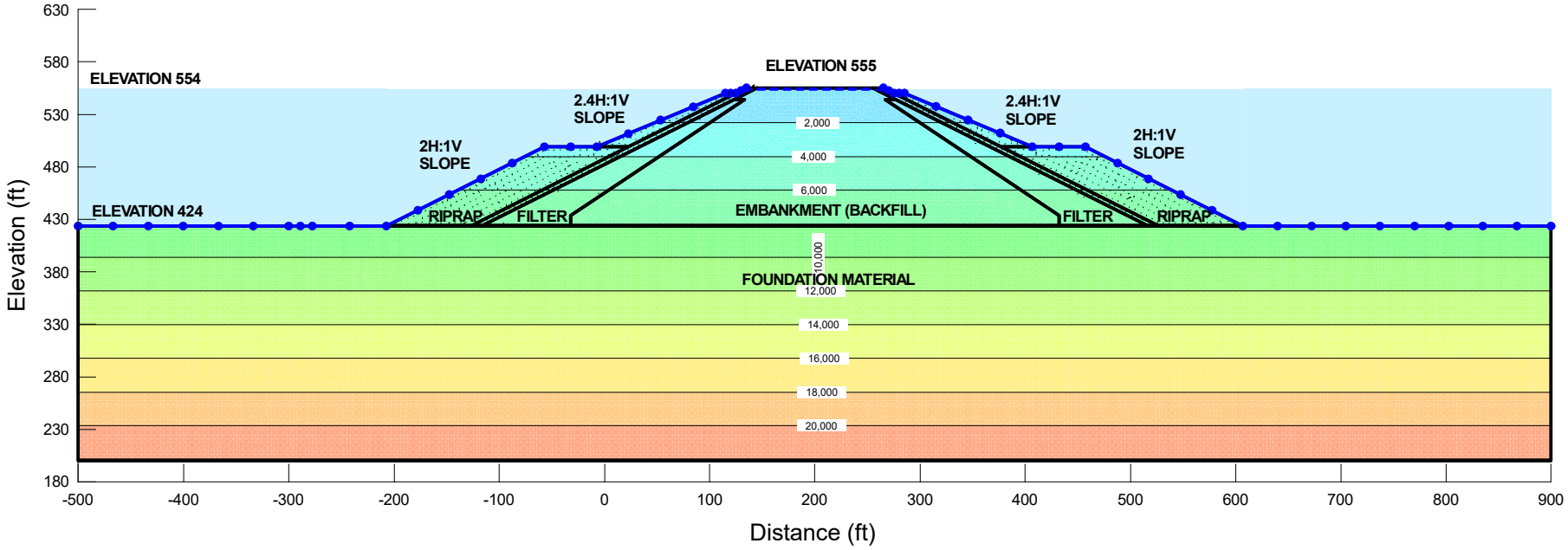
Benched Slope with Wave-Barrier Wall

Client: San Luis & Delta-Mendota Water Authority
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 2.1 Modified Steady State (El. 554)
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Steady-State

Color	Name	Model	Sat Kx (ft/sec)	Volumetric Water Content	Vol. WC. Function	K-Function
	Embankment	Saturated / Unsaturated			Silty Clay	Silty Clay Conductivity
	Filter	Saturated / Unsaturated			Sand	Sand Conductivity
	Foundation	Saturated Only	3e-07	0.4		
	Riprap	Saturated / Unsaturated			Gravel	Gravel Conductivity



Prepared By: Applegate, Kermit
Date: 05/21/2020

Design Alternative No. 2

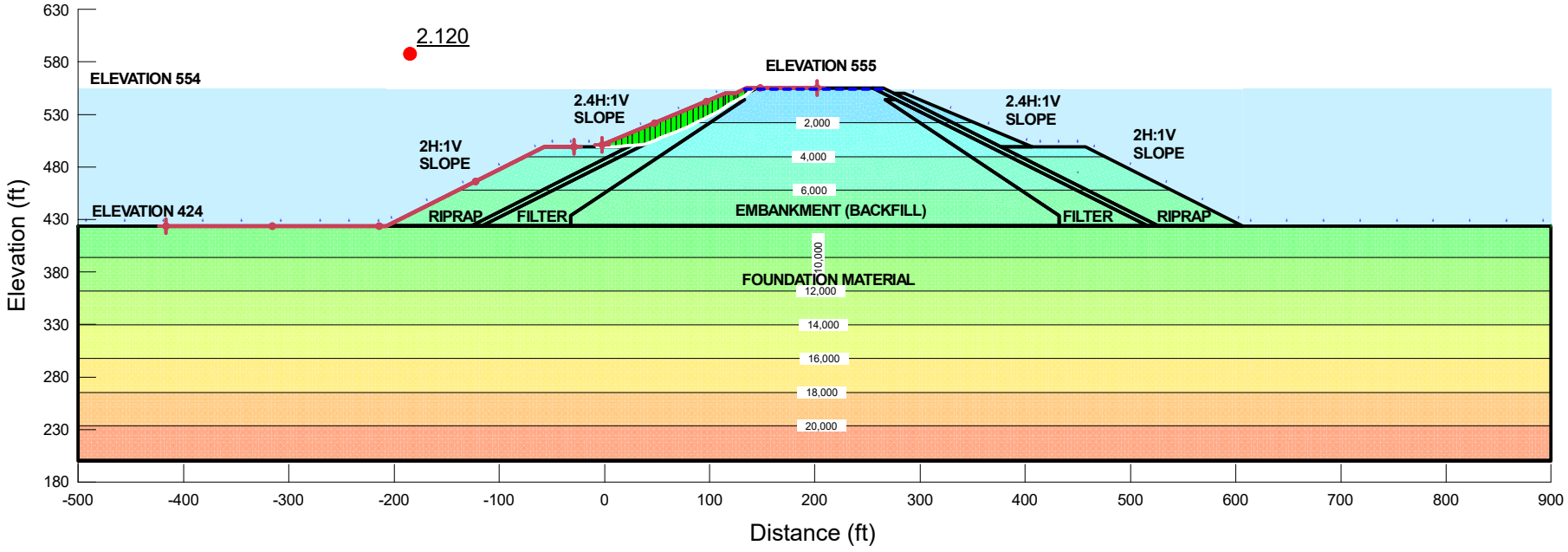
Benched Slope with Wave-Barrier Wall

Client: San Luis & Delta-Mendota Water Authority
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 2.1.1 Modified Steady State Static Stability
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment	Mohr-Coulomb	130	0	35
	Filter	Mohr-Coulomb	110	0	34
	Foundation	Mohr-Coulomb	120	0	38
	Riprap	Mohr-Coulomb	140	0	45



Prepared By: Applegate, Kermit
Date: 05/21/2020

Design Alternative No. 2

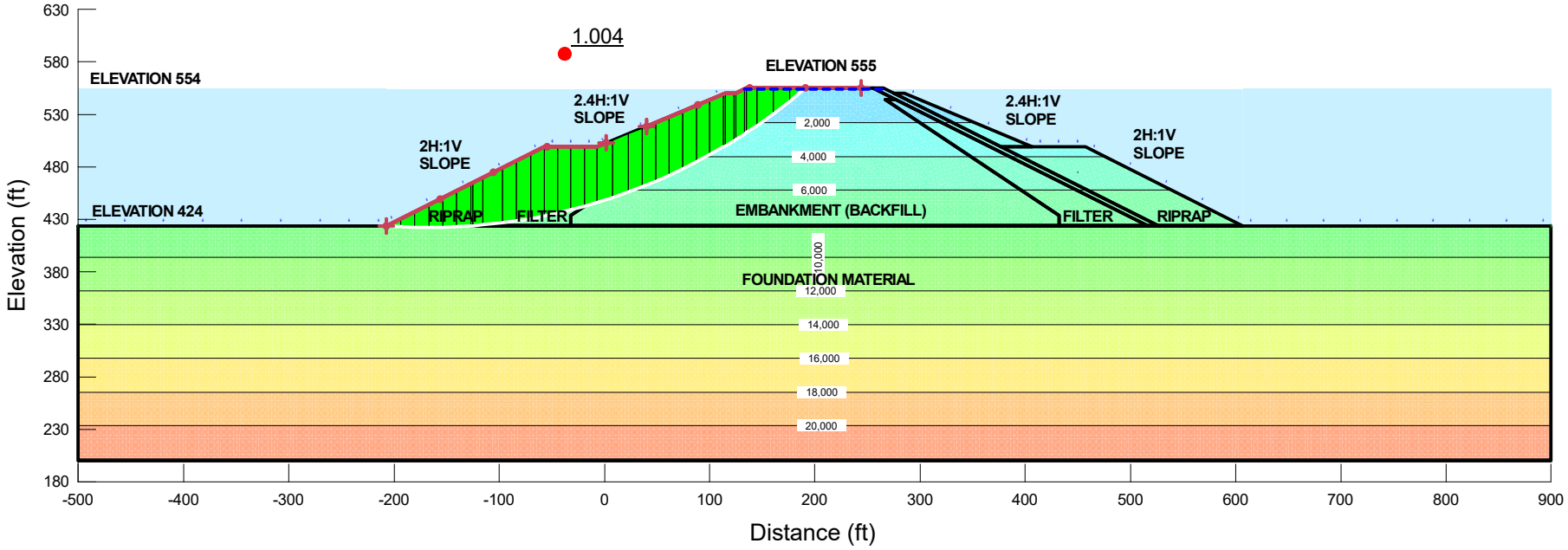
Benched Slope with Wave-Barrier Wall

Client: San Luis & Delta-Mendota Water Authority
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 2.1.2 Modified Steady State Pseudo-Static Stability
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Optimize Critical Slip Surface Location: No
Horz Seismic Coef.: 0.2

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment	Mohr-Coulomb	130	0	35
	Filter	Mohr-Coulomb	110	0	34
	Foundation	Mohr-Coulomb	120	0	38
	Riprap	Mohr-Coulomb	140	0	45



Prepared By: Applegate, Kermit
Date: 05/21/2020

Design Alternative No. 2

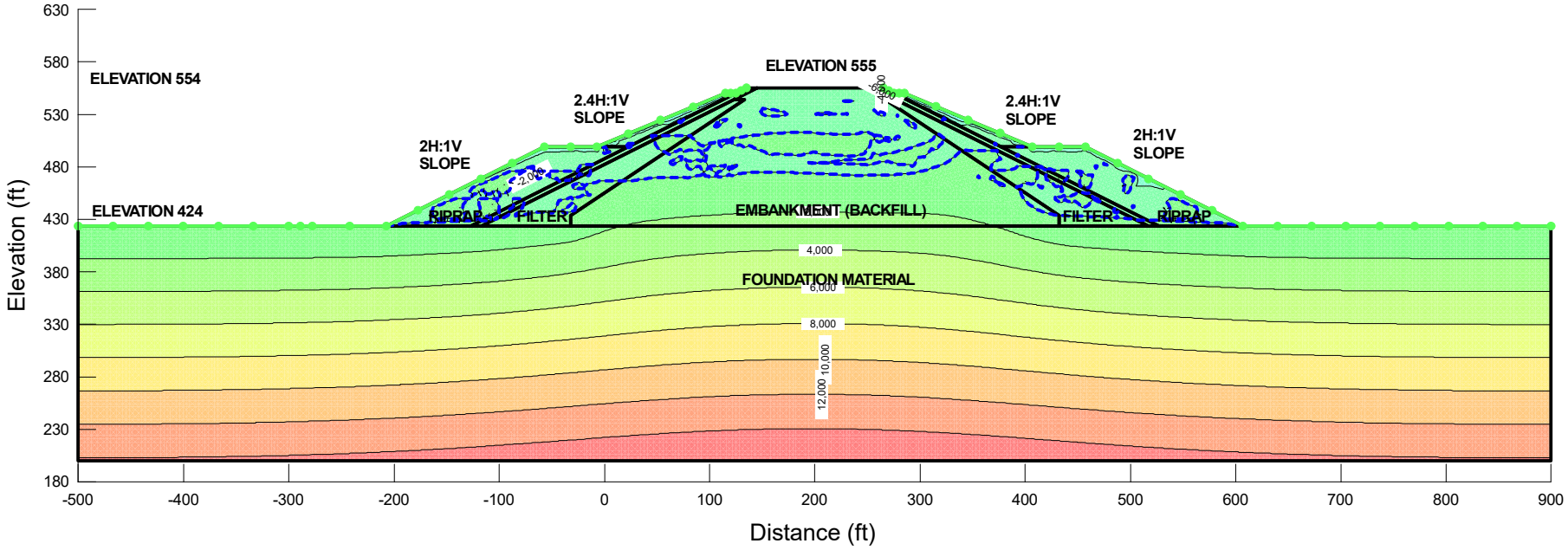
Benched Slope with Wave-Barrier Wall

Client: San Luis & Delta-Mendota Water Authority
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 2.2 Modified Transient State - Drawdown at 2 ft/day
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Transient

Color	Name	Model	Sat Kx (ft/sec)	Volumetric Water Content	Vol. WC. Function	K-Function
	Embankment	Saturated / Unsaturated			Silty Clay	Silty Clay Conductivity
	Filter	Saturated / Unsaturated			Sand	Sand Conductivity
	Foundation	Saturated Only	3e-07	0.4		
	Riprap	Saturated / Unsaturated			Gravel	Gravel Conductivity



Prepared By: Applegate, Kermit
Date: 05/21/2020

Design Alternative No. 2

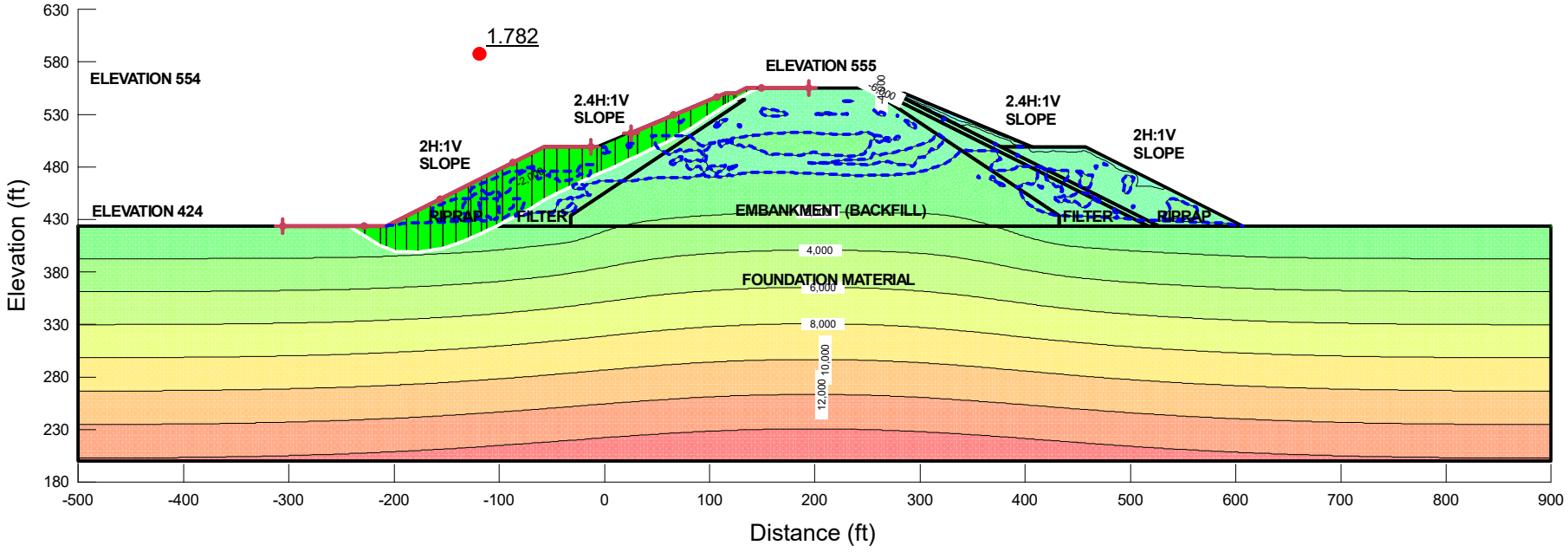
Benched Slope with Wave-Barrier Wall

Client: San Luis & Delta-Mendota Water Authority
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 2.2.1 Drawdown Stability (2 ft/day)
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment	Mohr-Coulomb	130	0	35
	Filter	Mohr-Coulomb	110	0	34
	Foundation	Mohr-Coulomb	120	0	38
	Riprap	Mohr-Coulomb	140	0	45



Prepared By: Applegate, Kermit
Date: 05/21/2020

Design Alternative No. 2

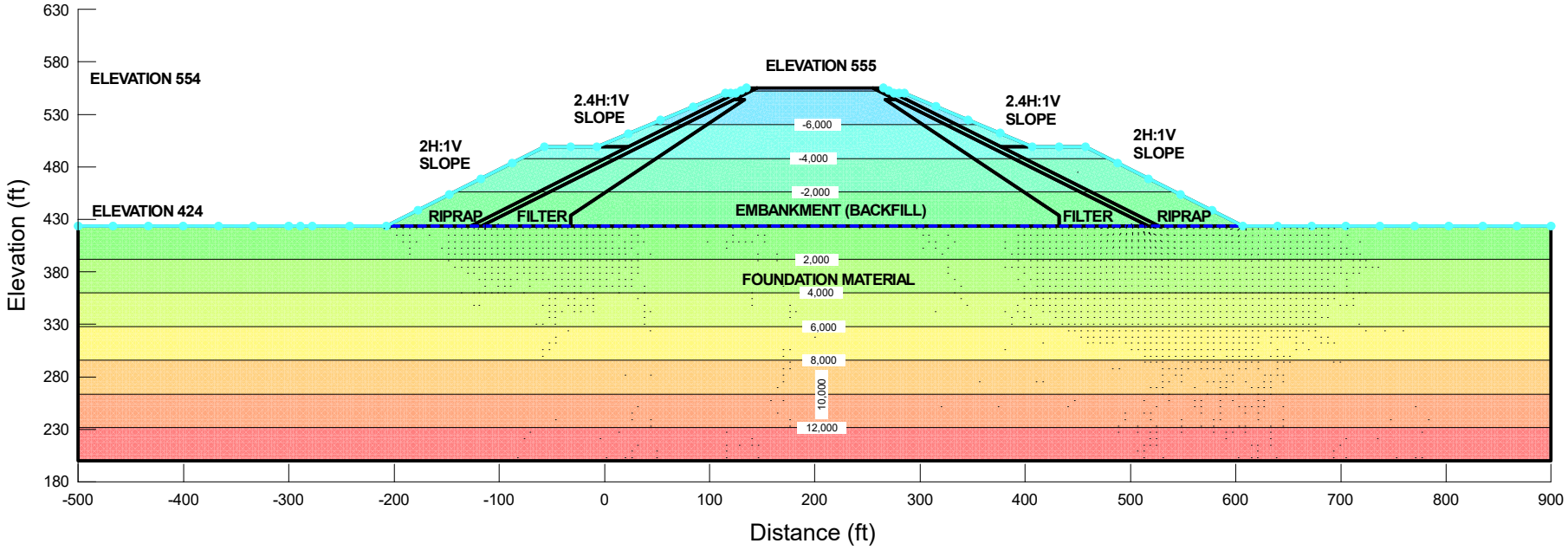
Benched Slope with Wave-Barrier Wall

Client: San Luis & Delta-Mendota Water Authority
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 2.3 Low-Water Steady State (El. 424)
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Steady-State

Color	Name	Model	Sat Kx (ft/sec)	Volumetric Water Content	Vol. WC. Function	K-Function
	Embankment	Saturated / Unsaturated			Silty Clay	Silty Clay Conductivity
	Filter	Saturated / Unsaturated			Sand	Sand Conductivity
	Foundation	Saturated Only	3e-07	0.4		
	Riprap	Saturated / Unsaturated			Gravel	Gravel Conductivity



Prepared By: Applegate, Kermit
Date: 05/21/2020

Design Alternative No. 2

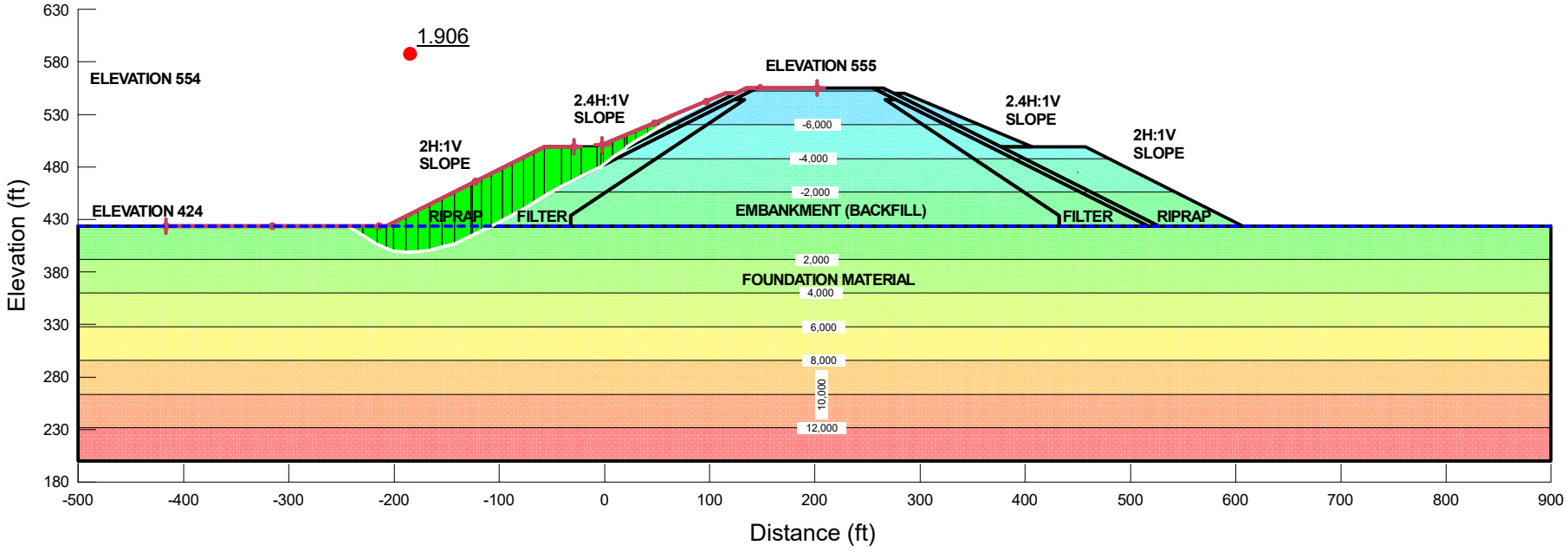
Benched Slope with Wave-Barrier Wall

Client: San Luis & Delta-Mendota Water Authority
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 2.3.1 Low-Water Steady State Static Stability
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment	Mohr-Coulomb	130	0	35
	Filter	Mohr-Coulomb	110	0	34
	Foundation	Mohr-Coulomb	120	0	38
	Riprap	Mohr-Coulomb	140	0	45



Prepared By: Applegate, Kermit
Date: 05/21/2020

Design Alternative No. 2

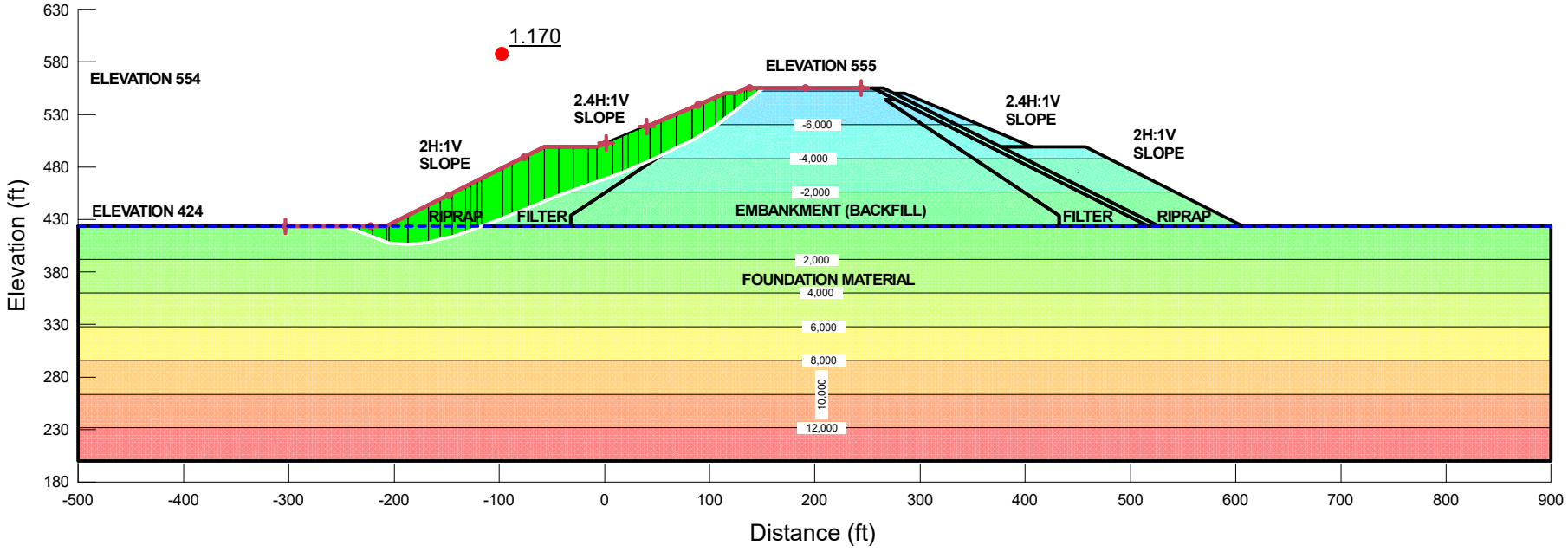
Benched Slope with Wave-Barrier Wall

Client: San Luis & Delta-Mendota Water Authority
Project: B.F. Sisk Dam Raise Project
Task: Design Alternative Analyses
Detail: Slope Stability for Design Alternatives

Analysis Details

Design Scenario: 2.3.2 Low-Water Steady State Pseudo-Static Stability
Design Cross-Section: Deepest Section of the Valley (Bottom El. 424)
Analysis Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Optimize Critical Slip Surface Location: Yes
Horz Seismic Coef.: 0.2

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment	Mohr-Coulomb	130	0	35
	Filter	Mohr-Coulomb	110	0	34
	Foundation	Mohr-Coulomb	120	0	38
	Riprap	Mohr-Coulomb	140	0	45



Prepared By: Applegate, Kermit
Date: 05/21/2020

CLIENT:	Caltrans			**PROJECT:**	Sisk Dam -SR 152 Raising
BY:	KNA	**DATE:**	10-Jun-20	**Job No.:**	141064-242990
CHKD BY:	EOT	**DATE:**	11-Jun-20	**SHEET No.:**	1

SUBJECT: Minimum Freeboard and Riprap Sizing Requirements - South Side of SR 152 Embankment - Alternate 1

Developed by K. Applegate; Charlotte, NC — Mathcad 15, PTC.

1. Purpose/Objective

To estimate the required freeboard and riprap gradation limits at the Sisk Dam site based on the methods presented in Chapter 6 and Chapter 7 of the U.S. Department of the Interior Bureau of Reclamation's *Design Standards No. 13 - Embankment Dams* manual.

2. Procedure

a. Develop necessary input parameters for the freeboard and riprap calculations.

b. Follow the calculations presented in the worksheet.

1. Calculate the Fetch for the reservoir.
2. Determine design wind velocity (based on CA Dept. of Water Resourcese - California Data Exchange Center).
3. Calculate the design wave height.
4. Estimate the wave runup for the proposed embankment geometry.
5. Estimate the wind setup for the proposed embankment geometry.
6. Calculate the required freeboard.
7. Calculate the required mean rock weight (W_{50}) and minimum riprap thickness (T_{min}).
8. Calculate the design wave height for riprap design (H_{10}).
9. Determine the riprap gradation requirements.

c. Enter/change input parameters in the yellow boxes .

d. The calculated design parameters are auto-populated and provided in green boxes .

3. References/Data Sources

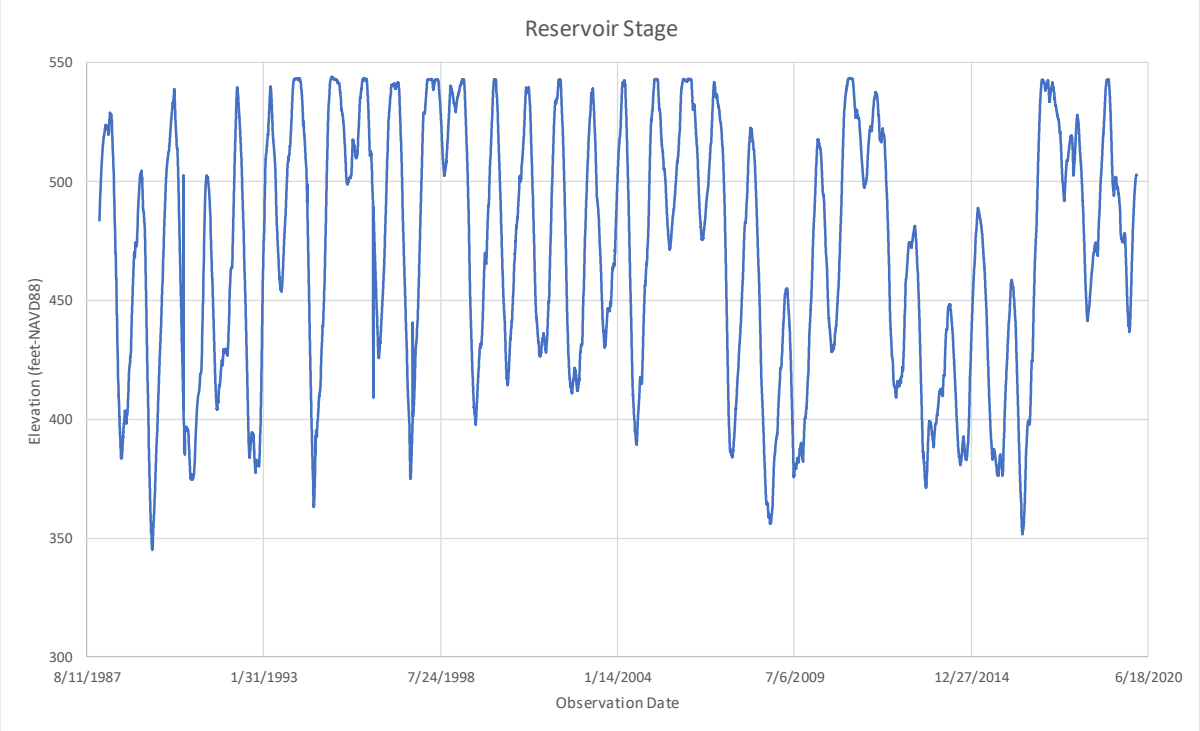
a. U.S. Department of the Interior Bureau of Reclamation, *Design Standards No. 13 - Embankment Dams*, September 2012.

b. CA Dept. of Water Resourcese - California Data Exchange Center, *cdec.water.ca.gov/cdecstation2/?sta=BLN.*

c. California Department of Water Resources - Resevoir stage data for the San Luis Reservoir, recorded between January 4, 1988 and February 11, 2020.

4. Assumptions and Limitations

a. The calculated runup will be applied to the maximum pool storage elevation. The reservoir stage continually fluctuates, and the reservoir may stay at or near maximum pool elevation for long periods of time. See the plot of historic reservoir stage data, below.



b. The maximum wind velocity was determined using the CA Dept. of Water Resourcese - California Data Exchange Center data records.

c. The wind velocity corresponding to the maximum recorded peak wind velocity was selected for the basis of design.

d. The wind velocities provided represent wind gusts above the ground surface. These values need to be adjusted to a 1-hour sustained wind velocity. USACE EM 1110-2-1100 guidance was used to convert the wind velocities to 1-hour sustained wind velocities.

e. The embankment is modeled with a riprap lined upstream slope for the runup calculations.

f. The embankment does not have an intermediate berm on the upstream slope.

g. The wave height distribution can be statistically modeled as a Rayleigh distribution.

h. Tolerable damage will be allowed for the riprap design.

i. The average depth over the length of the Fetch is assumed as 170 feet. This value was estimated based on the water volume (2,041,000 acre feet) and the surface area (12,700 acres) reported on Wikipedia. These values were reported for the existing maximum pool elevation of 544 feet. The proposed maximum pool elevation will be raised to elevation 554 feet.

D := 170ft - Assumed average depth along the length of the Fetch

5A. Calculation Input Data

Wind Velocity Data:

- Design Wind loads are based on CA Dept. of Water Resourcese - California Data Exchange Center data records at the LBN (Los Banos) station, see the table below.

San Luis Reservoir Wind Direction and Speed

Month	Direction (DEG)[1]	Speed (MPH)[1]	Avg Peak Wind Speed (MPH)[2]	Max Peak Wind Speed (MPH)[2]
January	167	4.87	9	48
February	188	5.95	11	54
March	206	6.62	12	44
April	230	8.03	15	45
May	243	9.30	17	46
June	243	9.63	18	46
July	172	8.60	16	42
August	197	7.91	15	41
September	200	7.29	14	43
October	195	6.18	11	49
November	176	5.05	9	40
December	168	4.89	9	52

1. Hourly wind direction and speed reported from 1/1/1995 to 6/2/2020
2. Hourly peak wind speed reported from 7/17/2003 to 6/2/2020

$$VL_CDEC := \begin{pmatrix} 38 \\ 42 \\ 48 \\ 54 \\ 60 \end{pmatrix} \cdot mph$$

- Max peak wind velocities based on recorded wind data.

$dvi := 3$ - Design velocity vector indice value for final riprap recommendations:

$tw := 3$ - Wind duration associated with the provided velocities (in seconds).

Slope Geometry Data:

$Slope := \frac{3}{1}$ - Embankment slope: Horizontal is numerator, Vertical is denominator

Riprap Design Parameters:

$Gs_{riprap} := 2.65$ - Specific gravity of rock for the riprap borrow material.

$\gamma_{riprap} := 160 \cdot pcf$ - Design unit weight for riprap material.

5B. Design Calculations

Step 1: Calculate Fetch - Refer to Figure 2 for Fetch calculation details

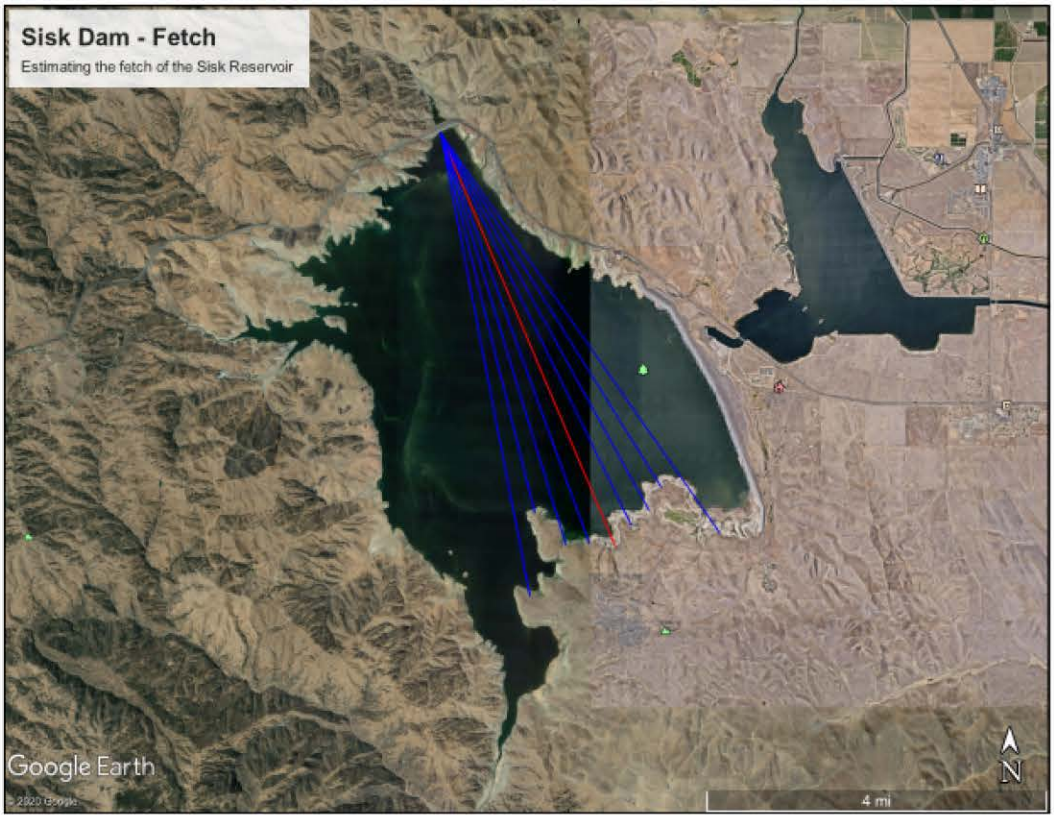


Figure 2: Geometry for Fetch Calculations

$Fsum := 5.55mi + 4.61mi + 5.07mi + 5.13mi + 5.29mi + 5.13mi + 5.08mi + 4.91mi + 5.74mi$

$Fetch := \frac{Fsum}{9}$ - Longest average distance from dam crest to opposite shoreline

$Fetch = 5.168 \cdot mi$

Table B-1, below, provides simplified freeboard estimates for "Small Dams" based on the Fetch.

Table B-1. Approximation of minimum and normal freeboard [10]

Longest fetch (miles)	Normal freeboard (added to the normal water surface) (feet)	Minimum freeboard (added to the maximum water surface) (feet)
<1	4	3
1	5	4
2.5	6	5
5	8	6
10	10	7

Note: These values were based on a wind velocity of 100 mi/h blowing over the normal reservoir water surface and 50 mi/h blowing over the MRWS. The effect of wind setup is not considered in the values shown. For embankment dams with soil-cement or other smooth upstream faces, depending on the smoothness of the surface, the values shown should be increased by a factor of up to 1.5.

Step 2: Determine Design Wind Velocity Parameters

Utilize online ASCE 7 Hazard Tool to estimate the design wind velocities at the proposed site (input values in Section 5A).

$$VL_CDEC = \begin{pmatrix} 38 \\ 42 \\ 48 \\ 54 \\ 60 \end{pmatrix} \cdot mph$$ - Peak Wind Velocities:

$tw = 3$ - Provided burst duration (sec)

Adjust the 3-second wind gust velocities (VL_CDEC) to 1-hour sustained wind velocities (VL_1hour) based on USACE EM 1110-2-1100:

$$Ratio_1hour := 1.277 + 0.296 \cdot \tanh\left(0.9 \cdot \log\left(\frac{45}{tw}\right)\right)$$

$Ratio_1hour = 1.509$

$$\frac{U_T}{U_{3600}} \text{ for } t < 3600$$

$$VL_1hour := VL_CDEC \cdot \frac{1}{Ratio_1hour}$$

$$VL_1hour = \begin{pmatrix} 25.176 \\ 27.826 \\ 31.801 \\ 35.776 \\ 39.751 \end{pmatrix} \cdot mph$$

Adjust over land velocities to over water velocities (VW), see Figure B-2:

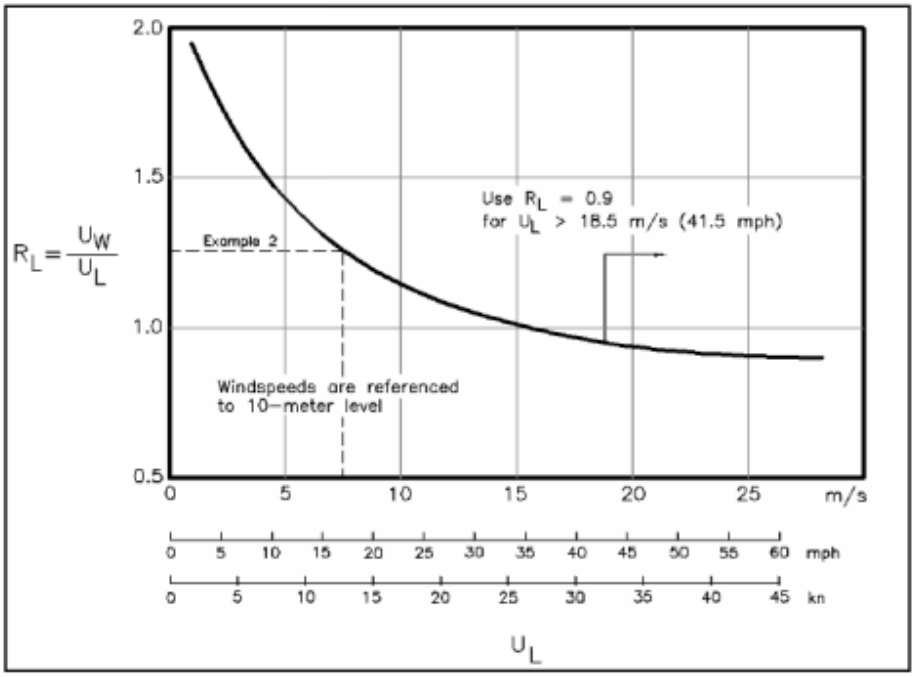


Figure B-2. Ratio of wind speed over water to wind speed over land as a function of wind speed over land [16a].

RL := 1.0

VW_1hour := RL·VL_1hour

$$VW_1hour = \begin{pmatrix} 25.176 \\ 27.826 \\ 31.801 \\ 35.776 \\ 39.751 \end{pmatrix} \cdot mph$$

- Sustained 1-hour duration wind velocities over water

Estimate the minimum duration needed to genterate the highest waves

$$tmin := 1.87 \cdot \left[\frac{\left(\frac{Fetch}{mi} \right)^{0.67}}{\left(\frac{VW_1hour}{mph} \right)^{0.34}} \right] \cdot hr$$

$$tmin = \begin{pmatrix} 1.877 \\ 1.814 \\ 1.734 \\ 1.665 \\ 1.607 \end{pmatrix} \cdot hr$$

- tmin values represent the minimum sustained wind duration required for the design wave to reach the significant heights estimated in Step 3, below.

The minimum duration required to fully mobilize the design wave heights is greater than the 1-hour assumed duration, so the waves will be fetch-limited, i.e. smaller than reported. However, we have conservatively used the 1-hour duration velocities reported above for the design calculations.

VW := VW_1hour

Step 3: Calculate Design Wave Height

The significant wave height (H_s) is defined as the average of the highest one-third of the waves in a wave field.

$i := 0..4$

$$Hs_i := 0.0245 \cdot \left(\frac{Fetch}{mi}\right)^{0.5} \cdot \frac{VW_i}{mph} \cdot \left(1.1 + 0.0156 \cdot \frac{VW_i}{mph}\right)^{0.5} \cdot ft$$

$$Hs = \begin{pmatrix} 1.713 \\ 1.92 \\ 2.238 \\ 2.566 \\ 2.904 \end{pmatrix} \cdot ft$$

- Significant wave height

Assuming the wave height distribution can be described using a Rayleigh distribution, Table B-2 may be used to estimate additional statistical wave heights. Since overtopping is not permissible at this site, a wave height of 1.67 times the significant height should be used for design. This design wave level corresponds to the highest 1 percent of waves.

If the maximum Fetch is not perpendicular to the dam crest, the wave height needs to be reduced to account for the angle of incidence. Based on an incidence angle that is perpendicular, the reduction factor is 1.0 based on Figure B-3.

Table B-2. Common wave height relationships

Percent of total number of waves in series averaged to compute specific wave height (H)	Ratio of specific wave height, H, to average wave height, H_{ave} (H/H_{ave})	Ratio of specific wave height, H, to significant wave height H_s (H/H_s)	Percent of waves exceeding specific wave height (H)
1	2.66	1.67	0.4
5	2.24	1.40	2
10	2.03	1.27	4
20	1.80	1.12	8
25	1.71	1.07	10
30	1.64	1.02	12
33.33	1.60	1.00	13
40	1.52	0.95	16
50	1.42	0.89	20
75	1.20	0.75	32
100	1.00	0.62	46

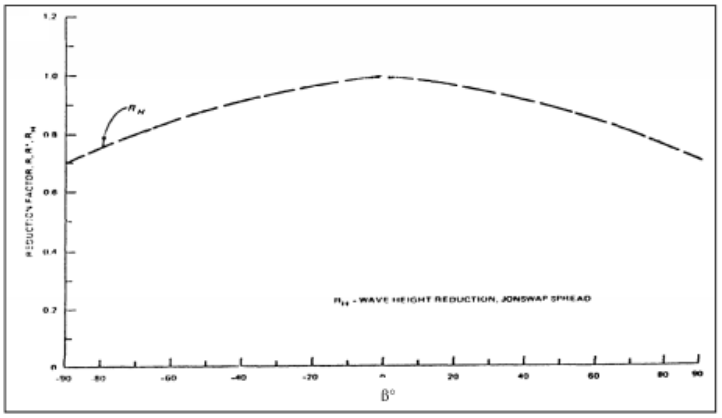


Figure B-3. Wave height reduction due to angular spread [16a].

Where:

β° = The angle between the fetch and the dam axis (degrees). (0° is normal incidence and is commonly used to compute fetch, which is directly perpendicular to the dam axis).

$$Hdw := 1.67 \cdot Hs \cdot 1.0$$

$$Hdw = \begin{pmatrix} 2.861 \\ 3.206 \\ 3.737 \\ 4.285 \\ 4.849 \end{pmatrix} \cdot ft$$

- factored design wave height for runup and setup estimates.

Step 4: Estimate Wave Runup on Upstream Slope of Dam

Estimate wave length (Lw) and wave period (Tw) for runup calculations

$$Tw_i := 0.464 \cdot \left(\frac{Fetch}{mi}\right)^{\frac{1}{3}} \cdot \left(\frac{VW_i}{mph}\right)^{\frac{1}{3}} \cdot \left(1.1 + 0.0156 \cdot \frac{VW_i}{mph}\right)^{\frac{1}{6}} \cdot s$$

$$Tw = \begin{pmatrix} 2.513 \\ 2.611 \\ 2.748 \\ 2.876 \\ 2.997 \end{pmatrix} s$$

- Estimated wave period

$$Lw := 5.12 \cdot \left(\frac{Tw}{s}\right)^2 \cdot ft$$

$$Lw = \begin{pmatrix} 32.346 \\ 34.895 \\ 38.651 \\ 42.342 \\ 45.983 \end{pmatrix} \cdot ft$$

- Estimated wave length

Estimate steepness of peak waves based on design wave height and wave length

$$sp := \frac{Hdw}{Lw}$$

$$sp = \begin{pmatrix} 0.088 \\ 0.092 \\ 0.097 \\ 0.101 \\ 0.105 \end{pmatrix}$$

- Steepness of the design wave

Estimate surf similarity factor for peak wave heights

$$\alpha := \operatorname{atan}\left(\frac{1}{Slope}\right)$$

$$\alpha = 18.435 \cdot °$$

- Angle of the upstream slope from horizontal, i.e. inverse of slope

$$\xi p := \frac{\tan(\alpha)}{sp^{0.5}}$$

$$\xi p = \begin{pmatrix} 1.121 \\ 1.1 \\ 1.072 \\ 1.048 \\ 1.026 \end{pmatrix}$$

- Surf similarity factor

Identify coefficeints A and C based on the surf similarity factor and Table B-4

Table B-4. Values for variables *A* and *C* of the runup equation [16b]

ξ-Limits	*A*	*C*
$\xi_p \le 2.5$	1.6	0
$2.5 < \xi_p < 9$	-0.2	4.5

$Ar := 1.6$

$Cr := 0$

Identify reduction factors for the runup calculations

$\gamma r := 0.55$ - Slope roughness reduction factor (γ_r), based on Table B-3. For riprap, a value of 0.55 is recommended.

Table B-3. Surface roughness reduction factor (valid for $1 < \xi_p < 3\text{-}4$) [16b]

Type of slope surface	γ_r
Smooth, concrete, asphalt	1.0
Smooth block revetment	1.0
Grass (3 centimeters in length)	0.90 – 1.0
One layer of rock, diameter D, (H_s/D = 1.5 – 3.0)	0.55 – 0.6
Two or more layers of rock, (H_s/D = 1.5 – 6.0)	0.50 – 0.55

$\gamma b := 1.0$ - Berm reduction factor (γ_b), 1.0 if no berm

$\gamma h := 1.0$ - Shallow-water reduction factor (γ_h), 1.0 if Rayleigh distributed waves

$\gamma \beta := 1.0$ - Direction of fetch reduction factor (γ_β), see Figure B-4, below.

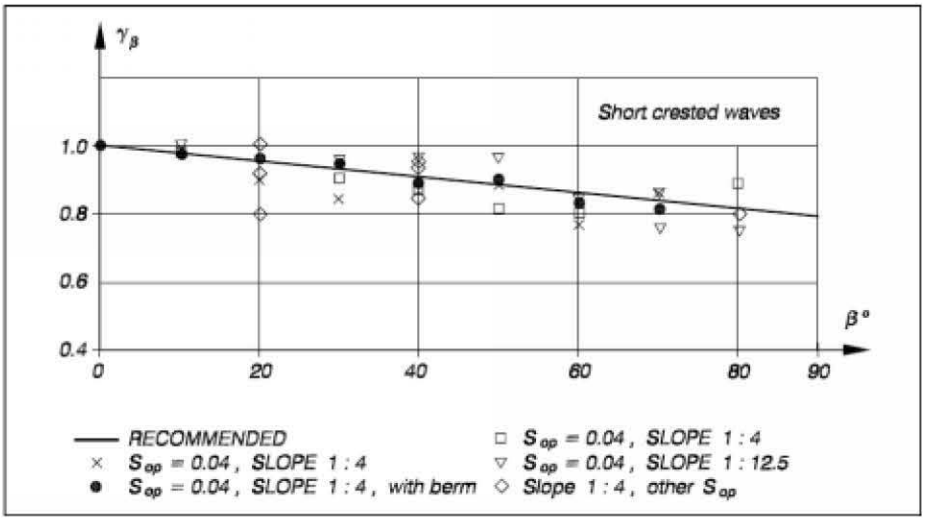


Figure B-4. Influence of angle of incidence, β, and the directional spreading on runup on smooth slopes at Delft Hydraulics [16b].

Calculate runup

$$Runup_i := Hdw_i \cdot (Ar \cdot \xi p_i + Cr) \cdot \gamma r \cdot \gamma b \cdot \gamma h \cdot \gamma \beta$$

$$Runup = \begin{pmatrix} 2.822 \\ 3.102 \\ 3.525 \\ 3.951 \\ 4.38 \end{pmatrix} \cdot ft$$

Step 5: Estimate Wind Setup on Dam Slope

$$Setup := \frac{\left(\frac{VW}{mph}\right)^2 \cdot ft \cdot \frac{Fetch}{mi}}{1400 \cdot \frac{D}{ft}}$$

$$Setup = \begin{pmatrix} 0.014 \\ 0.017 \\ 0.022 \\ 0.028 \\ 0.034 \end{pmatrix} \cdot ft$$

Step 6: Compare Calculated Freeboard Estimates

NRWSmin := 8ft Minimum freeboard for NRWS level (Table B-1, above).

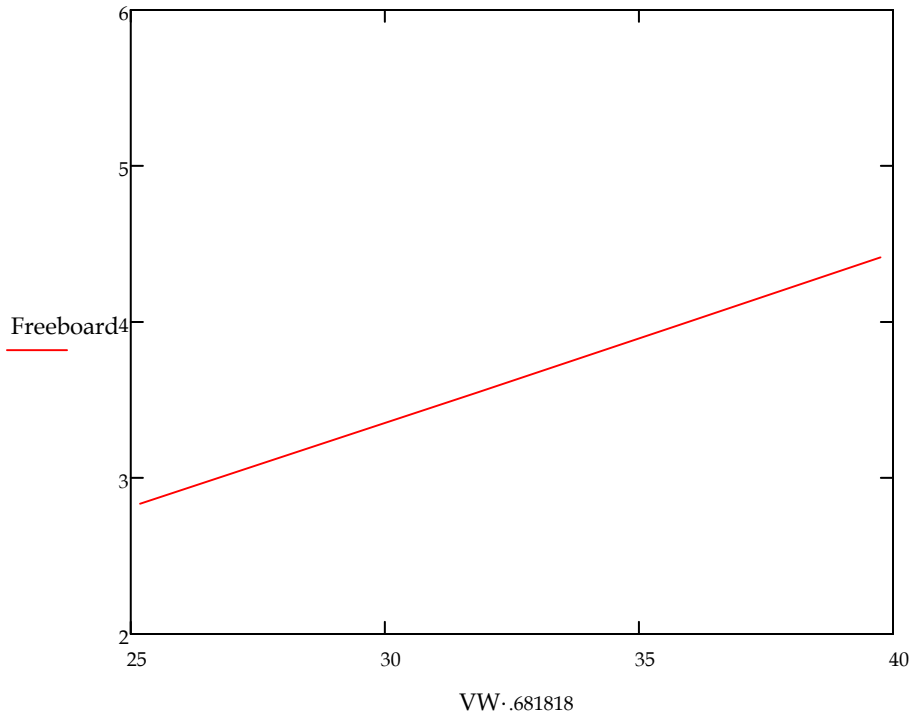
MRWSmin := 6ft Minimum freeboard for MRWS level (Table B-1, above).

Calculated freeboard requirements.

Freeboard := Runup + Setup

$$Freeboard = \begin{pmatrix} 2.836 \\ 3.119 \\ 3.547 \\ 3.979 \\ 4.414 \end{pmatrix} \cdot ft$$

Plot of Design Wind Velocity over Water versus Required Freeboard



RIPRAP DESIGN SECTION

Step 7: Calculate Design Wave Height for Riprap Design

According to Chapter 7 of the *Design Standards No. 13* manual, the 10-percent wave height (H_{10}), based on the derived significant wave height, results in riprap sizes that perform well.

Assuming the wave height distribution can be described using a Rayleigh distribution, a wave height of 1.27 times the significant height should be used for design. This design wave level corresponds to the highest 10 percent of waves.

$H10 := 1.27 \cdot Hs$

$$H10 = \begin{pmatrix} 2.176 \\ 2.438 \\ 2.842 \\ 3.259 \\ 3.688 \end{pmatrix} \text{ ft}$$

- 10-percent wave height

Step 8: Calculate Required Rock Weight and Riprap Thickness

For cases where **tolerable damage** is allowed, W_{50} is calculated as:

$$W50td := \gamma_riprap \cdot \frac{H10^3}{4.37 \cdot (Gs_riprap - 1)^3 \cdot \cot(\alpha)}$$

$$W50td = \begin{pmatrix} 27.981 \\ 39.36 \\ 62.351 \\ 94.001 \\ 136.246 \end{pmatrix} \text{ lbf}$$

- Mean rock weight for tolerable damage condition

Volume, Weight, and Diameter Relationship: $V_{50} = W_{50} / g_r = 0.75(D_{50})^3$

$$V50td_i := \frac{W50td_i}{\gamma_riprap}$$

$$V50td = \begin{pmatrix} 0.175 \\ 0.246 \\ 0.39 \\ 0.588 \\ 0.852 \end{pmatrix} \text{ ft}^2 \cdot \text{ft}$$

- Mean rock volume for tolerable damage condition

$$D50td := \left(\frac{V50td}{0.75}\right)^{\left(\frac{1}{3}\right)}$$

$$D50td = \begin{pmatrix} 0.615 \\ 0.69 \\ 0.804 \\ 0.922 \\ 1.043 \end{pmatrix} \text{ ft}$$

- Mean rock diameter for tolerable damage condition

$Tmintd := 2 \cdot D50td$

$$Tmintd = \begin{pmatrix} 1.231 \\ 1.379 \\ 1.608 \\ 1.844 \\ 2.086 \end{pmatrix} \text{ ft}$$

- Minimum Thickness of Riprap for tolerable damage condition

For cases where **zero damage** is allowed, W_{50} is calculated as:

$$W50zd := \gamma_riprap \cdot \frac{H10^3}{3.62 \cdot (Gs_riprap - 1)^3 \cdot \cot(\alpha)^{0.667}}$$

$$W50zd = \begin{pmatrix} 48.698 \\ 68.503 \\ 108.517 \\ 163.601 \\ 237.125 \end{pmatrix} \text{ lbf}$$

- Mean rock weight for zero damage condition

Volume, Weight, and Diameter Relationship: $V_{50} = W_{50}/g_r = 0.75(D_{50})^3$

$$V50zd_i := \frac{W50zd_i}{\gamma_riprap}$$

$$V50zd = \begin{pmatrix} 0.304 \\ 0.428 \\ 0.678 \\ 1.023 \\ 1.482 \end{pmatrix} \text{ ft}^2 \cdot \text{ft}$$

- Mean rock volume for zero damage condition

$$D50zd := \left(\frac{V50zd}{0.75}\right)^{\left(\frac{1}{3}\right)}$$

$$D50zd = \begin{pmatrix} 0.74 \\ 0.83 \\ 0.967 \\ 1.109 \\ 1.255 \end{pmatrix} \text{ ft}$$

- Mean rock diameter for zero damage condition

$Tminzd := 2 \cdot D50zd$

$$Tminzd = \begin{pmatrix} 1.481 \\ 1.659 \\ 1.934 \\ 2.218 \\ 2.51 \end{pmatrix} \text{ ft}$$

- Minimum Thickness of Riprap for zero damage condition

Step 9: Calculate Riprap Gradation

Calculations for **Tolerable Damage** sizes: $Wtdmax := 4 \cdot W50td$ $Wtdmin := \frac{W50td}{8}$

$$Wtdmax = \begin{pmatrix} 111.923 \\ 157.439 \\ 249.404 \\ 376.003 \\ 544.983 \end{pmatrix} \text{lbf} \qquad Wtdmin = \begin{pmatrix} 3.498 \\ 4.92 \\ 7.794 \\ 11.75 \\ 17.031 \end{pmatrix} \text{lbf}$$

Calculations for **Zero Damage** sizes: $Wzdmax := 4 \cdot W50zd$ $Wzdmin := \frac{W50zd}{8}$

$$Wzdmax = \begin{pmatrix} 194.793 \\ 274.01 \\ 434.068 \\ 654.404 \\ 948.5 \end{pmatrix} \text{lbf} \qquad Wzdmin = \begin{pmatrix} 6.087 \\ 8.563 \\ 13.565 \\ 20.45 \\ 29.641 \end{pmatrix} \text{lbf}$$

20% and 35% Band Limit Calculations:

20-percent band coarse-limit curve	
Weight of rock fragment	**% finer by weight**
W_{max}	100
$0.5\,W_{max}$	70
W_{50}	35
W_{min}	0
20-percent band fine-limit curve	
Weight of rock fragment	**% finer by weight**
$0.5\,W_{max}$	90
W_{50}	55
W_{min}	20

35-percent band coarse-limit curve	
Weight of rock fragment	**% finer by weight**
W_{max}	100
$0.5\,W_{max}$	55
W_{50}	25
W_{min}	0
35-percent band fine-limit curve	
Weight of rock fragment	**% finer by weight**
0.5 x W_{max}	90
W_{50}	60
W_{min}	20

Values for the Coarse-Limit Curve

$$CLC20pf := \begin{pmatrix} 100 \\ 70 \\ 35 \\ 0 \end{pmatrix} \quad CLC35pf := \begin{pmatrix} 100 \\ 55 \\ 25 \\ 0 \end{pmatrix}$$

- Vector of % Finer by Weight values for Coarse-Limit Curve, 20% and 35% Band, respectively.

$$CLCwrftd := \begin{pmatrix} Wtdmax_{dvi} \\ 0.5 \cdot Wtdmax_{dvi} \\ W50td_{dvi} \\ Wtdmin_{dvi} \end{pmatrix} \quad CLCwrftd = \begin{pmatrix} 376.003 \\ 188.002 \\ 94.001 \\ 11.75 \end{pmatrix} lbf$$

- Vector of Weight of Rock Fragments associated with the % Finer data above.

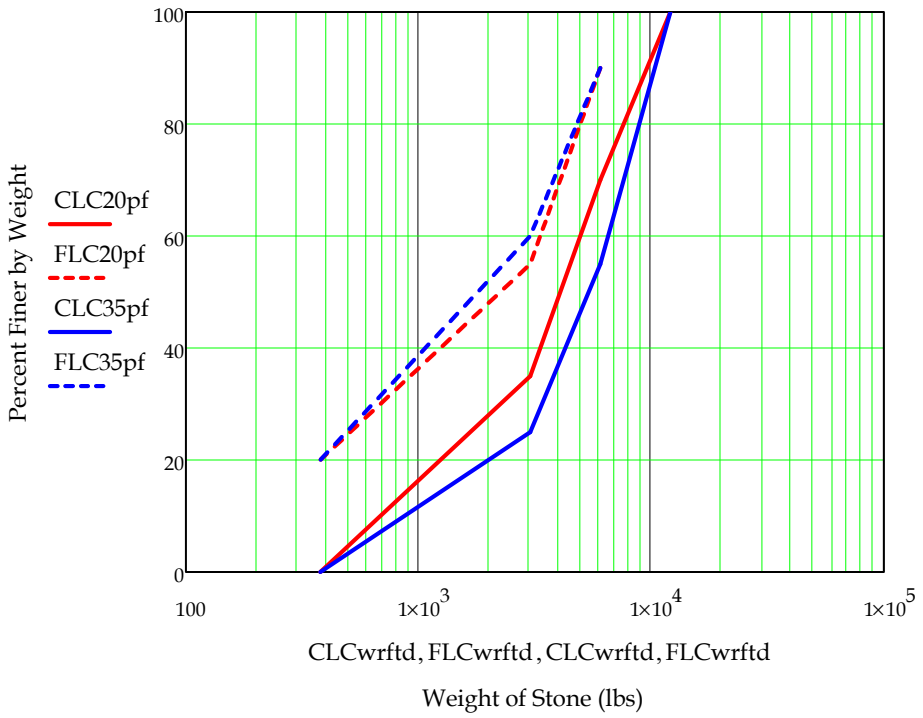
Values for the Fine-Limit Curve

$$FLC20pf := \begin{pmatrix} 90 \\ 55 \\ 20 \end{pmatrix} \quad FLC35pf := \begin{pmatrix} 90 \\ 60 \\ 20 \end{pmatrix}$$

- Vector of % Finer by Weight values for Fine-Limit Curve, 20% and 35% Band, respectively.

$$FLCwrftd := \begin{pmatrix} 0.5 \cdot Wtdmax_{dvi} \\ W50td_{dvi} \\ Wtdmin_{dvi} \end{pmatrix} \quad FLCwrftd = \begin{pmatrix} 188.002 \\ 94.001 \\ 11.75 \end{pmatrix} lbf$$

- Vector of Weight of Rock Fragments associated with the % Finer data above.



6. Conclusions/Results

1. For design wind velocities corresponding to maximum recorded peak wind velocities, the minimum required freeboard ranges from approximately 2.8 feet to 4.4 feet above the water surface.
2. For the maximum pool elevation and the maximum recorded peak wind velocity, the minimum freeboard was calculated at 3.98 feet. The design freeboard of 11 feet easily exceeds this condition as well as the maximum pool and normal pool minimum recommended values provided in Table B-1 of Chapter 6 of the U.S. Department of the Interior Bureau of Reclamation's *Design Standards No. 13 - Embankment Dams* manual. .
3. Based on the riprap calculation proceedure for a limited damage case, the average rock diameter is 0.92 feet (11 inches) and a minimum riprap thickness of 1.85 feet.

CLIENT:	Caltrans			**PROJECT:**	Sisk Dam -SR 152 Raising
BY:	KNA	**DATE:**	10-Jun-20	**Job No.:**	141064-242990
CHKD BY:	EOT	**DATE:**	11-Jun-20	**SHEET No.:**	1

SUBJECT: Minimum Freeboard and Riprap Sizing Requirements - North Side of SR 152 Embankment - Alternate 1

Developed by K. Applegate; Charlotte, NC — Mathcad 15, PTC.

1. Purpose/Objective

To estimate the required freeboard and riprap gradation limits at the Sisk Dam site based on the methods presented in Chapter 6 and Chapter 7 of the U.S. Department of the Interior Bureau of Reclamation's *Design Standards No. 13 - Embankment Dams* manual.

2. Procedure

a. Develop necessary input parameters for the freeboard and riprap calculations.

b. Follow the calculations presented in the worksheet.

1. Calculate the Fetch for the reservoir.
2. Determine design wind velocity (based on CA Dept. of Water Resourcese - California Data Exchange Center).
3. Calculate the design wave height.
4. Estimate the wave runup for the proposed embankment geometry.
5. Estimate the wind setup for the proposed embankment geometry.
6. Calculate the required freeboard.
7. Calculate the required mean rock weight (W_{50}) and minimum riprap thickness (T_{min}).
8. Calculate the design wave height for riprap design (H_{10}).
9. Determine the riprap gradation requirements.

c. Enter/change input parameters in the yellow boxes .

d. The calculated design parameters are auto-populated and provided in green boxes .

3. References/Data Sources

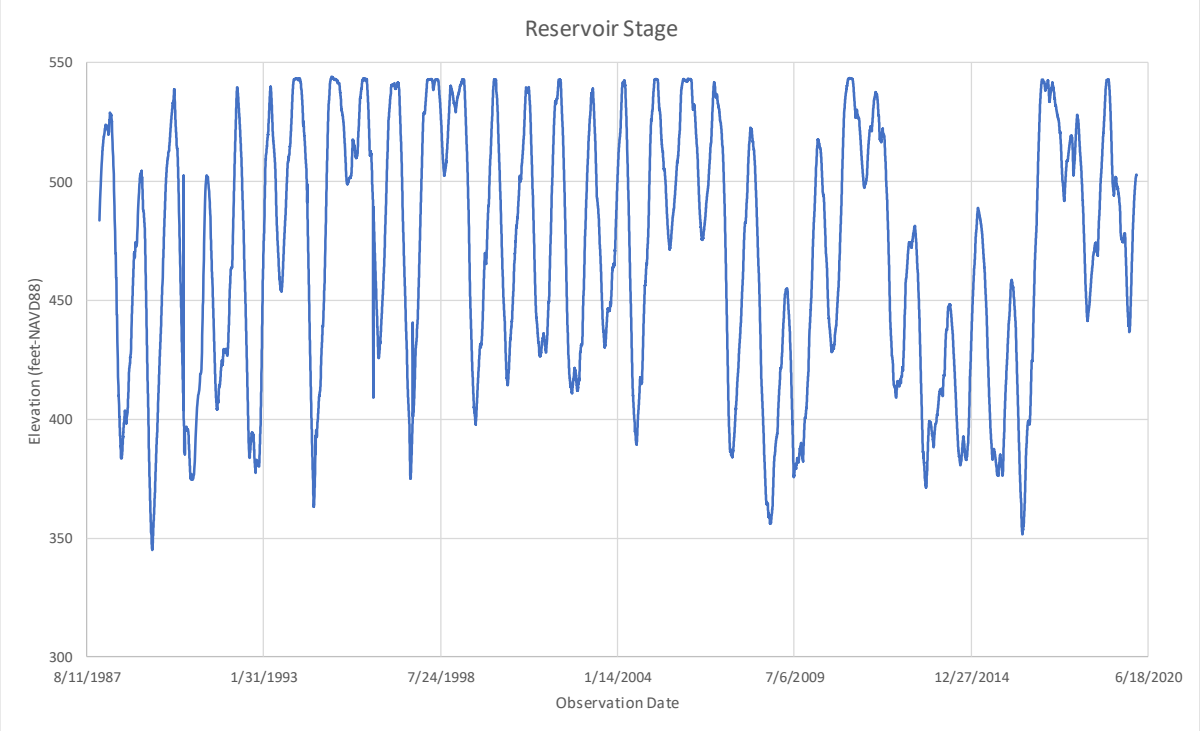
a. U.S. Department of the Interior Bureau of Reclamation, *Design Standards No. 13 - Embankment Dams*, September 2012.

b. A Dept. of Water Resourcese - California Data Exchange Center, *cdec.water.ca.gov/cdecstation2/?sta=BLN.*

c. California Department of Water Resources - Resevoir stage data for the San Luis Reservoir, recorded between January 4, 1988 and February 11, 2020.

4. Assumptions and Limitations

a. The calculated runup will be applied to the maximum pool storage elevation. The reservoir stage continually fluctuates, and the reservoir may stay at or near maximum pool elevation for long periods of time. See the plot of historic reservoir stage data, below.



b. The maximum wind velocity was determined using the CA Dept. of Water Resourcese - California Data Exchange Center data records.

c. The wind velocity corresponding to the maximum recorded peak wind velocity was selected for the basis of design.

d. The wind velocities provided represent wind gusts above the ground surface. These values need to be adjusted to a 1-hour sustained wind velocity. USACE EM 1110-2-1100 guidance was used to convert the wind velocities to 1-hour sustained wind velocities.

e. The embankment is modeled with a riprap lined upstream slope for the runup calculations.

f. The embankment does not have an intermediate berm on the slope.

g. The wave height distribution can be statistically modeled as a Rayleigh distribution.

h. Tolerable damage will be allowed for the riprap design.

i. The average depth over the length of the Fetch is assumed as 70 feet. This value was estimated based on historical Google Earth imagery and the existing slope design.

j. The fetch was estimated as 1 mile. This estimate is approximately the linear length of Cottonwood Bay which is a conservative estimate.

$D := 70ft$ - Assumed average depth along the length of the Fetch

5A. Calculation Input Data

Wind Velocity Data:

- Design Wind loads are based on CA Dept. of Water Resourcese - California Data Exchange Center data records at the LBN (Los Banos) station, see the table below.

San Luis Reservoir Wind Direction and Speed

Month	Direction (DEG)[1]	Speed (MPH)[1]	Avg Peak Wind Speed (MPH)[2]	Max Peak Wind Speed (MPH)[2]
January	167	4.87	9	48
February	188	5.95	11	54
March	206	6.62	12	44
April	230	8.03	15	45
May	243	9.30	17	46
June	243	9.63	18	46
July	172	8.60	16	42
August	197	7.91	15	41
September	200	7.29	14	43
October	195	6.18	11	49
November	176	5.05	9	40
December	168	4.89	9	52

1. Hourly wind direction and speed reported from 1/1/1995 to 6/2/2020
2. Hourly peak wind speed reported from 7/17/2003 to 6/2/2020

$$VL_CDEC := \begin{pmatrix} 38 \\ 42 \\ 48 \\ 54 \\ 60 \end{pmatrix} \cdot mph$$

- Max peak wind velocities based on recorded wind data.

$dvi := 3$ - Design velocity vector indice value for final riprap recommendations:

$tw := 3$ - Wind duration associated with the provided velocities (in seconds).

Slope Geometry Data:

$Slope := \frac{3}{1}$ - Embankment slope: Horizontal is numerator, Vertical is denominator

Riprap Design Parameters:

$G_{s_riprap} := 2.65$ - Specific gravity of rock for the riprap borrow material.

$\gamma_{_riprap} := 160 \cdot pcf$ - Design unit weight for riprap material.

5B. Design Calculations

Step 1: Estimate Fetch - Refer to Figure 2 for Fetch calculation details

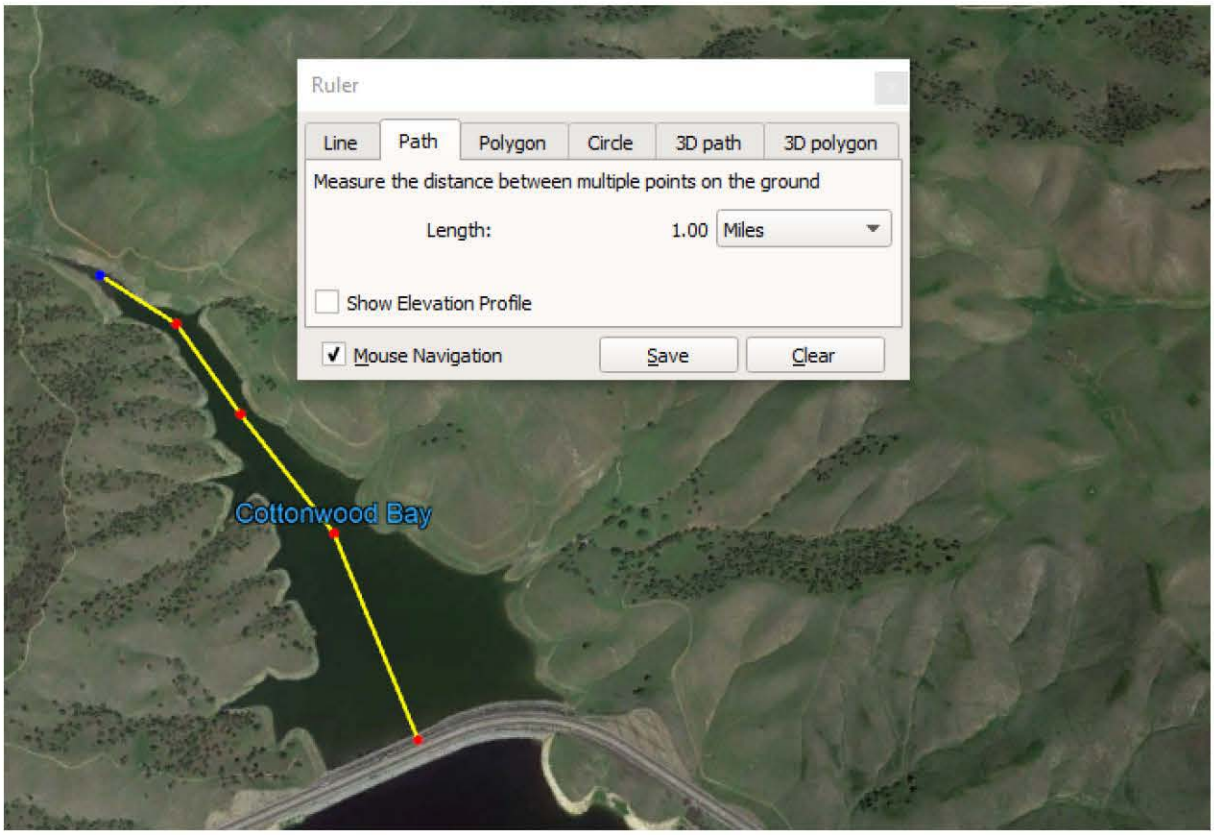


Figure 2: Geometry for Fetch Estimate

$Fetch := 1mi$ - Longest distance from dam crest to opposite shoreline

Table B-1, below, provides simplified freeboard estimates for "Small Dams" based on the Fetch.

Table B-1. Approximation of minimum and normal freeboard [10]

Longest fetch (miles)	Normal freeboard (added to the normal water surface) (feet)	Minimum freeboard (added to the maximum water surface) (feet)
<1	4	3
1	5	4
2.5	6	5
5	8	6
10	10	7

Note: These values were based on a wind velocity of 100 mi/h blowing over the normal reservoir water surface and 50 mi/h blowing over the MRWS. The effect of wind setup is not considered in the values shown. For embankment dams with soil-cement or other smooth upstream faces, depending on the smoothness of the surface, the values shown should be increased by a factor of up to 1.5.

Step 2: Determine Design Wind Velocity Parameters

Estimate the design wind velocities at the proposed site (input values in Section 5A).

$$VL_CDEC = \begin{pmatrix} 38 \\ 42 \\ 48 \\ 54 \\ 60 \end{pmatrix} \cdot mph$$

- Wind Velocities for 3-second gusts measured at 33 feet above the ground surface:

$tw = 3$ - Provided burst duration (sec)

Adjust the 3-second wind gust velocities (VL_CDEC) to 1-hour sustained wind velocities (VL_1hour) based on USACE EM 1110-2-1100:

$$Ratio_1hour := 1.277 + 0.296 \cdot \tanh\left(0.9 \cdot \log\left(\frac{45}{tw}\right)\right)$$

$Ratio_1hour = 1.509$

$\frac{U_T}{U_{3600}}$ for $t < 3600$

$$VL_1hour := VL_CDEC \cdot \frac{1}{Ratio_1hour}$$

$$VL_1hour = \begin{pmatrix} 25.176 \\ 27.826 \\ 31.801 \\ 35.776 \\ 39.751 \end{pmatrix} \cdot mph$$

Adjust over land velocities to over water velocities (VW), see Figure B-2:

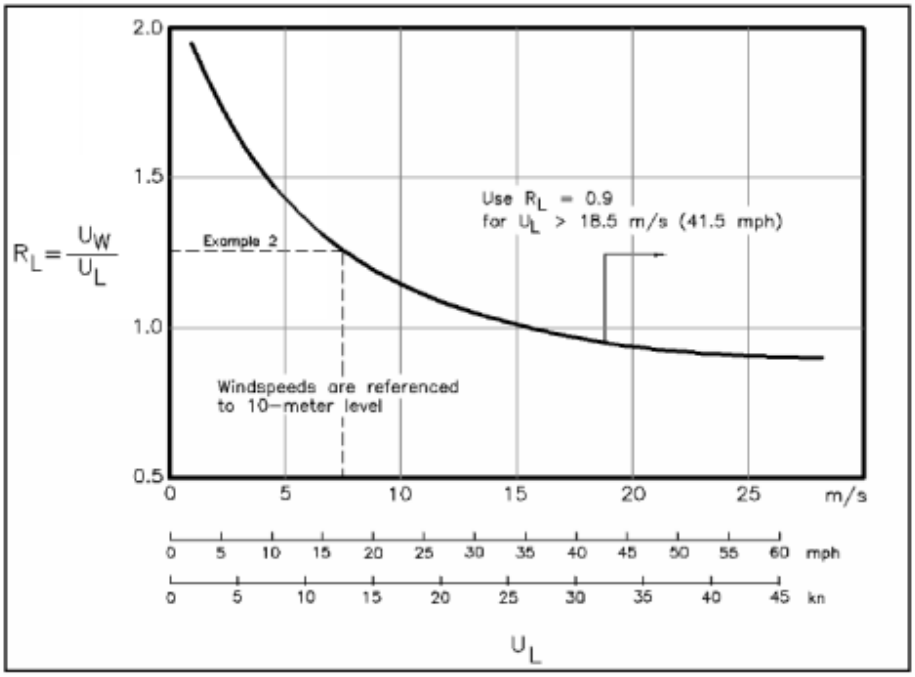


Figure B-2. Ratio of wind speed over water to wind speed over land as a function of wind speed over land [16a].

RL := 1.0

VW_1hour := RL·VL_1hour

$$VW_1hour = \begin{pmatrix} 25.176 \\ 27.826 \\ 31.801 \\ 35.776 \\ 39.751 \end{pmatrix} \cdot mph$$

- Sustained 1-hour duration wind velocities over water

Estimate the minimum duration needed to genterate the highest waves (assuming Risk Category IV)

$$tmin := 1.87 \cdot \left[\frac{\left(\frac{Fetch}{mi} \right)^{0.67}}{\left(\frac{VW_1hour}{mph} \right)^{0.34}} \right] \cdot hr$$

$$tmin = \begin{pmatrix} 0.624 \\ 0.604 \\ 0.577 \\ 0.554 \\ 0.535 \end{pmatrix} \cdot hr$$

- tmin values represent the minimum sustained wind duration required for the design wave to reach the significant heights estimated in Step 3, below.

The minimum duration required to fully mobilize the design wave heights is less than the 1-hour assumed duration, so the waves will not be fetch-limited.

VW := VW_1hour

Step 3: Calculate Design Wave Height

The significant wave height (H_s) is defined as the average of the highest one-third of the waves in a wave field.

$i := 0..4$

$$Hs_i := 0.0245 \cdot \left(\frac{Fetch}{mi}\right)^{0.5} \cdot \frac{VW_i}{mph} \cdot \left(1.1 + 0.0156 \cdot \frac{VW_i}{mph}\right)^{0.5} \cdot ft$$

$$Hs = \begin{pmatrix} 0.754 \\ 0.844 \\ 0.984 \\ 1.129 \\ 1.277 \end{pmatrix} \cdot ft$$

- Significant wave height

Assuming the wave height distribution can be described using a Rayleigh distribution, Table B-2 may be used to estimate additional statistical wave heights. Since overtopping is not permissible at this site, a wave height of 1.67 times the significant height should be used for design. This design wave level corresponds to the highest 1 percent of waves.

If the maximum Fetch is not perpendicular to the dam crest, the wave height needs to be reduced to account for the angle of incidence. Based on an incidence angle that is perpendicular, the reduction factor is 1.0 based on Figure B-3.

Table B-2. Common wave height relationships

Percent of total number of waves in series averaged to compute specific wave height (H)	Ratio of specific wave height, H, to average wave height, H_{ave} (H/H_{ave})	Ratio of specific wave height, H, to significant wave height H_s (H/H_s)	Percent of waves exceeding specific wave height (H)
1	2.66	1.67	0.4
5	2.24	1.40	2
10	2.03	1.27	4
20	1.80	1.12	8
25	1.71	1.07	10
30	1.64	1.02	12
33.33	1.60	1.00	13
40	1.52	0.95	16
50	1.42	0.89	20
75	1.20	0.75	32
100	1.00	0.62	46

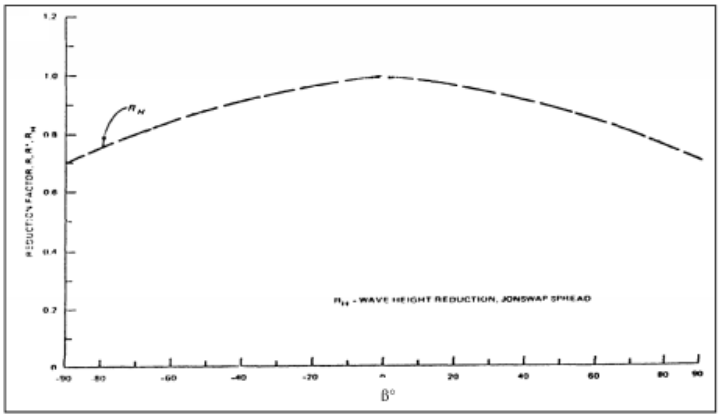


Figure B-3. Wave height reduction due to angular spread [16a].

Where:

β° = The angle between the fetch and the dam axis (degrees). (0° is normal incidence and is commonly used to compute fetch, which is directly perpendicular to the dam axis).

$$Hdw := 1.67 \cdot Hs \cdot 1.0$$

$$Hdw = \begin{pmatrix} 1.259 \\ 1.41 \\ 1.644 \\ 1.885 \\ 2.133 \end{pmatrix} \cdot ft$$

- factored design wave height for runup and setup estimates.

Step 4: Estimate Wave Runup on Upstream Slope of Dam

Estimate wave length (Lw) and wave period (Tw) for runup calculations

$$Tw_i := 0.464 \cdot \left(\frac{Fetch}{mi}\right)^{\frac{1}{3}} \cdot \left(\frac{VW_i}{mph}\right)^{\frac{1}{3}} \cdot \left(1.1 + 0.0156 \cdot \frac{VW_i}{mph}\right)^{\frac{1}{6}} \cdot s$$

$$Tw = \begin{pmatrix} 1.454 \\ 1.51 \\ 1.589 \\ 1.663 \\ 1.733 \end{pmatrix} s$$

- Estimated wave period

$$Lw := 5.12 \cdot \left(\frac{Tw}{s}\right)^2 \cdot ft$$

$$Lw = \begin{pmatrix} 10.822 \\ 11.674 \\ 12.931 \\ 14.166 \\ 15.384 \end{pmatrix} \cdot ft$$

- Estimated wave length

Estimate steepness of peak waves based on design wave height and wave length

$$sp := \frac{Hdw}{Lw}$$

$$sp = \begin{pmatrix} 0.116 \\ 0.121 \\ 0.127 \\ 0.133 \\ 0.139 \end{pmatrix}$$

- Steepness of the design wave

Estimate surf similarity factor for peak wave heights

$$\alpha := \operatorname{atan}\left(\frac{1}{Slope}\right)$$

$$\alpha = 18.435 \cdot °$$

- Angle of the upstream slope from horizontal, i.e. inverse of slope

$$\xi p := \frac{\tan(\alpha)}{sp^{0.5}}$$

$$\xi p = \begin{pmatrix} 0.977 \\ 0.959 \\ 0.935 \\ 0.914 \\ 0.895 \end{pmatrix}$$

- Surf similarity factor

Identify coefficeints A and C based on the surf similarity factor and Table B-4

Table B-4. Values for variables *A* and *C* of the runup equation [16b]

ξ-Limits	*A*	*C*
$\xi_p \le 2.5$	1.6	0
$2.5 < \xi_p < 9$	-0.2	4.5

$Ar := 1.6$

$Cr := 0$

Identify reduction factors for the runup calculations

$\gamma r := 0.55$ - Slope roughness reduction factor (γ_r), based on Table B-3. For riprap, a value of 0.55 is recommended.

Table B-3. Surface roughness reduction factor (valid for $1 < \xi_p < 3\text{-}4$) [16b]

Type of slope surface	γ_r
Smooth, concrete, asphalt	1.0
Smooth block revetment	1.0
Grass (3 centimeters in length)	0.90 – 1.0
One layer of rock, diameter D, (H_s/D = 1.5 – 3.0)	0.55 – 0.6
Two or more layers of rock, (H_s/D = 1.5 – 6.0)	0.50 – 0.55

$\gamma b := 1.0$ - Berm reduction factor (γ_b), 1.0 if no berm

$\gamma h := 1.0$ - Shallow-water reduction factor (γ_h), 1.0 if Rayleigh distributed waves

$\gamma \beta := 1.0$ - Direction of fetch reduction factor (γ_β), see Figure B-4, below.

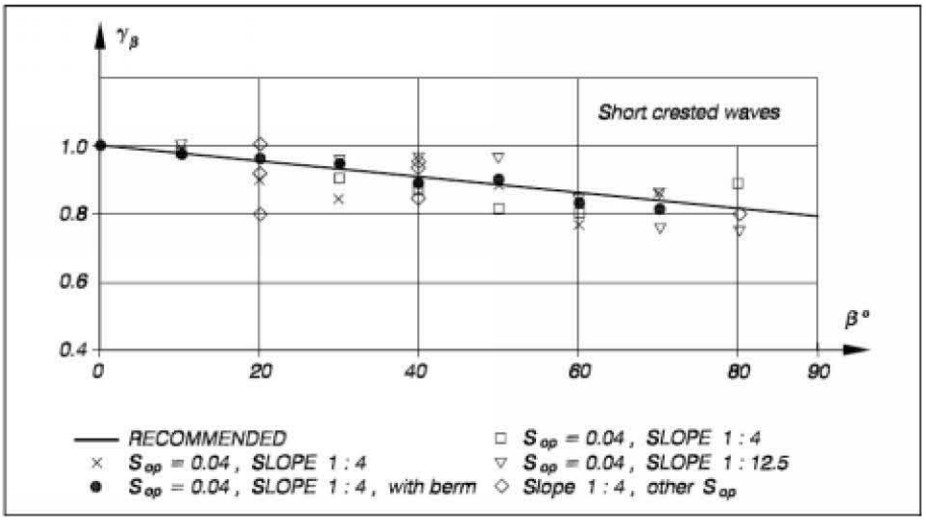


Figure B-4. Influence of angle of incidence, β, and the directional spreading on runup on smooth slopes at Delft Hydraulics [16b].

Calculate runup

$$Runup_i := Hdw_i \cdot (Ar \cdot \xi p_i + Cr) \cdot \gamma r \cdot \gamma b \cdot \gamma h \cdot \gamma \beta$$

$$Runup = \begin{pmatrix} 1.083 \\ 1.19 \\ 1.352 \\ 1.516 \\ 1.68 \end{pmatrix} \cdot ft$$

Step 5: Estimate Wind Setup on Dam Slope

$$Setup := \frac{\left(\frac{VW}{mph}\right)^2 \cdot ft \cdot \frac{Fetch}{mi}}{1400 \cdot \frac{D}{ft}}$$

$$Setup = \begin{pmatrix} 6.468 \times 10^{-3} \\ 7.901 \times 10^{-3} \\ 0.01 \\ 0.013 \\ 0.016 \end{pmatrix} \cdot ft$$

Step 6: Compare Calculated Freeboard Estimates

NRWSmin := 8ft Minimum freeboard for NRWS level (Table B-1, above).

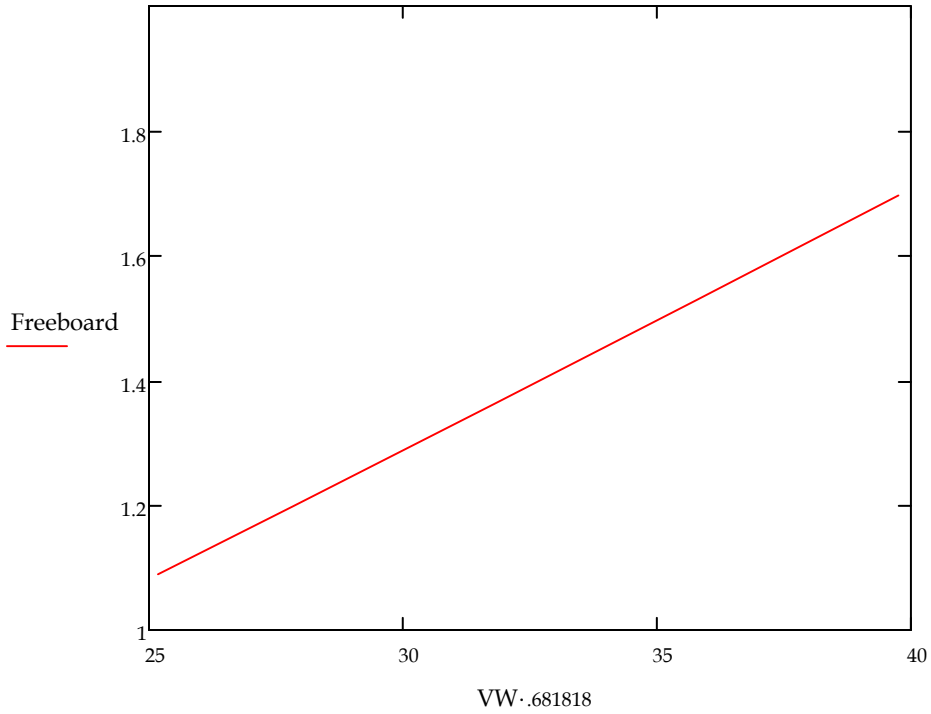
MRWSmin := 6ft Minimum freeboard for MRWS level (Table B-1, above).

Calculated freeboard requirements.

Freeboard := Runup + Setup

$$Freeboard = \begin{pmatrix} 1.089 \\ 1.198 \\ 1.363 \\ 1.529 \\ 1.696 \end{pmatrix} \cdot ft$$

Plot of Design Wind Velocity over Water versus Required Freeboard



RIPRAP DESIGN SECTION

Step 7: Calculate Design Wave Height for Riprap Design

According to Chapter 7 of the *Design Standards No. 13* manual, the 10-percent wave height (H_{10}), based on the derived significant wave height, results in riprap sizes that perform well.

Assuming the wave height distribution can be described using a Rayleigh distribution, a wave height of 1.27 times the significant height should be used for design. This design wave level corresponds to the highest 10 percent of waves.

$H10 := 1.27 \cdot Hs$

$$H10 = \begin{pmatrix} 0.957 \\ 1.072 \\ 1.25 \\ 1.433 \\ 1.622 \end{pmatrix} \text{ ft}$$

- 10-percent wave height

Step 8: Calculate Required Rock Weight and Riprap Thickness

For cases where **tolerable damage** is allowed, W_{50} is calculated as:

$$W50td := \gamma_riprap \cdot \frac{H10^3}{4.37 \cdot (Gs_riprap - 1)^3 \cdot \cot(\alpha)}$$

$$W50td = \begin{pmatrix} 2.382 \\ 3.35 \\ 5.307 \\ 8.002 \\ 11.598 \end{pmatrix} \text{ lbf}$$

- Mean rock weight for tolerable damage condition

Volume, Weight, and Diameter Relationship: $V_{50} = W_{50} / g_r = 0.75(D_{50})^3$

$$V50td_i := \frac{W50td_i}{\gamma_riprap}$$

$$V50td = \begin{pmatrix} 0.015 \\ 0.021 \\ 0.033 \\ 0.05 \\ 0.072 \end{pmatrix} \text{ ft}^2 \cdot \text{ft}$$

- Mean rock volume for tolerable damage condition

$$D50td := \left(\frac{V50td}{0.75}\right)^{\left(\frac{1}{3}\right)}$$

$$D50td = \begin{pmatrix} 0.271 \\ 0.303 \\ 0.354 \\ 0.406 \\ 0.459 \end{pmatrix} \text{ ft}$$

- Mean rock diameter for tolerable damage condition

$Tmintd := 2 \cdot D50td$

$$Tmintd = \begin{pmatrix} 0.542 \\ 0.607 \\ 0.707 \\ 0.811 \\ 0.918 \end{pmatrix} \text{ ft}$$

- Minimum Thickness of Riprap for tolerable damage condition

For cases where **zero damage** is allowed, W_{50} is calculated as:

$$W50zd := \gamma_riprap \cdot \frac{H10^3}{3.62 \cdot (Gs_riprap - 1)^3 \cdot \cot(\alpha)^{0.667}}$$

$$W50zd = \begin{pmatrix} 4.145 \\ 5.831 \\ 9.237 \\ 13.926 \\ 20.185 \end{pmatrix} \text{ lbf}$$

- Mean rock weight for zero damage condition

Volume, Weight, and Diameter Relationship: $V_{50} = W_{50}/g_r = 0.75(D_{50})^3$

$$V50zd_i := \frac{W50zd_i}{\gamma_riprap}$$

$$V50zd = \begin{pmatrix} 0.026 \\ 0.036 \\ 0.058 \\ 0.087 \\ 0.126 \end{pmatrix} \text{ ft}^2 \cdot \text{ft}$$

- Mean rock volume for zero damage condition

$$D50zd := \left(\frac{V50zd}{0.75}\right)^{\left(\frac{1}{3}\right)}$$

$$D50zd = \begin{pmatrix} 0.326 \\ 0.365 \\ 0.425 \\ 0.488 \\ 0.552 \end{pmatrix} \text{ ft}$$

- Mean rock diameter for zero damage condition

$Tminzd := 2 \cdot D50zd$

$$Tminzd = \begin{pmatrix} 0.651 \\ 0.73 \\ 0.851 \\ 0.976 \\ 1.104 \end{pmatrix} \text{ ft}$$

- Minimum Thickness of Riprap for zero damage condition

Step 9: Calculate Riprap Gradation

Calculations for **Tolerable Damage** sizes: $Wtdmax := 4 \cdot W50td$ $Wtdmin := \frac{W50td}{8}$

$$Wtdmax = \begin{pmatrix} 9.527 \\ 13.402 \\ 21.23 \\ 32.006 \\ 46.39 \end{pmatrix} lbf \qquad Wtdmin = \begin{pmatrix} 0.298 \\ 0.419 \\ 0.663 \\ 1 \\ 1.45 \end{pmatrix} lbf$$

Calculations for **Zero Damage** sizes: $Wzdmax := 4 \cdot W50zd$ $Wzdmin := \frac{W50zd}{8}$

$$Wzdmax = \begin{pmatrix} 16.581 \\ 23.324 \\ 36.949 \\ 55.704 \\ 80.739 \end{pmatrix} lbf \qquad Wzdmin = \begin{pmatrix} 0.518 \\ 0.729 \\ 1.155 \\ 1.741 \\ 2.523 \end{pmatrix} lbf$$

20% and 35% Band Limit Calculations:

20-percent band coarse-limit curve	
Weight of rock fragment	**% finer by weight**
W_{max}	100
$0.5\,W_{max}$	70
W_{50}	35
W_{min}	0
20-percent band fine-limit curve	
Weight of rock fragment	**% finer by weight**
$0.5\,W_{max}$	90
W_{50}	55
W_{min}	20

35-percent band coarse-limit curve	
Weight of rock fragment	**% finer by weight**
W_{max}	100
$0.5\,W_{max}$	55
W_{50}	25
W_{min}	0
35-percent band fine-limit curve	
Weight of rock fragment	**% finer by weight**
0.5 x W_{max}	90
W_{50}	60
W_{min}	20

Values for the Coarse-Limit Curve

$$CLC20pf := \begin{pmatrix} 100 \\ 70 \\ 35 \\ 0 \end{pmatrix} \quad CLC35pf := \begin{pmatrix} 100 \\ 55 \\ 25 \\ 0 \end{pmatrix}$$

- Vector of % Finer by Weight values for Coarse-Limit Curve, 20% and 35% Band, respectively.

$$CLCwrftd := \begin{pmatrix} Wtdmax_{dvi} \\ 0.5 \cdot Wtdmax_{dvi} \\ W50td_{dvi} \\ Wtdmin_{dvi} \end{pmatrix} \quad CLCwrftd = \begin{pmatrix} 32.006 \\ 16.003 \\ 8.002 \\ 1 \end{pmatrix} lbf$$

- Vector of Weight of Rock Fragments associated with the % Finer data above.

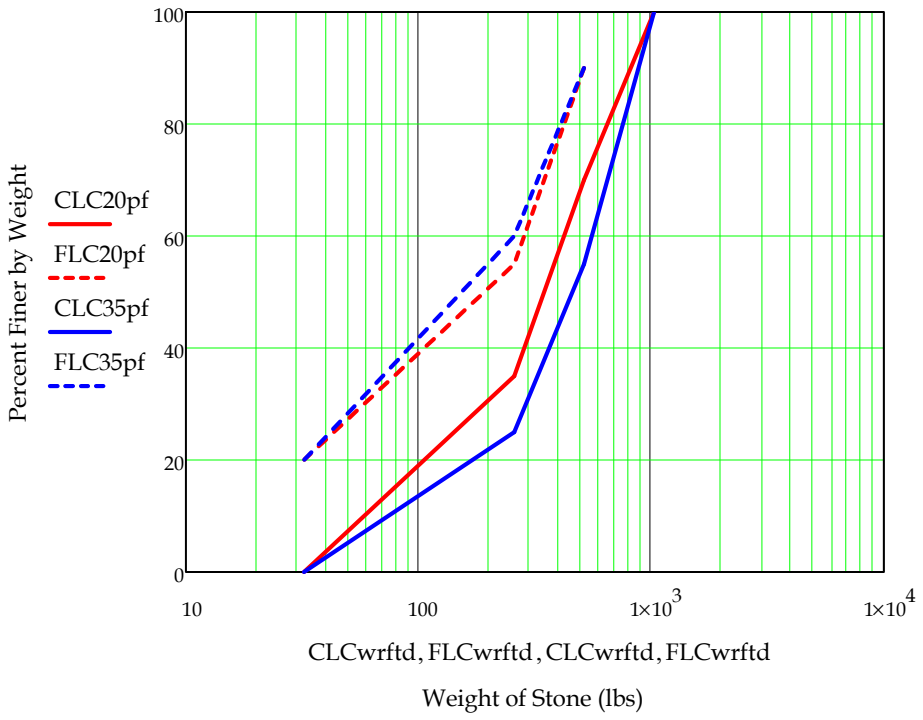
Values for the Fine-Limit Curve

$$FLC20pf := \begin{pmatrix} 90 \\ 55 \\ 20 \end{pmatrix} \quad FLC35pf := \begin{pmatrix} 90 \\ 60 \\ 20 \end{pmatrix}$$

- Vector of % Finer by Weight values for Fine-Limit Curve, 20% and 35% Band, respectively.

$$FLCwrftd := \begin{pmatrix} 0.5 \cdot Wtdmax_{dvi} \\ W50td_{dvi} \\ Wtdmin_{dvi} \end{pmatrix} \quad FLCwrftd = \begin{pmatrix} 16.003 \\ 8.002 \\ 1 \end{pmatrix} lbf$$

- Vector of Weight of Rock Fragments associated with the % Finer data above.



6. Conclusions/Results

1. For design wind velocities corresponding to maximum recorded peak wind velocities, the minimum required freeboard ranges from approximately 1.1 feet to 1.7 feet above the water surface.
2. For the maximum pool elevation and the maximum recorded peak wind velocity, the minimum freeboard was calculated at 1.53 feet. The design freeboard of 11 feet easily exceeds this condition as well as the maximum pool and normal pool minimum recommended values provided in Table B-1 of Chapter 6 of the U.S. Department of the Interior Bureau of Reclamation's *Design Standards No. 13 - Embankment Dams* manual. .
3. Based on the riprap calculation proceedure for a limited damage case, the average rock diameter is 0.41 feet (4.9 inches) and a minimum riprap thickness of 0.8 feet.

CDM Smith

CLIENT: San Luis & Delta-Mendota Water Authority **PROJECT:** Sisk Dam -SR 152 Raising

BY: KNA **DATE:** 10-Jun-20 **Job No.:** 141064-242990

CHKD BY: EOT **DATE:** 11-Jun-20 **SHEET No.:** 1

SUBJECT: Minimum Freeboard and Riprap Sizing Requirements - South Side of SR 152 Embankment - Alternate 2

Developed by K. Applegate; Charlotte, NC Mathcad 15, PTC.

1. Purpose/Objective

To estimate the required freeboard and riprap gradation limits at the Sisk Dam site based on the methods presented in Chapter 6 and Chapter 7 of the U.S. Department of the Interior Bureau of Reclamation's *Design Standards No. 13 - Embankment Dams* manual.

2. Procedure

a. Develop necessary input parameters for the freeboard and riprap calculations.

b. Follow the calculations presented in the worksheet.

1. Calculate the Fetch for the reservoir.
2. Determine design wind velocity (based on CA Dept. of Water Resourcese - California Data Exchange Center).
3. Calculate the design wave height.
4. Estimate the wave runup for the proposed embankment geometry.
5. Estimate the wind setup for the proposed embankment geometry.
6. Calculate the required freeboard.
7. Calculate the required mean rock weight (W_{50}) and minimum riprap thickness (T_{min}).
8. Calculate the design wave height for riprap design (H_{10}).
9. Determine the riprap gradation requirements.

c. Enter/change input parameters in the yellow boxes .

d. The calculated design parameters are auto-populated and provided in green boxes .

3. References/Data Sources

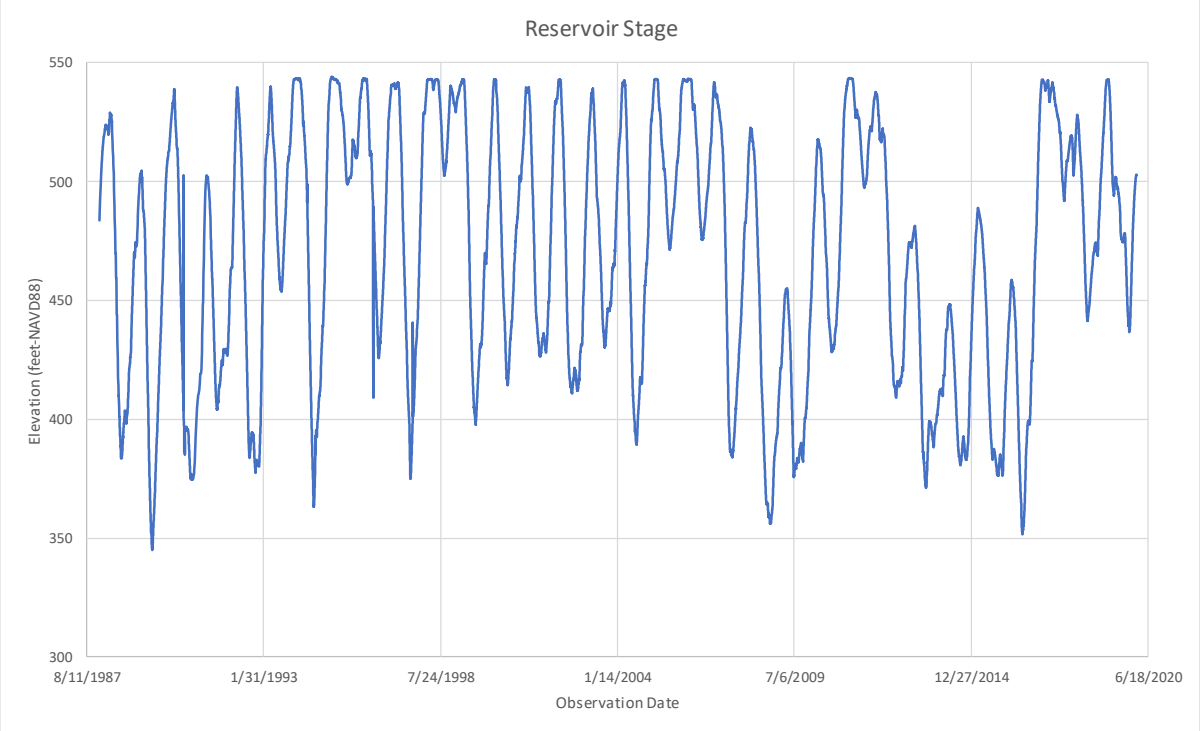
a. U.S. Department of the Interior Bureau of Reclamation, *Design Standards No. 13 - Embankment Dams*, September 2012.

b. CA Dept. of Water Resourcese - California Data Exchange Center, *cdec.water.ca.gov/cdecstation2/?sta=BLN.*

c. California Department of Water Resources - Resevoir stage data for the San Luis Reservoir, recorded between January 4, 1988 and February 11, 2020.

4. Assumptions and Limitations

a. The calculated runup will be applied to the maximum pool storage elevation. The reservoir stage continually fluctuates, and the reservoir may stay at or near maximum pool elevation for long periods of time. See the plot of historic reservoir stage data, below.



b. The maximum wind velocity was determined using the CA Dept. of Water Resourcese - California Data Exchange Center data records.

c. The wind velocity corresponding to the maximum recorded peak wind velocity was selected for the basis of design.

d. The wind velocities provided represent wind gusts above the ground surface. These values need to be adjusted to a 1-hour sustained wind velocity. USACE EM 1110-2-1100 guidance was used to convert the wind velocities to 1-hour sustained wind velocities.

e. The embankment is modeled with a riprap lined upstream slope for the runup calculations.

f. The intermediate berm was not considered in the design runup calculations. This is a conservative assumption.

g. The wave height distribution can be statistically modeled as a Rayleigh distribution.

h. Tolerable damage will be allowed for the riprap design.

i. The average depth over the length of the Fetch is assumed as 170 feet. This value was estimated based on the water volume (2,041,000 acre feet) and the surface area (12,700 acres) reported on Wikipedia. These values were reported for the existing maximum pool elevation of 544 feet. The proposed maximum pool elevation will be raised to elevation 554 feet.

D := 170ft - Assumed average depth along the length of the Fetch

5A. Calculation Input Data

Wind Velocity Data:

- Design Wind loads are based on CA Dept. of Water Resourcese - California Data Exchange Center data records at the LBN (Los Banos) station, see the table below.

San Luis Reservoir Wind Direction and Speed

Month	Direction (DEG)[1]	Speed (MPH)[1]	Avg Peak Wind Speed (MPH)[2]	Max Peak Wind Speed (MPH)[2]
January	167	4.87	9	48
February	188	5.95	11	54
March	206	6.62	12	44
April	230	8.03	15	45
May	243	9.30	17	46
June	243	9.63	18	46
July	172	8.60	16	42
August	197	7.91	15	41
September	200	7.29	14	43
October	195	6.18	11	49
November	176	5.05	9	40
December	168	4.89	9	52

1. Hourly wind direction and speed reported from 1/1/1995 to 6/2/2020
2. Hourly peak wind speed reported from 7/17/2003 to 6/2/2020

$$VL_CDEC := \begin{pmatrix} 38 \\ 42 \\ 48 \\ 54 \\ 60 \end{pmatrix} \cdot mph$$

- Max peak wind velocities based on recorded wind data.

$dvi := 3$ - Design velocity vector indice value for final riprap recommendations:

$tw := 3$ - Wind duration associated with the provided velocities (in seconds).

Slope Geometry Data:

$$Slope := \frac{2.4}{1}$$

- Embankment slope: Horizontal is numerator, Vertical is denominator

Riprap Design Parameters:

$Gs_{riprap} := 2.65$ - Specific gravity of rock for the riprap borrow material.

$\gamma_{riprap} := 160 \cdot pcf$ - Design unit weight for riprap material.

5B. Design Calculations

Step 1: Calculate Fetch - Refer to Figure 2 for Fetch calculation details

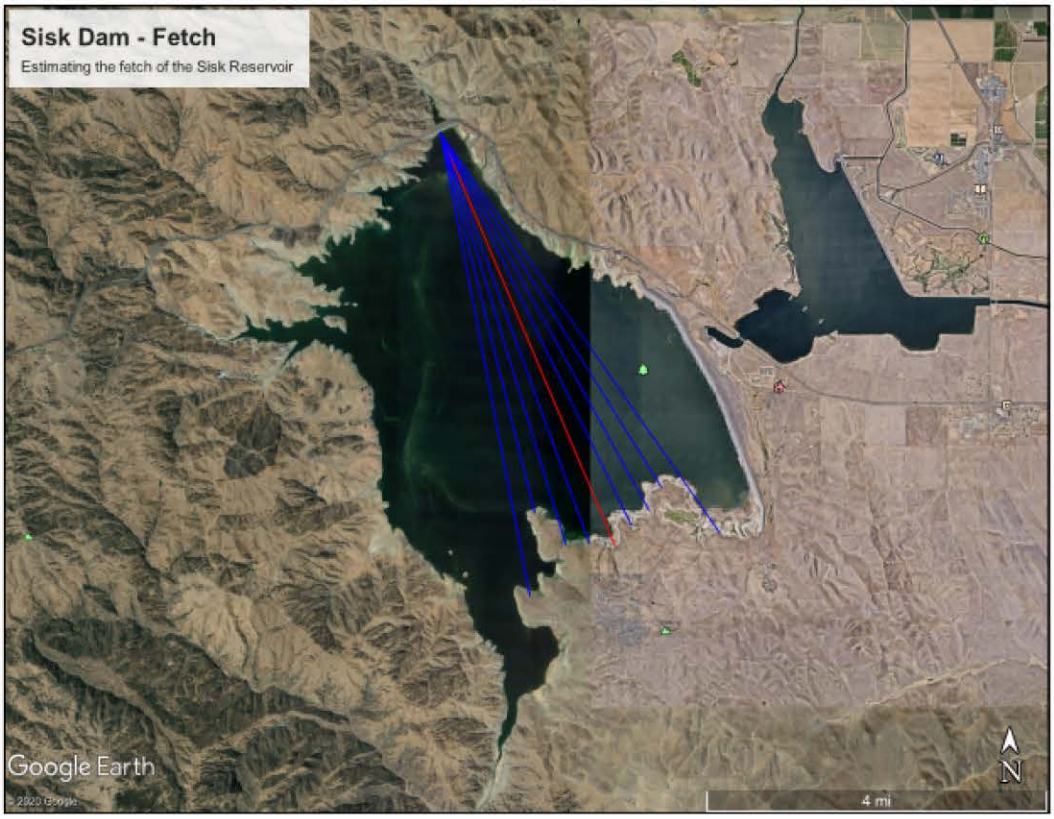


Figure 2: Geometry for Fetch Calculations

$Fsum := 5.55mi + 4.61mi + 5.07mi + 5.13mi + 5.29mi + 5.13mi + 5.08mi + 4.91mi + 5.74mi$

$Fetch := \frac{Fsum}{9}$ - Longest average distance from dam crest to opposite shoreline

$Fetch = 5.168 \cdot mi$

Table B-1, below, provides simplified freeboard estimates for "Small Dams" based on the Fetch.

Table B-1. Approximation of minimum and normal freeboard [10]

Longest fetch (miles)	Normal freeboard (added to the normal water surface) (feet)	Minimum freeboard (added to the maximum water surface) (feet)
<1	4	3
1	5	4
2.5	6	5
5	8	6
10	10	7

Note: These values were based on a wind velocity of 100 mi/h blowing over the normal reservoir water surface and 50 mi/h blowing over the MRWS. The effect of wind setup is not considered in the values shown. For embankment dams with soil-cement or other smooth upstream faces, depending on the smoothness of the surface, the values shown should be increased by a factor of up to 1.5.

Step 2: Determine Design Wind Velocity Parameters

Estimate the design wind velocities at the proposed site (input values in Section 5A).

$$VL_CDEC = \begin{pmatrix} 38 \\ 42 \\ 48 \\ 54 \\ 60 \end{pmatrix} \cdot mph$$

- Wind Velocities for 3-second gusts measured at 33 feet above the ground surface:

$tw = 3$ - Provided burst duration (sec)

Adjust the 3-second wind gust velocities (VL_CDEC) to 1-hour sustained wind velocities (VL_1hour) based on USACE EM 1110-2-1100:

$$Ratio_1hour := 1.277 + 0.296 \cdot \tanh\left(0.9 \cdot \log\left(\frac{45}{tw}\right)\right)$$

$Ratio_1hour = 1.509$

$\frac{U_T}{U_{3600}}$ for $t < 3600$

$$VL_1hour := VL_CDEC \cdot \frac{1}{Ratio_1hour}$$

$$VL_1hour = \begin{pmatrix} 25.176 \\ 27.826 \\ 31.801 \\ 35.776 \\ 39.751 \end{pmatrix} \cdot mph$$

Adjust over land velocities to over water velocities (VW), see Figure B-2:

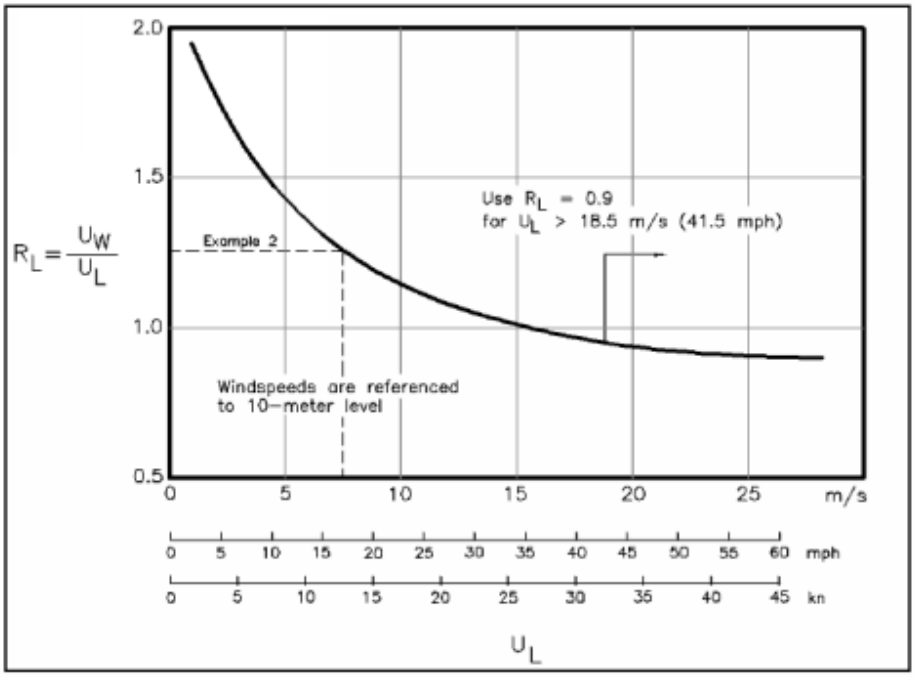


Figure B-2. Ratio of wind speed over water to wind speed over land as a function of wind speed over land [16a].

RL := 1.0

VW_1hour := RL·VL_1hour

$$VW_1hour = \begin{pmatrix} 25.176 \\ 27.826 \\ 31.801 \\ 35.776 \\ 39.751 \end{pmatrix} \cdot mph$$

- Sustained 1-hour duration wind velocities over water

Estimate the minimum duration needed to genterate the highest waves

$$tmin := 1.87 \cdot \left[\frac{\left(\frac{Fetch}{mi} \right)^{0.67}}{\left(\frac{VW_1hour}{mph} \right)^{0.34}} \right] \cdot hr$$

$$tmin = \begin{pmatrix} 1.877 \\ 1.814 \\ 1.734 \\ 1.665 \\ 1.607 \end{pmatrix} \cdot hr$$

- tmin values represent the minimum sustained wind duration required for the design wave to reach the significant heights estimated in Step 3, below.

The minimum duration required to fully mobilize the design wave heights is greater than the 1-hour assumed duration, so the waves will be fetch-limited, i.e. smaller than reported. However, we have conservatively used the 1-hour duration velocities reported above for the design calculations.

VW := VW_1hour

Step 3: Calculate Design Wave Height

The significant wave height (H_s) is defined as the average of the highest one-third of the waves in a wave field.

$i := 0..4$

$$Hs_i := 0.0245 \cdot \left(\frac{Fetch}{mi}\right)^{0.5} \cdot \frac{VW_i}{mph} \cdot \left(1.1 + 0.0156 \cdot \frac{VW_i}{mph}\right)^{0.5} \cdot ft$$

$$Hs = \begin{pmatrix} 1.713 \\ 1.92 \\ 2.238 \\ 2.566 \\ 2.904 \end{pmatrix} \cdot ft$$

- Significant wave height

Assuming the wave height distribution can be described using a Rayleigh distribution, Table B-2 may be used to estimate additional statistical wave heights. Since overtopping is not permissible at this site, a wave height of 1.67 times the significant height should be used for design. This design wave level corresponds to the highest 1 percent of waves.

If the maximum Fetch is not perpendicular to the dam crest, the wave height needs to be reduced to account for the angle of incidence. Based on an incidence angle that is perpendicular, the reduction factor is 1.0 based on Figure B-3.

Table B-2. Common wave height relationships

Percent of total number of waves in series averaged to compute specific wave height (H)	Ratio of specific wave height, H, to average wave height, H_{ave} (H/H_{ave})	Ratio of specific wave height, H, to significant wave height H_s (H/H_s)	Percent of waves exceeding specific wave height (H)
1	2.66	1.67	0.4
5	2.24	1.40	2
10	2.03	1.27	4
20	1.80	1.12	8
25	1.71	1.07	10
30	1.64	1.02	12
33.33	1.60	1.00	13
40	1.52	0.95	16
50	1.42	0.89	20
75	1.20	0.75	32
100	1.00	0.62	46

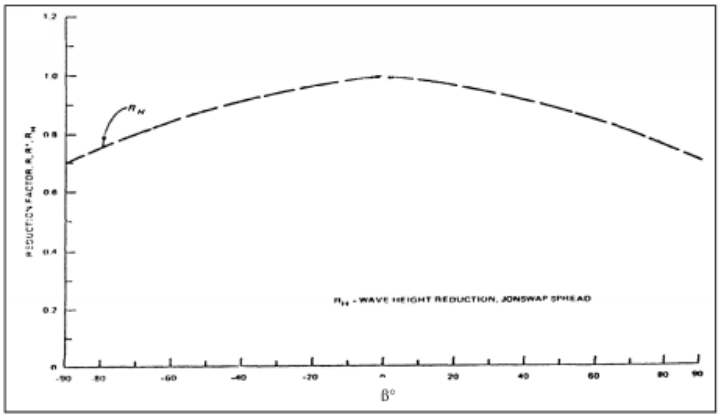


Figure B-3. Wave height reduction due to angular spread [16a].

Where:

β° = The angle between the fetch and the dam axis (degrees). (0° is normal incidence and is commonly used to compute fetch, which is directly perpendicular to the dam axis).

$$Hdw := 1.67 \cdot Hs \cdot 1.0$$

$$Hdw = \begin{pmatrix} 2.861 \\ 3.206 \\ 3.737 \\ 4.285 \\ 4.849 \end{pmatrix} \cdot ft$$

- factored design wave height for runup and setup estimates.

Step 4: Estimate Wave Runup on Upstream Slope of Dam

Estimate wave length (Lw) and wave period (Tw) for runup calculations

$$Tw_i := 0.464 \cdot \left(\frac{Fetch}{mi}\right)^{\frac{1}{3}} \cdot \left(\frac{VW_i}{mph}\right)^{\frac{1}{3}} \cdot \left(1.1 + 0.0156 \cdot \frac{VW_i}{mph}\right)^{\frac{1}{6}} \cdot s$$

$$Tw = \begin{pmatrix} 2.513 \\ 2.611 \\ 2.748 \\ 2.876 \\ 2.997 \end{pmatrix} s$$

- Estimated wave period

$$Lw := 5.12 \cdot \left(\frac{Tw}{s}\right)^2 \cdot ft$$

$$Lw = \begin{pmatrix} 32.346 \\ 34.895 \\ 38.651 \\ 42.342 \\ 45.983 \end{pmatrix} \cdot ft$$

- Estimated wave length

Estimate steepness of peak waves based on design wave height and wave length

$$sp := \frac{Hdw}{Lw}$$

$$sp = \begin{pmatrix} 0.088 \\ 0.092 \\ 0.097 \\ 0.101 \\ 0.105 \end{pmatrix}$$

- Steepness of the design wave

Estimate surf similarity factor for peak wave heights

$$\alpha := \operatorname{atan}\left(\frac{1}{Slope}\right)$$

$$\alpha = 22.62 \cdot °$$

- Angle of the upstream slope from horizontal, i.e. inverse of slope

$$\xi p := \frac{\tan(\alpha)}{sp^{0.5}}$$

$$\xi p = \begin{pmatrix} 1.401 \\ 1.375 \\ 1.34 \\ 1.31 \\ 1.283 \end{pmatrix}$$

- Surf similarity factor

Identify coefficeints A and C based on the surf similarity factor and Table B-4

Table B-4. Values for variables *A* and *C* of the runup equation [16b]

ξ-Limits	*A*	*C*
$\xi_p \le 2.5$	1.6	0
$2.5 < \xi_p < 9$	-0.2	4.5

$Ar := 1.6$

$Cr := 0$

Identify reduction factors for the runup calculations

$\gamma r := 0.55$ - Slope roughness reduction factor (γ_r), based on Table B-3. For riprap, a value of 0.55 is recommended.

Table B-3. Surface roughness reduction factor (valid for 1 < ξ_p <3-4) [16b]

Type of slope surface	γ_r
Smooth, concrete, asphalt	1.0
Smooth block revetment	1.0
Grass (3 centimeters in length)	0.90 – 1.0
One layer of rock, diameter D, (H_s/D = 1.5 – 3.0)	0.55 – 0.6
Two or more layers of rock, (H_s/D = 1.5 – 6.0)	0.50 – 0.55

$\gamma b := 1.0$ - Berm reduction factor (γ_b), 1.0 if no berm

$\gamma h := 1.0$ - Shallow-water reduction factor (γ_h), 1.0 if Rayleigh distributed waves

$\gamma \beta := 1.0$ - Direction of fetch reduction factor (γ_β), see Figure B-4, below.

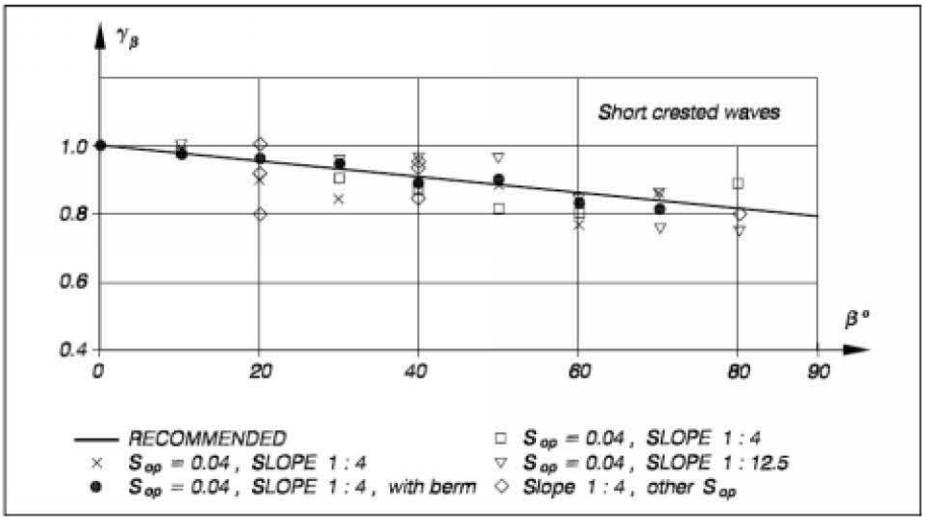


Figure B-4. Influence of angle of incidence, β, and the directional spreading on runup on smooth slopes at Delft Hydraulics [16b].

Calculate runup

$$Runup_i := Hdw_i \cdot (Ar \cdot \xi p_i + Cr) \cdot \gamma r \cdot \gamma b \cdot \gamma h \cdot \gamma \beta$$

$$Runup = \begin{pmatrix} 3.527 \\ 3.878 \\ 4.407 \\ 4.939 \\ 5.475 \end{pmatrix} \cdot ft$$

Step 5: Estimate Wind Setup on Dam Slope

$$Setup := \frac{\left(\frac{VW}{mph}\right)^2 \cdot ft \cdot \frac{Fetch}{mi}}{1400 \cdot \frac{D}{ft}}$$

$$Setup = \begin{pmatrix} 0.014 \\ 0.017 \\ 0.022 \\ 0.028 \\ 0.034 \end{pmatrix} \cdot ft$$

Step 6: Compare Calculated Freeboard Estimates

NRWSmin := 8ft Minimum freeboard for NRWS level (Table B-1, above).

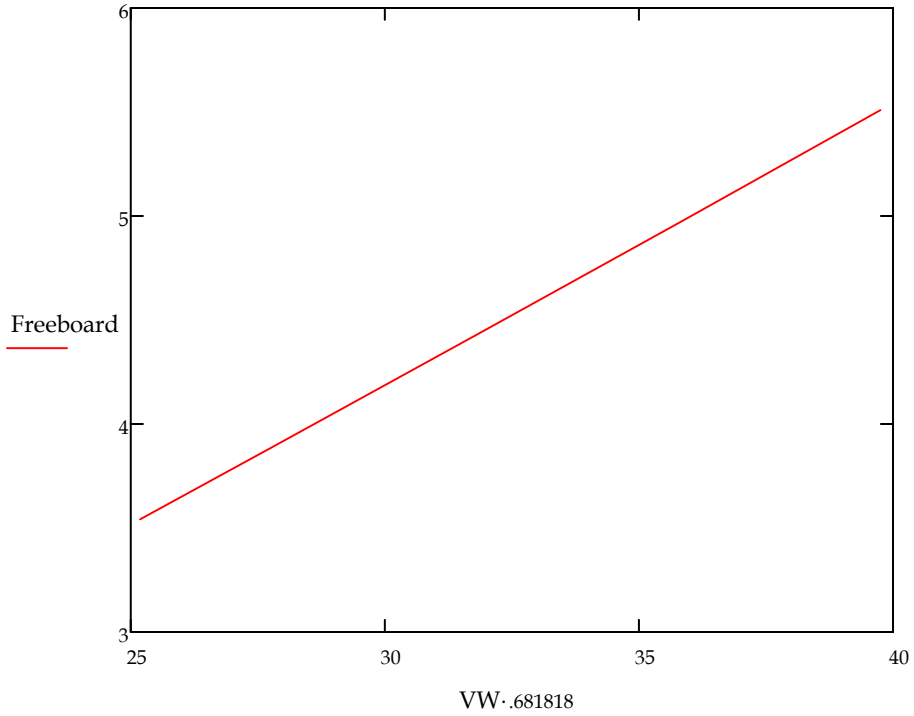
MRWSmin := 6ft Minimum freeboard for MRWS level (Table B-1, above).

Calculated freeboard requirements.

Freeboard := Runup + Setup

$$Freeboard = \begin{pmatrix} 3.541 \\ 3.895 \\ 4.429 \\ 4.967 \\ 5.51 \end{pmatrix} \cdot ft$$

Plot of Design Wind Velocity over Water versus Required Freeboard



RIPRAP DESIGN SECTION

Step 7: Calculate Design Wave Height for Riprap Design

According to Chapter 7 of the *Design Standards No. 13* manual, the 10-percent wave height (H_{10}), based on the derived significant wave height, results in riprap sizes that perform well.

Assuming the wave height distribution can be described using a Rayleigh distribution, a wave height of 1.27 times the significant height should be used for design. This design wave level corresponds to the highest 10 percent of waves.

$H10 := 1.27 \cdot Hs$

$$H10 = \begin{pmatrix} 2.176 \\ 2.438 \\ 2.842 \\ 3.259 \\ 3.688 \end{pmatrix} \text{ ft}$$

- 10-percent wave height

Step 8: Calculate Required Rock Weight and Riprap Thickness

For cases where **tolerable damage** is allowed, W_{50} is calculated as:

$$W50td := \gamma_riprap \cdot \frac{H10^3}{4.37 \cdot (Gs_riprap - 1)^3 \cdot \cot(\alpha)}$$

$$W50td = \begin{pmatrix} 34.976 \\ 49.2 \\ 77.939 \\ 117.501 \\ 170.307 \end{pmatrix} \text{ lbf}$$

- Mean rock weight for tolerable damage condition

Volume, Weight, and Diameter Relationship: $V_{50} = W_{50} / g_r = 0.75(D_{50})^3$

$$V50td_i := \frac{W50td_i}{\gamma_riprap}$$

$$V50td = \begin{pmatrix} 0.219 \\ 0.307 \\ 0.487 \\ 0.734 \\ 1.064 \end{pmatrix} \text{ ft}^2 \cdot \text{ft}$$

- Mean rock volume for tolerable damage condition

$$D50td := \left(\frac{V50td}{0.75}\right)^{\left(\frac{1}{3}\right)}$$

$$D50td = \begin{pmatrix} 0.663 \\ 0.743 \\ 0.866 \\ 0.993 \\ 1.124 \end{pmatrix} \text{ ft}$$

- Mean rock diameter for tolerable damage condition

$Tmintd := 2 \cdot D50td$

$$Tmintd = \begin{pmatrix} 1.326 \\ 1.486 \\ 1.732 \\ 1.986 \\ 2.248 \end{pmatrix} \text{ ft}$$

- Minimum Thickness of Riprap for tolerable damage condition

For cases where **zero damage** is allowed, W_{50} is calculated as:

$$W50zd := \gamma_riprap \cdot \frac{H10^3}{3.62 \cdot (Gs_riprap - 1)^3 \cdot \cot(\alpha)^{0.667}}$$

$$W50zd = \begin{pmatrix} 56.514 \\ 79.496 \\ 125.932 \\ 189.856 \\ 275.18 \end{pmatrix} \text{ lbf}$$

- Mean rock weight for zero damage condition

Volume, Weight, and Diameter Relationship: $V_{50} = W_{50}/g_r = 0.75(D_{50})^3$

$$V50zd_i := \frac{W50zd_i}{\gamma_riprap}$$

$$V50zd = \begin{pmatrix} 0.353 \\ 0.497 \\ 0.787 \\ 1.187 \\ 1.72 \end{pmatrix} \text{ ft}^2 \cdot \text{ft}$$

- Mean rock volume for zero damage condition

$$D50zd := \left(\frac{V50zd}{0.75}\right)^{\left(\frac{1}{3}\right)}$$

$$D50zd = \begin{pmatrix} 0.778 \\ 0.872 \\ 1.016 \\ 1.165 \\ 1.319 \end{pmatrix} \text{ ft}$$

- Mean rock diameter for zero damage condition

$Tminzd := 2 \cdot D50zd$

$$Tminzd = \begin{pmatrix} 1.556 \\ 1.743 \\ 2.032 \\ 2.33 \\ 2.637 \end{pmatrix} \text{ ft}$$

- Minimum Thickness of Riprap for zero damage condition

Step 9: Calculate Riprap Gradation

Calculations for **Tolerable Damage** sizes: $Wtdmax := 4 \cdot W50td$ $Wtdmin := \frac{W50td}{8}$

$$Wtdmax = \begin{pmatrix} 139.904 \\ 196.799 \\ 311.755 \\ 470.004 \\ 681.229 \end{pmatrix} \text{lbf} \qquad Wtdmin = \begin{pmatrix} 4.372 \\ 6.15 \\ 9.742 \\ 14.688 \\ 21.288 \end{pmatrix} \text{lbf}$$

Calculations for **Zero Damage** sizes: $Wzdmax := 4 \cdot W50zd$ $Wzdmin := \frac{W50zd}{8}$

$$Wzdmax = \begin{pmatrix} 226.054 \\ 317.985 \\ 503.729 \\ 759.425 \\ 1.101 \times 10^3 \end{pmatrix} \text{lbf} \qquad Wzdmin = \begin{pmatrix} 7.064 \\ 9.937 \\ 15.742 \\ 23.732 \\ 34.397 \end{pmatrix} \text{lbf}$$

20% and 35% Band Limit Calculations:

20-percent band coarse-limit curve	
Weight of rock fragment	**% finer by weight**
W_{max}	100
$0.5\,W_{max}$	70
W_{50}	35
W_{min}	0
20-percent band fine-limit curve	
Weight of rock fragment	**% finer by weight**
$0.5\,W_{max}$	90
W_{50}	55
W_{min}	20

35-percent band coarse-limit curve	
Weight of rock fragment	**% finer by weight**
W_{max}	100
$0.5\,W_{max}$	55
W_{50}	25
W_{min}	0
35-percent band fine-limit curve	
Weight of rock fragment	**% finer by weight**
0.5 x W_{max}	90
W_{50}	60
W_{min}	20

Values for the Coarse-Limit Curve

$$CLC20pf := \begin{pmatrix} 100 \\ 70 \\ 35 \\ 0 \end{pmatrix} \quad CLC35pf := \begin{pmatrix} 100 \\ 55 \\ 25 \\ 0 \end{pmatrix}$$

- Vector of % Finer by Weight values for Coarse-Limit Curve, 20% and 35% Band, respectively.

$$CLCwrftd := \begin{pmatrix} Wtdmax_{dvi} \\ 0.5 \cdot Wtdmax_{dvi} \\ W50td_{dvi} \\ Wtdmin_{dvi} \end{pmatrix} \quad CLCwrftd = \begin{pmatrix} 470.004 \\ 235.002 \\ 117.501 \\ 14.688 \end{pmatrix} lbf$$

- Vector of Weight of Rock Fragments associated with the % Finer data above.

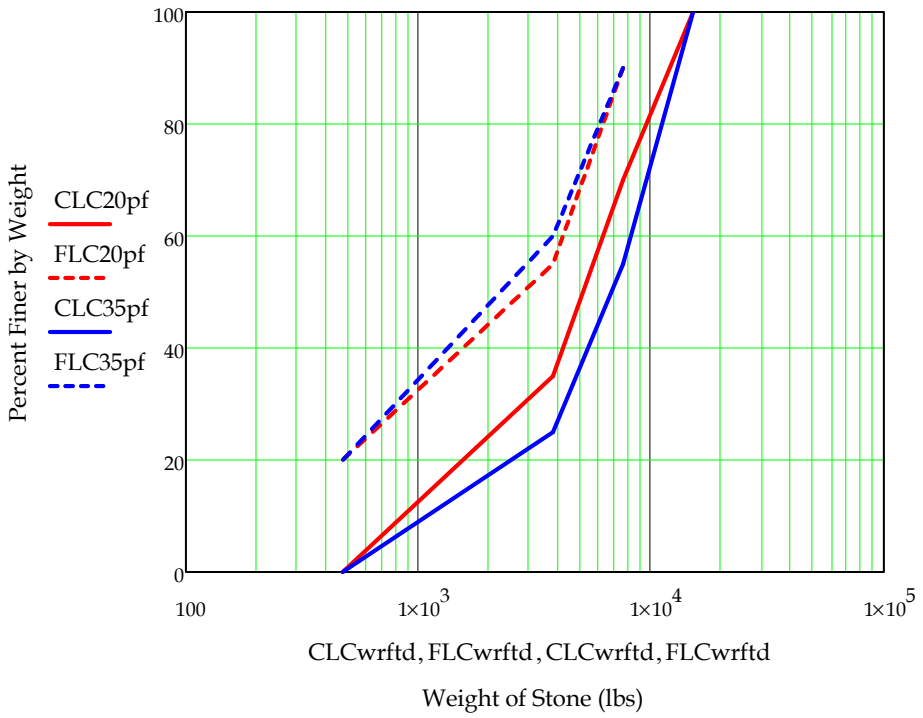
Values for the Fine-Limit Curve

$$FLC20pf := \begin{pmatrix} 90 \\ 55 \\ 20 \end{pmatrix} \quad FLC35pf := \begin{pmatrix} 90 \\ 60 \\ 20 \end{pmatrix}$$

- Vector of % Finer by Weight values for Fine-Limit Curve, 20% and 35% Band, respectively.

$$FLCwrftd := \begin{pmatrix} 0.5 \cdot Wtdmax_{dvi} \\ W50td_{dvi} \\ Wtdmin_{dvi} \end{pmatrix} \quad FLCwrftd = \begin{pmatrix} 235.002 \\ 117.501 \\ 14.688 \end{pmatrix} lbf$$

- Vector of Weight of Rock Fragments associated with the % Finer data above.



6. Conclusions/Results

1. For design wind velocities corresponding to maximum recorded peak wind velocities, the minimum required freeboard ranges from approximately 3.5 feet to 5.5 feet above the water surface.
2. For the maximum pool elevation and the maximum recorded peak wind velocity, the minimum freeboard was calculated at 4.97 feet. The design freeboard of 11 feet easily exceeds this condition as well as the maximum pool and normal pool minimum recommended values provided in Table B-1 of Chapter 6 of the U.S. Department of the Interior Bureau of Reclamation's *Design Standards No. 13 - Embankment Dams* manual. .
3. Based on the riprap calculation proceedure for a limited damage case, the average rock diameter is 0.99 feet (12 inches) and a minimum riprap thickness of 2.00 feet.

CLIENT:	Caltrans			**PROJECT:**	Sisk Dam -SR 152 Raising
BY:	KNA	**DATE:**	10-Jun-20	**Job No.:**	141064-242990
CHKD BY:	EOT	**DATE:**	11-Jun-20	**SHEET No.:**	1

SUBJECT: Minimum Freeboard and Riprap Sizing Requirements - North Side of SR 152 Embankment - Alternate 2

Developed by K. Applegate; Charlotte, NC — Mathcad 15, PTC.

1. Purpose/Objective

To estimate the required freeboard and riprap gradation limits at the Sisk Dam site based on the methods presented in Chapter 6 and Chapter 7 of the U.S. Department of the Interior Bureau of Reclamation's *Design Standards No. 13 - Embankment Dams* manual.

2. Procedure

a. Develop necessary input parameters for the freeboard and riprap calculations.

b. Follow the calculations presented in the worksheet.

1. Calculate the Fetch for the reservoir.
2. Determine design wind velocity (based on CA Dept. of Water Resourcese - California Data Exchange Center).
3. Calculate the design wave height.
4. Estimate the wave runup for the proposed embankment geometry.
5. Estimate the wind setup for the proposed embankment geometry.
6. Calculate the required freeboard.
7. Calculate the required mean rock weight (W_{50}) and minimum riprap thickness (T_{min}).
8. Calculate the design wave height for riprap design (H_{10}).
9. Determine the riprap gradation requirements.

c. Enter/change input parameters in the yellow boxes .

d. The calculated design parameters are auto-populated and provided in green boxes .

3. References/Data Sources

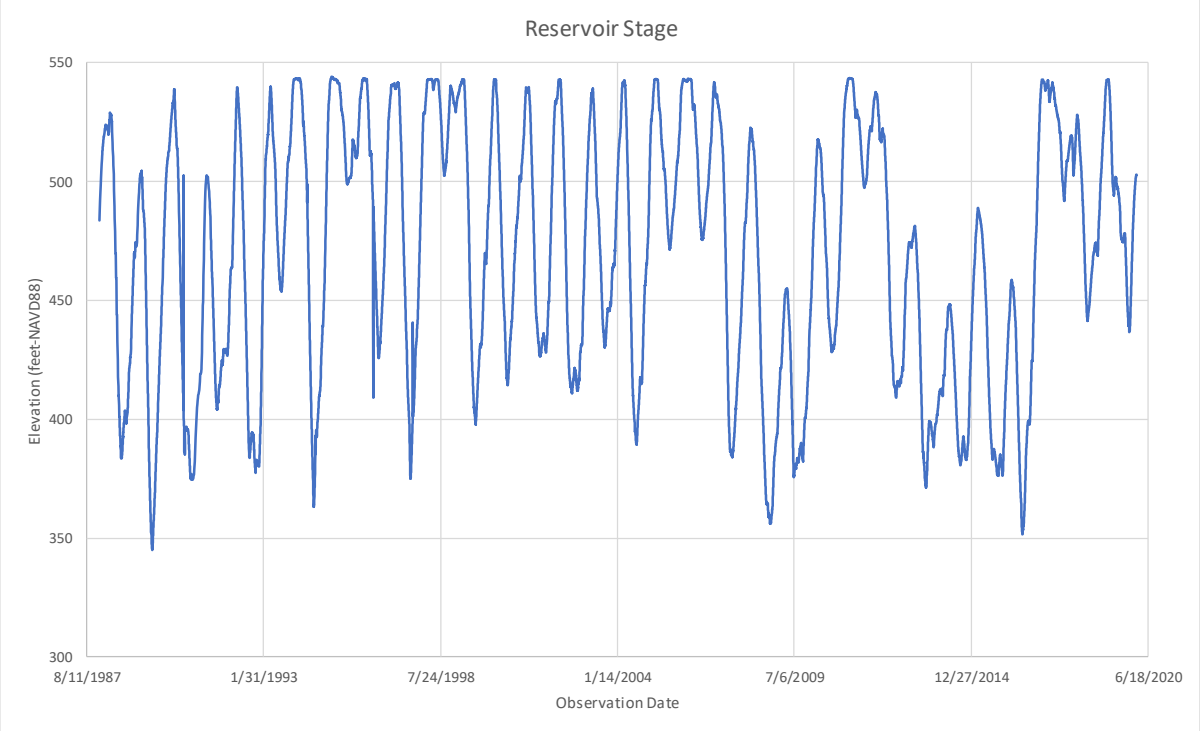
a. U.S. Department of the Interior Bureau of Reclamation, *Design Standards No. 13 - Embankment Dams*, September 2012.

b. Dept. of Water Resourcese - California Data Exchange Center, *cdec.water.ca.gov/cdecstation2/?sta=BLN.*

c. California Department of Water Resources - Resevoir stage data for the San Luis Reservoir, recorded between January 4, 1988 and February 11, 2020.

4. Assumptions and Limitations

a. The calculated runup will be applied to the maximum pool storage elevation. The reservoir stage continually fluctuates, and the reservoir may stay at or near maximum pool elevation for long periods of time. See the plot of historic reservoir stage data, below.



b. The maximum wind velocity was determined using the CA Dept. of Water Resourcese - California Data Exchange Center data records.

c. The wind velocity corresponding to the maximum recorded peak wind velocity was selected for the basis of design.

d. The wind velocities provided represent wind gusts above the ground surface. These values need to be adjusted to a 1-hour sustained wind velocity. USACE EM 1110-2-1100 guidance was used to convert the wind velocities to 1-hour sustained wind velocities.

e. The embankment is modeled with a riprap lined upstream slope for the runup calculations.

f. The embankment does not have an intermediate berm on the slope.

g. The wave height distribution can be statistically modeled as a Rayleigh distribution.

h. Tolerable damage will be allowed for the riprap design.

i. The average depth over the length of the Fetch is assumed as 70 feet. This value was estimated based on historical Google Earth imagery and the existing slope design.

j. The fetch was estimated as 1 mile. This estimate is approximately the linear length of Cottonwood Bay which is a conservative estimate.

$D := 70ft$ - Assumed average depth along the length of the Fetch

5A. Calculation Input Data

Wind Velocity Data:

- Design Wind loads are based on CA Dept. of Water Resourcese - California Data Exchange Center data records at the LBN (Los Banos) station, see the table below.

San Luis Reservoir Wind Direction and Speed

Month	Direction (DEG)[1]	Speed (MPH)[1]	Avg Peak Wind Speed (MPH)[2]	Max Peak Wind Speed (MPH)[2]
January	167	4.87	9	48
February	188	5.95	11	54
March	206	6.62	12	44
April	230	8.03	15	45
May	243	9.30	17	46
June	243	9.63	18	46
July	172	8.60	16	42
August	197	7.91	15	41
September	200	7.29	14	43
October	195	6.18	11	49
November	176	5.05	9	40
December	168	4.89	9	52

1. Hourly wind direction and speed reported from 1/1/1995 to 6/2/2020
2. Hourly peak wind speed reported from 7/17/2003 to 6/2/2020

$$VL_CDEC := \begin{pmatrix} 38 \\ 42 \\ 48 \\ 54 \\ 60 \end{pmatrix} \cdot mph$$

- Max peak wind velocities based on recorded wind data.

$dvi := 3$ - Design velocity vector indice value for final riprap recommendations:

$tw := 3$ - Wind duration associated with the provided velocities (in seconds).

Slope Geometry Data:

$$Slope := \frac{2.4}{1}$$

- Embankment slope: Horizontal is numerator, Vertical is denominator

Riprap Design Parameters:

$G_{s_riprap} := 2.65$ - Specific gravity of rock for the riprap borrow material.

$\gamma_{_riprap} := 160 \cdot pcf$ - Design unit weight for riprap material.

5B. Design Calculations

Step 1: Estimate Fetch - Refer to Figure 2 for Fetch calculation details

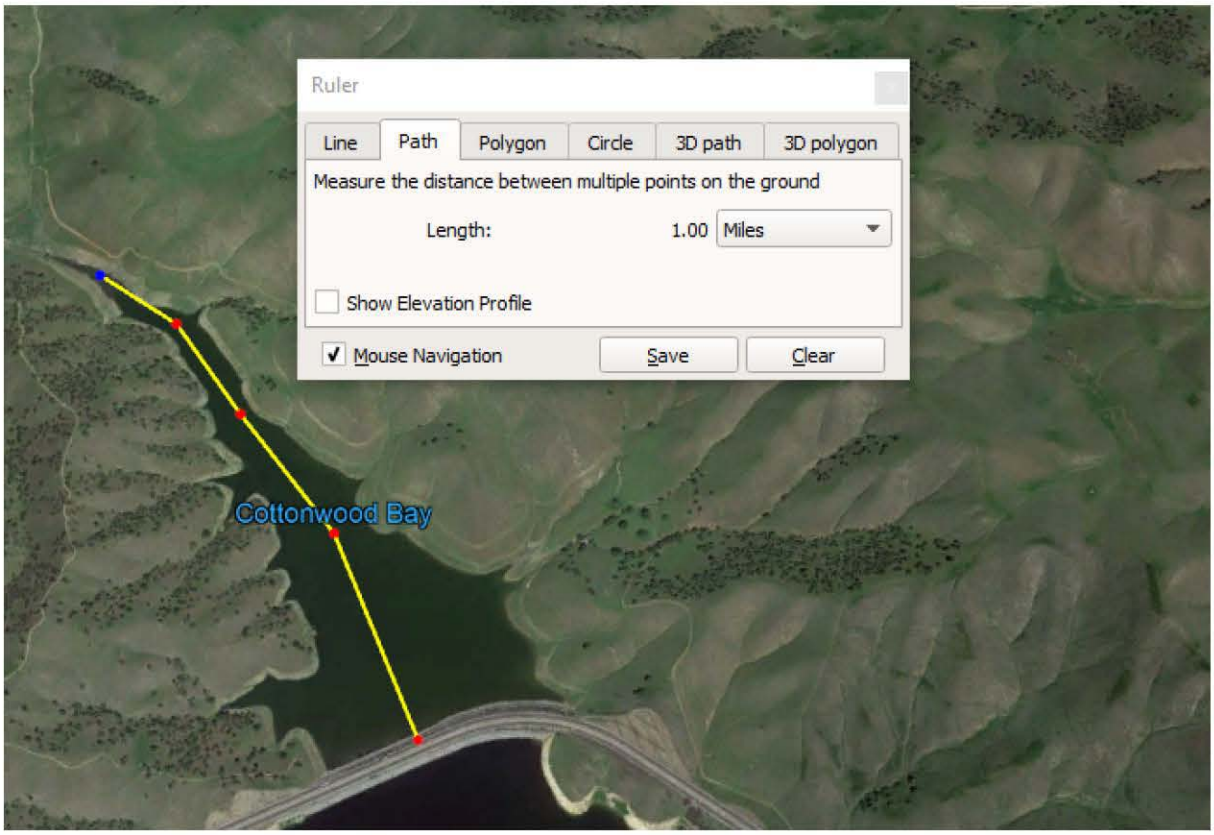


Figure 2: Geometry for Fetch Estimate

$Fetch := 1mi$ - Longest distance from dam crest to opposite shoreline

Table B-1, below, provides simplified freeboard estimates for "Small Dams" based on the Fetch.

Table B-1. Approximation of minimum and normal freeboard [10]

Longest fetch (miles)	Normal freeboard (added to the normal water surface) (feet)	Minimum freeboard (added to the maximum water surface) (feet)
<1	4	3
1	5	4
2.5	6	5
5	8	6
10	10	7

Note: These values were based on a wind velocity of 100 mi/h blowing over the normal reservoir water surface and 50 mi/h blowing over the MRWS. The effect of wind setup is not considered in the values shown. For embankment dams with soil-cement or other smooth upstream faces, depending on the smoothness of the surface, the values shown should be increased by a factor of up to 1.5.

Step 2: Determine Design Wind Velocity Parameters

Estimate the design wind velocities at the proposed site (input values in Section 5A).

$$VL_CDEC = \begin{pmatrix} 38 \\ 42 \\ 48 \\ 54 \\ 60 \end{pmatrix} \cdot mph$$

- Wind Velocities for 3-second gusts measured at 33 feet above the ground surface:

$tw = 3$ - Provided burst duration (sec)

Adjust the 3-second wind gust velocities (VL_CDEC) to 1-hour sustained wind velocities (VL_1hour) based on USACE EM 1110-2-1100:

$$Ratio_1hour := 1.277 + 0.296 \cdot \tanh\left(0.9 \cdot \log\left(\frac{45}{tw}\right)\right)$$

$Ratio_1hour = 1.509$

$\frac{U_T}{U_{3600}}$ for $t < 3600$

$$VL_1hour := VL_CDEC \cdot \frac{1}{Ratio_1hour}$$

$$VL_1hour = \begin{pmatrix} 25.176 \\ 27.826 \\ 31.801 \\ 35.776 \\ 39.751 \end{pmatrix} \cdot mph$$

Adjust over land velocities to over water velocities (VW), see Figure B-2:

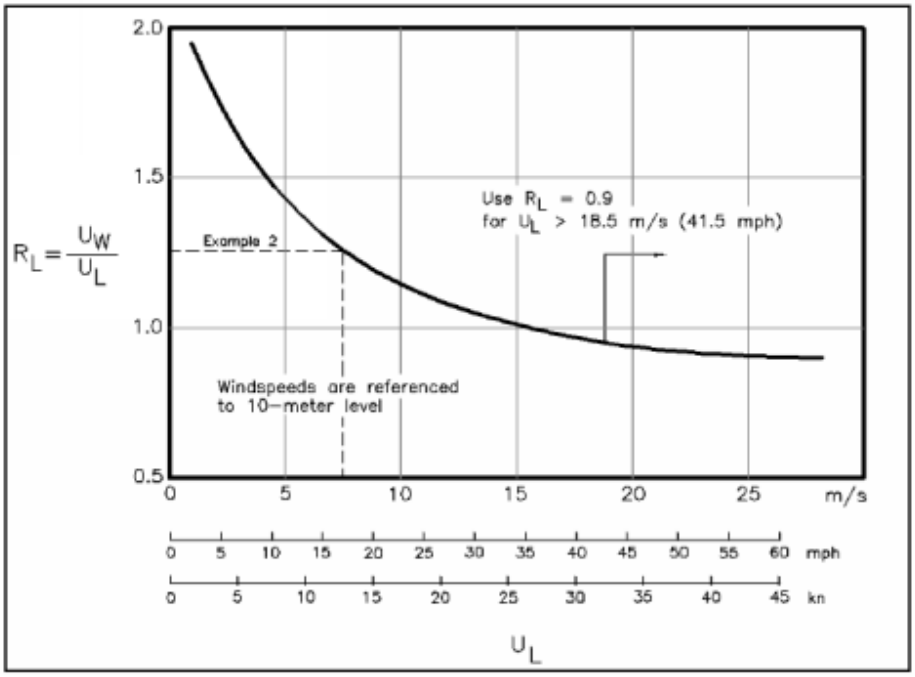


Figure B-2. Ratio of wind speed over water to wind speed over land as a function of wind speed over land [16a].

RL := 1.0

VW_1hour := RL·VL_1hour

$$VW_1hour = \begin{pmatrix} 25.176 \\ 27.826 \\ 31.801 \\ 35.776 \\ 39.751 \end{pmatrix} \cdot mph$$

- Sustained 1-hour duration wind velocities over water

Estimate the minimum duration needed to genterate the highest waves

$$tmin := 1.87 \cdot \left[\frac{\left(\frac{Fetch}{mi} \right)^{0.67}}{\left(\frac{VW_1hour}{mph} \right)^{0.34}} \right] \cdot hr$$

$$tmin = \begin{pmatrix} 0.624 \\ 0.604 \\ 0.577 \\ 0.554 \\ 0.535 \end{pmatrix} \cdot hr$$

- tmin values represent the minimum sustained wind duration required for the design wave to reach the significant heights estimated in Step 3, below.

The minimum duration required to fully mobilize the design wave heights is less than the 1-hour assumed duration, so the waves will not be fetch-limited.

VW := VW_1hour

Step 3: Calculate Design Wave Height

The significant wave height (H_s) is defined as the average of the highest one-third of the waves in a wave field.

$i := 0..4$

$$Hs_i := 0.0245 \cdot \left(\frac{Fetch}{mi}\right)^{0.5} \cdot \frac{VW_i}{mph} \cdot \left(1.1 + 0.0156 \cdot \frac{VW_i}{mph}\right)^{0.5} \cdot ft$$

$$Hs = \begin{pmatrix} 0.754 \\ 0.844 \\ 0.984 \\ 1.129 \\ 1.277 \end{pmatrix} \cdot ft$$

- Significant wave height

Assuming the wave height distribution can be described using a Rayleigh distribution, Table B-2 may be used to estimate additional statistical wave heights. Since overtopping is not permissible at this site, a wave height of 1.67 times the significant height should be used for design. This design wave level corresponds to the highest 1 percent of waves.

If the maximum Fetch is not perpendicular to the dam crest, the wave height needs to be reduced to account for the angle of incidence. Based on an incidence angle that is perpendicular, the reduction factor is 1.0 based on Figure B-3.

Table B-2. Common wave height relationships

Percent of total number of waves in series averaged to compute specific wave height (H)	Ratio of specific wave height, H, to average wave height, H_{ave} (H/H_{ave})	Ratio of specific wave height, H, to significant wave height H_s (H/H_s)	Percent of waves exceeding specific wave height (H)
1	2.66	1.67	0.4
5	2.24	1.40	2
10	2.03	1.27	4
20	1.80	1.12	8
25	1.71	1.07	10
30	1.64	1.02	12
33.33	1.60	1.00	13
40	1.52	0.95	16
50	1.42	0.89	20
75	1.20	0.75	32
100	1.00	0.62	46

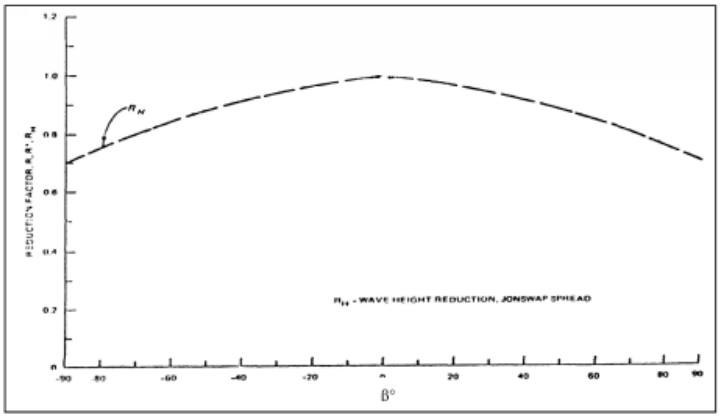


Figure B-3. Wave height reduction due to angular spread [16a].

Where:

β° = The angle between the fetch and the dam axis (degrees). (0° is normal incidence and is commonly used to compute fetch, which is directly perpendicular to the dam axis).

$$Hdw := 1.67 \cdot Hs \cdot 1.0$$

$$Hdw = \begin{pmatrix} 1.259 \\ 1.41 \\ 1.644 \\ 1.885 \\ 2.133 \end{pmatrix} \cdot ft$$

- factored design wave height for runup and setup estimates.

Step 4: Estimate Wave Runup on Upstream Slope of Dam

Estimate wave length (Lw) and wave period (Tw) for runup calculations

$$Tw_i := 0.464 \cdot \left(\frac{Fetch}{mi}\right)^{\frac{1}{3}} \cdot \left(\frac{VW_i}{mph}\right)^{\frac{1}{3}} \cdot \left(1.1 + 0.0156 \cdot \frac{VW_i}{mph}\right)^{\frac{1}{6}} \cdot s$$

$$Tw = \begin{pmatrix} 1.454 \\ 1.51 \\ 1.589 \\ 1.663 \\ 1.733 \end{pmatrix} s$$

- Estimated wave period

$$Lw := 5.12 \cdot \left(\frac{Tw}{s}\right)^2 \cdot ft$$

$$Lw = \begin{pmatrix} 10.822 \\ 11.674 \\ 12.931 \\ 14.166 \\ 15.384 \end{pmatrix} \cdot ft$$

- Estimated wave length

Estimate steepness of peak waves based on design wave height and wave length

$$sp := \frac{Hdw}{Lw}$$

$$sp = \begin{pmatrix} 0.116 \\ 0.121 \\ 0.127 \\ 0.133 \\ 0.139 \end{pmatrix}$$

- Steepness of the design wave

Estimate surf similarity factor for peak wave heights

$$\alpha := \operatorname{atan}\left(\frac{1}{Slope}\right)$$

$$\alpha = 22.62 \cdot °$$

- Angle of the upstream slope from horizontal, i.e. inverse of slope

$$\xi p := \frac{\tan(\alpha)}{sp^{0.5}}$$

$$\xi p = \begin{pmatrix} 1.222 \\ 1.199 \\ 1.169 \\ 1.142 \\ 1.119 \end{pmatrix}$$

- Surf similarity factor

Identify coefficeints A and C based on the surf similarity factor and Table B-4

Table B-4. Values for variables *A* and *C* of the runup equation [16b]

ξ-Limits	*A*	*C*
$\xi_p \le 2.5$	1.6	0
$2.5 < \xi_p < 9$	-0.2	4.5

$Ar := 1.6$

$Cr := 0$

Identify reduction factors for the runup calculations

$\gamma r := 0.55$ - Slope roughness reduction factor (γ_r), based on Table B-3. For riprap, a value of 0.55 is recommended.

Table B-3. Surface roughness reduction factor (valid for 1 < ξ_p <3-4) [16b]

Type of slope surface	γ_r
Smooth, concrete, asphalt	1.0
Smooth block revetment	1.0
Grass (3 centimeters in length)	0.90 – 1.0
One layer of rock, diameter D, (H_s/D = 1.5 – 3.0)	0.55 – 0.6
Two or more layers of rock, (H_s/D = 1.5 – 6.0)	0.50 – 0.55

$\gamma b := 1.0$ - Berm reduction factor (γ_b), 1.0 if no berm

$\gamma h := 1.0$ - Shallow-water reduction factor (γ_h), 1.0 if Rayleigh distributed waves

$\gamma \beta := 1.0$ - Direction of fetch reduction factor (γ_β), see Figure B-4, below.

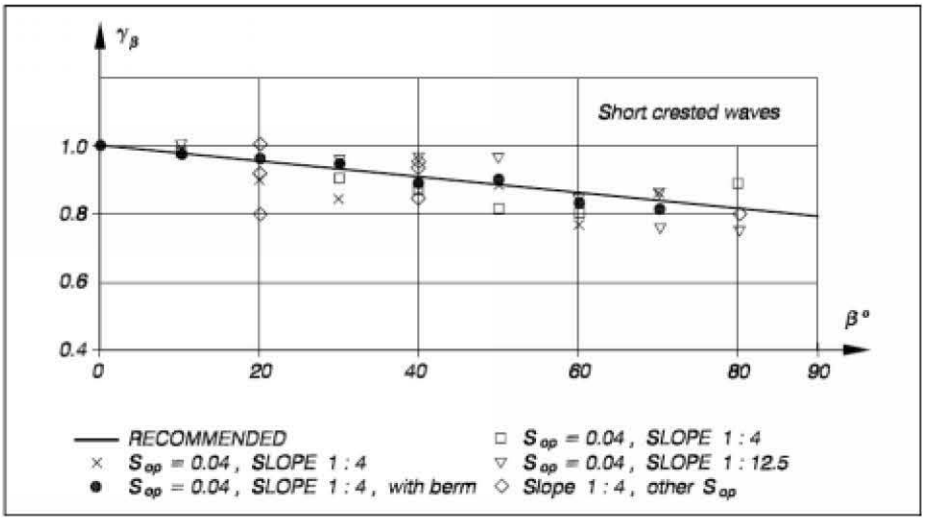


Figure B-4. Influence of angle of incidence, β, and the directional spreading on runup on smooth slopes at Delft Hydraulics [16b].

Calculate runup

$$Runup_i := Hdw_i \cdot (Ar \cdot \xi p_i + Cr) \cdot \gamma r \cdot \gamma b \cdot \gamma h \cdot \gamma \beta$$

$$Runup = \begin{pmatrix} 1.353 \\ 1.488 \\ 1.69 \\ 1.895 \\ 2.1 \end{pmatrix} \cdot ft$$

Step 5: Estimate Wind Setup on Dam Slope

$$Setup := \frac{\left(\frac{VW}{mph}\right)^2 \cdot ft \cdot \frac{Fetch}{mi}}{1400 \cdot \frac{D}{ft}}$$

$$Setup = \begin{pmatrix} 6.468 \times 10^{-3} \\ 7.901 \times 10^{-3} \\ 0.01 \\ 0.013 \\ 0.016 \end{pmatrix} \cdot ft$$

Step 6: Compare Calculated Freeboard Estimates

NRWSmin := 8ft Minimum freeboard for NRWS level (Table B-1, above).

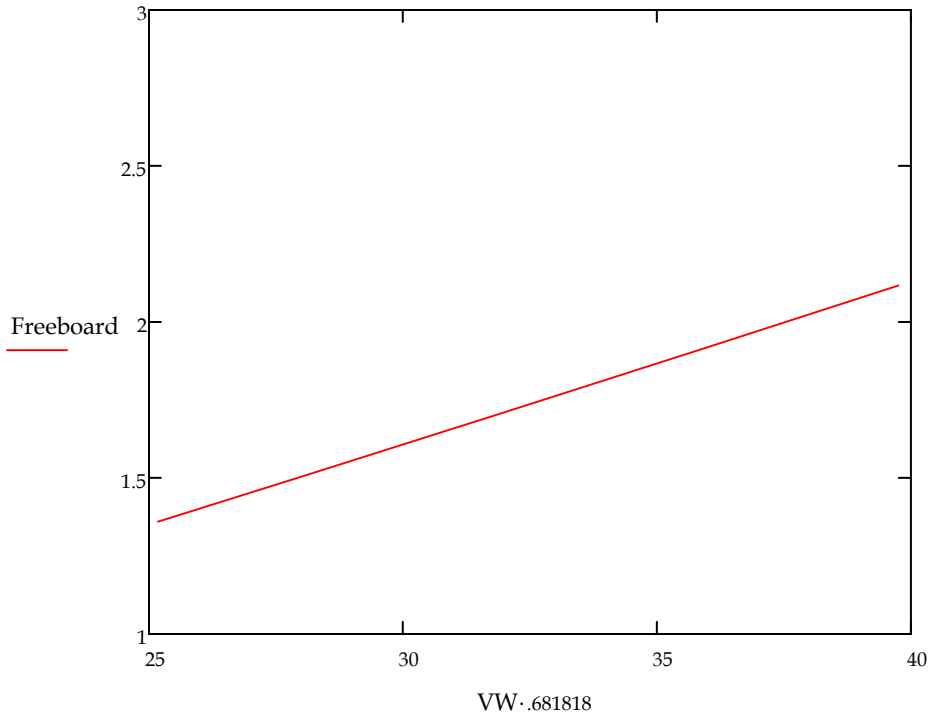
MRWSmin := 6ft Minimum freeboard for MRWS level (Table B-1, above).

Calculated freeboard requirements.

Freeboard := Runup + Setup

$$Freeboard = \begin{pmatrix} 1.36 \\ 1.496 \\ 1.701 \\ 1.908 \\ 2.117 \end{pmatrix} \cdot ft$$

Plot of Design Wind Velocity over Water versus Required Freeboard



RIPRAP DESIGN SECTION

Step 7: Calculate Design Wave Height for Riprap Design

According to Chapter 7 of the *Design Standards No. 13* manual, the 10-percent wave height (H_{10}), based on the derived significant wave height, results in riprap sizes that perform well.

Assuming the wave height distribution can be described using a Rayleigh distribution, a wave height of 1.27 times the significant height should be used for design. This design wave level corresponds to the highest 10 percent of waves.

$H10 := 1.27 \cdot Hs$

$$H10 = \begin{pmatrix} 0.957 \\ 1.072 \\ 1.25 \\ 1.433 \\ 1.622 \end{pmatrix} \text{ ft}$$

- 10-percent wave height

Step 8: Calculate Required Rock Weight and Riprap Thickness

For cases where **tolerable damage** is allowed, W_{50} is calculated as:

$$W50td := \gamma_riprap \cdot \frac{H10^3}{4.37 \cdot (Gs_riprap - 1)^3 \cdot \cot(\alpha)}$$

$$W50td = \begin{pmatrix} 2.977 \\ 4.188 \\ 6.634 \\ 10.002 \\ 14.497 \end{pmatrix} \text{ lbf}$$

- Mean rock weight for tolerable damage condition

Volume, Weight, and Diameter Relationship: $V_{50} = W_{50} / g_r = 0.75(D_{50})^3$

$$V50td_i := \frac{W50td_i}{\gamma_riprap}$$

$$V50td = \begin{pmatrix} 0.019 \\ 0.026 \\ 0.041 \\ 0.063 \\ 0.091 \end{pmatrix} \text{ ft}^2 \cdot \text{ft}$$

- Mean rock volume for tolerable damage condition

$$D50td := \left(\frac{V50td}{0.75}\right)^{\left(\frac{1}{3}\right)}$$

$$D50td = \begin{pmatrix} 0.292 \\ 0.327 \\ 0.381 \\ 0.437 \\ 0.494 \end{pmatrix} \text{ ft}$$

- Mean rock diameter for tolerable damage condition

$Tmintd := 2 \cdot D50td$

$$Tmintd = \begin{pmatrix} 0.583 \\ 0.654 \\ 0.762 \\ 0.874 \\ 0.989 \end{pmatrix} \text{ ft}$$

- Minimum Thickness of Riprap for tolerable damage condition

For cases where **zero damage** is allowed, W_{50} is calculated as:

$$W50zd := \gamma_riprap \cdot \frac{H10^3}{3.62 \cdot (Gs_riprap - 1)^3 \cdot \cot(\alpha)^{0.667}}$$

$$W50zd = \begin{pmatrix} 4.811 \\ 6.767 \\ 10.72 \\ 16.161 \\ 23.424 \end{pmatrix} \text{ lbf}$$

- Mean rock weight for zero damage condition

Volume, Weight, and Diameter Relationship: $V_{50} = W_{50}/g_r = 0.75(D_{50})^3$

$$V50zd_i := \frac{W50zd_i}{\gamma_riprap}$$

$$V50zd = \begin{pmatrix} 0.03 \\ 0.042 \\ 0.067 \\ 0.101 \\ 0.146 \end{pmatrix} \text{ ft}^2 \cdot \text{ft}$$

- Mean rock volume for zero damage condition

$$D50zd := \left(\frac{V50zd}{0.75}\right)^{\left(\frac{1}{3}\right)}$$

$$D50zd = \begin{pmatrix} 0.342 \\ 0.383 \\ 0.447 \\ 0.513 \\ 0.58 \end{pmatrix} \text{ ft}$$

- Mean rock diameter for zero damage condition

$Tminzd := 2 \cdot D50zd$

$$Tminzd = \begin{pmatrix} 0.684 \\ 0.767 \\ 0.894 \\ 1.025 \\ 1.16 \end{pmatrix} \text{ ft}$$

- Minimum Thickness of Riprap for zero damage condition

Step 9: Calculate Riprap Gradation

Calculations for **Tolerable Damage** sizes: $Wtdmax := 4 \cdot W50td$ $Wtdmin := \frac{W50td}{8}$

$$Wtdmax = \begin{pmatrix} 11.909 \\ 16.752 \\ 26.537 \\ 40.008 \\ 57.988 \end{pmatrix} \text{lbf} \qquad Wtdmin = \begin{pmatrix} 0.372 \\ 0.524 \\ 0.829 \\ 1.25 \\ 1.812 \end{pmatrix} \text{lbf}$$

Calculations for **Zero Damage** sizes: $Wzdmax := 4 \cdot W50zd$ $Wzdmin := \frac{W50zd}{8}$

$$Wzdmax = \begin{pmatrix} 19.242 \\ 27.068 \\ 42.879 \\ 64.644 \\ 93.696 \end{pmatrix} \text{lbf} \qquad Wzdmin = \begin{pmatrix} 0.601 \\ 0.846 \\ 1.34 \\ 2.02 \\ 2.928 \end{pmatrix} \text{lbf}$$

20% and 35% Band Limit Calculations:

20-percent band coarse-limit curve	
Weight of rock fragment	**% finer by weight**
W_{max}	100
$0.5\,W_{max}$	70
W_{50}	35
W_{min}	0
20-percent band fine-limit curve	
Weight of rock fragment	**% finer by weight**
$0.5\,W_{max}$	90
W_{50}	55
W_{min}	20

35-percent band coarse-limit curve	
Weight of rock fragment	**% finer by weight**
W_{max}	100
$0.5\,W_{max}$	55
W_{50}	25
W_{min}	0
35-percent band fine-limit curve	
Weight of rock fragment	**% finer by weight**
0.5 x W_{max}	90
W_{50}	60
W_{min}	20

Values for the Coarse-Limit Curve

$$CLC20pf := \begin{pmatrix} 100 \\ 70 \\ 35 \\ 0 \end{pmatrix} \quad CLC35pf := \begin{pmatrix} 100 \\ 55 \\ 25 \\ 0 \end{pmatrix}$$

- Vector of % Finer by Weight values for Coarse-Limit Curve, 20% and 35% Band, respectively.

$$CLCwrftd := \begin{pmatrix} Wtdmax_{dvi} \\ 0.5 \cdot Wtdmax_{dvi} \\ W50td_{dvi} \\ Wtdmin_{dvi} \end{pmatrix} \quad CLCwrftd = \begin{pmatrix} 40.008 \\ 20.004 \\ 10.002 \\ 1.25 \end{pmatrix} lbf$$

- Vector of Weight of Rock Fragments associated with the % Finer data above.

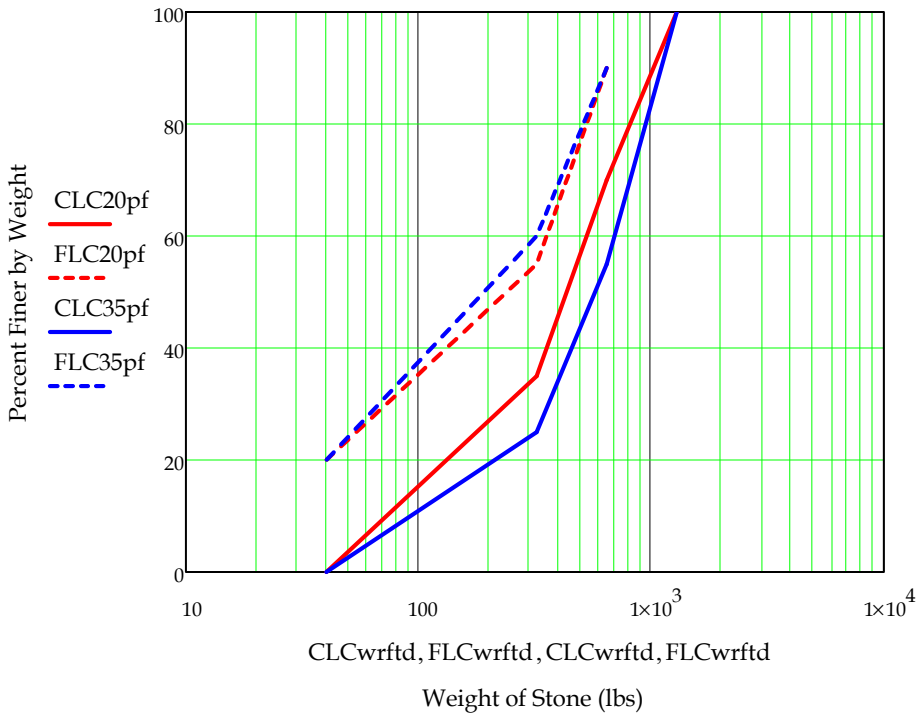
Values for the Fine-Limit Curve

$$FLC20pf := \begin{pmatrix} 90 \\ 55 \\ 20 \end{pmatrix} \quad FLC35pf := \begin{pmatrix} 90 \\ 60 \\ 20 \end{pmatrix}$$

- Vector of % Finer by Weight values for Fine-Limit Curve, 20% and 35% Band, respectively.

$$FLCwrftd := \begin{pmatrix} 0.5 \cdot Wtdmax_{dvi} \\ W50td_{dvi} \\ Wtdmin_{dvi} \end{pmatrix} \quad FLCwrftd = \begin{pmatrix} 20.004 \\ 10.002 \\ 1.25 \end{pmatrix} lbf$$

- Vector of Weight of Rock Fragments associated with the % Finer data above.



6. Conclusions/Results

1. For design wind velocities corresponding to maximum recorded peak wind velocities, the minimum required freeboard ranges from approximately 1.3 feet to 2.2 feet above the water surface.
2. For the maximum pool elevation and the maximum recorded peak wind velocity, the minimum freeboard was calculated at 1.91 feet. The design freeboard of 11 feet easily exceeds this condition as well as the maximum pool and normal pool minimum recommended values provided in Table B-1 of Chapter 6 of the U.S. Department of the Interior Bureau of Reclamation's *Design Standards No. 13 - Embankment Dams* manual. .
3. Based on the riprap calculation proceedure for a limited damage case, the average rock diameter is 0.44 feet (5.5 inches) and a minimum riprap thickness of 0.9 feet.

CLIENT:	Caltrans			**PROJECT:**	Sisk Dam -SR 152 Raising
BY:	KNA	**DATE:**	10-Jun-20	**Job No.:**	141064-242990
CHKD BY:	EOT	**DATE:**	11-Jun-20	**SHEET No.:**	1

SUBJECT: Minimum Freeboard and Riprap Sizing Requirements - Parking Lot

Developed by K. Applegate; Charlotte, NC — Mathcad 15, PTC.

1. Purpose/Objective

To estimate the required freeboard and riprap gradation limits at the Sisk Dam site based on the methods presented in Chapter 6 and Chapter 7 of the U.S. Department of the Interior Bureau of Reclamation's *Design Standards No. 13 - Embankment Dams* manual.

2. Procedure

a. Develop necessary input parameters for the freeboard and riprap calculations.

b. Follow the calculations presented in the worksheet.

1. Calculate the Fetch for the reservoir.
2. Determine design wind velocity (based on CA Dept. of Water Resourcese - California Data Exchange Center).
3. Calculate the design wave height.
4. Estimate the wave runup for the proposed embankment geometry.
5. Estimate the wind setup for the proposed embankment geometry.
6. Calculate the required freeboard.
7. Calculate the required mean rock weight (W_{50}) and minimum riprap thickness (T_{min}).
8. Calculate the design wave height for riprap design (H_{10}).
9. Determine the riprap gradation requirements.

c. Enter/change input parameters in the yellow boxes .

d. The calculated design parameters are auto-populated and provided in green boxes .

3. References/Data Sources

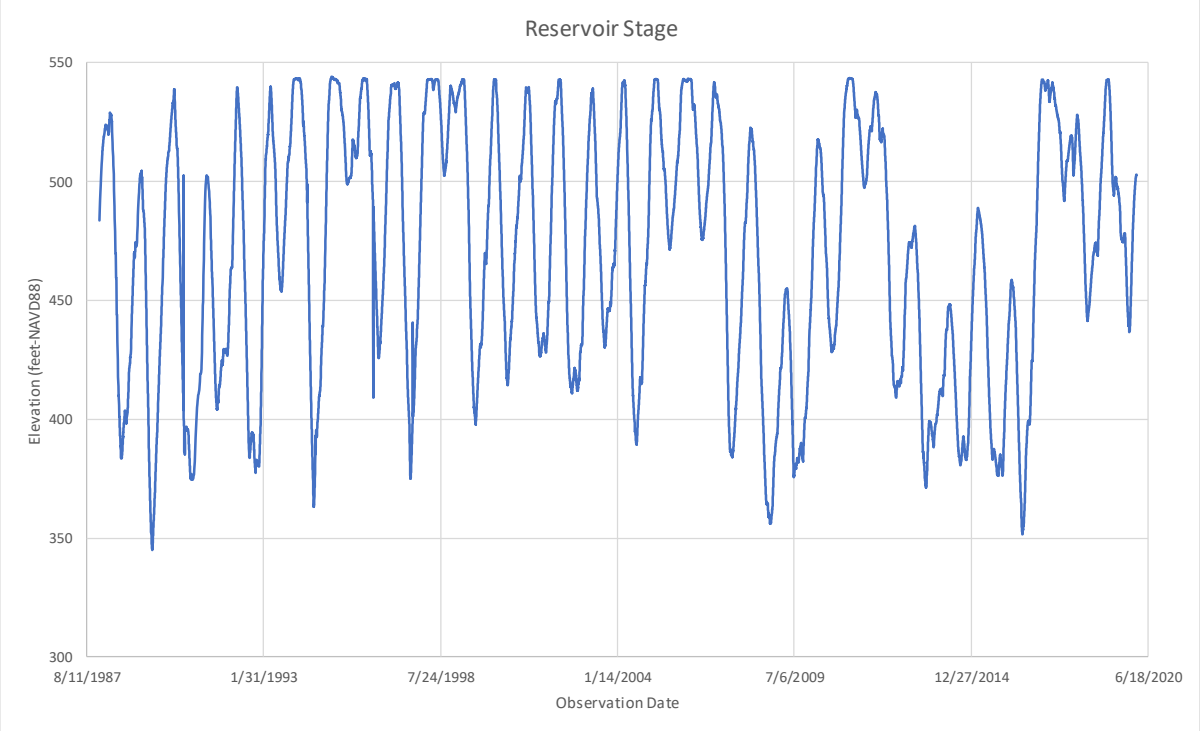
a. U.S. Department of the Interior Bureau of Reclamation, *Design Standards No. 13 - Embankment Dams*, September 2012.

b. Dept. of Water Resourcese - California Data Exchange Center, *cdec.water.ca.gov/cdecstation2/?sta=BLN.*

c. California Department of Water Resources - Resevoir stage data for the San Luis Reservoir, recorded between January 4, 1988 and February 11, 2020.

4. Assumptions and Limitations

a. The calculated runup will be applied to the maximum pool storage elevation. The reservoir stage continually fluctuates, and the reservoir may stay at or near maximum pool elevation for long periods of time. See the plot of historic reservoir stage data, below.



b. The maximum wind velocity was determined using the CA Dept. of Water Resourcese - California Data Exchange Center data records.

c. The wind velocity corresponding to the maximum recorded peak wind velocity was selected for the basis of design.

d. The wind velocities provided represent wind gusts above the ground surface. These values need to be adjusted to a 1-hour sustained wind velocity. USACE EM 1110-2-1100 guidance was used to convert the wind velocities to 1-hour sustained wind velocities.

e. The embankment is modeled with a riprap lined upstream slope for the runup calculations.

f. The embankment does not have an intermediate berm on the upstream slope.

g. The wave height distribution can be statistically modeled as a Rayleigh distribution.

h. Tolerable damage will be allowed for the riprap design.

i. The average depth over the length of the Fetch is assumed as 150 feet. This value was estimated based on the water volume (2,041,000 acre feet) and the surface area (12,700 acres) reported on Wikipedia and the relative location of the fetch radials. These values were reported for the existing maximum pool elevation of 544 feet. The proposed maximum pool elevation will be raised to elevation 554 feet.

$D := 150ft$ - Assumed average depth along the length of the Fetch

5A. Calculation Input Data

Wind Velocity Data:

- Design Wind loads are based on CA Dept. of Water Resourcese - California Data Exchange Center data records at the LBN (Los Banos) station, see the table below.

San Luis Reservoir Wind Direction and Speed

Month	Direction (DEG)[1]	Speed (MPH)[1]	Avg Peak Wind Speed (MPH)[2]	Max Peak Wind Speed (MPH)[2]
January	167	4.87	9	48
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1. Hourly wind direction and speed reported from 1/1/1995 to 6/2/2020
2. Hourly peak wind speed reported from 7/17/2003 to 6/2/2020

$$VL_CDEC := \begin{pmatrix} 38 \\ 42 \\ 48 \\ 54 \\ 60 \end{pmatrix} \cdot mph$$

- Max peak wind velocities based on recorded wind data.

$dvi := 3$ - Design velocity vector indice value for final riprap recommendations:

$tw := 3$ - Wind duration associated with the provided velocities (in seconds).

Slope Geometry Data:

$$Slope := \frac{6}{1}$$

- Embankment slope: Horizontal is numerator, Vertical is denominator

Riprap Design Parameters:

$Gs_{riprap} := 2.65$ - Specific gravity of rock for the riprap borrow material.

$\gamma_{riprap} := 160 \cdot pcf$ - Design unit weight for riprap material.

5B. Design Calculations

Step 1: Calculate Fetch - Refer to Figure 2 for Fetch calculation details

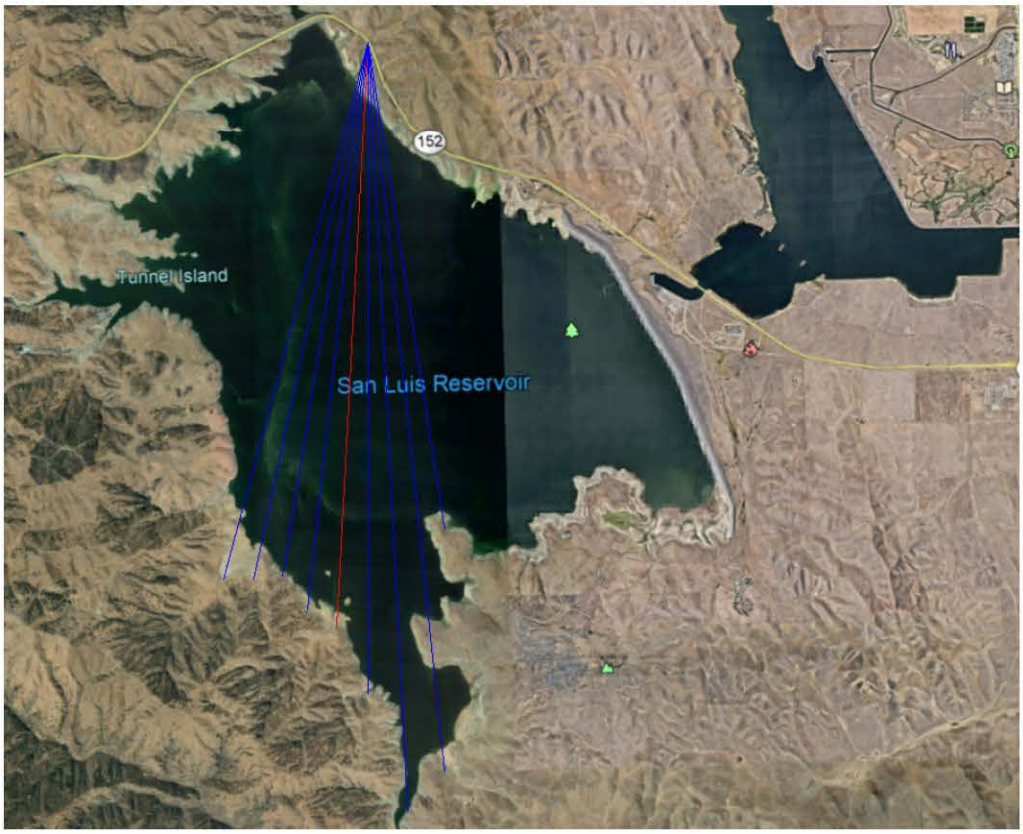


Figure 2: Geometry for Fetch Calculations

$Fsum := 5.27mi + 5.14mi + 5.87mi + 4.86mi + 6.94mi + 4.94mi + 6.60mi + 5.01mi + 4.44mi$

$Fetch := \frac{Fsum}{9}$ - Longest average distance from dam crest to opposite shoreline

$Fetch = 5.452 \cdot mi$

Table B-1, below, provides simplified freeboard estimates for "Small Dams" based on the Fetch.

Table B-1. Approximation of minimum and normal freeboard [10]

Longest fetch (miles)	Normal freeboard (added to the normal water surface) (feet)	Minimum freeboard (added to the maximum water surface) (feet)
<1	4	3
1	5	4
2.5	6	5
5	8	6
10	10	7

Note: These values were based on a wind velocity of 100 mi/h blowing over the normal reservoir water surface and 50 mi/h blowing over the MRWS. The effect of wind setup is not considered in the values shown. For embankment dams with soil-cement or other smooth upstream faces, depending on the smoothness of the surface, the values shown should be increased by a factor of up to 1.5.

Step 2: Determine Design Wind Velocity Parameters

Estimate the design wind velocities at the proposed site (input values in Section 5A).

$$VL_CDEC = \begin{pmatrix} 38 \\ 42 \\ 48 \\ 54 \\ 60 \end{pmatrix} \cdot mph$$

- Wind Velocities for 3-second gusts measured at 33 feet above the ground surface:

$tw = 3$ - Provided burst duration (sec)

Adjust the 3-second wind gust velocities (VL_CDEC) to 1-hour sustained wind velocities (VL_1hour) based on USACE EM 1110-2-1100:

$$Ratio_1hour := 1.277 + 0.296 \cdot \tanh\left(0.9 \cdot \log\left(\frac{45}{tw}\right)\right)$$

$Ratio_1hour = 1.509$

$\frac{U_T}{U_{3600}}$ for $t < 3600$

$$VL_1hour := VL_CDEC \cdot \frac{1}{Ratio_1hour}$$

$$VL_1hour = \begin{pmatrix} 25.176 \\ 27.826 \\ 31.801 \\ 35.776 \\ 39.751 \end{pmatrix} \cdot mph$$

Adjust over land velocities to over water velocities (VW), see Figure B-2:

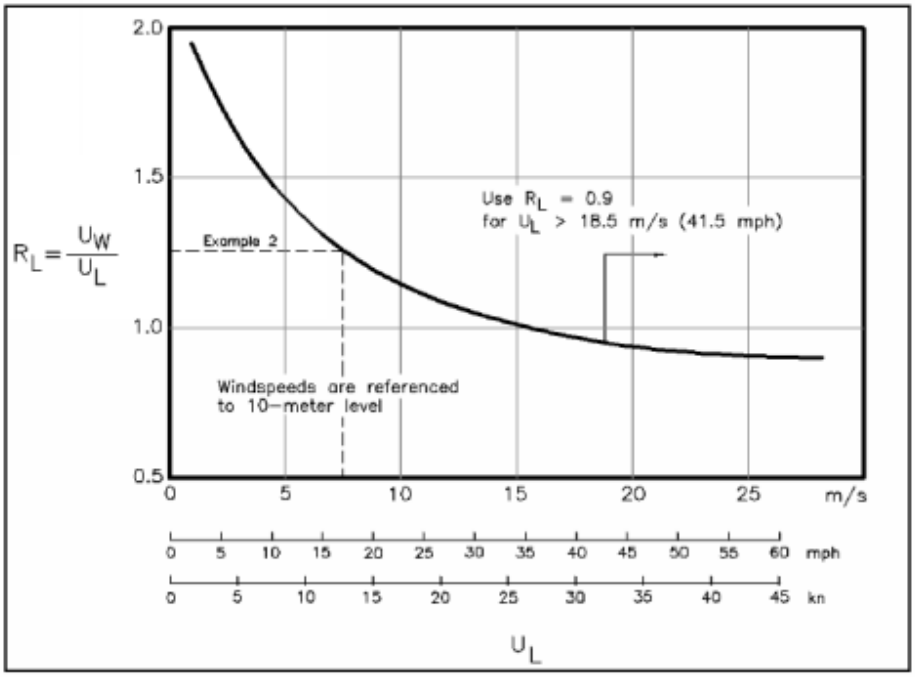


Figure B-2. Ratio of wind speed over water to wind speed over land as a function of wind speed over land [16a].

RL := 1.0

VW_1hour := RL·VL_1hour

$$VW_1hour = \begin{pmatrix} 25.176 \\ 27.826 \\ 31.801 \\ 35.776 \\ 39.751 \end{pmatrix} \cdot mph$$

- Sustained 1-hour duration wind velocities over water

Estimate the minimum duration needed to genterate the highest waves (assuming Risk Category IV)

$$tmin := 1.87 \cdot \left[\frac{\left(\frac{Fetch}{mi} \right)^{0.67}}{\left(\frac{VW_1hour}{mph} \right)^{0.34}} \right] \cdot hr$$

$$tmin = \begin{pmatrix} 1.945 \\ 1.88 \\ 1.797 \\ 1.726 \\ 1.666 \end{pmatrix} \cdot hr$$

- tmin values represent the minimum sustained wind duration required for the design wave to reach the significant heights estimated in Step 3, below.

The minimum duration required to fully mobilize the design wave heights is greater than the 1-hour assumed duration, so the waves will be fetch-limited, i.e. smaller than reported. However, we have conservatively used the 1-hour duration velocities reported above for the design calculations.

VW := VW_1hour

Step 3: Calculate Design Wave Height

The significant wave height (H_s) is defined as the average of the highest one-third of the waves in a wave field.

$i := 0..4$

$$Hs_i := 0.0245 \cdot \left(\frac{Fetch}{mi}\right)^{0.5} \cdot \frac{VW_i}{mph} \cdot \left(1.1 + 0.0156 \cdot \frac{VW_i}{mph}\right)^{0.5} \cdot ft$$

$$Hs = \begin{pmatrix} 1.76 \\ 1.972 \\ 2.298 \\ 2.635 \\ 2.983 \end{pmatrix} \cdot ft$$

- Significant wave height

Assuming the wave height distribution can be described using a Rayleigh distribution, Table B-2 may be used to estimate additional statistical wave heights. Since overtopping is not permissible at this site, a wave height of 1.67 times the significant height should be used for design. This design wave level corresponds to the highest 1 percent of waves.

If the maximum Fetch is not perpendicular to the dam crest, the wave height needs to be reduced to account for the angle of incidence. Based on an incidence angle that is perpendicular, the reduction factor is 1.0 based on Figure B-3.

Table B-2. Common wave height relationships

Percent of total number of waves in series averaged to compute specific wave height (H)	Ratio of specific wave height, H, to average wave height, H_{ave} (H/H_{ave})	Ratio of specific wave height, H, to significant wave height H_s (H/H_s)	Percent of waves exceeding specific wave height (H)
1	2.66	1.67	0.4
5	2.24	1.40	2
10	2.03	1.27	4
20	1.80	1.12	8
25	1.71	1.07	10
30	1.64	1.02	12
33.33	1.60	1.00	13
40	1.52	0.95	16
50	1.42	0.89	20
75	1.20	0.75	32
100	1.00	0.62	46

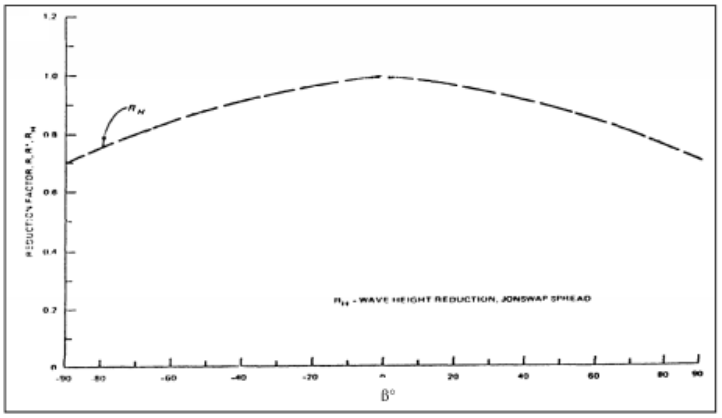


Figure B-3. Wave height reduction due to angular spread [16a].

Where:

β° = The angle between the fetch and the dam axis (degrees). (0° is normal incidence and is commonly used to compute fetch, which is directly perpendicular to the dam axis).

$$Hdw := 1.67 \cdot Hs \cdot 1.0$$

$$Hdw = \begin{pmatrix} 2.939 \\ 3.293 \\ 3.838 \\ 4.401 \\ 4.981 \end{pmatrix} \cdot ft$$

- factored design wave height for runup and setup estimates.

Step 4: Estimate Wave Runup on Upstream Slope of Dam

Estimate wave length (Lw) and wave period (Tw) for runup calculations

$$Tw_i := 0.464 \cdot \left(\frac{Fetch}{mi}\right)^{\frac{1}{3}} \cdot \left(\frac{VW_i}{mph}\right)^{\frac{1}{3}} \cdot \left(1.1 + 0.0156 \cdot \frac{VW_i}{mph}\right)^{\frac{1}{6}} \cdot s$$

$$Tw = \begin{pmatrix} 2.559 \\ 2.658 \\ 2.797 \\ 2.928 \\ 3.051 \end{pmatrix} s$$

- Estimated wave period

$$Lw := 5.12 \cdot \left(\frac{Tw}{s}\right)^2 \cdot ft$$

$$Lw = \begin{pmatrix} 33.523 \\ 36.164 \\ 40.056 \\ 43.882 \\ 47.655 \end{pmatrix} \cdot ft$$

- Estimated wave length

Estimate steepness of peak waves based on design wave height and wave length

$$sp := \frac{Hdw}{Lw}$$

$$sp = \begin{pmatrix} 0.088 \\ 0.091 \\ 0.096 \\ 0.1 \\ 0.105 \end{pmatrix}$$

- Steepness of the design wave

Estimate surf similarity factor for peak wave heights

$$\alpha := \operatorname{atan}\left(\frac{1}{Slope}\right)$$

$\alpha = 9.462 \cdot °$

- Angle of the upstream slope from horizontal, i.e. inverse of slope

$$\xi p := \frac{\tan(\alpha)}{sp^{0.5}}$$

$$\xi p = \begin{pmatrix} 0.563 \\ 0.552 \\ 0.538 \\ 0.526 \\ 0.516 \end{pmatrix}$$

- Surf similarity factor

Identify coefficeints A and C based on the surf similarity factor and Table B-4

Table B-4. Values for variables *A* and *C* of the runup equation [16b]

ξ-Limits	*A*	*C*
$\xi_p \le 2.5$	1.6	0
$2.5 < \xi_p < 9$	-0.2	4.5

$Ar := 1.6$

$Cr := 0$

Identify reduction factors for the runup calculations

$\gamma r := 0.55$ - Slope roughness reduction factor (γ_r), based on Table B-3. For riprap, a value of 0.55 is recommended.

Table B-3. Surface roughness reduction factor (valid for 1 < ξ_p <3-4) [16b]

Type of slope surface	γ_r
Smooth, concrete, asphalt	1.0
Smooth block revetment	1.0
Grass (3 centimeters in length)	0.90 – 1.0
One layer of rock, diameter D, (H_s/D = 1.5 – 3.0)	0.55 – 0.6
Two or more layers of rock, (H_s/D = 1.5 – 6.0)	0.50 – 0.55

$\gamma b := 1.0$ - Berm reduction factor (γ_b), 1.0 if no berm

$\gamma h := 1.0$ - Shallow-water reduction factor (γ_h), 1.0 if Rayleigh distributed waves

$\gamma \beta := 1.0$ - Direction of fetch reduction factor (γ_β), see Figure B-4, below.

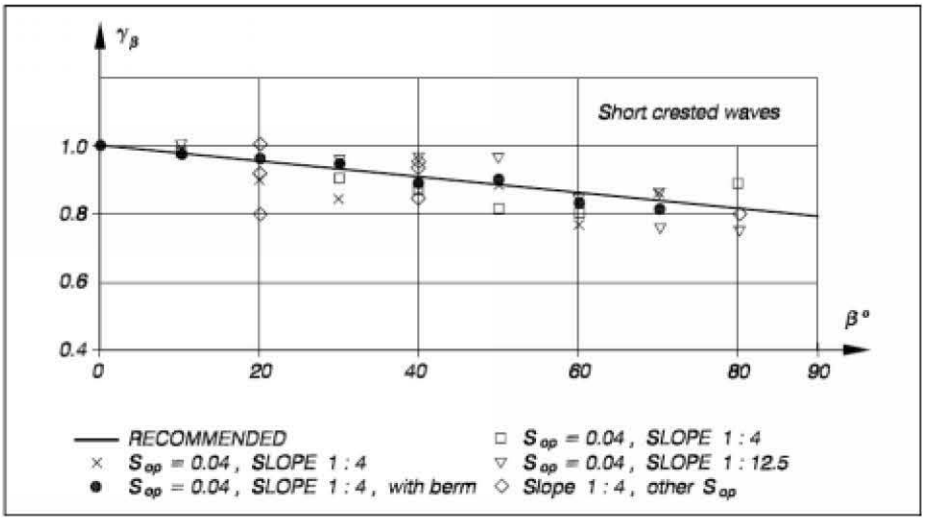


Figure B-4. Influence of angle of incidence, β, and the directional spreading on runup on smooth slopes at Delft Hydraulics [16b].

Calculate runup

$$Runup_i := Hdw_i \cdot (Ar \cdot \xi p_i + Cr) \cdot \gamma r \cdot \gamma b \cdot \gamma h \cdot \gamma \beta$$

$$Runup = \begin{pmatrix} 1.456 \\ 1.6 \\ 1.819 \\ 2.038 \\ 2.26 \end{pmatrix} \cdot ft$$

Step 5: Estimate Wind Setup on Dam Slope

$$Setup := \frac{\left(\frac{VW}{mph}\right)^2 \cdot ft \cdot \frac{Fetch}{mi}}{1400 \cdot \frac{D}{ft}}$$

$$Setup = \begin{pmatrix} 0.016 \\ 0.02 \\ 0.026 \\ 0.033 \\ 0.041 \end{pmatrix} \cdot ft$$

Step 6: Compare Calculated Freeboard Estimates

NRWSmin := 8ft Minimum freeboard for NRWS level (Table B-1, above).

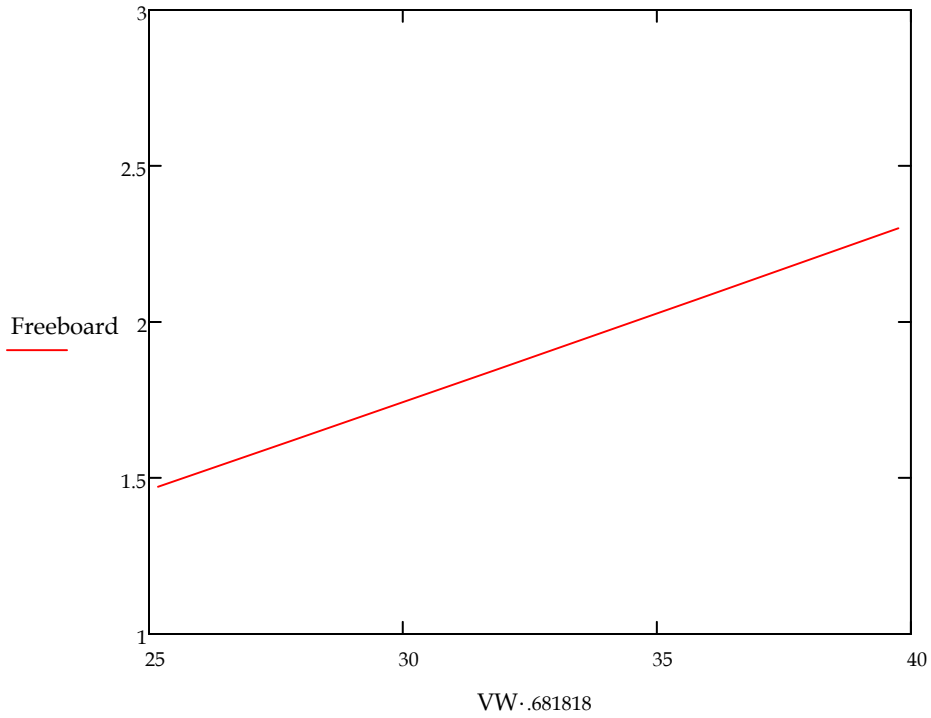
MRWSmin := 6ft Minimum freeboard for MRWS level (Table B-1, above).

Calculated freeboard requirements.

Freeboard := Runup + Setup

$$Freeboard = \begin{pmatrix} 1.472 \\ 1.621 \\ 1.845 \\ 2.071 \\ 2.301 \end{pmatrix} \cdot ft$$

Plot of Design Wind Velocity over Water versus Required Freeboard



RIPRAP DESIGN SECTION

Step 7: Calculate Design Wave Height for Riprap Design

According to Chapter 7 of the *Design Standards No. 13* manual, the 10-percent wave height (H_{10}), based on the derived significant wave height, results in riprap sizes that perform well.

Assuming the wave height distribution can be described using a Rayleigh distribution, a wave height of 1.27 times the significant height should be used for design. This design wave level corresponds to the highest 10 percent of waves.

$H10 := 1.27 \cdot Hs$

$$H10 = \begin{pmatrix} 2.235 \\ 2.504 \\ 2.919 \\ 3.347 \\ 3.788 \end{pmatrix} \text{ ft}$$

- 10-percent wave height

Step 8: Calculate Required Rock Weight and Riprap Thickness

For cases where **tolerable damage** is allowed, W_{50} is calculated as:

$$W50td := \gamma_riprap \cdot \frac{H10^3}{4.37 \cdot (Gs_riprap - 1)^3 \cdot \cot(\alpha)}$$

$$W50td = \begin{pmatrix} 15.161 \\ 21.327 \\ 33.785 \\ 50.934 \\ 73.824 \end{pmatrix} \text{ lbf}$$

- Mean rock weight for tolerable damage condition

Volume, Weight, and Diameter Relationship: $V_{50} = W_{50} / g_r = 0.75(D_{50})^3$

$$V50td_i := \frac{W50td_i}{\gamma_riprap}$$

$$V50td = \begin{pmatrix} 0.095 \\ 0.133 \\ 0.211 \\ 0.318 \\ 0.461 \end{pmatrix} \text{ ft}^2 \cdot \text{ft}$$

- Mean rock volume for tolerable damage condition

$$D50td := \left(\frac{V50td}{0.75}\right)^{\left(\frac{1}{3}\right)}$$

$$D50td = \begin{pmatrix} 0.502 \\ 0.562 \\ 0.655 \\ 0.752 \\ 0.85 \end{pmatrix} \text{ ft}$$

- Mean rock diameter for tolerable damage condition

$Tmintd := 2 \cdot D50td$

$$Tmintd = \begin{pmatrix} 1.004 \\ 1.124 \\ 1.311 \\ 1.503 \\ 1.701 \end{pmatrix} \text{ ft}$$

- Minimum Thickness of Riprap for tolerable damage condition

For cases where **zero damage** is allowed, W_{50} is calculated as:

$$W50zd := \gamma_riprap \cdot \frac{H10^3}{3.62 \cdot (Gs_riprap - 1)^3 \cdot \cot(\alpha)^{0.667}}$$

$$W50zd = \begin{pmatrix} 33.238 \\ 46.755 \\ 74.065 \\ 111.662 \\ 161.843 \end{pmatrix} \text{ lbf}$$

- Mean rock weight for zero damage condition

Volume, Weight, and Diameter Relationship: $V_{50} = W_{50}/g_r = 0.75(D_{50})^3$

$$V50zd_i := \frac{W50zd_i}{\gamma_riprap}$$

$$V50zd = \begin{pmatrix} 0.208 \\ 0.292 \\ 0.463 \\ 0.698 \\ 1.012 \end{pmatrix} \text{ ft}^2 \cdot \text{ft}$$

- Mean rock volume for zero damage condition

$$D50zd := \left(\frac{V50zd}{0.75}\right)^{\left(\frac{1}{3}\right)}$$

$$D50zd = \begin{pmatrix} 0.652 \\ 0.73 \\ 0.851 \\ 0.976 \\ 1.105 \end{pmatrix} \text{ ft}$$

- Mean rock diameter for zero damage condition

$Tminzd := 2 \cdot D50zd$

$$Tminzd = \begin{pmatrix} 1.304 \\ 1.461 \\ 1.703 \\ 1.953 \\ 2.21 \end{pmatrix} \text{ ft}$$

- Minimum Thickness of Riprap for zero damage condition

Step 9: Calculate Riprap Gradation

Calculations for **Tolerable Damage** sizes: $Wtdmax := 4 \cdot W50td$ $Wtdmin := \frac{W50td}{8}$

$$Wtdmax = \begin{pmatrix} 60.645 \\ 85.308 \\ 135.138 \\ 203.735 \\ 295.296 \end{pmatrix} \text{lbf} \qquad Wtdmin = \begin{pmatrix} 1.895 \\ 2.666 \\ 4.223 \\ 6.367 \\ 9.228 \end{pmatrix} \text{lbf}$$

Calculations for **Zero Damage** sizes: $Wzdmax := 4 \cdot W50zd$ $Wzdmin := \frac{W50zd}{8}$

$$Wzdmax = \begin{pmatrix} 132.951 \\ 187.019 \\ 296.262 \\ 446.646 \\ 647.374 \end{pmatrix} \text{lbf} \qquad Wzdmin = \begin{pmatrix} 4.155 \\ 5.844 \\ 9.258 \\ 13.958 \\ 20.23 \end{pmatrix} \text{lbf}$$

20% and 35% Band Limit Calculations:

20-percent band coarse-limit curve	
Weight of rock fragment	**% finer by weight**
W_{max}	100
$0.5\,W_{max}$	70
W_{50}	35
W_{min}	0
20-percent band fine-limit curve	
Weight of rock fragment	**% finer by weight**
$0.5\,W_{max}$	90
W_{50}	55
W_{min}	20

35-percent band coarse-limit curve	
Weight of rock fragment	**% finer by weight**
W_{max}	100
$0.5\,W_{max}$	55
W_{50}	25
W_{min}	0
35-percent band fine-limit curve	
Weight of rock fragment	**% finer by weight**
0.5 x W_{max}	90
W_{50}	60
W_{min}	20

Values for the Coarse-Limit Curve

$$CLC20pf := \begin{pmatrix} 100 \\ 70 \\ 35 \\ 0 \end{pmatrix} \quad CLC35pf := \begin{pmatrix} 100 \\ 55 \\ 25 \\ 0 \end{pmatrix}$$

- Vector of % Finer by Weight values for Coarse-Limit Curve, 20% and 35% Band, respectively.

$$CLCwrftd := \begin{pmatrix} Wtdmax_{dvi} \\ 0.5 \cdot Wtdmax_{dvi} \\ W50td_{dvi} \\ Wtdmin_{dvi} \end{pmatrix} \quad CLCwrftd = \begin{pmatrix} 203.735 \\ 101.868 \\ 50.934 \\ 6.367 \end{pmatrix} lbf$$

- Vector of Weight of Rock Fragments associated with the % Finer data above.

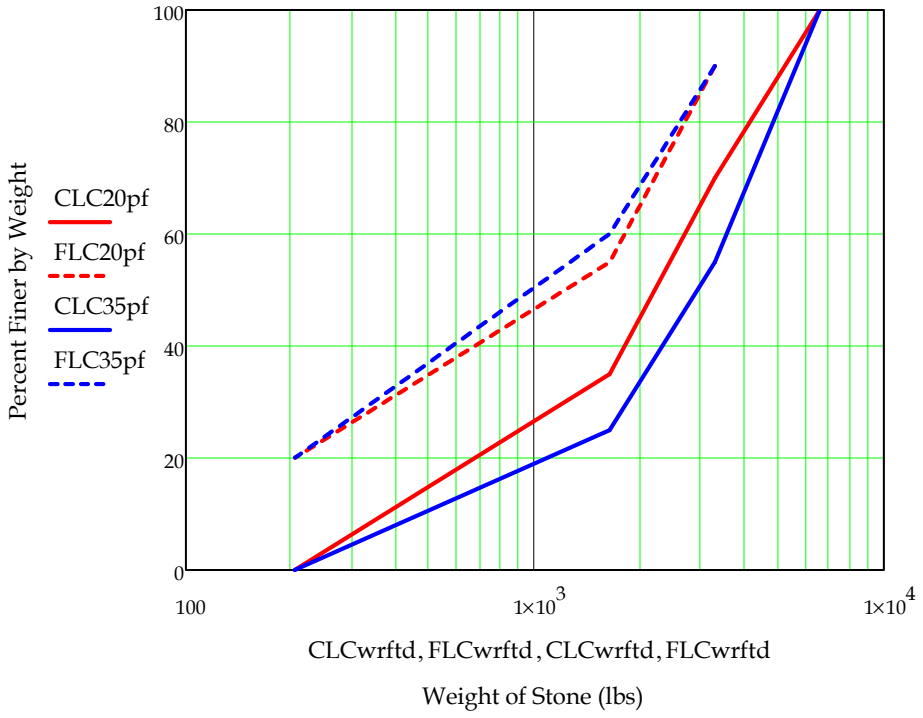
Values for the Fine-Limit Curve

$$FLC20pf := \begin{pmatrix} 90 \\ 55 \\ 20 \end{pmatrix} \quad FLC35pf := \begin{pmatrix} 90 \\ 60 \\ 20 \end{pmatrix}$$

- Vector of % Finer by Weight values for Fine-Limit Curve, 20% and 35% Band, respectively.

$$FLCwrftd := \begin{pmatrix} 0.5 \cdot Wtdmax_{dvi} \\ W50td_{dvi} \\ Wtdmin_{dvi} \end{pmatrix} \quad FLCwrftd = \begin{pmatrix} 101.868 \\ 50.934 \\ 6.367 \end{pmatrix} lbf$$

- Vector of Weight of Rock Fragments associated with the % Finer data above.



6. Conclusions/Results

1. For design wind velocities corresponding to maximum recorded peak wind velocities, the minimum required freeboard ranges from approximately 1.5 feet to 2.3 feet above the water surface.
2. For the maximum pool elevation and the maximum recorded peak wind velocity, the minimum freeboard was calculated at 2.07 feet. The design freeboard of 11 feet easily exceeds this condition as well as the maximum pool and normal pool minimum recommended values provided in Table B-1 of Chapter 6 of the U.S. Department of the Interior Bureau of Reclamation's *Design Standards No. 13 - Embankment Dams* manual. .
3. Based on the riprap calculation proceedure for a limited damage case, the average rock diameter is 0.75 feet (9 inches) and a minimum riprap thickness of 1.5 feet.

CLIENT:	San Luis & Delta-Mendota Water Authority			**PROJECT:**	Sisk Dam -SR 152 Raising
BY:	EOT	**DATE:**	1-May-20	**Job No.:**	141064-242990
CHKD BY:	KNA	**DATE:**	2-May-20	**SHEET No.:**	1
SUBJECT:	Fault Displacement Hazard Calculation				

Mathcad 15, PTC.

1. Purpose/Objective

To estimate the potential for fault displacement hazard associated with the faults that crosses the SR-152 embankment.

2. Procedure

a. Use ARS tool developed by Caltrans to determine the faults at the embankment location.
b. Calculate the seismicity at the embankment location using ARS tool .
c. Identify faults near the location of the embankment
d. Use Caltrans and USGS references to determine fault parameters for the primary fault.
d. Calculate the fault displacement potential following recommendations provided in the 20-10 Fault Rupture Memo dated January 2013.

3. References/Data Sources

a. Caltrans ARS Online, http://dap3.dot.ca.gov/ARS_Online/index.php
b. USGS, Earthquake Hazards Program, " Quaternary Fault and Fold Database of the United States", Ortigalita Fault Zone, Cottonwood Arm Section (Class A) No 52a, Last Review Date 2000-05-09
c. Petersen, M.D., Dawson, T.E., Chen, R., Cao, T., Wills, C.J., Schwartz, D.P., and Frankel, A.D., 2011, Fault Displacement Hazard for Strike-Slip Faults. Bulletin of the Seismological Society of America, v 101, n 2, p 805–825
d. Wells, D.L., and K.J. Coppersmith (1994) New Empirical Relationships among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement, Bulletin of the Seismological Society of America, v84, 974-1002.
e. Working Group on Northern California Earthquake Potential (1996) Database of Potential Sources for Earthquakes Larger than Magnitude 6 in Northern California" Open-File Report 96-705, US Department of the Interior U.S. Geological Survey.
f. Caltrans Geotechnical Manual

4. Assumptions and Limitations

a. The foundation material for the embankment is considered to be weathered rock or bedrock based on observations of outcrops and cuts in the site vicinity and has a shear wave velocity of at least 360 meters/second.
b. It is assumed that the Ortigalita Fault Zone (Ortigalita-Cottonwood Arm Section) traverses through the embankment as shown in the Caltrans' ARS tool.
c. The fault downdip width data is not available for the Ortigalita Fault Zone (Ortigalita-Cottonwood Arm Section). Based on the database prepared for the faults in Northern California by Working Group on Northern California Earthquake Potential (1996), it is assumed that the downdip rupture width is likely less than 15 kilometers, and the analysis is based on 15 kilometers fault downdip width conservatively.
d. The creep rate for the fault is assumed to be zero. Zero creep rate results in larger hazard.

5A. Calculation Input Data

Seismicity:

- Design seismicity for the Site is provided below as obtained from ARS Tool v 3.0.2:
  Latitude 37.104154 degrees and Longitude -121.132977 degrees (See Table **1**)

Table 1: Design Spectrum (5% Damping) as Obtained using ARS Tool v3.0.2

Period(s)	Sa_{2008}(g)	Sa_{2014}(g)	$Basin_{2008}$	$Basin_{2014}$	Near Fault Amp	Design Sa_{2008}(g)	Design Sa_{2014}(g)
PGA	0.65	0.77	1	1	1	0.65	0.77
0.10	1.19	1.38	1	1	1	1.19	1.38
0.20	1.48	1.8	1	1	1	1.48	1.8
0.30	1.42	1.89	1	1	1	1.42	1.89
0.50	1.17	1.6	1	1	1	1.17	1.6
0.75	0.89	1.21	1	1	1.1	0.98	1.33
1.0	0.68	0.93	1	1	1.2	0.82	1.11
2.0	0.29	0.39	1	1	1.2	0.35	0.47
3.0	0.17	0.23	1	1	1.2	0.21	0.28
4.0	0.12	0.16	1	1	1.2	0.14	0.19
5.0	0.09	0.11	1	1	1.2	0.11	0.14

- The latest ARS Tool does not provide the faults at the Site, as it no longer supports the deterministic seismic hazard analysis. For this reason, the previous version, ARS Tool v2.3.09 was utilized. The following are the significant faults for the hazard at the Site.
  1. Great Valley 08 (Quinto)
  2. Ortigalita Fault Zone

  The location of the Ortigalita Fault Zone as it goes through the embankment location is shown on Figure 1.
- The fault parameters are obtained from USGS, Earthquake Hazards Program, " Quaternary Fault and Fold Database of the United States". Based on the moment magnitude of 7, the approximate average deformation is about 3 ft as shown in Figure 2 based on Petersen et al. (2011).
- The probabilistic evaluation is based on the Fault Rupture Section of the Caltrans Geotechnical Manual. Caltrans stic (5% in 50 year) displacement hazard values. For strike-slip and normal faults, the method developed by Wells and Coppersmith (1994), and Abrahamson (2008) are used. The referred spreadsheet in the Caltrans Geotechnical Manual has been obtained from Caltrans and used for this calculation. The following are the input to the analysis:

  Slip rate = 0 (conservative assumption)
  Downdip fault rupture width = 15 kilometers (conservative assumption)
  Length = 71 kilometers
  Slip rate = 5 millimeters/ year

No site specific rupture observations are available, and the sigma-single site uncertainty parameter is assumed as 0.18 (log-space). With the mentioned inputs, the average slip is 3.9 feet, which is similar to the average slip rate reported in Figure 2. The probabilistic evaluation of the fault displacement hazard has been conducted using the spreadsheet provided by Caltrans and results are provided on Figure 3, and Appendix A. For the 50th percentile, the probability of exceedence for the 10 feet displacement potential is less than 10^{-4}.

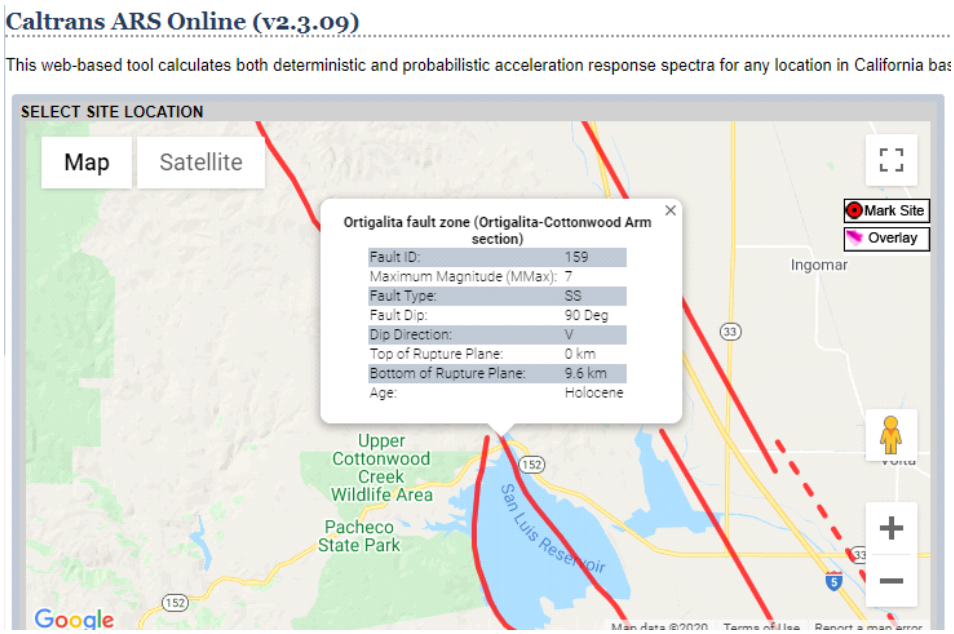


Figure 1. Location of Intersection of the Embankment Site and Ortigalita Fault Zone (Ortigalita-Cottonwood Arm Section)

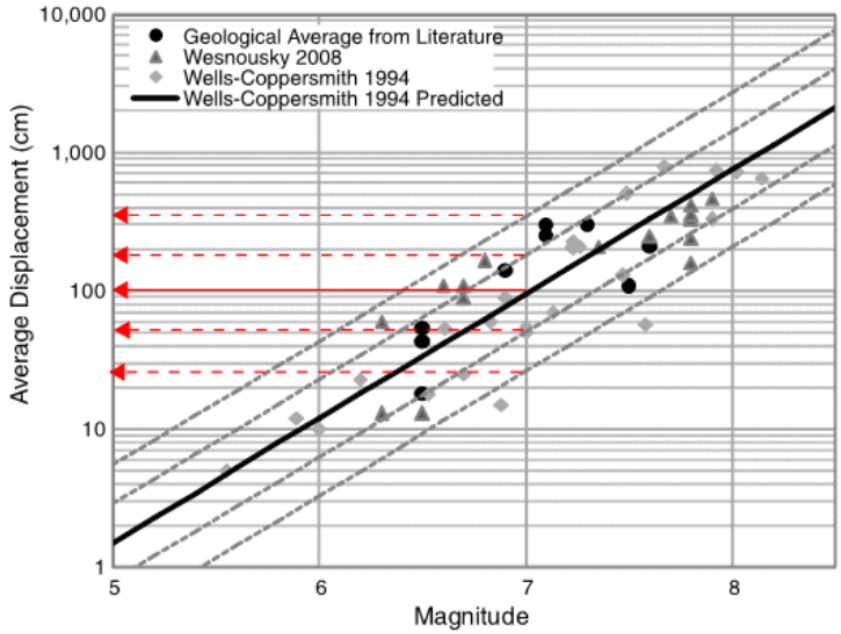


Figure 2. Average Displacement in Centimeters as Reported by Petersen et al. (2011)

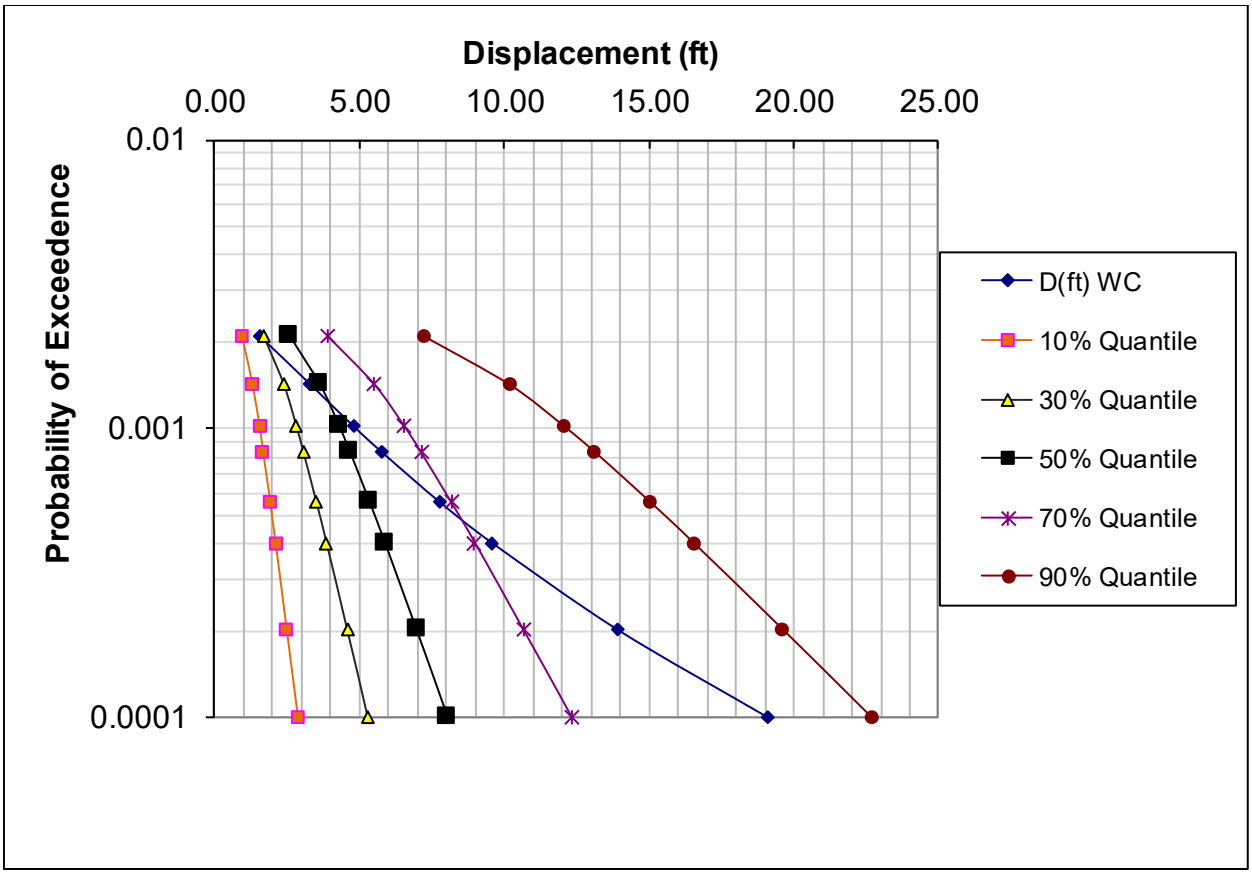


Figure 3. Probabilistic Evaluation of Fault Displacement Potential

6. Conclusions/Results

1. The PGA for the site is 0.77g as obtained from Caltrans ARS Tool. The return period corresponding to this PGA is 975 years.
2. The average expected fault displacement potential is between 3 feet and 4 feet.
3. Based on the 50th percentile evaluation, the probability of exceedence for the 10 feet displacement is less than 10^{-4}. Note that the width of the filter layer is 10 feet.

APPENDIX A SPREADSHEET-BASED PROBABILISTIC FAULT DISPLACEMENT HAZARD EVALUATION

		Fault Parameters			Uncertainty Characterization			
Creep Rate (mm/yr)	Width (km)	Length (km)	Slip Rate (mm/yr)	No.site-specific rupture observations (Ns)	Sigma-single site (Log 10)	Sigma-mean Disp (Log10)	Sigma-Total (Log10)	measured displacement (m) (If Ns>0)
0	15	71	5	0	0.18	0.35	0.3935734	

Magnitude (HB):	7.11
WC Avg Slip (m):	**1.19**

3.906651

Treatment of Creep (weight methods)		
Assumes surface creep applies equally at depth (UCERF-2) wt=(0 to 1)	Depth and rate dependent model (UCERF-3)	Limit Mo rate reduction to 50% (1=yes, 0=no)
0.33	0.67	1

Mo:	5.13E+26
adj Mo rate:	1.28E+24
recurrence (yrs):	401.02

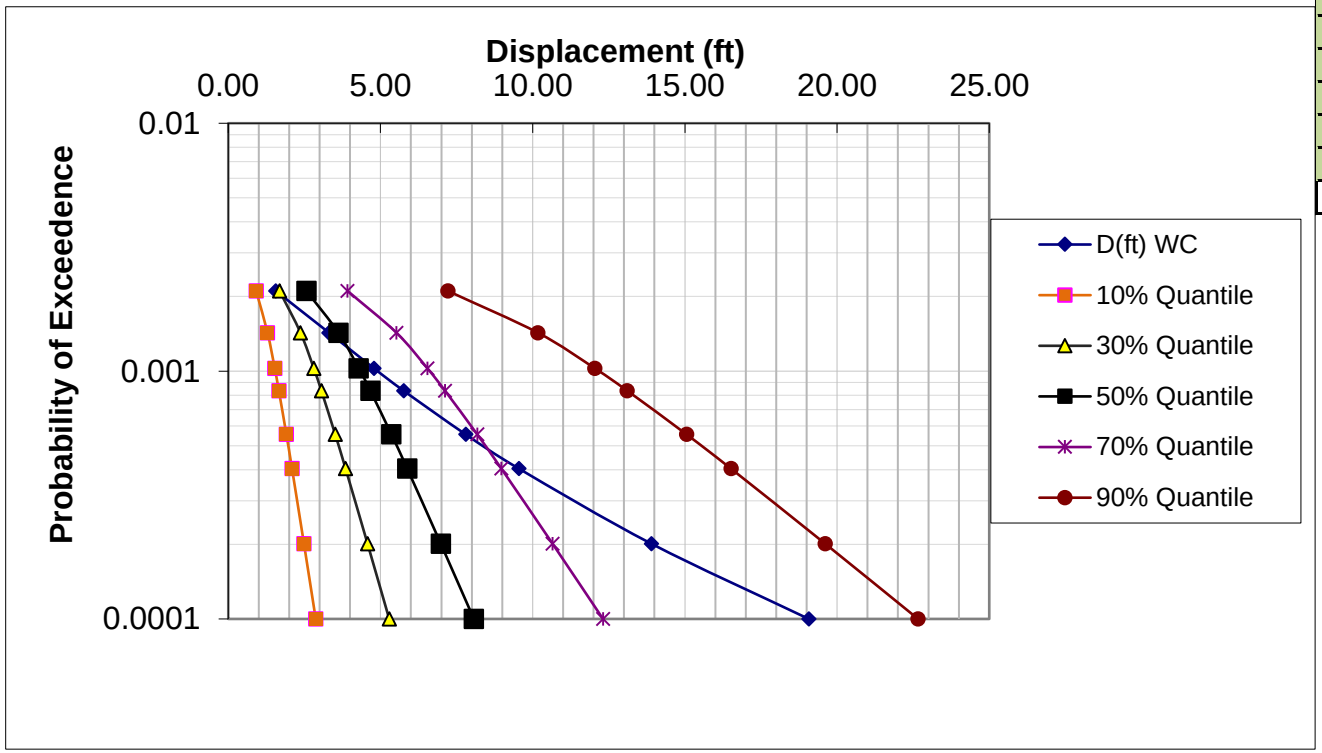
RESULTS

			Ns=0	Ns>0					
Hazard Level (annual return)	P(rup>z|M)	epsilon	D(ft)	D(m) Site-Specific	**Quantile**	**Quantile mean D (m)**	D (ft)-10	D (ft)-30	D (ft)-50
446	0.9	-1.281551566	1.22	0.00	**10**	**0.42**	0.8176779	1.505168446	2.296811134
475	0.844257	-1.01210954	1.56	0.00	**30**	**0.78**	0.9142854	1.683002147	2.568176393
700	0.572889	-0.183733628	3.31	0.00	**50**	**1.19**	1.2888117	2.372424139	3.62019958
975	0.411305	0.224189903	4.79	0.00	**70**	**1.82**	1.5262149	2.809432291	4.287051979
1200	0.334185	0.428385814	5.76	0.00	**90**	**3.34**	1.6610051	3.057551873	4.665669947
1800	0.22279	0.762804214	7.80	0.00			1.9079469	3.512118379	5.35931551
2475	0.162029	0.986152461	9.55	0.00			2.0929987	3.85275888	5.879115734
4975	0.080607	1.400997118	13.91	0.00			2.4856559	4.575555931	6.982067577
10000	0.040102	1.74950115	19.07	0.00			2.871916	5.286577391	8.067050464
580	0.691462	-0.5	2.48	0.00					

Minimum design displacement based on -0.5 epsilon criterion

NOTE: The -0.5 epsilon limit establishes a minimum

D (ft)-70	D (ft)-90	Rate of Exceedence
3.5048179	6.451613363	0.002244265
3.9189076	7.213863119	0.002105263
5.524242	10.16893711	0.001428571
6.5418251	12.04208802	0.001025641
7.119577	13.1056046	0.000833333
8.1780452	15.054016	0.000555556
8.9712341	16.51410561	0.00040404
10.654283	19.61223533	0.000201005
12.309912	22.65989127	0.0001
		0.00172425



Multi-Strand and Mapping Uncertainty

Specify displacement (m) for hazard of interest:	3

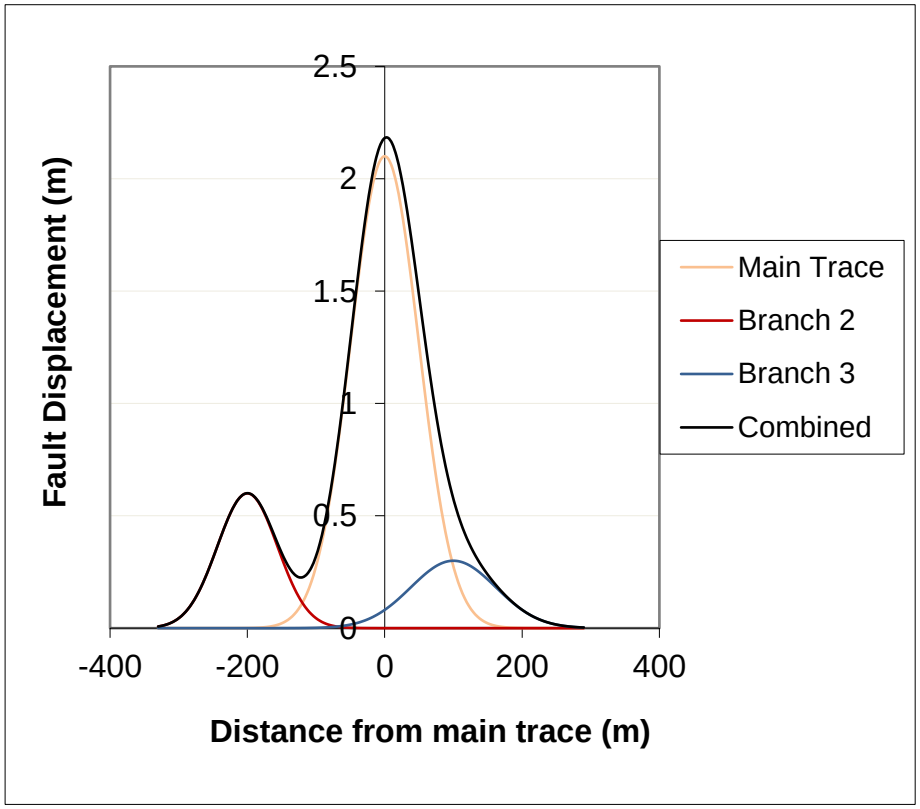
Map Quality Range: Accuate (1), Approximate (2), Concealed (3), Inferred (4)

	Main Trace	Branch 2	Branch 3

Map Rating:	4	2	3
Simple (1) or Complex (2)	1	1	1

Relative Slip of Multistrand Faults (percent)

Main Trace (%)	Branch 2 (%)	Branch 3 (%)	
70	20	10	
Distance from main strand (m): (pos. to the right, neg. to the left)	-200	100	
sigma:	49.6	43.8	61.9



Comment:

Updated on June 22, 2011 to Version 4. On Norm's recommendation, the slip estimate should be based on WC instead of HB. However, the magnitude estimate should be based on HB. This correction was implemented in V. 4.

normfactor	0.398942						
dmin	-330		6.2				
dmax	290						
				epsilon-Br2	Br. 2-D	epsilon-Br3	Br. 3-D
	d-range	epsilon-main	Main Trace-D	-2.96803653	0.0366622	-6.946688207	9.96232E-11
	-330	-6.653225806	7.32839E-10	-2.82648402	0.0552496	-6.846526656	1.98774E-10
	-323.8	-6.528225806	1.67031E-09	-2.68493151	0.081609	-6.746365105	3.92648E-10
	-317.6	-6.403225806	3.74802E-09	-2.543379	0.1181529	-6.646203554	7.67872E-10
	-311.4	-6.278225806	8.2798E-09	-2.40182648	0.1676674	-6.546042003	1.48668E-09
	-305.2	-6.153225806	1.80074E-08	-2.26027397	0.2332121	-6.445880452	2.84963E-09
	-299	-6.028225806	3.85565E-08	-2.11872146	0.3179446	-6.345718901	5.40759E-09
	-292.8	-5.903225806	8.12752E-08	-1.97716895	0.424864	-6.245557351	1.01593E-08
	-286.6	-5.778225806	1.68668E-07	-1.83561644	0.5564758	-6.1453958	1.88957E-08
	-280.4	-5.653225806	3.44604E-07	-1.69406393	0.7143987	-6.045234249	3.47942E-08
	-274.2	-5.528225806	6.93144E-07	-1.55251142	0.8989449	-5.945072698	6.34298E-08
	-268	-5.403225806	1.37259E-06	-1.4109589	1.108724	-5.844911147	1.14478E-07
	-261.8	-5.278225806	2.67591E-06	-1.26940639	1.3403302	-5.744749596	2.04548E-07
	-255.6	-5.153225806	5.1359E-06	-1.12785388	1.5881743	-5.644588045	3.61836E-07
	-249.4	-5.028225806	9.70456E-06	-0.98630137	1.8445163	-5.544426494	6.33681E-07
	-243.2	-4.903225806	1.8053E-05	-0.84474886	2.0997367	-5.444264943	1.09868E-06
	-237	-4.778225806	3.30626E-05	-0.70319635	2.3428537	-5.344103393	1.88589E-06
	-230.8	-4.653225806	5.96126E-05	-0.56164384	2.5622618	-5.243941842	3.20483E-06
	-224.6	-4.528225806	0.000105817	-0.42009132	2.7466279	-5.143780291	5.39183E-06
	-218.4	-4.403225806	0.00018492	-0.27853881	2.8858525	-5.04361874	8.9807E-06
	-212.2	-4.278225806	0.000318147	-0.1369863	2.9719838	-4.943457189	1.4809E-05
	-206	-4.153225806	0.000538873	0.00456621	2.9999687	-4.843295638	2.41761E-05
	-199.8	-4.028225806	0.000898585	0.146118721	2.9681443	-4.743134087	3.90742E-05
	-193.6	-3.903225806	0.001475183	0.287671233	2.878401	-4.642972536	6.25225E-05
	-187.4	-3.778225806	0.002384221	0.429223744	2.7359967	-4.542810985	9.90433E-05
	-181.2	-3.653225806	0.003793686	0.570776256	2.5490469	-4.442649435	0.000155331
	-175	-3.528225806	0.005942791	0.712328767	2.3277593	-4.342487884	0.000241175
	-168.8	-3.403225806	0.009165025	0.853881279	2.0835135	-4.242326333	0.000370723
	-162.6	-3.278225806	0.01391525	0.99543379	1.8279006	-4.142164782	0.000564172
	-156.4	-3.153225806	0.02079996	1.136986301	1.5718344	-4.042003231	0.000849993
	-150.2	-3.028225806	0.03060893	1.278538813	1.3248265	-3.94184168	0.001267834
	-144	-2.903225806	0.044345335	1.420091324	1.0944835	-3.841680129	0.0018722
	-137.8	-2.778225806	0.063250198	1.561643836	0.8862524	-3.741518578	0.002737067
	-131.6	-2.653225806	0.088815748	1.703196347	0.7034021	-3.641357027	0.003961517
	-125.4	-2.528225806	0.122781297	1.844748858	0.5472022	-3.541195477	0.0056765
	-119.2	-2.403225806	0.167104678	1.98630137	0.4172439	-3.441033926	0.008052723
	-113	-2.278225806	0.223902604	2.127853881	0.3118388	-3.340872375	0.011309617
	-106.8	-2.153225806	0.295354663	2.269406393	0.228438	-3.240710824	0.015725196
	-100.6	-2.028225806	0.383568264	2.410958904	0.1640229	-3.140549273	0.021646477

	-94.4	-1.903225806	0.490405859	2.552511416	0.1154353	-3.040387722	0.029499957
	-88.2	-1.778225806	0.61728082	2.694063927	0.0796289	-2.940226171	0.03980142
	-82	-1.653225806	0.764934175	2.835616438	0.0538395	-2.84006462	0.053164137
	-75.8	-1.528225806	0.933210237	2.97716895	0.0356803	-2.739903069	0.070304313
	-69.6	-1.403225806	1.120854069	3.118721461	0.0231769	-2.639741519	0.092042454
	-63.4	-1.278225806	1.325356769	3.260273973	0.0147564	-2.539579968	0.119299169
	-57.2	-1.153225806	1.542874767	3.401826484	0.0092088	-2.439418417	0.15308395
	-51	-1.028225806	1.76824607	3.543378995	0.0056328	-2.339256866	0.194475507
	-44.8	-0.903225806	1.995119324	3.684931507	0.0033771	-2.239095315	0.244592523
	-38.6	-0.778225806	2.216201259	3.826484018	0.0019845	-2.138933764	0.304554101
	-32.4	-0.653225806	2.423615204	3.96803653	0.0011431	-2.038772213	0.375429798
	-26.2	-0.528225806	2.609349711	4.109589041	0.0006453	-1.938610662	0.458179907
	-20	-0.403225806	2.7657636	4.251141553	0.0003571	-1.838449111	0.553587597
	-13.8	-0.278225806	2.88610398	4.392694064	0.0001937	-1.738287561	0.662185512
	-7.6	-0.153225806	2.964988681	4.534246575	0.000103	-1.63812601	0.784180447
	-1.4	-0.028225806	2.998805194	4.675799087	5.365E-05	-1.537964459	0.919380643
	4.8	0.096774194	2.985984972	4.817351598	2.74E-05	-1.437802908	1.067130945
	11	0.221774194	2.927124062	4.95890411	1.372E-05	-1.337641357	1.226261474
	17.2	0.346774194	2.824937154	5.100456621	6.731E-06	-1.237479806	1.395055436
	23.4	0.471774194	2.684049989	5.242009132	3.237E-06	-1.137318255	1.571241202
	29.6	0.596774194	2.510652224	5.383561644	1.526E-06	-1.037156704	1.752012757
	35.8	0.721774194	2.312047037	5.525114155	7.052E-07	-0.936995153	1.9340811
	42	0.846774194	2.096143067	5.666666667	3.194E-07	-0.836833603	2.113757246
	48.2	0.971774194	1.870937696	5.808219178	1.418E-07	-0.736672052	2.287065221
	54.4	1.096774194	1.644038102	5.949771689	6.168E-08	-0.636510501	2.449881068
	60.6	1.221774194	1.422258639	6.091324201	2.631E-08	-0.53634895	2.598091639
	66.8	1.346774194	1.211321515	6.232876712	1.1E-08	-0.436187399	2.727764925
	73	1.471774194	1.015674222	6.374429224	4.505E-09	-0.336025848	2.835322262
	79.2	1.596774194	0.838423762	6.515981735	1.809E-09	-0.235864297	2.917701957
	85.4	1.721774194	0.681376067	6.657534247	7.121E-10	-0.135702746	2.972503928
	91.6	1.846774194	0.545160424	6.799086758	2.747E-10	-0.035541195	2.998105833
	97.8	1.971774194	0.429413718	6.940639269	1.039E-10	0.064620355	2.993742849
	104	2.096774194	0.332998025	7.082191781	3.851E-11	0.164781906	2.959545622
	110.2	2.221774194	0.254226928	7.223744292	1.399E-11	0.264943457	2.896533772
	116.4	2.346774194	0.191080157	7.365296804	4.982E-12	0.365105008	2.806565392
	122.6	2.471774194	0.141391655	7.506849315	1.739E-12	0.465266559	2.692246037
	128.8	2.596774194	0.103002109	7.648401826	5.949E-13	0.56542811	2.556803422
	135	2.721774194	0.073872467	7.789954338	1.995E-13	0.665589661	2.403936232
	141.2	2.846774194	0.052159478	7.931506849	6.556E-14	0.765751212	2.237646916
	147.4	2.971774194	0.036257514	8.073059361	2.112E-14	0.865912763	2.062068969
	153.6	3.096774194	0.024812867	8.214611872	6.669E-15	0.966074313	1.881299007
	159.8	3.221774194	0.01671745	8.356164384	2.064E-15	1.066235864	1.699242952
	166	3.346774194	0.011088614	8.497716895	6.261E-16	1.166397415	1.51948403

	172.2	3.471774194	0.007241002	8.639269406	1.862E-16	1.266558966	1.345178182
	178.4	3.596774194	0.004655155	8.780821918	5.426E-17	1.366720517	1.178980171
	184.6	3.721774194	0.002946347	8.922374429	1.55E-17	1.466882068	1.023001331
	190.8	3.846774194	0.001835894	9.063926941	4.339E-18	1.567043619	0.878797694
	197	3.971774194	0.001126226	9.205479452	1.191E-18	1.66720517	0.747385435
	203.2	4.096774194	0.00068017	9.347031963	3.203E-19	1.767366721	0.62927918
	209.4	4.221774194	0.000404412	9.488584475	8.446E-20	1.867528271	0.524547846
	215.6	4.346774194	0.000236725	9.630136986	2.183E-20	1.967689822	0.432882336
	221.8	4.471774194	0.00013642	9.771689498	5.529E-21	2.067851373	0.35366952
	228	4.596774194	7.73976E-05	9.913242009	1.373E-21	2.168012924	0.286067429
	234.2	4.721774194	4.32305E-05	10.05479452	3.34E-22	2.268174475	0.229077378
	240.4	4.846774194	2.37721E-05	10.19634703	7.967E-23	2.368336026	0.181609686
	246.6	4.971774194	1.28694E-05	10.33789954	1.863E-23	2.468497577	0.142540679
	252.8	5.096774194	6.85905E-06	10.47945205	4.268E-24	2.568659128	0.110759669
	259	5.221774194	3.59901E-06	10.62100457	9.587E-25	2.668820679	0.085205472
	265.2	5.346774194	1.85916E-06	10.76255708	2.11E-25	2.768982229	0.064892774
	271.4	5.471774194	9.45507E-07	10.90410959	4.554E-26	2.86914378	0.04892921
	277.6	5.596774194	4.73398E-07	11.0456621	9.632E-27	2.969305331	0.036524399
	283.8	5.721774194	2.33347E-07	11.18721461	1.997E-27	3.069466882	0.026992366
	290	5.846774194	1.13238E-07				

0.691462461 579.9622873

D(ft)	WC		UCERF-2 Mo reduction factor	UCERF-3 Mo reduction factor	Weighted reduction	Capped reduction
	1.56	10% Quantile	0	0	0	0
	3.31	30% Quantile				
	4.79	50% Quantile				
	5.76	70% Quantile				
	7.80	90% Quantile				
	9.55					
	13.91					
	19.07					

Wt'd MT	Wt'd Br2	Wt'd Br3	Combined
5.12988E-10	0.007332447	9.96232E-12	0.007332447
1.16922E-09	0.011049926	1.98774E-11	0.011049927
2.62361E-09	0.016321791	3.92648E-11	0.016321793
5.79586E-09	0.023630572	7.67872E-11	0.023630578
1.26052E-08	0.033533483	1.48668E-10	0.033533496
2.69896E-08	0.046642421	2.84963E-10	0.046642448
5.68926E-08	0.063588926	5.40759E-10	0.063588984
1.18067E-07	0.084972793	1.01593E-09	0.084972912
2.41223E-07	0.111295163	1.88957E-09	0.111295406
4.85201E-07	0.142879749	3.47942E-09	0.142880238
9.60812E-07	0.179788976	6.34298E-09	0.179789943
1.87314E-06	0.221744793	1.14478E-08	0.221746678
3.59513E-06	0.268066038	2.04548E-08	0.268069654
6.79319E-06	0.317634854	3.61836E-08	0.317641684
1.26371E-05	0.368903266	6.33681E-08	0.368915967
2.31438E-05	0.419947347	1.09868E-07	0.4199706
4.17288E-05	0.46857075	1.88589E-07	0.468612667
7.40717E-05	0.512452363	3.20483E-07	0.512526755

0.000129444	0.549325573	5.39183E-07	0.549455556
0.000222703	0.577170502	8.9807E-07	0.577394103
0.000377211	0.594396754	1.4809E-06	0.594775446
0.000629009	0.599993745	2.41761E-06	0.600625172
0.001032628	0.593628863	3.90742E-06	0.594665398
0.001668955	0.575680193	6.25225E-06	0.5773554
0.00265558	0.547199331	9.90433E-06	0.549864816
0.004159954	0.509809378	1.55331E-05	0.513984865
0.006415518	0.46555187	2.41175E-05	0.471991505
0.009740675	0.416702708	3.70723E-05	0.426480455
0.014559972	0.365580112	5.64172E-05	0.380196501
0.021426251	0.314366886	8.49993E-05	0.335878136
0.031041735	0.264965309	0.000126783	0.296133827
0.044275138	0.218896709	0.00018722	0.263359067
0.062171024	0.177250488	0.000273707	0.239695219
0.085946908	0.140680415	0.000396152	0.227023475
0.116973274	0.109440441	0.00056765	0.226981365
0.156731823	0.083448785	0.000805272	0.24098588
0.206748264	0.062367767	0.001130962	0.270246993
0.268497785	0.045687602	0.00157252	0.315757906
0.343284101	0.032804583	0.002164648	0.378253332
0.432096574	0.023087062	0.002949996	0.458133632
0.535453922	0.015925784	0.003980142	0.555359848
0.653247166	0.010767899	0.005316414	0.669331478
0.784597849	0.00713607	0.007030431	0.79876435
0.927749738	0.004635379	0.009204245	0.941589362
1.080012337	0.002951273	0.011929917	1.094893527
1.237772249	0.001841753	0.015308395	1.254922397
1.396583527	0.001126553	0.019447551	1.41715763
1.551340882	0.000675413	0.024459252	1.576475547
1.696530643	0.000396904	0.03045541	1.727382957
1.826544798	0.000228612	0.03754298	1.86431639
1.93603452	0.000129066	0.045817991	1.981981577
2.020272786	7.14203E-05	0.05535876	2.075702966

2.075492076	3.87374E-05	0.066218551	2.141749365
2.099163636	2.05938E-05	0.078418045	2.177602274
2.090189481	1.0731E-05	0.091938064	2.182138276
2.048986843	5.48078E-06	0.106713095	2.155705419
1.977456008	2.74373E-06	0.122626147	2.100084899
1.878834992	1.34629E-06	0.139505544	2.018341882
1.757456557	6.47495E-07	0.15712412	1.914581325
1.618432926	3.05232E-07	0.175201276	1.793634507
1.467300147	1.41033E-07	0.19340811	1.660708398
1.309656387	6.38722E-08	0.211375725	1.521032176
1.150826671	2.83531E-08	0.228706522	1.379533222
0.995581047	1.23363E-08	0.244988107	1.240569166
0.84792506	5.26102E-09	0.259809164	1.107734229
0.710971956	2.19914E-09	0.272776493	0.98374845
0.586896633	9.01015E-10	0.283532226	0.87042886
0.476963247	3.61834E-10	0.291770196	0.768733443
0.381612297	1.42425E-10	0.297250393	0.678862689
0.300589603	5.4949E-11	0.299810583	0.600400186
0.233098617	2.07793E-11	0.299374285	0.532472902
0.177958849	7.70196E-12	0.295954562	0.473913412
0.13375611	2.79814E-12	0.289653377	0.423409487
0.098974159	9.96403E-13	0.280656539	0.379630698
0.072101476	3.47776E-13	0.269224604	0.34132608
0.051710727	1.18976E-13	0.255680342	0.307391069
0.036511635	3.98952E-14	0.240393623	0.276905258
0.02538026	1.31123E-14	0.223764692	0.249144951
0.017369007	4.2241E-15	0.206206897	0.223575904
0.011702215	1.33379E-15	0.188129901	0.199832116
0.00776203	4.12801E-16	0.169924295	0.177686325
0.005068701	1.25225E-16	0.151948403	0.157017104
0.003258609	3.72338E-17	0.134517818	0.137776427
0.002062443	1.08513E-17	0.117898017	0.11996046
0.001285126	3.09976E-18	0.102300133	0.103585259
0.000788358	8.67899E-19	0.087879769	0.088668128

0.000476119	2.38182E-19	0.074738543	0.075214663
0.000283088	6.40688E-20	0.062927918	0.063211006
0.000165708	1.68921E-20	0.052454785	0.052620492
9.54942E-05	4.36532E-21	0.043288234	0.043383728
5.41784E-05	1.10573E-21	0.035366952	0.03542113
3.02614E-05	2.74522E-22	0.028606743	0.028637004
1.66405E-05	6.68045E-23	0.022907738	0.022924378
9.00859E-06	1.59342E-23	0.018160969	0.018169977
4.80134E-06	3.72525E-24	0.014254068	0.014258869
2.51931E-06	8.53644E-25	0.011075967	0.011078486
1.30141E-06	1.91733E-25	0.008520547	0.008521849
6.61855E-07	4.22099E-26	0.006489277	0.006489939
3.31379E-07	9.10814E-27	0.004892921	0.004893252
1.63343E-07	1.92639E-27	0.00365244	0.003652603
7.92668E-08	3.99351E-28	0.002699237	0.002699316

B.F. Sisk Dam Raise and Reservoir Expansion Project
Feasibility Design Report- SR 152 Modifications

Attachment D Cost Estimate

Mining costs include equipment, processing, and stockpiling of product at the quarry site, assuming 100 percent of the material will be coming from Basalt Hill and that rock blasting is allowed. This estimate was based on riprap sizes Class II through Class III (9- to 12-inch diameter) at $26.67/ton and Class 3 permeable material of 1.5-inch diameter at $22.85/ton. It was determined that the total project costs decreased by approximately 20–27 percent by opting to mine rather than to buy material from commercial sources. Direct costs for each alternative are as follows:

- **Mining Alternative 1** → $56.8 M
- **Mining Alternative 2** → $34.4 M

Additional assumptions in developing the cost-estimate components, as specified for Alternative 1 by way of example, are as follows:

1. **Truck Haul from Basalt Hill Quarry to Dock Stockpile, $9.9 M:** There will be five rear-dump trucks CAT 777 filled by three loaders CAT 988 with 12 cy buckets up to 80 tons per load. A total of 55 to 61 trips per day will be required, based on a total cycle time of 0.72 hours per load.
2. **Additional Crane Support, $1.3 M:** One 100 MT all terrain crane, Manitowac 3900 with 9 cy clamshell attachments for the duration of the construction schedule will be used for production support at the Cottonwood Bay side riprap construction, backup for the crane barges, moving equipment within a work area, and unloading construction materials.
3. **Dewatering Cottonwood Bay, $2.7 M:** Approximately 204 M gallons will be pumped out of the Cottonwood Bay at a rate of 29 mgd using multiple pumps. A 600 LF × 12-foot/0-inch portadam will be installed at the north end of cotton bay to protect the construction crew working dry at El 450 and above. Pumps will be provided for the duration of the project, depending on the rate of increase in water levels after the existing submerged RCP pipe is capped. Twenty months of intermittent pumping of 29 mgd with BakerCorp tanks is budgeted.
4. **Riprap from Basalt Hill Dock Stockpile to the Conveyor Hopper, $2.8 M:** There will be 6 CAT C963 Crawler Loaders at the Basalt Hill Dock to feed aggregate into the Dock Conveyor Hopper and to manage the upkeep of the stockpile. Including allowance for waste, a total of 946,598 cy will be loaded into the conveyor system. To minimize the disturbed areas at the dock area, a portion of the material will be stockpiled in a one-acre area adjacent to the conveyors at the dock to ensure a constant supply of materials upon demand.
5. **Concrete Support Structures for Conveying Systems, $414 K:** A total of 115 cy of concrete will be sourced from a nearby batch plant in Los Banos for the construction of one 40-foot × 35-foot × 12-inch thickened slab on grade at both the bay side and the lake side. The slabs are required to support the conveyor belt bridge columns. It is assumed that a concrete slab will not be required for the midspan supports. Instead, concrete columns by Sonotube® may be installed at midspan and are included in the budget for the conveyor system. A total of 1,594 cy of compacted backfill on the existing 2:1 slope will be required for the slab construction.

6. **Conveyor Belt Systems, $19.5 M:** There are a total of eight conveyor systems. Each conveyor system will be provided with a specialized O&M crew.
    a. There are four 150-ton-per-hour telestackers, Superior Industries Model TS150, 42-inch belt width, that will be mounted on barges. The unextended length is about 84 feet and fully extended it is 150 feet. Aggregate may be dropped from the ends of the conveyor at a height of 16- to 50-feet. Barge costs are separate and are not included in this cost element. Each telestacker is provided with one 100 kw generator, one 1,000-gallon fuel tank, and fuel based on 6.1 gph fuel consumption. Each tank will be refilled every 16 days.
    b. Similarly, there will be one 250-ton-per-hour telestacker at the bay side, Superior Industries Model TS200, to support the riprap placement, complete with one 100 kw generator, one 1,000-gallon fuel tank, and fuel based on 6.1 gph fuel consumption. Each tank will be refilled every 16 days.
    c. One Canning Conveyor Model CVR06, 500-ton-per-hour barge-loading conveyor system will be installed at the Basalt Hill Dock spanning approximately 65 feet from shore to ship and a 180° swivel that can be raised and lowered by about 15 feet to accommodate the varying water levels will be provided. A 150 kw generator, one 1,000-gallon fuel tank, and fuel based on 11 gph fuel consumption. Each tank will be refilled every 9 days.
    d. One Canning Conveyor Model TBD, 350-ton-per-hour conveyor with a horizontal section for conveyor sitting between two supports spanning over 120 feet across SR 152, with lead-on/lead-off controls on either side. The bridge section is fitted with a walkway on each side for ease of maintenance, and is fully contained to prevent spillage falling below. Each end of the conveyor will be provided with inclined pivoting sections so that they can be raised or lowered to suit the differing terrain levels on either side of the road. A 150 kw generator, one 1,000-gallon fuel tank, and fuel based on 11 gph fuel consumption. Each tank will be refilled every 9 days.
    e. One Canning Conveyor Model TBD, 350-ton-per-hour conveyor spanning approximately 65 feet from shore to ship and a 180° swivel that can be raised and lowered by about 15 feet to accommodate the varying water levels will be provided for loading aggregate from the conveyor barge to the bridge conveyor system. A 150 kw generator, one 1,000-gallon fuel tank, and fuel based on 11 gph fuel consumption. Each tank will be refilled every 9 days.
7. **RCP Culvert, $343 K:** Both existing submerged 24-inch and 66-inch RCP pipes at the lake and bay sides will be provided with 120-lineal-feet extensions of RCP Class IV pipe, complete with a precast culvert end/vault as an inlet/outlet structure. A total of 480 LF will be provided complete with temporary plugs to facilitate the Cottonwood bay side dewatering. Once dewatered, 21 cy of concrete will be poured on the cottonwood bay side to ensure that, in the event of a temporary plug blowout, no water transmission from the lake side. Installation support will be provided by a marine diving crew for 15 days and a crane barge at the San Luis lake side.
8. **Riprap Base and Armor, Exposed Aggregate (Sloped), San Luis, Alternative 1, $5.7 M:** 403,000 cy or 900,000 (Sg=2.65) tons of Class II, 9-inch-diameter, 60# riprap and 98,000 cy or 219,000 tons of Class III, 12-inch-diameter, 150# riprap will be spread on an existing 2:1 slope over an area of approximately 80,773 sy with varying thicknesses, thus achieving a 3:1

slope. The raw material cost is $0.00 per cy (no fees to use riprap mined from the quarry). The mining cost is included in a separate bid item. It is assumed that 100 percent of the riprap requirement will be produced from the Basalt Hill Quarry. There will be no trucking required to haul import material because all material will be manufactured at the Basalt Hill Quarry. Once the riprap is transported to the SR 152 site using barges, CAT 349 excavators with long reach booms and thumb attachments will be used on the dry side of the slope while the majority of the material is placed by Caltrans Method B (dumping) using a conveyor system mounted on a barge. It is assumed that riprap placement in the wet will result in material wastes of about 25–30 percent. On the other hand, the design volumes are based on bank quantities with average porosities of 15–20 percent. As a result, the volumes in the estimate were increased by an average of 10 percent to account for the net effect of waste regarding porosities. Conveyor barges are not part of this cost (see marine equipment cost).

9. **Riprap Base and Armor, Exposed Aggregate (Sloped), Cottonwood, Alternative 1, $11.3 M:** 309,000 cy or 690,000 tons of Class II, 9-inch-diameter, 60# riprap and 75,000 cy or 168,000 tons of Class III, 12-inch-diameter, 150# riprap will be spread on an existing 2:1 slope over an area of about 61,905 sy with varying thicknesses, thus achieving a 3:1 slope. Cost and volume assumptions used in San Luis Lakeside were also used in developing the slope protection estimate on the Cottonwood bay side. Means and methods are different because riprap on the bay side will be placed in the dry. Six CAT 963 Crawler Loaders, two dump trucks, one mobile telestacker conveyor, and four CAT 349 excavators with long reach booms and thumb attachments will be used. Riprap placement will be per Caltrans Method B (dumping).

10. **Riprap Barge Haul, Alternative 1, $32.2 M:** Sixteen barges will be assembled at the Basalt Hill Docking Area: eight 1000-ton riprap barges measuring 60 × 200 × 7 feet, four telestacker conveyor barges assembly 300-1 measuring 80 × 90 × 7 feet, and four 100 MT crane barges assembly 100-6 measuring 60 × 60 × 7 feet.

    a. Total of 392 floats: 272 floats measuring 10 × 40 × 7 feet plus 120 floats measuring 10 × 20 × 7 feet. In addition, 48 end rakes/ramps measuring 10 × 10 feet. All floats were priced based on Robishaw Engineering Inc.'s Flexifloat™ May 2020 rental rates.

    b. Six assembly crews, each consisting of six laborers and one crane operator, will be used to assemble all 16 barges on-site in one month. Six 100 MT all terrain cranes will be used for assembling the floats.

    c. Trucking is based on round-trip freight cost of $9,900 for delivery and pickup from Houston, Texas. There will be 177 truck deliveries and 177 truck pickups.

    d. Riprap and conveyor barges will be provided with floor protection, comprised of 760 steel plates measuring 8-foot × 20-foot × $^{3}/_{16}$-inch with welded picking lugs that will be installed and removed.

    e. Riprap barges will be provided with 1,440 LF of perimeter steel fence barriers and four gates.

    f. Two 51-foot tugboats, each with a crew for the duration of the project, will be provided. These will be used to navigate the barges as well as provide support for the marine diving crew.

g. The marine diving crew was based on a two-man crew costing $1,500/day, which includes subsistence and special equipment rental totaling $250/day.

11. **Filter Aggregate, Alternative 1, $2.1 M:** 61,697 cy or 138,000 tons of Class 3 permeable material passing will be spread on an existing 2:1 slope:
    - $1^{1}/_{2}$-inch (100 percent), 1-inch (88–100 percent), $^{3}/_{4}$-inch (52–85 percent), $^{3}/_{8}$-inch (15–38 percent), No.4 (0–16 percent), No.8 (0–6 percent)
    - 140,000 sy of geotextile filter fabric GN60 6-ounce nonwoven will be installed. Similar to the riprap material, 100 percent of the filter aggregate material will be mined from Basalt Hill.
12. **Lakeside Embankment STA 299+00 to STA 322+00, $2.9 M:** 51,080 cy of embankment fill sourced from Borrow #6, located less than 10 miles away from SR 152, will be placed with 43,470 sy of Geotextile Filter Fabric GN60. Traffic control is included in this cost.
13. **Lakeside Pavement STA 299+00 to STA 322+00, $2.0 M:** 2,300 lineal feet of A/C Pavement with 12-inch A/C base, 4-inch A/C intermediate, 4-inch A/C top course layers. Provisions include 6-inch compacted subgrade and 36-inch aggregate subbase. 700 lineal feet of asphalt curb and 233 sy of asphalt plumes are included. Demolition of 55,200 sf of A/C pavement with no hazardous contamination is assumed. Dump site for the demolished material is approximately 60 miles – Merced County Regional Waste Authority's Highway 59 Landfill (7040 N. State Highway 59, Merced, CA 95348). At the time of the estimate, Billy Wright Landfill, which is a 30-minute drive, was not accepting A/C pavement materials.
14. **Bayside Embankment STA 299+00 to STA 322+00, $2.7 M:** The same quantities and cost elements as the lakeside embankment, except that there are no requirements for geotextile fabric.
15. **Bayside Pavement STA 299+00 to STA 322+00, $2.0 M:** The same quantities and cost elements as the lakeside pavement, except that 1,600 lineal feet of asphalt curb and 533 sy of asphalt flumes will be provided.
16. **Stormwater System, $701 K:** 3,400 lineal feet of RCP, Class IV pipe and fittings will be installed and connected to the existing storm drain system. Top of pipe will be a minimum of 3 feet below the gravel surface.
17. **Riprap, Exposed Aggregate (Sloped), East Overlook, Alternative 1, $713 K:** 1,457 cy of Class II, 9-inch-diameter, 60# will be spread on an existing 2:1 slope over an area of approximately 2,105 sy with varying thicknesses, thus achieving a 3:1 slope. The cost elements are the same as in San Luis lakeside, except that the riprap material will be delivered from the source directly to East Overlook without having to stockpile in the Basalt Hill Quarry.
18. **East Overlook Grading, $0.1 M:** Minor grading will be required over 1,952 sy, and 1,314 cy of fill material will be imported from Borrow #6.
19. **East Overlook Parking Pavement Demo and Rebuild, $1.3 M:** 1,556 sy of A/C parking pavement consisting of a tack coat on a 4-inch surface/wearing course, 3-inch binder/intermediate course, 10-inch base course will replace the existing A/C pavement. It is assumed that 6 inches of subgrade import fill will be compacted along with 12 inches of #67 subbase. Demolition assumes no hazardous materials and the dumpsite for will be the same as previously described in Item 12.

20. **Riprap Fill for Basalt Hill Dock Conveyor, Alternative 1, $1.2 M:** 6,080 cy of Class III, 12-inch-diameter, 150# riprap will be spread over an area of 30,000 sf. In addition, 30,000 sf of grouted riprap will be provided for the installation of the conveyor belt system, as well as dump truck access to the dock stockpile.
21. **Temporary Roadway and Grade Reduction Basalt Hill Haul Route, $5.0 M:** A 50-feet-wide × 9,504-lineal-feet aggregate road suitable for CAT 777 traffic will be developed with 78,731 cy of aggregate, 475,200 sf of surface, and 55,804 cy of berm material. In addition, 20 inches of subgrade engineered fill, 17 inches of sub-base sand fill, 9 inches of base #1 rock, and 8 inches of surface #2 rock courses are all assumed to be imported within a 20-mile radius.

Similarly, for Alternative 2, the cost elements are the same as Alternative 1 except that the embankment will be raised 2 vertical lineal feet for a total length of 800 LF from STA 304+00 TO STA 312+00 and slope protection consists of 563,895 cy or 1,260,000 tons of Class II, 9-inch, 60# riprap. Means and methods will be the same as Alternative 1. In addition, 2,719 cy of 4,500 psi concrete with 300#/cy of reinforcement for the wave barrier concrete walls will be constructed. Quantities shown include both the Cottonwood Bay and San Luis lake side. Bid Items 03 and 04 are the same.

1. **Wave Protection Walls – Cottonwood Bay side STA 303+20 to STA 315+15, $3.3 M:** 1,018 cy of 4,500 psi concrete with 300 lbs/cy of reinforcement will be poured for 1,195 lineal feet of wave protection wall. The wave protection wall consists of a 5-feet-wide × 12-inch-thick slab with a 12-inch-thick shear key and varying wall heights averaging 11 feet 4 inches and a tapered wall thickness of 18 inches at the top to 24 inches at the bottom. The wave protection walls will be straight throughout the stations. The bottom of the slab will be 6 feet 8 inches below the finished grade. If the walls will be built after the road is complete, provisions are included to protect the newly built road via shoring.
2. **Wave Protection Walls – San Luis lake side STA 301+60 to STA 321+96, $5.2 M:** 1,701 cy of 4,500 psi concrete with 300 lbs/cy of reinforcement will be poured for 2,036 lineal feet of wave protection wall. The barrier wall consists of a 5-feet-wide × 12-inch-thick slab with a 12-inch-thick shear key and varying wall heights averaging 13 feet 2 inches and a tapered wall thickness of 18 inches at the top to 24 inches at the bottom. The wave protection walls will be 1,340 lineal feet straight while the remaining 696 lineal feet will be curved. The bottom of the slab will be 6 feet 8 inches below the finished grade. If the walls will be built after the road is complete, provisions are included to protect the newly built road via shoring.

Opportunities for further cost-saving measures:

1. Basalt Hill Truck Haul Aggregate Road – $5 M is fully allocated to this project. There may be opportunities to share this cost with concurrent projects that will utilize the Basalt Hill Quarry.
2. Canning/Interquip conveyor system prices were based on the initial design using Class V riprap with a 36-inch-diameter maximum size with a median particle weight of ¼ ton. Currently, the maximum riprap size is 24 inches for Class III with a median particle weight of 150#. The conveyor system dimensions/capacities may be reduced and could result in a price reduction in the magnitude of $0.5 to $1 M. At the time of the report, a new quote based on the smaller riprap sizes was still being developed by the vendor.

3. What would the elevation have to be to decrease riprap waste ($1 – $2 M) and dewatering costs ($0.5 M)? Further, marine equipment rentals may be decreased (–$16 M) and supplemented with traditional earth-moving equipment (+$11 M), which could result in lower equipment assembly, operating, and mobilization expenses in the magnitude of $5 M. Hence, a guaranteed water elevation may alter the equipment selection and means and methods that may result in a total project cost reduction of up to $5 M.
4. Newly fabricated $^{3}/_{16}$-inch thick steel plates were used to protect the aggregate and telestacker barge floor surface area (121,600 sf). $2.8 M was budgeted for the supply, installation, and removal. Alternatives to use repurposed or other salvaged material may cut this budget in the magnitude of $1 M.

These estimates include the following allocations and are subject to change:

- 25-percent markup for all subcontractors
  - *Depending on market conditions, this may be decreased to 15 percent.*
- 10 percent for general conditions
  - *For this type of work and the magnitude of the project, 8 percent may be sufficient.*
- 0.4 percent for building permits
- 0.25 percent for builder's risk insurance
- 2 percent for insurance
- 1 percent for bonds
- 10-percent contractor total overhead and profit
  - *For this type of work and the magnitude of the project, as well as market conditions, this percentage may be decreased to 8 percent.*
- 25 percent for contingency
  - *This is a construction contingency and does not include design contingencies.*
- 8-percent escalation (4 percent per year)
  - *This is based on current San Francisco ENR indices. However, based on a 15-year period using linear regression, this could be decreased to 3.5 percent per year.*

Issues for further discussion:

1. Constructability
2. Concurrent projects
3. Coordination with authorities having jurisdiction (e.g., Caltrans, Mendocino County Air Quality Management District)
4. Right-of-way (e.g., staging, laydown, dock, truck haul route)

FEATURE: Raise SR 152 Embankment by 10 VLF Alternative	**PROJECT:** Sisk Dam Raise Feasibility Highway 152 Embankment
	WOID:
	ESTIMATE LEVEL: Feasibility
	REGION: Mid Pacific
	UNIT PRICE LEVEL: January 2020
	FILE: c:\pw_pl1\lawsonlc\d2231642\[05, Sisk Dam Raise SR152 Bid 1 Alternative Cost Estimate_DEC Findings Update 20200710.xlsx]Summary

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	Design Contingency Cost	Contract Cost[1]		Construction Contingency Cost	Field Cost (Contract Cost + Construction Contingency)
Property Class 01 - Reservoirs and Dams								
Identified Property 01 - San Luis Reservoir and Cottonwood Bay								
01		RAISE EMBANKMENT BY 10 VLF		$20,320,000	$155,785,000		$38,946,000	$194,731,000
03		EAST OVERLOOK GRADING AND PAVEMENT		$491,000	$3,768,000		$942,000	$4,710,000
04		BASALT HILL SITE DEVELOPMENT		$1,541,000	$11,814,000		$2,954,000	$14,768,000
05		BASALT HILL MINING OPERATIONS WITH ROCK BLASTING		$14,455,000	$110,821,000		$27,705,000	$138,526,000
		SUBTOTAL FIELD COST			$282,188,000		$70,547,000	$352,735,000
		Escalation to Mid-Point Construction			$23,949,000		$5,987,000	$29,937,000
		2.75% per Year (June 2022 - June 2024)						
		TOTAL FIELD COST			$306,137,000		$76,534,000	$382,672,000
Indirect Costs								
		Program Cost (0%)						
		TOTAL PROJECT COST						$383,000,000
		Notes:						
		1. Contract cost includes the 15% Design Contingency.						

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Jesus Quimpo	Onur Tastan	J. Quimpo	B. Brick / C. Park
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
07/10/20	Ames / 06/11/2020	07/10/20	07/10/20

FEATURE: Raise SR 152 Embankment by 10 VLF Alternative

PROJECT: Sisk Dam Raise Feasibility Highway 152 Embankment

WOID:

ESTIMATE LEVEL: Feasibility

REGION: Mid Pacific

UNIT PRICE LEVEL: January 2020

FILE: c:\pw_pl1\lawsonlc\d2231642\[05, Sisk Dam Raise SR152 Bid 1 Alternative Cost Estimate_DEC Findings Update 20200710.xlsx]Summary

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE (UPDATED 06/2020)	Markups[1]	AMOUNT
Property Class 01 - Reservoirs and Dams								
Identified Property 01 - San Luis Reservoir and Cottonwood Bay								
01		RAISE EMBANKMENT BY 10 VLF						
	1	QUARRY STOCKPILE HAUL TO DOCK STOCKPILE		946,599	CY	$15	$4,794,205	$4,794,220
	2	DEWATERING FRAC TANK SYSTEM, COTTONWOOD BAY		20	EA	$166,151	$1,124,239	$1,290,391
	3	DOCK STOCKPILE HAUL TO DOCK CONVEYOR		946,599	CY	$4	$1,070,702	$4,495,044
	4	CONCRETE, BRIDGE CONVEYOR SLAB		115	CY	$920	$33,734	$139,528
	5	CONVEYOR SYSTEMS WITH TEMP POWER		8	EA	$2,823,897	$7,925,277	$30,516,450
	6	RCP CULVERT		480	LF	$680	$104,502	$430,902
	7	RIPRAP		884,902	CY	$59	$15,850,560	$68,462,096
	8	FILTER		61,697	CY	$38	$710,002	$3,076,793
	9	LAKESIDE EMBANKMENT STA 304+00 TO STA 312+00		51,080	CY	$64	$1,066,477	$4,326,427
	10	LAKESIDE PAVEMENT STA 304+00 TO STA 312+00		2,300	LF	$1,034	$787,266	$3,164,331
	11	BAYSIDE EMBANKMENT STA 304+00 TO STA 312+00		51,080	CY	$59	$988,961	$4,005,393
	12	BAYSIDE PAVEMENT STA 304+00 TO STA 312+00		2,300	LF	$1,040	$791,898	$3,183,952
	13	STORMWATER SYSTEM		3,450	LF	$250	$267,434	$1,128,567
		Subtotal						$129,014,094
	14	Mobilization (5%)						$6,450,705
	15	Environmental Mitigation (0% of all above)						
	16	Design Contingencies (15% of all above)						$20,319,720
		Contract Cost						$155,784,518
		Construction Contingencies (25%)						$38,946,130
		Field Cost						$194,730,648
		Notes:						
		1. The Markups are made up of: Loss of Productivity (0.0% of total raw construction cost) Building Permits (0.4% of the total raw construction cost) Sales Tax (8.75% of materials, equipment and other) Insurance and Bonds (3.3% of the total raw construction cost) Field Office Overhead (5% of direct costs) General Contractor's Overhead and Profit (12% of direct costs + permits + sales tax + insurance & bonds) Contractor General Conditions (6% of direct costs + permits + sales tax + insurance & bonds)							

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Jesus Quimpo	Onur Tastan	J. Quimpo	B. Brick / C. Park
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
07/10/20	Ames / 06/11/2020	07/10/20	07/10/20

FEATURE: Raise SR 152 Embankment by 10 VLF Alternative

PROJECT: Sisk Dam Raise Feasibility Highway 152 Embankment

WOID:

ESTIMATE LEVEL: Feasibility

REGION: Mid Pacific

UNIT PRICE LEVEL: January 2020

FILE: c:\pw_pl1\lawsonlc\d2231642\[05, Sisk Dam Raise SR152 Bid 1 Alternative Cost Estimate_DEC Findings Update 20200710.xlsx]Summary

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE (UPDATED 06/2020)	Markups[1]	AMOUNT
Property Class 01 - Reservoirs and Dams								
Identified Property 01 - San Luis Reservoir and Cottonwood Bay								
3		EAST OVERLOOK GRADING AND PAVEMENT						
	1	RIPRAP		18,942	SF	$46	$299,814	$1,172,406
	2	EAST OVERLOOK GRADING		17,570	SF	$4	$21,221	$85,839
	3	EAST OVERLOOK PARKING PAVEMENT DEMO AND REBUILD		14,000	SF	$101	$447,988	$1,862,088
		Subtotal						$3,120,334
	4	Mobilization (5%)						$156,017
	5	Environmental Mitigation (0% of all above)						
	6	Design Contingencies (15% of all above)						$491,453
		Contract Cost						$3,767,803
		Construction Contingencies (25%)						$941,951
		Field Cost						$4,709,753
		Notes:						
		1. The Markups are made up of:						
		Loss of Productivity (0.0% of total raw construction cost)						
		Building Permits (0.4% of the total raw construction cost)						
		Sales Tax (8.75% of materials, equipment and other)						
		Insurance and Bonds (3.3% of the total raw construction cost)						
		Field Office Overhead (5% of direct costs)						
		General Contractor's Overhead and Profit (12% of direct costs + permits + sales tax + insurance & bonds)						
		Contractor General Conditions (6% of direct costs + permits + sales tax + insurance & bonds)						

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FEATURE: Raise SR 152 Embankment by 10 VLF Alternative

PROJECT: Sisk Dam Raise Feasibility Highway 152 Embankment

WOID:

ESTIMATE LEVEL: Feasibility

REGION: Mid Pacific

UNIT PRICE LEVEL: January 2020

FILE: c:\pw_pl1\lawsonlc\d2231642\[05, Sisk Dam Raise SR152 Bid 1 Alternative Cost Estimate_DEC Findings Update 20200710.xlsx]Summary

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE (UPDATED 06/2020)	Markups[1]	AMOUNT
Property Class 01 - Reservoirs and Dams								
Identified Property 01 - San Luis Reservoir and Cottonwood Bay								
4		BASALT HILL SITE DEVELOPMENT						
	1	BASALT HILL DOCKING AREA		30,000	SF	$48	$403,796	$1,851,863
	2	BASALT HILL AGGREGATE ROAD DEVELOPMENT		9,504	LF	$627	$1,969,555	$7,932,056
		Subtotal						$9,783,919
	3	Mobilization (5%)						$489,196
	4	Environmental Mitigation (0% of all above)						
	5	Design Contingencies (15% of all above)						$1,540,967
		Contract Cost						$11,814,082
		Construction Contingencies (25%)						$2,953,521
		Field Cost						$14,767,603
		1. The Markups are made up of: Loss of Productivity (0.0% of total raw construction cost) Building Permits (0.4% of the total raw construction cost) Sales Tax (8.75% of materials, equipment and other) Insurance and Bonds (3.3% of the total raw construction cost) Field Office Overhead (5% of direct costs) General Contractor's Overhead and Profit (12% of direct costs + permits + sales tax + insurance & bonds) Contractor General Conditions (6% of direct costs + permits + sales tax + insurance & bonds)						

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FEATURE: Raise SR 152 Embankment by 10 VLF Alternative

PROJECT: Sisk Dam Raise Feasibility Highway 152 Embankment

WOID:

ESTIMATE LEVEL: Feasibility

REGION: Mid Pacific

UNIT PRICE LEVEL: January 2020

FILE: c:\pw_pl1\lawsonlc\d2231642\[05, Sisk Dam Raise SR152 Bid 1 Alternative Cost Estimate_DEC Findings Update 20200710.xlsx]Summary

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE (UPDATED 06/2020)	Markups[1]	AMOUNT
Property Class 01 - Reservoirs and Dams								
Identified Property 01 - San Luis Reservoir and Cottonwood Bay								
5		BASALT HILL MINING OPERATIONS WITH ROCK BLASTING						
	1	BASALT HILL MINING		2,113,148	TONS	$32.04	$22,955,829	$90,661,674
	2	BASALT HILL SCREENING AND STOCKPILE		946,559	CY	$0.90	$263,064	$1,115,603
		Subtotal						$91,777,277
	3	Mobilization (5%)						$4,588,864
	4	Environmental Mitigation (0% of all above)						
	5	Design Contingencies (15% of all above)						$14,454,921
		Contract Cost						$110,821,062
		Construction Contingencies (25%)						$27,705,265
		Field Cost						$138,526,327
		1. The Markups are made up of: Loss of Productivity (0.0% of total raw construction cost) Building Permits (0.4% of the total raw construction cost) Sales Tax (8.75% of materials, equipment and other) Insurance and Bonds (3.3% of the total raw construction cost) Field Office Overhead (5% of direct costs) General Contractor's Overhead and Profit (12% of direct costs + permits + sales tax + insurance & bonds) Contractor General Conditions (6% of direct costs + permits + sales tax + insurance & bonds)						

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BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** SHEET 1 OF 5

FEATURE: Seismic Retrofit	**PROJECT:** Sisk Dam Raise Feasibility Highway 152 Embankment
	WOID:
	ESTIMATE LEVEL: Feasibility
	REGION: Mid Pacific
	UNIT PRICE LEVEL: January 2020
	FILE: c:\pw_pl1\lawsonlc\d2231642\[03, Sisk Dam Raise SR152 Bid 2A Alternative Cost Estimate_DEC Findings Update 20200710.xlsx]Summary

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	Design Contingency Cost	Contract Cost[1]		Construction Contingency Cost	Field Cost (Contract Cost + Construction Contingency)
Property Class 01 - Reservoirs and Dams								
Identified Property 01 - San Luis Reservoir and Cottonwood Bay								
02		SEISMIC RETROFIT		$14,481,000	$111,024,000		$27,756,000	$138,779,000
04		BASALT HILL SITE DEVELOPMENT		$1,541,000	$11,814,000		$2,954,000	$14,768,000
06		BASALT HILL MINING OPERATIONS WITH ROCK BLASTING		$8,638,000	$66,224,000		$16,556,000	$82,780,000
		SUBTOTAL FIELD COST			$189,062,000		$47,266,000	$236,327,000
		Escalation to Mid-Point Construction			$16,046,000		$4,011,000	$20,057,000
		2.75% per Year (June 2022 - Dec 2023)						
		TOTAL FIELD COST			$205,108,000		$51,277,000	$256,384,000
Indirect Costs								
		Program Cost (0%)						
		TOTAL PROJECT COST						$256,000,000
		Notes:						
		1. Contract cost includes the 15% Design Contingency.						

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FEATURE: Seismic Retrofit	**PROJECT:** Sisk Dam Raise Feasibility Highway 152 Embankment
	WOID:
	ESTIMATE LEVEL: Feasibility
	REGION: Mid Pacific
	UNIT PRICE LEVEL: January 2020
	FILE: c:\pw_pl1\lawsonlc\d2231642\{03, Sisk Dam Raise SR152 Bid 2A Alternative Cost Estimate_DEC Findings Update 20200710.xlsx]Summary

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE (UPDATED 06/2020)	Markups[1]	AMOUNT
Property Class 01 - Reservoirs and Dams								
Identified Property 01 - San Luis Reservoir and Cottonwood Bay								
02A		SEISMIC RETROFIT						
	1	QUARRY STOCKPILE HAUL TO DOCK STOCKPILE		563,895	CY	$15	$2,874,260	$2,874,275
	2	DEWATERING FRAC TANK SYSTEM, COTTONWOOD BAY		20	EA	$146,297	$979,460	$1,125,758
	3	DOCK STOCKPILE HAUL TO DOCK CONVEYOR		563,895	CY	$4	$637,825	$2,677,729
	4	CONCRETE, BRIDGE CONVEYOR SLAB		115	CY	$920	$33,734	$139,528
	5	CONVEYOR SYSTEMS WITH TEMP POWER		8	EA	$2,542,162	$7,142,424	$27,479,718
	6	RCP CULVERT		480	LF	$680	$104,502	$430,902
	7	RIPRAP		563,895	CY	$78	$13,307,453	$57,217,059
		Subtotal						$91,944,969
	15	Mobilization (5%)						$4,597,248
	16	Environmental Mitigation (0% of all above)						
	17	Design Contingencies (15% of all above)						$14,481,333
		Contract Cost						$111,023,550
		Construction Contingencies (25%)						$27,755,887
		Field Cost						$138,779,437
		Notes:						
		1. The Markups are made up of:						
		Loss of Productivity (0.0% of total raw construction cost)						
		Building Permits (0.4% of the total raw construction cost)						
		Sales Tax (8.75% of materials, equipment and other)						
		Insurance and Bonds (3.3% of the total raw construction cost)						
		Field Office Overhead (5% of direct costs)						
		General Contractor's Overhead and Profit (12% of direct costs + permits + sales tax + insurance & bonds)						
		Contractor General Conditions (6% of direct costs + permits + sales tax + insurance & bonds)						

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FEATURE: Seismic Retrofit

PROJECT: Sisk Dam Raise Feasibility Highway 152 Embankment

WOID:

ESTIMATE LEVEL: Feasibility

REGION: Mid Pacific

UNIT PRICE LEVEL: January 2020

FILE: c:\pw_pl1\lawsonlc\d2231642\{03, Sisk Dam Raise SR152 Bid 2A Alternative Cost Estimate_DEC Findings Update 20200710.xlsx]Summary

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE (UPDATED 06/2020)	Markups[1]	AMOUNT
Property Class 01 - Reservoirs and Dams								
Identified Property 01 - San Luis Reservoir and Cottonwood Bay								
04		BASALT HILL SITE DEVELOPMENT						
	1	BASALT HILL DOCKING AREA		30,000	SF	$48	$403,796	$1,851,863
	2	BASALT HILL AGGREGATE ROAD DEVELOPMENT		9,504	LF	$627	$1,969,555	$7,932,056
		Subtotal						$9,783,919
	3	Mobilization (5%)						$489,196
	4	Environmental Mitigation (0% of all above)						
	5	Design Contingencies (15% of all above)						$1,540,967
		Contract Cost						$11,814,082
		Construction Contingencies (25%)						$2,953,521
		Field Cost						$14,767,603
		1. The Markups are made up of: Loss of Productivity (0.0% of total raw construction cost) Building Permits (0.4% of the total raw construction cost) Sales Tax (8.75% of materials, equipment and other) Insurance and Bonds (3.3% of the total raw construction cost) Field Office Overhead (5% of direct costs) General Contractor's Overhead and Profit (12% of direct costs + permits + sales tax + insurance & bonds) Contractor General Conditions (6% of direct costs + permits + sales tax + insurance & bonds)					

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FEATURE: Seismic Retrofit	**PROJECT:** Sisk Dam Raise Feasibility Highway 152 Embankment
	WOID:
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	REGION: Mid Pacific
	UNIT PRICE LEVEL: January 2020
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE (UPDATED 06/2020)	Markups[1]	AMOUNT
Property Class 01 - Reservoirs and Dams								
Identified Property 01 - San Luis Reservoir and Cottonwood Bay								
06		BASALT HILL MINING OPERATIONS WITH ROCK BLASTING						
	1	BASALT HILL MINING		1,258,817	TONS	$32.12	$13,669,851	$54,100,360
	2	BASALT HILL SCREENING AND STOCKPILE		563,895	CY	$1.01	$175,376	$743,735
		Subtotal						$54,844,096
	3	Mobilization (5%)						$2,742,205
	4	Environmental Mitigation (0% of all above)						
	5	Design Contingencies (15% of all above)						$8,637,945
		Contract Cost						$66,224,245
		Construction Contingencies (25%)						$16,556,061
		Field Cost						$82,780,307
		1. The Markups are made up of: Loss of Productivity (0.0% of total raw construction cost) Building Permits (0.4% of the total raw construction cost) Sales Tax (8.75% of materials, equipment and other) Insurance and Bonds (3.3% of the total raw construction cost) Field Office Overhead (5% of direct costs) General Contractor's Overhead and Profit (12% of direct costs + permits + sales tax + insurance & bonds) Contractor General Conditions (6% of direct costs + permits + sales tax + insurance & bonds)						

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B.F. Sisk Dam Raise and Reservoir Expansion Project
Feasibility Design Report- SR 152 Modifications

Attachment E Construction Schedule

												Oct-21	Oct-21	Oct-21	Oct-21	Nov-21	Nov-21	Nov-21	Nov-21	Dec-21	Dec-21	Dec-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
ACTIVITY	WBS	ACTIVITY DESCRIPTION	Critical Path, days	Duration, calendar days	Sequence	Predecessor 1	Predecessor 2	Predecessor 3	Successor 1	Successor 2	Successor 3	WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9	WK10	WK11	WK12	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15
001	Mobilization/Demobilization	Mobilization		28	1							Y	Y	Y	Y									X											
014	Construction - Concrete	Install Slab for Conveyor Bridge at Bayside and Lakeside		28	2	001	006		016					Y	Y	Y	Y							X											
002	Site Development	Site Development - Basalt Hill Aggregate Road Construction	28	28	2	001			017			CP	CP	CP	CP									X											
005	Site Development	Site Development - Basalt Hill Quarry - Clear and Grub and Grading		28	2	001			013			Y	Y	Y	Y									X											
006	Site Development	Site Development - Bayside Staging Area - Grading		14	2	001			014			Y	Y											X											
016	Equipment Assembly	Receive and Install Bridge Conveyor		28	3	014			023									Y	Y	Y	Y			X											
015	Equipment Assembly	Receive and Install Bridge to Barge Pivoting Conveyor		14	3	014			023									Y	Y					X											
009	Equipment Assembly	Receive and Install Telestackers for Cottonbay Install		7	3	006			023					Y										X											
013	Stockpile Riprap and Fill Materials	Receive Import Material and Stockpile at Basalt Hill Quarry		288	3	002	005		017							Y	Y	Y	Y					X	X	X	X	X	X	X	X	X	X	X	X
004	Site Development	Site Development - Basalt Hill Dock - Barge Assembly Area	14	14	3	001	002		007							CP	CP							X											
003	Site Development	Site Development - Basalt Hill Dock - Grouted Riprap for Conveyor Support		21	3	001	002		010							Y	Y	Y						X											
010	Equipment Assembly	Receive and Install Conveyor at Basalt Hill Dock		7	4	003			018										Y					X											
007	Equipment Assembly	Receive and Assemble Marine Barges	28	28	4	004			011	012								CP	Y	Y	Y			X											
008	Equipment Assembly	Receive and Launch Tug Boats	7	7	4	004			021	020	018							CP						X											
012	Equipment Assembly	Receive and Install Telestackers for Conveyors Barges		14	5	007			021										Y	Y				X											
011	Equipment Assembly	Receive and Install Cranes for Marine Barges	14	14	5	007			020										CP	Y				X											
025	Construction - Pipe	Install RCP Culvert Extension - Lakeside Submerged	14	14	6	008	011		022											CP	CP			X											
021	Equipment Assembly	Set in Place Conveyor Barges at SR152		7	6	012			022												Y			X											
020	Equipment Assembly	Set in Place Crane Barges at SR152		21	6	011			025										Y	Y	Y			X											
017	Stockpile Riprap and Fill Materials	Truck Haul Material from Basalt Hill Quarry Stockpile to Dock Conveyor		288	6	013	010		018											Y	Y	Y	Y	X	X	X	X	X	X	X	X	X	X	X	X
018	Stockpile Riprap and Fill Materials	Load Aggregate Barge from Dock Conveyor		288	7	017			019											Y	Y	Y	Y	X	X	X	X	X	X	X	X	X	X	X	X
026	Construction - Pipe	Plug Culvert Extension - Lakeside	7	7	7	025			027												CP			X											
019	Stockpile Riprap and Fill Materials	Barge Haul Material from Basalt Hill Dock to SR152		260	8	018			022	023														X	X	X	X	X	X	X	X	X	X	X	X
027	Site Development	Dewater Bayside and Install Portadam	21	21	8	026			028													CP	CP	X											
023	Stockpile Riprap and Fill Materials	Feed Aggregate on Conveyor Bridge for Bayside		260	9	015	016	009	024															X	X	X	X	X	X	X	X	X	X	X	X
028	Construction - Pipe	Install RCP Culvert Extension - Bayside		2	9	027			024															X											
022	Construction - Slope Protection	Place Aggregate Lakeside		260	9	019			040															X	X	X	X	X	X	X	X	X	X	X	X
024	Construction - Slope Protection	Place Aggregate Bayside	365	260	10	023			039															CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP	CP
035	Construction - Demolition	Demo of Existing Overlook Pavement		7	11	001			036															X											
029	Construction - Demolition	Demo of SR152 Eastbound Pavement		120	11	022			030									X	X	X	X														
036	Construction - Slope Protection	Construct East Overlook Grading		14	12	035			041															X											
041	Construction - Slope Protection	Construct East Overlook Riprap		14	12	029			042															X	X										
042	Construction - Slope Protection	Construct East Overlook Pavement		14	12	036			039															X											
030	Construction - Embankment	Construct Embankment SR152 Eastbound Pavement			12	029			031									X	X	X	X														
031	Construction - Pavement	Construct Pavement, SR152 Eastbound Pavement			13	030			037										X	X	X														
031	Construction - Pipe	Construct Stormwater, SR152 Eastbound Pavement			13	030			037										X	X	X														
037	Construction - Concrete	Construct Wave Barrier Walls, SR 152 Eastbound			14	031			039													X	X												
032	Construction - Demolition	Demo of SR152 Westbound Pavement		120	14	039			033													X	X	X	X										
033	Construction - Embankment	Construct Embankment SR152 Westbound Pavement			15	032			034													X	X	X	X										
034	Construction - Pavement	Construct Pavement, SR152 Westbound Pavement			16	033			038														X	X	X										
034	Construction - Pipe	Construct Stormwater, SR152 Westbound Pavement			16	033			038														X	X	X										
038	Construction - Concrete	Construct Wave Barrier Walls, SR 152 Westbound			17	034			039																								X	X	
039	Site Development	Clean and Rebuild Disturbed Areas			18	024	042		040																									X	
040	Mobilization/Demobilization	Demobilize			19	039																												X	

B.F. Sisk Dam Raise and Reservoir Expansion Project

Final Feasibility Report

Appendix C: Economic Benefits Evaluation



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RECLAMATION



December 2020

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List of Acronyms

AF	acre-feet
CCWD	Contra Costa Water District
CDFW	California Department of Fish and Wildlife
CDPR	California Department of Parks and Recreation
CEQA	California Environmental Quality Act
CNP	Current Normalized Prices
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPM	Central Valley Production Model
CWC	California Water Commission
Delta	Sacramento-San Joaquin Delta
D&S	Directives and Standards
DAU	Detailed Analysis Units
DFG	Department of Fish and Game
DMC	Delta Mendota Canal
DRMS	Delta Risk Management Strategy
DWR	California Department of Water Resources
EQ	Environmental Quality
ESA	Endangered Species Act
EWA	Environmental Water Account
FY	Fiscal Year
GAO	General Accounting Office
GRCD	Grassland Resources Conservation District
IDC	interest during construction
IMPLAN	IMpact analysis for PLANning
I-O	input-output
M&I	municipal and industrial
MIG	Minnesota IMPLAN Group
MSL	mean sea level
NCCP	Natural Community Conservation Plan
NED	National Economic Development
NEPA	National Environmental Policy Act
NIPA	National Income and Product Accounts
NMFS	National Marine Fisheries Service
O&M	operations and maintenance
OM&R	operations, maintenance, and replacement

OSE	Other Social Effects
P&Gs	Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies
PMP	Positive Mathematical Programming
PR&G	Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies
Reclamation	United States Department of the Interior, Bureau of Reclamation
RED	Regional Economic Development
RWSP	Refuge Water Supply Program
SCCC	South-Central California Coast
SCRB	Separable Cost-Remaining Benefits
Valley Water	Santa Clara Valley Water District
SFPUC	San Francisco Public Utilities Commission
SGMA	Sustainable Groundwater Management Act
SOD	Safety of Dams
SWAP	Statewide Agricultural Production Model
SWP	State Water Project
TAF	thousand acre-feet
TSC	Reclamation Technical Services Center (
U.S.	United States
UCCE	University of California Cooperative Extension
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
WEAP	Water Evaluation and Planning
WSCP	Water Shortage Consistency Plan
WSIP	Water Storage Investment Program
WTP	Water Treatment Plants
YR	year

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Chapter 1 Background and Project Description

This technical appendix to the Feasibility Report for the B.F. Sisk Dam Raise and Reservoir Expansion Project documents National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE) accounts to support federal plan formulation and evaluation.

The purpose of the B.F. Sisk Dam Raise and Reservoir Expansion Project is to facilitate and approve the expansion of San Luis Reservoir's capacity, to secure a more reliable long-term water supply for the San Luis and Delta-Mendota Water Authority (SLDMWA) and their member agencies, and to address water supply reliability problems across Central Valley Project (CVP) and State Water Project (SWP) service areas.

Decreased water supply reliability affects CVP and SWP contractors' ability to meet water demands. Stringent flow and water quality requirements in the Delta continue to restrict the amount of water that CVP and SWP can pump. These limitations cause water supply reliability concerns for CVP and SWP contractors that receive Delta exports. Regulatory changes, project operations, and growth in water demand are expected to increase reliance on San Luis Reservoir supplies. These conditions necessitate actions to improve water supply reliability and operational flexibility.

1.1 Background

B.F. Sisk Dam was constructed to create the offstream San Luis Reservoir, which provides supplemental storage capacity for CVP and SWP. Currently, San Luis Reservoir provides 2,027,840 acre-feet of water storage for CVP and SWP. The water stored in the reservoir is managed for federal (48 percent) and state (52 percent) uses as part of CVP and SWP, respectively. Typically, during the winter and early spring, water conveyed from the Sacramento-San Joaquin River Delta (Delta) by the Delta-Mendota Canal (a CVP facility) and California Aqueduct (a SWP facility) is lifted from O'Neill Forebay into San Luis Reservoir for storage using the pump-turbines in the Gianelli Pumping-Generating Plant. Later in the year, when CVP and SWP demand increases, water is released from San Luis Reservoir through O'Neill Forebay and conveyed via the Delta-Mendota Canal or the California Aqueduct for use by municipal and agricultural water users (Reclamation 2019). As water is released back through the Gianelli Pumping-Generating Plant, the plant generates hydropower, which is used to offset the energy demand of the project operations. Water is also diverted from the west side of San Luis Reservoir at the Pacheco Pumping Plant to supply water to CVP contractors, the Santa Clara Valley Water District, and the San Benito County Water District (Reclamation 2019). In addition to storing and supplying water, San Luis Reservoir provides recreation opportunities.

The B.F. Sisk Safety of Dams (SOD) Modification Project is a federal project that has the potential to influence water supply conditions in San Luis Reservoir. In 2006, Reclamation completed a risk

analysis of B.F. Sisk Dam that concluded there is justification to take action to reduce risk to the downstream public from a potential severe earthquake. Consequently, Reclamation, in coordination with the California Department of Water Resources, completed a corrective action study in December 2019. The Crest Raise Alternative, one of the alternatives evaluated in the study that would reduce the dam safety risk, was selected to be implemented. Raising the crest elevation 12 feet would increase the distance between the water surface and the dam crest (freeboard) to prevent reservoir overtopping and failure in the event of dam deformation from a seismic event.

As a connected action to the B.F. Sisk Dam SOD Modification Project, Reclamation and SLDMWA seek to evaluate an increase in storage capacity of San Luis Reservoir. The increased storage capacity would be achieved by an additional 10-foot raise of the B.F. Sisk Dam embankment across the entire dam crest above the level proposed for dam safety purposes. This additional 10 feet of dam embankment could add approximately 130,000 AF of water storage to San Luis Reservoir. SLDMWA, in coordination with Reclamation, is conducting a feasibility study to evaluate the Project and a potential cost-share in accordance with the Reclamation SOD Act and the Water Infrastructure Improvements for the Nation (WIIN) Act (P.L. 114-322) §4007.

1.2 Study Location

The study area for this EIR/Supplemental EIS (Figure 1-1) includes San Luis Reservoir and its related water infrastructure, the Delta, California Aqueduct, Delta-Mendota Canal, and South-of-Delta CVP and SWP contractors' service areas.

1.3 Project Objectives

The purpose of the Proposed Action, the B.F. Sisk Dam Raise and Reservoir Expansion Project is to facilitate and approve the expansion of San Luis Reservoir's capacity, to secure a more reliable long-term water supply for SLDMWA and their member agencies, and to address water supply reliability problems across CVP and SWP service areas.

Decreased water supply reliability affects CVP and SWP contractors' ability to meet water demands. Stringent flow and water quality requirements in the Delta continue to restrict the amount of water that CVP and SWP can pump. These limitations cause water supply reliability concerns for CVP and SWP contractors that receive Delta exports. Regulatory changes, project operations, and growth in water demand are expected to increase reliance on San Luis Reservoir supplies. These conditions all contribute to a need for actions to improve water supply reliability and operational flexibility.

CEQA and NEPA require an EIR and EIS, respectively, to identify a reasonable range of alternatives and provide guidance on the identification and screening of such alternatives. Both NEPA and CEQA include provisions that alternatives reasonably meet the purpose and need/ project objectives and be potentially feasible. SLDMWA and Reclamation followed a structured, documented process to identify and screen alternatives for inclusion in the EIR/Supplemental EIS under development for the B.F. Sisk Dam Raise and Reservoir Expansion Project. Appendix A describes, in detail, this process and the alternatives considered.

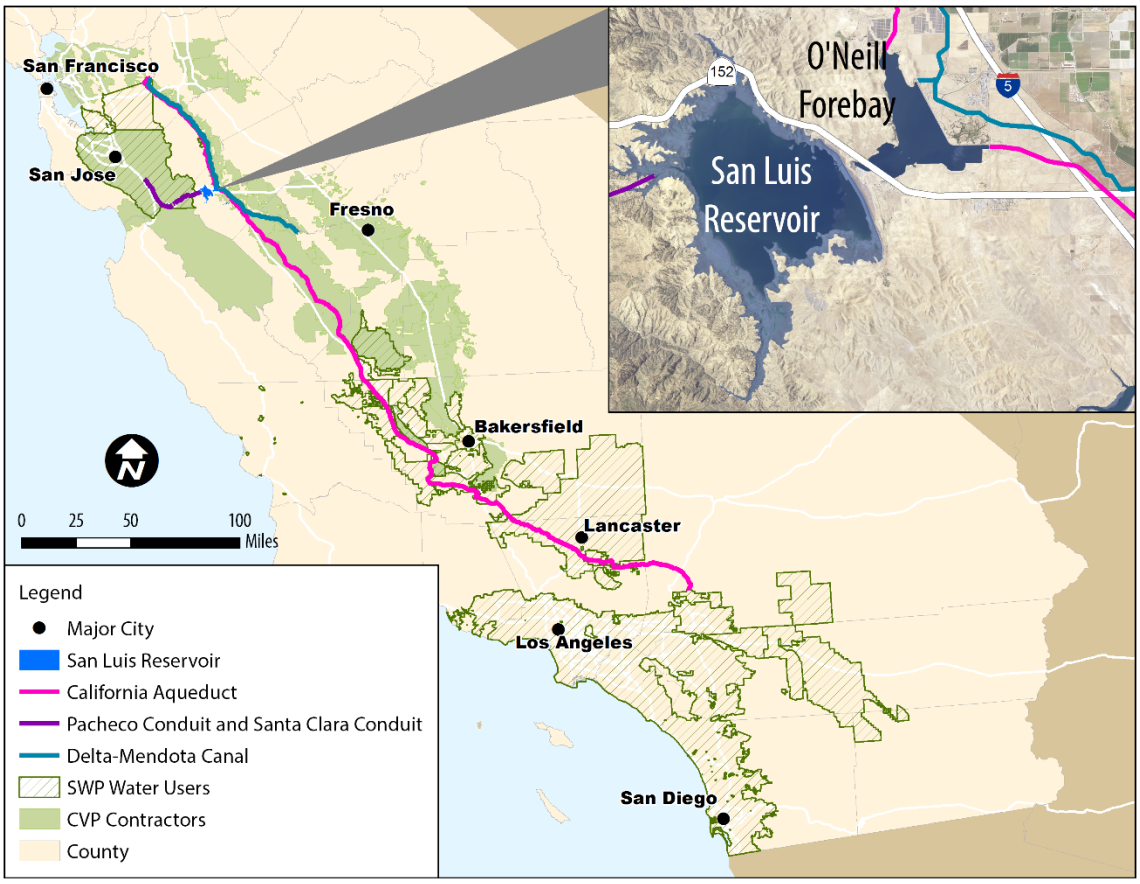


Figure 1-1. B.F. Sisk Dam Raise and Reservoir Expansion Project Study Location

SLDMWA and Reclamation started the process by identifying the purpose and need/project objectives (operational flexibility and water supply reliability). SLDMWA and its member agencies and Reclamation reviewed the purpose and need/project objectives and previous studies in their initial effort to develop conceptual alternatives. This process identified an initial list of 16 measures that could, in part, contribute to the purpose and need/project objectives. The three criteria developed to evaluate each measure include (1) the ability of the measure to address the purpose and need of the project, (2) the reliability and quantity of yearly allocations and increasing the certainty of access to supplies for South-of-Delta contractors, as well as the cost effectiveness of the measure, and (3) the acceptability of the environmental impacts. Measures were scored qualitatively for each of the three screening criteria. The metrics used were:

- Measure fully addressed the screening criteria.
- Measure partially addressed the screening criteria.
- Measure did not address the screening criteria.

Measures that scored highest moved forward to be incorporated into the alternatives. These measures, and their performance, are documented in the Alternatives Development Report (see Appendix A). The measures remaining after the initial screening were combined into two action

alternatives that were selected to move forward for analysis (in addition to the No Project/ No Action Alternative).

1.4 Final Alternatives Considered in the Feasibility Report

1.4.1 Alternative 1 – No Action/No Project Alternative

Both CEQA Guidelines (Section 15126.6) and NEPA regulations (40 Code of Federal Regulations [CFR] 1502.14(d)) require the evaluation of a No Project/No Action Alternative, which presents the reasonably foreseeable future conditions in the absence of the proposed project. The purpose of the No Project/No Action Alternative is to allow decision makers to compare the impacts of approving the project to the impacts of not approving the project. Under CEQA, existing conditions (conditions at the time of the Notice of Preparation) serve as the baseline to determine potential impacts of the alternatives. This differs from NEPA in that the No Action Alternative serves as the baseline to which action alternatives are compared to determine potential impacts. The No Project/No Action Alternative may differ from existing conditions if there are actions that could occur in the study area in the future that (1) currently do not exist and (2) do not rely on approval or implementation of the proposed project.

Under Alternative 1, the No Project/No Action Alternative, crest raise actions from the B.F. Sisk SOD Modification Project would be implemented. The Crest Raise Action includes increasing the dam crest by 12 feet to reduce safety concerns for the downstream public by reducing the likelihood of overtopping if slumping were to occur during a seismic event (Reclamation 2019). As discussed in the B.F. Sisk SOD Modification Project ROD, the Crest Raise Action includes implementation of several mitigation measures to reduce environmental impacts. These mitigation measures, herein discussed as environmental commitments (see Section 2.3 for the list of environmental commitments), are evaluated as project actions under the No Project/No Action Alternative analysis in this EIR/Supplemental EIS.

The No Project/No Action Alternative includes current conditions in the study area at the time of the Lead Agencies' release of the Notice of Intent and Notice of Preparation for the EIS/EIR and was analyzed to be consistent with the Reinitiation of Consultation on the Coordinated Long-Term Operations of CVP and SWP (ROC on LTO) and the 2018 Addendum to the Coordinated Operation Agreement CVP/SWP ROD.

1.4.2 Alternative 2 – Non-Structural Alternative

Under Alternative 2, Non-Structural Alternative, operational measures would be used to meet project objective/project purpose and need.[1]

Alternative 2 would rely on a change in the current approach for annual CVP Project water supply allocations. San Luis Reservoir's maximum capacity is 2,027,840 AF, with a federal share of 966 TAF and state share of 1,062 TAF. The annual allocation of CVP supplies is managed by

[1] *Directive and Standard* 557 (08/18/2016) – *Developing Additional Project Benefits in Conjunction with a Safety of Dams Modification Project* (Reclamation 2016) established requirements for developing additional project benefits in conjunction with a SOD modification project. This directive and standard included the requirement for the evaluation of "a non-structural alternative that meets the needs and objectives of the additional benefits of the additional benefits project."

Reclamation. Reclamation develops the annual allocation to fully utilize stored CVP supply in the reservoir to meet CVP contractors' contracts and the requirements of other authorized purposes, such as CVPIA refuge water supplies. Under the Non-Structural Alternative, Reclamation would change its annual allocation process to reserve up to 310 TAF of stored CVP supply in San Luis Reservoir at the end of wetter years. This water would be reserved in San Luis Reservoir for allocation in subsequent drier years to South-of-Delta CVP contractors. In these drier years, the 310 TAF in reserved supply would be allocated to South-of-Delta CVP water contractors consistent with the CVP's current allocation of water supply stored in San Luis Reservoir, but only if supply is sufficient to meet the demands of senior water rights contractors. Under Alternative 2, water supply reserved in wetter water years (by Reclamation) for delivery to South-of Delta CVP contractors in drier years could potentially be diverted for delivery to the Exchange Contractors in critical water year types. Under this new operational configuration, allocated water supply not used by CVP contractors could not be carried over for use in a subsequent year.

This change in San Luis Reservoir operations to increase water supply available in dry and critical years would adversely impact average water supply deliveries to CVP and SWP contractors. The Non-Structural Alternative would not require any additional construction or maintenance actions beyond actions identified under the No Project/No Action Alternative. Therefore, there are no costs associated with the Non-Structural Alternative.

1.4.3 Alternative 3 – Dam Raise Alternative (Proposed Action)

The Dam Raise Alternative would be completed by placing additional fill material on the dam embankment to raise the dam crest an additional 10 feet above the 12-foot embankment raise under development by the B.F. Sisk Dam SOD Modification Project. The 10-foot embankment raise would support an increase in reservoir storage capacity of 130 TAF. The 10-foot increase in San Luis Reservoir's maximum surface elevation would inundate 445 acres of new land around the shore of the reservoir when the reservoir is full. The newly inundated lands are public lands and would not require additional land acquisitions.

The Dam Raise Alternative would build upon the seismic modifications to B.F. Sisk Dam being completed under the B.F. Sisk Dam SOD Modification Project. Construction actions under this alternative would add onto the actions under the B.F. Sisk Dam SOD Modification Project and are evaluated as a connected action in this feasibility report.

With increased reservoir surface elevations, modifications would also be made at multiple locations along State Route (SR) 152 to prevent inundation of the roadway when the enlarged reservoir is filled to capacity. The SR 152 embankment at Cottonwood Bay would be raised 10 feet (for adequate freeboard) to protect against wave action. Modifications to the Dinosaur Point Boat Launch and the Goosehead Point Boat Launch would be made to increase the ramp's operating elevation by 10 feet. The existing berm developed during construction of the Pacheco Pumping Plant would be reconstructed with a higher crest elevation to protect the plant at high storage levels.

Under this alternative, there are three subalternatives that evaluate different operational configurations of this new storage capacity. The subalternatives cover varying assignment and use of the increased storage space, as described in more detail below.

1.4.3.1 Elements Common to all Subalternatives

Project Facilities All of the subalternatives under the Dam Raise Alternative would include modifications to the following project facilities:

B.F. Sisk Dam Embankment and Reservoir Facilities In addition to the increase in dam embankment elevation, all subalternatives would include (1) installation of downstream stability berms and crack filters, and (2) raising the existing outlet works intake towers, access bridge, and spillway intake by 10 feet.

The existing saddle dike, known as the East Dike, approximately 1,300 feet north of the main embankment, would be modified by adding a downstream filter. With increased reservoir surface elevations, modifications would also be made to the Dinosaur Point Boat Launch and the Goosehead Point Boat Launch (Basalt Use Area) to increase the ramps' operating elevation by 10 feet.

SR 152 Facilities The increase in storage levels will require modifications to a section of SR 152 where it crosses over Cottonwood Creek. The current maximum water level at San Luis Reservoir is 544 feet. Under the Alternative 3 subalternatives, the maximum water level would increase 10 feet. The current elevation of the road surface of SR 152 near Cottonwood Creek crossing ranges in elevation from 555 to 558 feet and up. With the lowest point of SR 152 approximately 1 foot above the proposed maximum water storage level, it is assumed that modifications will be needed to protect the roadway from wave action. The SR 152 embankment between milepost MER R5.239 and MER R5.806 would be modified to allow adequate freeboard to protect against wave action. The feasibility-level design used as the basis for this document evaluated two design options for the SR 152 modification. The first configuration's design includes raising the embankment by 11 feet and flattening the side slopes to a three-to-one (3:1) slope. The second configuration's design includes installing wave barrier walls without raising the embankment. This EIR/Supplemental EIS evaluates effects potentially generated from implementation of the first configuration, given its larger construction footprint, longer potential construction schedule and larger potential environmental impacts. In addition to the embankment modification at Cottonwood Bay, the embankment at milepost MER R6.295 would require the placement of downslope fill to prevent inundation of the roadway when the enlarged reservoir is filled to capacity.

Construction of Dam Raise Construction of the additional 10-foot embankment and associated modifications would initiate during construction of the B.F. Sisk SOD Modification Project, currently scheduled to start in September 2021 and continue through December 2029.

The downstream stability berms would be constructed by first excavating the existing liquefiable and soft foundation soils. The rock blanket or slope protection would also be removed to the top elevation of the embankment and stockpiled downstream of the toe. Next, the existing toe drain would be removed by excavation. After completion of the excavations, the existing filters/drains located at the downstream toe would be re-established and a new toe drain seepage collection system would be installed, similar to the one currently in place. Stronger material would then be placed as backfill and compacted. At 480 feet, a two-stage downstream crack filter would be constructed. Above an elevation of 550 feet, the raised crest would be developed by simultaneously placing riprap and bedding, core, a two-stage chimney filter and the downstream shell. Materials

used would be stockpiled downstream of the toe and in Borrow Area 6. After fill placement is completed, road base and paving of the dam crest complete the overlay raise.

Items in the staging areas would include trailers, equipment, and stockpiled materials. Construction staging and stockpile areas would include the area south of the Gianelli Pumping-Generating Plant off of Basalt Road, the area north of the Gianelli Pumping-Generating Plant off of Gonzaga Road, and Dinosaur Point. The access route to the two main staging areas would be SR 152 to Basalt Road. Temporary traffic signals would be installed at the current left turn crossing on SR 152 at Basalt Road and at the access road to the Romero Visitor Center for the duration of the project. Up to 240 large deliveries or waste material transports off-site per day could be expected, along with the transport and disposal of material to local landfills and the regular commuting of construction personnel.

Aside from areas dedicated to construction staging and transportation, all remaining available space at the areas next to B.F. Sisk Dam would be needed for stockpiling materials. These areas around the dam would be used as a staging area for the full duration of construction. These areas would be returned to pre-construction condition after the project is completed. Equipment used to construct the dam raise action would include:

3 Excavators	2 Scrapers
4 Bulldozers	5 Loaders (2 small, 3 large)
5 Cranes/Lifts	13 Dump trucks
5 Compactors	5 Water trucks
1 Graders	1 Barge
4 Flatbed Trucks	2 Wheel Trenchers
2 Concrete Saw Cutters	2 Concrete Pumpers

Equipment used to construction the SR 152 modification would include:

27 Cranes	4 Pavers	9 Tractors/Loaders/Backhoes	18 Plate Compactors
8 Crawler Tractors	9 Rollers	9 Dump Truck	1 Rollers
8 Excavators	5 Rough Terrain Forklifts	2 Flatbed Truck	1 Pumps
4 Graders	5 Rubber Tired Loaders	7 Haul Truck	2 Welders
5 Off-Highway Trucks	1 Skid Steer Loaders	2 Concrete/Industrial Saws	7 Generators
9 Water Truck	16 Barges (8 aggregate, 4 conveyor, 4 crane)		

Recreational activities would be suspended for safety reasons for the full duration of construction at Basalt Use Area and Medeiros Use Area, and during active construction at Dinosaur Point Use Area (approximately 1 year). Recreational use for boating would be suspended for the full year that both the Basalt and Dinosaur Point use areas are closed and would be limited to areas of the reservoir away from B.F. Sisk Dam for the full construction schedule and other sections of the reservoir near active construction during that work. The closed Basalt Campground would be utilized as a temporary camping area for construction workers.

Final design of the dam raise would include the development of a construction schedule that times the completion work in the direct path of potential flood flows or on infrastructure specifically designed to direct flood flows to occur in periods of the year when rain is unlikely and reservoir levels are lower. In addition, the contractor would be required to develop a Health and Safety Plan (HASP) that includes a response plan to flood forecasts that would require the suspension of construction activities and the movement of construction equipment to higher ground.

Construction of the dam raise action is expected to coincide with the construction of the SOD Modification Project whose construction duration is anticipated to last approximately 8 years. Construction duration is based on 130 anticipated workers on-site during the day shift and 87 workers on-site during the night shift. Work would be performed 24 hours per day, 7 days per week, 12 months per year. The 24-hour work day would consist of two 10-hour work shifts, with a half-hour for lunch each shift, plus a 3-hour maintenance period. Blasting operations at Basalt Hill would be limited to the hours between 6:00 a.m. and 6:00 p.m. It is assumed that construction would start in September 2025.

Construction of SR 152 Modification SR 152 Modification construction is expected to last approximately 18–24 months from summer 2027. The construction duration is based on approximately 75–130 workers on-site. Work would be performed from 6:00 a.m. to 6:00 p.m., 7 days per week, 12 months per year. A smaller crew of 10–20 people would be active at the site performing equipment maintenance, repair activities, crushing operations at Basalt Hill, and borrow operations in Borrow Area 6 from 6:00 p.m. to 6:00 a.m.

1.4.3.2 Operation of Dam Raise Alternative

The SLDMWA and its member agencies, Reclamation, and DWR coordinated on the identification of several operational configurations of the Dam Raise Alternative. Those subalternatives have been further configured as "bookends" to capture the range of stakeholder-requested configurations and cover the high- and low-end of potential environmental effects. These effects include potential growth-inducing impacts from increases in municipal and industrial (M&I) water supply reliability and potential environmental impacts to aquatic resources in the Delta resulting from changes in water deliveries conveyed through the Delta.

CVP-Only Storage The additional storage in San Luis Reservoir would be Reclamation-owned CVP storage and would be operated consistent with current CVP operations. The new reservoir capacity would be used to store CVP Project water, carried-over water,[2] and non-Project water.[3] The maximum quantity of carried-over water would be the same as recent operations under the current rescheduling guidelines. Based on a review of historical rescheduling quantities and the most recent annual rescheduling guidelines, an upper quantity of 180 TAF was used to estimate the aggregate

[2] Carried-over water refers to Rescheduled Water. Rescheduled Water is defined as allocated CVP water carried over to subsequent water year(s) by the water contractor, pursuant to Reclamation's then-current Rescheduling Guidelines. The water contractors, in storing this carried-over supply in San Luis Reservoir, take on a risk of potentially losing it if San Luis Reservoir fills the next year and that supply is "spilled" (converted to CVP supplies for following year's allocation).

[3] Non-Project water includes transfer water acquired by existing South-of-Delta CVP contractors. or other non-Project water currently stored in San Luis Reservoir such as conserved water. The water contractors can store non-Project water in San Luis Reservoir under the Warren Act. Similar to carried-over water, the contractors take on a risk of potentially losing non-Project water if San Luis Reservoir fills the next year and that supply is "spilled" (converted to CVP supplies for following year's allocation).

total of carried-over water in high-allocation water years. As an operational bookend, this upper limit was allocated 98 percent to agricultural and 2 percent to M&I South-of-Delta CVP water contractors.

Storage priority will follow current rescheduling guidelines with carried-over water and non-Project water being subject to spill consistent with current operating criteria.

CVP/SWP Split Storage The additional storage would be split between the CVP and SWP, consistent with the current 45-percent CVP and 55-percent SWP split of the overall reservoir storage. The additional storage would follow current operating criteria and the storage priority will follow the current rescheduling guidelines.

Investor-Directed Storage Under this subalternative's four operational configurations, the use of the proposed storage (expanded capacity) would be primarily investor directed. Remaining expanded capacity not in use by the investors, at any given time, would be available to Reclamation to store CVP water.

Investors could store allocated CVP Project water carried-over water, and non-Project water in the expanded capacity. Investors could forgo delivery of their allocated CVP Project water for delivery in subsequent year(s). This unused CVP Project water would be carried over to subsequent year(s) and continue to be stored in San Luis Reservoir until investor requests delivery of the water without the risk of "spill." Carried-over water in the expanded capacity would be subject to evaporation at the same rate as CVP Project water stored in San Luis Reservoir. Investors would have first priority in storing carried-over water and non-Project water in the expanded capacity without the risk of "spill."

Configuration A – The upper target quantity of carried-over water in San Luis Reservoir would be 180 TAF. The delivery of the carried-over water and CVP Project water was allocated proportionally among the SLDMWA investor group at 78 percent to agriculture, 7 percent to M&I, and 15 percent to federal refuge water users.

Configuration B – The upper target quantity of carried-over water in San Luis Reservoir would be 180 TAF. The delivery of the carried-over water and CVP Project water was allocated proportionally among the SLDMWA investor group at 90 percent to M&I and 10 percent to agricultural water contractors.

Configuration C – The upper target quantity of carried over water in San Luis Reservoir would be 310 TAF. The delivery of the carried-over water and CVP Project water was allocated proportionally among the SLDMWA investor group at 78 percent to agriculture, 7 percent to M&I, and 15 percent to federal refuge water contractors.

Configuration D – The upper target quantity of carried over water in San Luis Reservoir would be 310 TAF. The delivery of the carried-over water and CVP Project water was allocated proportionally among the SLDMWA investor group at 90 percent to M&I and 10 percent to agricultural water contractors.

1.5 Organization of This Appendix

This appendix is organized as follows:

Chapter 1, Background and Project Description, provides an overview of the investigation.

Chapter 2, Economic Principles and Methods, describes methods for economics analysis in the Feasibility Report and specific valuation approaches for each benefit category.

Chapter 3, Safety of Dams Connected Action, describes cost savings generated by the B.F. Sisk Dam Raise and Reservoir Expansion Project's connection to the B.F. Sisk Dam SOD Modification Project.

Chapter 4, NED Municipal and Industrial Water Supply Reliability Benefits, describes M&I water supply reliability benefits of the Dam Raise Alternatives.

Chapter 5, NED Irrigation Water Supply Reliability Benefits, describes irrigation water supply reliability benefits.

Chapter 6, NED Enhanced Emergency M&I Water Supply Benefits, describes emergency water supply benefits of the Dam Raise Alternatives.

Chapter 7, NED Transportation Safety Benefits, describes loss of function transportation benefits of the Dam Raise Alternatives.

Chapter 8, NED Refuge Water Supply Benefits, describes refuge water supply benefits of the Dam Raise Alternatives.

Chapter 9, Other NED Benefits, describes other nonquantifiable benefits identified by Reclamation and SLDMWA.

Chapter 10, NED Benefits Summary, summarizes NED benefits.

Chapter 11, RED Account, describes regional economic development benefits of the Dam Raise Alternatives.

Chapter 12, EQ Account, describes environmental impacts and benefits of the Dam Raise Alternatives.

Chapter 13, OSE Account, describes social impacts and benefits of the Dam Raise Alternatives.

Chapter 14, References, contains sources of information used to prepare the appendix.

Chapter 2 Economic Principles and Methods

This chapter describes Federal economic principles and methods related to plan formulation, estimation of project benefits, and derivation of total annual equivalent benefits. This chapter also describes potential economic valuation methods applied to the B.F. Sisk Dam Raise Project.

2.1 Guidelines

The economic valuation approach for Federal water resource projects and the B.F. Sisk Dam Raise Project is consistent with the *Federal Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) (Water Resource Council 1983). In 2015, the Council on Environmental Quality completed an interagency effort to update the 1983 P&G. This effort led to the development of the *Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies* (PR&G). The PR&G apply only to plans or projects that are initiated after the PR&G take effect; therefore, the P&G are the primary guidelines used for the B.F. Sisk Dam Raise Project. The approaches to quantifying and monetizing benefits in the PR&G and the P&G are not significantly different (DOI 2015).

The P&G indicate the Federal objective of water and related land resources project planning is to contribute to national economic development consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Further, numerous Federal laws (e.g., the Endangered Species Act [ESA] [1973], Clean Water Act [1972]) establish policy and Federal interest in the protection, restoration, conservation, and management of protecting environmental quality.

The Federal Objective as updated and specified in the Water Resources Development Act of 2007 is that Federal water resources investments shall reflect national priorities, encourage economic development, and protect the environment by:

- Seeking to maximize sustainable economic development
- Seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used
- Protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems

In the Water Resources Development Act of 2007, Congress instructed the Secretary of the Army to develop a new P&G for the U.S. Army Corps of Engineers (USACE) to promote consistency and informed decision-making among Federal agencies. In 2009, the Obama Administration began the process of updating the P&G for Federal agencies engaged in water resources planning, including USACE, U.S. Environmental Protection Agency (USEPA), U.S. Department of Agriculture, U.S. Department of the Interior (US DOI), National Oceanic and Atmospheric Administration (NOAA),

Tennessee Valley Authority, Federal Emergency Management Agency (FEMA), and Office of Management and Budget.

In March 2013, the administration released the principles and requirements that lay out broad principles to guide Federal investments in water management (White House 2013). In addition, *Draft Interagency Guidelines* for implementing the principles and requirements were released. The modernized principles and requirements, together with agency specific guidelines (PR&G), will allow agencies to better consider the full range of long-term economic, social, environmental, cultural, and other benefits of infrastructure projects.

In consideration of the many complex water management challenges and competing demands for limited Federal resources, it is intended that Federal investments in water resources should strive to maximize public benefits, particularly in comparison to costs. Public benefits encompass environmental, economic, and social goals, include monetary and nonmonetary effects and allow for the inclusion of quantified and nonquantified measures. Stakeholders and decision-makers expect the formulation and evaluation of a diverse range of alternative solutions. Such solutions may produce varying degrees of effects relative to the three goals specified above, and as a result, tradeoffs among potential solutions will need to be assessed and properly communicated during the decision-making process.

Thus, in addition to traditional, monetized economic development, projects that contribute to Federal ecosystem and species restoration goals, public health and safety, environmental justice, community benefits, and support recreation opportunities are relevant components of water project planning and development.

Economic evaluation provides a way to understand and evaluate trade-offs that can be quantified and monetized and that must be made between alternatives with respect to objectives, investments, and other social goals. It also provides a means to identify the plan that is acceptable, effective, efficient, and complete, and contributes the most favorably to national priorities. The Federal P&G established four main accounts for organizing, displaying, and analyzing project alternatives:

- National Economic Development (NED)
- Regional Economic Development (RED)
- Environmental Quality (EQ)
- Other Social Effects (OSE)

The above accounts encompass all significant effects of a plan, consistent with National Environmental Policy Act (NEPA) of 1970 (42 United States Code 4321 et seq.) and other Federal guidance. The NED account is the only required account under the 1983 P&G, although information that could affect Federal decision-making should be presented in the other accounts.

2.1.1 National Economic Development Account

The NED account identifies the alternative providing the greatest net economic benefits to the nation. The NED account considers and displays the potential changes and effects in the total value of the national output of goods and services from an alternative plan, expressed in monetary units. Contributions to NED are increases in the total value of the national output of goods and services, expressed in monetary units. NED benefits are the direct net benefits that would be expected to

accrue in the primary study area and the rest of the nation if a project or program is implemented. They include increases in the net value of those goods and services that are marketed and of those that may not be marketed.

The NED account describes the portion of the NEPA human environment, as defined in 40 Code of Federal Regulations 1508.14 that identifies beneficial and adverse effects on the economy that occur as a result of water resources planning and development. The NED account considers the estimated benefits and costs of the action alternatives. Beneficial effects could include (1) increases in the economic value of the national output of goods and services from a plan, (2) the value of output resulting from external economies caused by a plan, and (3) the value associated with the use of otherwise unemployed or underemployed labor resources. Adverse effects in the NED account would be the opportunity costs of resources used in implementing a plan. Such opportunity costs could include decreases in output in other sectors or employment losses. These effects usually include (1) implementation outlays, (2) associated costs, and (3) other direct costs.

After displaying and comparing the estimated benefits and costs for the Dam Raise Alternative actions, the NED analysis considers the monetary and nonmonetary trade-offs and culminates in identifying the alternative that would reasonably provide the greatest net economic benefits to the nation while protecting the environment. As required by the P&G, the plan with the greatest net NED benefits (NED benefits minus NED costs) is identified as the NED Plan and is usually selected for recommendation to Congress for approval, unless the Secretary of the Interior grants an exception based on overriding considerations and merits of another plan. If another plan is recommended instead of the NED Plan, such as a locally preferred plan, the NED Plan is still presented as a basis of comparison to define the extent of Federal financial interest in the plan recommended for implementation.

2.1.2 Regional Economic Development Account

The RED account examines and displays potential changes in the value of economic activity at the local or regional level for the alternative plans. RED analysis may reflect only a shift in economic productivity from one region to another, not the change in output at the national level required in Federal analysis. Because local and regional economic activity is of great interest to decision-makers and stakeholders, RED analysis may be included to assess changes in regional personal income and employment and can be part of an analysis of trade-offs, as can the EQ account and OSE account described below. Chapter 11 presents the RED account.

2.1.3 Environmental Quality Account

The EQ account examines and displays the effects of alternative plans on significant EQ resources and attributes of the NEPA human environment that is essential to a reasoned choice among alternative plans. Beneficial effects in the EQ account are favorable changes in the ecological, aesthetic, and cultural attributes of natural and cultural resources. Adverse effects in the EQ account are unfavorable changes in the ecological, aesthetic, and cultural attributes of natural and cultural resources. Chapter 12 presents the EQ account.

2.1.4 Other Social Effects Account

The OSE examines and displays the potential changes of alternative plans on other social effects not covered under the NED, RED, and EQ accounts. The effects quantified by OSE include urban and community impacts, such as effects on income or population distribution, fiscal conditions of the

State and local governments, the quality of community life, and similar impacts. OSE includes impacts to life, health, and safety, including the risk of flood, drought, or disaster; the potential loss of life, property, and essential services; and environmental effects not covered under the NED and EQ accounts. Chapter 13 presents the OSE account.

2.2 Other Considerations

Authorization for Federal financial participation in the B.F. Sisk Dam Raise feasibility investigation is established by the Water Infrastructure Improvements for the Nation (WIIN) Act, 2015–2016 (Public Law 114-322). The B.F. Sisk Dam Raise feasibility investigation is a qualified federally owned storage project as defined in Section 4007 (a)(1).

A major constraint on Federal cost-sharing is provided in subsection 4007(b) of the WIIN Act:

> *(2) Federal cost share. - Subject to the requirements of this subsection, the Secretary of the Interior may participate in a federally owned storage project in an amount equal to not more than 50 percent of the total cost of the federally owned storage project.*

The WIIN Act defines the scope for Federal interest in federally owned storage projects as (1) feasible in accordance with Reclamation laws, (2) providing Federal benefits in proportion to the Federal cost-share investment.

The Recommended Plan, B.F. Sisk Dam Raise and Reservoir Expansion, is formulated to provide a range of benefits that include:

1. M&I water supply reliability to SLDMWA by capturing and storing natural inflow and integrating operations of B.F. Sisk Dam with San Luis Reservoir

2. Irrigation water supply to SLDMWA by capturing and storing natural inflow and integrating operations of B.F. Sisk Dam with San Luis Reservoir

3. Enhanced emergency M&I water supply to SLDMWA by increasing the storage capacity

4. Improved transportation safety by modifying multiple locations along SR 152 to prevent inundation of the roadway when the enlarged reservoir is filled to capacity

5. Refuge water supply, through increased reliability and deliveries of Incremental Level 4 water

6. Recreation through increased water surface area at the reservoir

2.3 NED Benefit Evaluation Procedures

In general, the objectives of federally financed water resources projects are to enhance NED, the quality of the environment, the well-being of people in the United States, and regional economic development. NED costs and benefits are the decrease or increase in the value of the national output of goods and services, expressed in dollars. NED figures measure costs and benefits to the nation, rather than to a particular region. This section generally describes the procedures used to identify the alternative that maximizes NED benefits.

As described in the P&G, water resources project plans shall be formulated to alleviate problems and take advantage of opportunities in ways that contribute to NED. The alternative plan with the greatest net NED economic benefit is identified as the NED plan and often has the greatest potential for Federal investment. The NED account includes the following categories of goods and services: (1) M&I water supply; (2) agricultural floodwater, erosion, and sediment reduction; (3) agricultural drainage; (4) agricultural irrigation; (5) urban flood damage reduction; (6) power (hydropower); (7) transportation (inland navigation); (8) transportation (deep draft navigation); (9) recreation; (10) commercial fishing; and (11) other categories of benefits for which procedures are documented in the planning report and are consistent with the general measurement standard in the P&Gs. While multipurpose projects may provide additional types of benefits, these categories coincide with project purposes in which an established Federal financial interest exists. Other categories of benefits may be allowed or may be included in congressional authorization for a specific project.

Environmental benefits are typically included in the EQ account if monetary units cannot be attributed to these benefits. However, in some cases, environmental benefits may be developed as monetary units and may be included in the NED account under "other categories of benefits." For this analysis, refuge water supply benefits are based on the water transfer price and are quantified in the NED account.

NED costs are the opportunity costs of resource use and require consideration of the private and public uses that producers and consumers are making of available resources, now and in the future. For goods and services produced in a competitive market, price is often used to reflect opportunity cost. Consequently, market prices should be used to determine NED costs, provided market prices reflect the full economic value of a resource to society. The market price approach should reflect the interaction of supply and demand. If market prices do not reflect total resource values, surrogate values may be used that approximate opportunity costs based on an equivalent use or condition.

The two primary decision criteria used in a Federal economic analysis are net benefits and the benefit-cost ratio. The net benefit is the difference between the net present value of benefits and costs, and it measures the extent to which benefits to the nation exceed project costs. The benefit-cost ratio is calculated by dividing annual project benefits by annual project costs. The net benefits and costs of alternative plans are compared to identify the plan that reasonably maximizes net benefits, or the NED Plan. The NED Plan is not necessarily the plan with the greatest benefits but rather the plan that maximizes benefits given the cost to the nation. Section 1.10.2 of the P&G requires that the NED Plan be selected unless the Secretary of the Interior grants an exception.

2.4 NED Benefit Evaluation Procedures

Economic valuation methods generally fall into one of two categories: market valuation or nonmarket valuation. Market values refer to conditions for which a price can be observed, such as for human consumptive uses. Nonmarket valuation methods usually apply to a resource for which there is no established market to observe values, such as ecosystem restoration or wildlife conservation. As recommended in the P&G, economic benefits may be determined by one of four valuation approaches:

- Actual or simulated market prices
- Change in net income
- Cost of the most likely alternative
- Administratively established values

In general, the P&G indicate that the value of goods and services should be based on willingness to pay. Revealed and stated preferences are two approaches for measuring willingness to pay for goods and services. Revealed preferences are based on observed behavior that reflects preferences, while stated preferences are based on directly asking individuals to indicate preferences in a hypothetical setting. Demand functions cannot always be estimated for many goods and services due to a lack of observed market data or the ability to obtain survey data. In lieu of demand function estimation, the P&G recommend the use of actual or simulated market prices, where available, because they represent a close approximation of total willingness to pay value. Other generally acceptable approaches under the P&G include cost-based approaches. In addition, benefits transfer, which uses values from previous economic studies (developed with any of the four valuation approaches indicated by the P&G), may be used to estimate willingness to pay provided they are relevant to the study area and output being valued. Each valuation approach indicated by the P&G to estimate NED economic benefits is briefly described below.

2.4.1 Actual or Simulated Market Prices Method

In cases when a demand curve cannot be directly estimated, market prices may be used to estimate society's willingness to pay for a good or service. The P&G provide some limited guidance on the use of market prices when the output of the plan is expected to have a significant effect on market price. Prices should be expressed in real terms (inflation adjusted). Real prices should be adjusted throughout the planning period to account for expected changes in demand and supply conditions. The methods include revealed preferences, which rely on market-based data; contingent valuation, which uses surveys to directly elicit consumer benefits; and benefits transfer. A well-designed contingent valuation survey represents one possible method to measure willingness to pay in a developing market. However, conducting a primary revealed preference or contingent valuation study is often prohibitively time-consuming and expensive.

2.4.2 Change in Net Income Method

When willingness to pay and market price methods cannot be implemented, the P&G allow estimation of the change in net income to producers associated with a project to obtain an estimate of total value. This method is most frequently applied to circumstances when water supply from a project will be used as an input in a production process.

2.4.3 Cost of the Most Likely Alternative Method

In situations where water supply alternatives to a proposed project exist, the cost of the most likely alternative to obtain the same level of output can be used as a proxy measure of NED benefits. When applying this method, it is important to consider alternatives that would realistically be implemented in the absence of the proposed project. This method is generally considered for benefit categories that cannot be estimated through the market-based methods described above. This cost of the most likely alternative method identifies the cost of obtaining or developing the next unit of a resource to meet a particular objective. The net benefit is estimated by subtracting the cost of developing the project under consideration from the cost of the alternative unit. For water supply reliability benefits, for example, the cost of the most likely alternative represents the next unit of water supply the water user would purchase or develop if the project under consideration were not in place. The cost of the alternative that would be reasonably expected to be implemented in the absence of the NED Plan would be the most likely alternative. If the NED Plan provides the same output as the most likely alternative at a lower cost, the net benefit of the NED Plan is equal to the difference in the project costs.

2.4.4 Administratively Established Values Methods

Administratively established values are representative values for specific goods and services that are cooperatively established by the water resources agencies. This method is the least preferred approach to estimating economic benefits identified in the P&G and is only implemented when other options cannot be completed.

2.5 Dam Raise Alternatives Valuation Approaches

This section briefly describes economic analysis parameters. Valuation approaches are presented for M&I water supply reliability, irrigation water supply reliability, emergency water supply, transportation safety, and environmental benefits that include refuge water supply. Additional information on each benefit category and the category's respective valuation approach is provided in the sections that follow.

2.5.1 Economic Analysis Parameters

Economic parameters and future without-project conditions that form the basis for the economic analysis presented in this section. Parameters specific to the Dam Raise Alternative include period of analysis and discount rate, as summarized below.

- **Period of analysis** – The period of analysis is the anticipated period over which project effects are likely to accumulate. The P&G allow for a period of analysis for up to 100 years based on anticipated project life. A 100-year period of analysis is believed appropriate for the Dam Raise Alternative evaluation because of the anticipated longevity of a dam and reservoir project. The economic benefits of the project would begin to accrue the year construction is completed. For consistency purposes, annual benefits are estimated for the year 2030 as an approximation of the benefits that would be obtained from completion of a planning horizon analysis. By many accounts, real water values are rising faster than the current Federal discount rate. As a result, applying the estimated 2030 benefits is a conservative approach.

- **Discount rate** – The discount rate is the rate at which society as a whole is willing to trade off present for future benefits. NED impacts are compared at a common point in time in average annual equivalent terms. This can be accomplished by discounting benefits, capital costs, deferred installation costs, and operation, maintenance, and replacement costs to the beginning of the period of analysis using an established Federal discount rate. For this study, annual benefits are estimated at a 2030 level of development and assumed to be constant over the planning horizon. The Federal discount rate is used estimate interest during construction costs and to amortize costs over the 100-year planning horizon. The Federal discount rate for plan formulation and evaluation is established annually by the Secretary of the Treasury pursuant to 42 United States Code (U.S.C.) 1962d-1. The Federal discount rate of 2.75 percent (fiscal year [FY] 2020) is used in this economic analysis.

2.5.2 NED M&I Water Supply Reliability Benefits

Water supplies from the Dam Raise Alternative would improve water supply reliability to M&I water users in South-of-Delta CVP and SWP service area.

In the absence of the B.F. Sisk Dam Raise Project, SLDMWA will pursue development of alternative water supply sources to satisfy dry-year and water supply reliability needs. SLDMWA have identified various potential sources of future water supplies in their urban water management plans and other documents, including increasing reliance on out-of-basin water transfers, groundwater, conservation, recycling, and desalination. Few opportunities exist to develop new surface water supplies within SLDMWA service area. Groundwater is a largely developed resource and groundwater overdraft are problematic for further development. Desalination of brackish water or seawater has been gaining interest in California, and a group of San Francisco Bay Area (Bay Area) water providers is developing studies toward completion of a 25-million-gallons-per-day (mgd) regional desalination plant that would operate in conjunction with Dam Raise Alternative.

Opportunities to develop new onstream or offstream surface water storage in SLDMWA service area are limited, and out-of-basin water transfers are already relied upon in dry and critical years to meet current demands. In addition, during recent, extended, multiyear droughts in California, the availability of out-of-basin water transfers has been limited. Consequently, the next increment of water supply reliability for SLDMWA would likely be obtained by higher-cost water transfers (either long-term or short-term) and increased reliance on desalination and recycled water projects.

2.5.3 NED Irrigation Water Supply Reliability Benefits

The Dam Raise Alternatives provide opportunities to improve water supply to agricultural producers in the Central Valley through CVP water deliveries from San Luis Reservoir. The Statewide Agricultural Production (SWAP) model is used to evaluate the effects of changes in water supply to agriculture in Central Valley regions. As water supply conditions change within a region as a result of the project alternatives, growers may change the cropping pattern, fallow land, and adjust input use in the production of crops. The SWAP model evaluates these effects; results for each alternative are compared to the results of the NAA to quantify changes in agricultural production, irrigated acreage, water use, and gross farm revenues.

2.5.4 NED Emergency M&I Water Supply Benefits

An additional benefit related to water supply reliability is the creation of emergency storage in an expanded reservoir. These benefits are measured according to the willingness to pay, to avoid water shortages in the event of emergencies that result in infrequent shortages or outages in water supply. This might include supply disruption caused by a levee failure in the Delta that causes water quality to degrade or an earthquake that damages a major distribution or supply pipeline. Estimation of the NED benefits associated with avoiding shortages in emergencies and outages requires careful consideration of (1) the types of emergencies likely to occur, (2) their expected intensity and frequency, and (3) the expected economic costs for each level of intensity and frequency in the without-project and with-project conditions. In this analysis, economic methods applied in previous studies are used to estimate the economic effects of Delta levee failures and to estimate the value of emergency water supplies provided alternatives.

2.5.5 NED Transportation Safety Benefits

The Dam Raise Alternative would improve transportation safety to the surround areas. The modifications at multiple location along SR 152 would provide benefits to public safety by preventing inundation of the roadway when the enlarged reservoir is filled to capacity. The modifications to the Dinosaur Point Boat Launch and Goosehead Point Boat Launch would be made to increase the ramps operating elevation by 10 feet, and the crest of an existing berm developed during construction of the Pacheco Pumping Plant would be raised to protect the plant at high storage levels. The estimated economic benefits are based on a "least-cost" most likely alternative approach.

2.5.6 NED Refuge Water Supply Benefits

The Dam Raise Alternative provides opportunities to improve long-term water supplies and habitat conditions for refuges. Reclamation delivers water to wildlife refuges in the San Joaquin Valley as a requirement of the Central Valley Project Improvement Act (CVPIA), as Level 2 supply (firm supply) and Incremental Level 4 supply (acquired from willing parties). Operations of the Dam Raise Alternative integrated with San Luis Reservoir operations would allow for capture and deliveries of South-of-Delta surplus flows to refuges.

The economic benefits associated with refuge water supplies provided by the Dam Raise Alternatives are estimated using the same water transfer cost model used to estimate M&I and irrigation water supply benefits. This approach is based on the premise that water supplies and operations for refuge purposes would improve water supply reliability and improve refuge conditions with respect to water quantity, timing and location of supplies, and environmental benefits as compared to existing conditions.

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Chapter 3 Safety of Dams Connected Actions

3.1 Introduction

In December 2015, the Reclamation Dam Safety Act was amended to authorize the Secretary to develop additional project benefits in conjunction with SOD actions. The amendment, Section 5B, allows Reclamation to consider alternative modification to existing dams, including raising the dam to address dam safety issues and the need for development of additional project benefits. Reclamation developed Directives and Standards FAC TRMR-95 (D&S) to set forth requirements for developing additional project benefits in conjunction with SOD modifications.

Per the D&S, requirements related to projects involving development of additional project benefits in conjunction with SOD modifications include:

- "….Additional project benefits are necessary and in the interest of the United States and the project…"
- "…proposed development of additional project benefits is consistent with the purposes of the SOD Act."
- Pursuing development of additional project benefits will not adversely affect the timely implementation of appropriate public safety risk reduction activities.
- Sufficient water rights exist, or can be acquired, to utilize additional project capacities resulting from the development of additional project benefits.
- Demonstration by beneficiaries of the economic and environmental feasibility of the project.

SLDMWA sent a letter to Reclamation in May 2019 requesting the development of additional project benefit be considered and incorporated into the planned SOD modifications of B.F. Sisk Dam. Reclamation concurred with the request in August 2019, determining the inclusion of additional project benefits as proposed by SLDMWA should be pursued through feasibility level and construction if determine feasible and economically viable by the non-Federal cost partner. Reclamation acknowledged that the additional project benefits, including water supply and reliability and environmental benefits available from increasing South-of-Delta storage are in the interest of the nation and implementing the two projects as a connected action uniquely provides benefits of public safety from seismic risk reduction and increased water supplies.

3.2 Cost Savings

Implementation of the Dam Raise Alternative in conjunction with the connected SOD modifications results in efficiencies and construction cost savings when compared to a stand-alone project. Cost savings include consolidation of mobilization and demobilization activities at the start and end of the project, reduced startup costs at the quarry and borrow areas in the form of material manufacturing and material transport equipment, reduced overlap in construction activities associated with the intake towers, spillway modification, and roadway rebuilding activities across the dam crest. Additional cost savings would be realized in the reduction of excavation, storage and placement back on the embankment of rip rap materials removed from the embankment shell to access and modify embankment core and filter layers. Mobilization and demobilization costs included for the implementation of the Dam Raise Alternative are specific to work on SR 152. The cost estimate developed by Reclamation for the dam raise at B.F. Sisk Dam relied on a TSC estimate that was prepared in 2015 for a combined SOD Project and Dam Raise Project. This combined estimate included mobilization and demobilization costs as a percentage of the subtotal for the work. The Reclamation estimate presented in Appendix B escalated that 2015 combined cost estimate and applied an assumed fraction to shared activities common to both Safety of Dam actions and the Raise (i.e. embankment raise). The fraction was not applied to the Dam Raise specific activities including modifications to the intake towers, spillway, highway, saddle dikes and recreation facilities. The total cost for those items were included in full under the Dam Raise cost estimates. The fractional split and the shared cost items were identified by the TSC design team that had developed the original combined estimate.

Given this approach, the Dam Raise Alternative's cost estimate presented in Appendix B includes mobilization and demobilization as a fraction of the combined project's total mobilization and demobilization costs. This fractional cost estimate benefits from the savings generated by implementing the projects together and does not include the full cost of mobilization and demobilization activities that would be required for a standalone project.

Chapter 4 M&I Water Supply Benefits

4.1 Introduction

The Dam Raise Alternatives affects water supplies to M&I water users in all water year types. This chapter presents a summary of how these water supply benefits were quantified and monetized, the results of that evaluation, and the potential risks and uncertainties with those results.

4.2 Physical Benefit Quantification

An analysis was performed to value the benefits of improved M&I water supply reliability from the Dam Raise Alternatives under 2030 future conditions for all water year types. The CalSim II model was used to estimate possible increases in water supply reliability for all the Dam Raise Alternatives. Estimated urban water deliveries associated with Dam Raise Alternatives are reported in Table 4-1. Refer to Appendix B of the Feasibility Report for details of the hydrologic model analysis and results.

Table 4-1. Estimated Change in Municipal and Industrial Water Supply Reliability Provided by the Dam Raise Subalternatives (TAF/year)

Year Type[1]	Non-Structural Alternative	Dam Raise Alternative					
		CVP-Only	CVP/SWP Split	Investor-Directed Storage Subalternative A	Investor-Directed Storage Subalternative B	Investor-Directed Storage Subalternative C	Investor-Directed Storage Subalternative D
Wet	0	4.54	1.30	7.46	68.21	3.39	23.78
Above Normal	–1	–0.53	4.55	–0.96	25.07	–3.04	1.11
Below Normal	0	4.61	–21.09	4.35	34.57	2.45	14.40
Dry	0	4.20	–18.16	3.50	19.07	4.11	25.73
Critical	2	–0.92	26.33	–1.47	5.84	–0.70	14.53
Average Annual Additional Water Quantity	0	2.87	–2.27	3.43	35.74	1.82	18.05

Note:
[1] Sacramento Valley 40-30-30 Water Year Hydrologic Classification Index used to define water year types.
Modeling Period 1922–2003. Data results from CalSim modeling.
Key:
Above Normal = Total SWP and CVP deliveries are 82 percent of contracted volume.
Below Normal = Total SWP and CVP deliveries are 65 percent of contracted volume.
Critical = Total SWP and CVP deliveries are 34 percent of contracted volume.
Dry = Total SWP and CVP deliveries are 59 percent of contracted volume.
Wet = Total SWP and CVP deliveries is 89 percent of contracted volume.

4.3 NED Benefit Monetization

4.3.1 Economic Methods

In this analysis, the benefits to M&I water users are measured according to the cost of the most likely alternative water supply that would be pursued in the absence of development of the Dam Raise Alternatives. For water supply reliability benefits, the cost of the most likely alternative represents the next unit of water supply the water user would purchase, or develop, if the project under consideration were not in place. The cost of the most likely alternative assumes that if the preferred alternative is not implemented, the alternative action most likely to take place provides a relevant comparison. The valuation approach relies upon the costs associated with observed market transactions for water.

4.3.2 Economic Analysis

M&I water users rely on the water transfer market to augment existing supplies and avoid shortages. For example, Bay Area water providers purchased more than 40 TAF during 2015 at unit prices between $300 and $700 per acre-foot (AF) (not including conveyance costs). In addition, water market purchases are included as part of the long-term water supply portfolio for many water providers in the region. This analysis relies in part on market prices paid to purchase water on an annual basis from willing sellers. The market prices are reported according to the payments made directly to the sellers. The buyers incur additional costs to convey the water to their M&I service areas. These costs include both conveyance losses, which diminish the volume of water delivered to end users, as well as wheeling and power charges. The conveyance costs are estimated for M&I water users benefiting from the alternatives and added to the estimated market prices to acquire the water to develop an estimate of the full cost associated with additional water supply obtained in the transfer market. Figure 4-1 illustrates the information used to estimate the value of M&I water supplies.

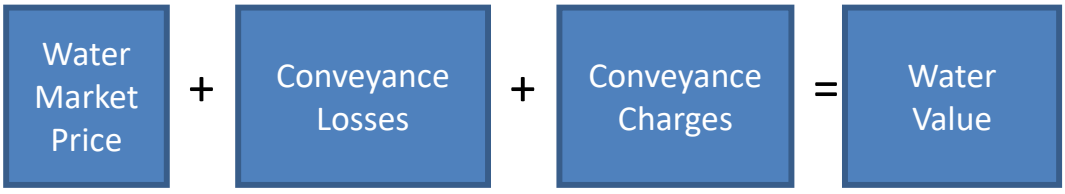


Figure 4-1. General M&I Water Value Estimation Procedures

4.3.2.1 Water Transfers Pricing Database

A database of California water market sales was developed for use in this analysis. Spot market (single year) transactions from 1990 through 2019 were developed using publicly available data from the following sources:

- Water Acquisition Program, Reclamation
- Resources Management Division, Environmental Water Account
- State Water Bank, California Department of Water Resources (DWR)
- OnTap database, DWR
- State Water Board, California Environmental Protection Agency
- Various irrigation districts and water agencies

Information for each transaction was researched and recorded to allow statistical analysis of a variety of factors influencing water trading activity and prices. During the research, transactions occurring from 1990 through 2019 were documented. The transactions were filtered for this analysis according to the following criteria:

- Water sales originating outside the operating region of the SWP facilities were excluded. These regions include the North Coast, North Lahontan, and South Lahontan regions.
- This analysis is intended to estimate spot market prices and trading activity. Thus, multiyear transfers and permanent water entitlement sales were excluded.
- "Within-project" transfers were removed from the analysis because they do not reflect "arm's length transactions."
- Transactions associated with SWP Turnback Pool supplies were excluded because they are associated with rules that limit market participation.
- Purchases of "flood" supplies were excluded.
- Reclaimed and desalination water sales were removed from the analysis.
- Water sales with incomplete or inadequate information were excluded.
- Water sales that involve a buyer's commitment to return a specified volume of water to the seller in future years were excluded.

Following application of the above criteria, 1,030 spot market transfers remained to support the statistical analysis. All prices were adjusted to January 2020 dollars using the Consumer Price Index.[4] Prices and volumes are presented from the seller's perspective and do not include conveyance charges or losses incurred by the buyer.

The regression model theorizes that the price of water traded can be estimated through consideration of the following market factors: water supply, geographic location, municipal demand, buyer type, and state and federal water supply acquisition programs.[5] These factors are described below.

Although federal and state government agencies have recently been more active in recording some information related to water sales or leases, California has few sources that track water transfers between private entities. Most of the recorded transfers involve a federal or state government party either because an agency had to approve the transfer, as is the case when a transfer involves CVP or SWP water, or because the government agency was directly involved in the transfer as a purchaser or a seller. Transfers involving private parties are more difficult to track because the State does not have any reporting requirements.

In California, single-year transfers of water entitlements issued before 1914 are allowed without review by the State Water Resources Control Board (State Water Board) as long as they do not adversely impact the water rights of a third party (CALFED 2000). For entitlements issued after 1914, the buyer and seller can petition the State Water Board for a 1-year temporary transfer.

[4] Consumer Price Index is considered the most appropriate index for adjusting water prices, as it is commonly applied to adjust water prices in long-term agreements.

[5] Additional demand and supply factors were tested in the model but did not result in an improvement in overall explanatory power.

Nonetheless, prices for these transfers are not well documented. As a result, the data for this study were obtained from a mixture of public and private sources.

These sources provided information on the Water Acquisition Program, Environmental Water Account, State Water Bank, and other public water transfers. State Water Bank observations included transfers to the State Water Bank to capture the price the seller receives.

Information on water transfers also was obtained from the January 1990 through December 2010 issues of the *Water Strategist*. The publication, previously called *Water Intelligence Monthly*, assembles information on public and private water transfers. Although not all transfers are recorded in the *Water Strategist*, the publication represents a primary source for water market research. Many of the transfers reported in the *Water Strategist* were independently researched to obtain more specific information and confirm transaction terms. The *Water Strategist* ceased to report on transactions in 2010. In addition, transactions not covered by the *Water Strategist* were researched and verified through direct communication with the transfer participants.

4.3.2.2 Spot Market Transaction Data Summary

This section provides a summary of the water transaction data applied in this analysis. As described above, the data include single-year transactions from 1990 through 2019 of surface water supplies originating in California's SWP and CVP service areas. This section summarizes more recent transfers occurring from 2000 through 2019. During this period, there were 218 transactions for municipal uses, 541 for agricultural uses, and 113 purchases by environmental users. Figure 4-2 shows the number of transactions by end use from 2000 through 2019. As shown, all three end uses are active buyers in most years. However, environmental buyers did not complete any spot market transactions in 2008, 2009, and 2017. For example, in 2008 and 2009, spot market prices were high because of the extended drought, and environmental buyers were unable or unwilling to purchase water during the year. In contrast, 2017 was an extremely wet year that resulted in no demand for environmental spot market purchases.

Annual spot market trading varies widely according to annual CVP and SWP allocations, reservoir storage, and other factors. Figure 4-3 provides the volume of spot market purchases by end use. As shown, spot market purchases spiked in 2001 when nearly 800 TAF was purchased because of dry conditions. Since then, the volume of water traded in the spot market has been lower. In the past 5 years, the total volume traded has averaged approximately 340 TAF. The decline may be due to a number of factors, including conveyance constraints in the Delta, development of alternative water supplies such as long-term agreements, recycling and groundwater banking, and increased plantings of permanent crops both north and south of the Delta that have limited the potential supply to the spot market from crop fallowing.

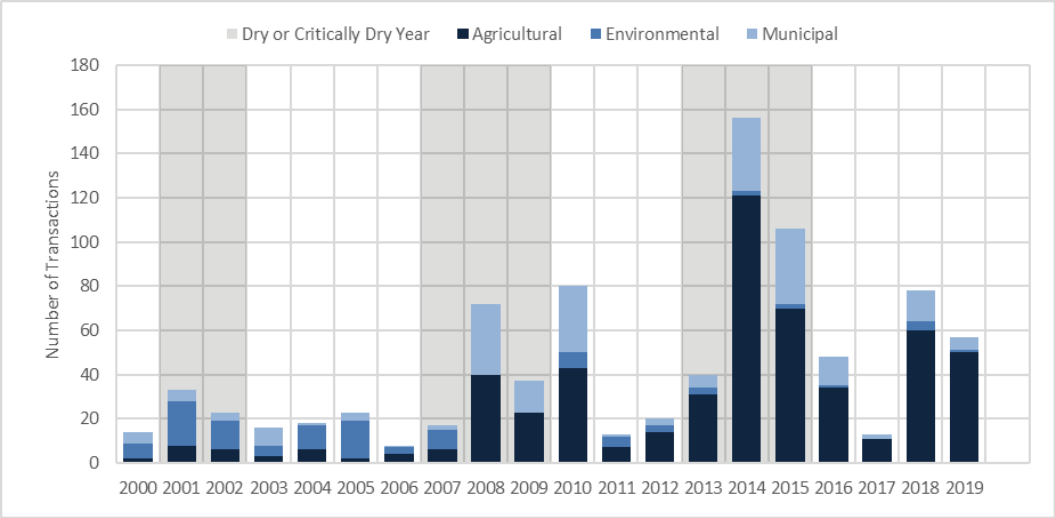


Figure 4-2. Spot Market Transactions by End Use, 2000–2019

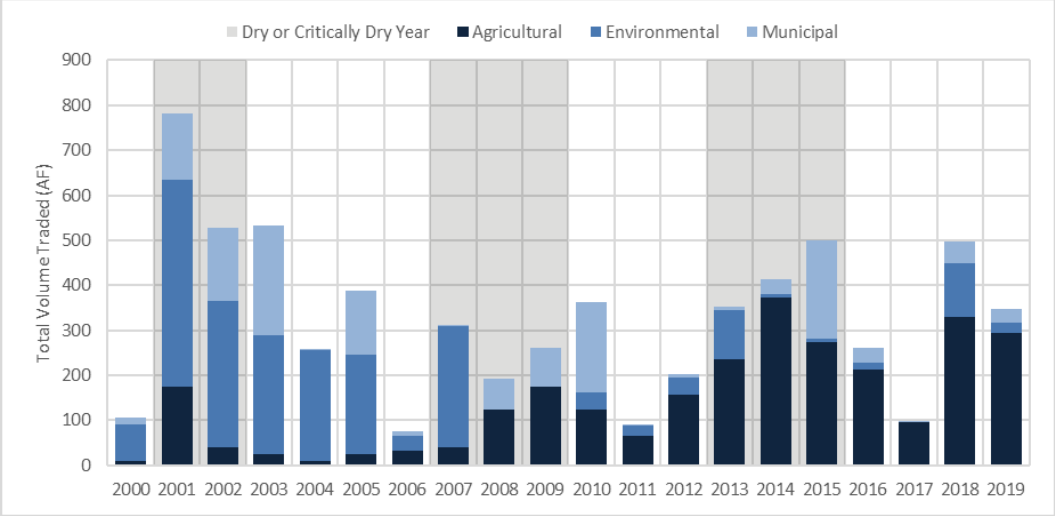


Figure 4-3. Spot Market Volume Purchased by End Use

Figure 4-4 provides average annual spot market prices by end use.[6] As shown, the average annual prices for each end use category tended to move together until the most recent drought when agricultural prices skyrocketed. This is largely due to the proliferation of permanent crop plantings coupled with severe drought conditions. Some municipal buyers have recently developed longer-term and more reliable solutions to meeting water demands and are less reliant on spot market transfers. Environmental buyers are being priced out of the market as prices increase in relation to hardening agricultural demand.

[6] All prices used to develop the chart were not adjusted for inflation.

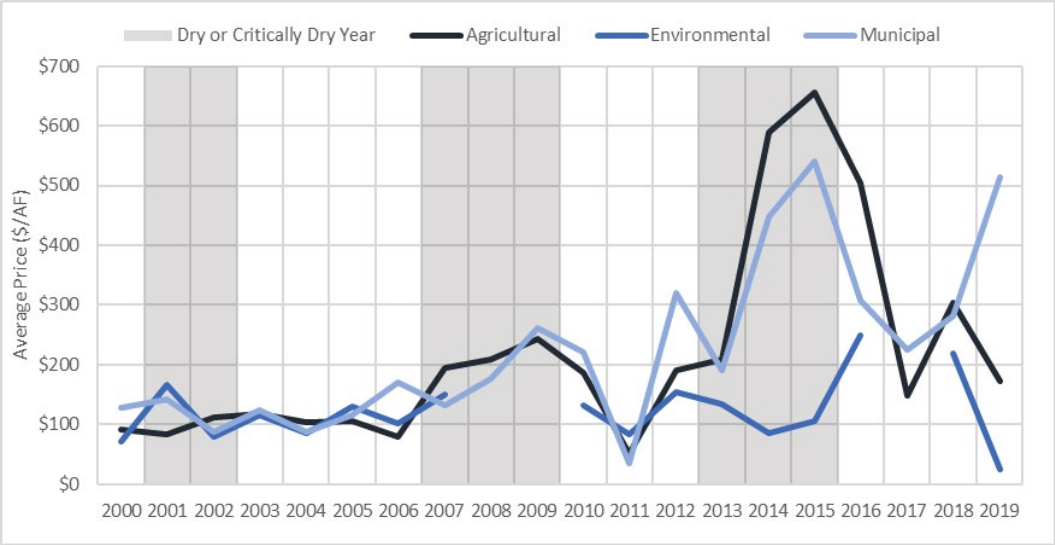


Figure 4-4. Spot Market Average Unit Price by End Use

4.3.2.3 Water Transfers Pricing Regression Model

This study applies a water transfer pricing regression model and builds on a previous analysis completed by Mann and Hatchett (2006) by applying an expanded dataset and considering additional factors that influence water market trading prices. The water transfer pricing model developed in this study uses an ordinary least squares equation to estimate unit prices for spot market water transfers. The coefficients from the models may be used to forecast future water prices North-of-Delta and South-of-Delta.

The regression model theorizes that prices and volume of water traded can be estimated through consideration of the following market factors: water supply, geographic location, real water price escalation, buyer type, and state and federal water supply acquisition programs.[7] These factors are described below.

Water Supply Hydrologic conditions are a primary driver of water transfer market activity and prices. Therefore, it is important to include variables that appropriately capture water supply conditions to describe water trading activity and prices. In this analysis, water supply conditions are measured using the final annual SWP allocation (DWR 2019) and the final CVP allocation (Reclamation 2019).

Geographic Location Water prices and trading activity vary by location according to water year type. Consequently, the origin of the water source for each transaction is used to determine geographic differences in water prices. Water sales applied in the regression analysis were allocated among the hydrologic regions identified by DWR (DWR 2017). Binary variables are used to denote the different geographic regions of buyers and sellers, including a variable identifying spot market transfers that involved through-Delta conveyance.

[7] Additional demand and supply factors were tested in the model but did not result in an improvement in overall explanatory power.

Urban Water Demand Because of the growing urban water demand in the State, water transfer prices are anticipated to increase over time. The model includes population as an independent variable to capture the price impact of increased urban water demands (California Department of Finance 2018). Future water market prices are estimated using forecasted population.

Buyer Type Previous economic analyses of water prices have concluded that the type of buyer (e.g., M&I, agricultural, and environmental) influences water prices. The water pricing equation tests the influence of buyer type on water price and trading. In this analysis, binary variables are used to estimate price differences among environmental, urban, and agricultural buyers. Water authorities and associations occasionally negotiate water transfers on behalf of member units through dry-year water purchase programs. This analysis includes a binary variable for purchases made by buyers' groups under dry-year transfer programs.

Seller Type CVP and SWP agricultural contractors are the most common water sellers in the spot market. To test the influence of the two projects on water prices, a binary variable identifying sellers that are SWP contractors is included in the model.

Drought Water Bank and Environmental Water Account The State has participated in the water market during drought years to facilitate trades. Under this program, DWR establishes a State Water Bank to facilitate water transfers, primarily from North-of-Delta agricultural users to South-of-Delta buyers.

The Environmental Water Account (EWA)[8] acquired water supplies for environmental purposes annually between 2001 and 2007. The implementation of the EWA impacted spot market trading and prices by introducing a large, new demand for water supplies. A dummy variable separating acquisitions by the State Water Bank and the EWA from other buyers is included to test for the price impacts of the programs. A binary variable is included in the model to test the influence of the two programs on prices and trading activity.

4.3.3 Results

The regression model terms are described below. Table 4-2 presents the results of the regression analysis.

[8] The EWA was a program implemented by state and federal agencies that purchased water from willing sellers to benefit fish species in the Sacramento-San Joaquin Delta.

Lnadjprice = scbuyer + nodbuyer + nodtosod + lnpopulation + twppercent + ag + env + dwbewa+ swpseller + swpag + dytp + e

where:

lnadjprice = Natural Logarithm of Price per Acre-Foot, Adjusted to July 2015 Dollars

scbuyer = 1 if South Coast Region Water Buyer (binary)

nodbuyer = 1 if the Buyer is North of the Delta (binary)

nodtosod =1 if North-of-Delta Water Supplier and South-of-Delta Buyer (binary)

lnpopulation = Natural Log of the Population in the Year of the Transfer

twppercent = Percentage of Project Water (SWP and CVP) that was Allocated in the Year the Transfer Occurred

ag = 1 if Agricultural Water End Use (binary)

env =1 if Environmental Water End Use (binary)

dwbewa = 1 if State Water Bank/Dry Year Water Acquisitions or the Environmental Water Account Acquisitions (binary)

swpseller = 1 if the Seller was a State Water Project Contractor (binary)

swpag = 1 if the Buyer was an Agricultural State Water Project Contractor (binary)

dytp = 1 if State Water Contractors, Tehama-Colusa Canal Authority, or San Luis & Delta-Mendota Water Authority dry-year transfer program (binary)

e = Error Term

Table 4-2. Regression Model Results

Dependent Variables	Observations	Parameters	RMSE	R-Squared	F-Statistic	P-Value (P > F)
lnadjprice	1030	11	0.63	0.53	106.22	0
Independent Variables	**Coefficient**	**Standard Error**	**t-Statistic**	**P-Value (P > |t|)**	**95-percent Confidence Interval**	
scbuyer	0.19	0.09	2.07	0.04	0.01	0.36
nodbuyer	−0.36	0.06	−5.90	0.00	−0.48	−0.24
nodtosod	−0.10	0.07	−1.43	0.15	−0.23	0.04
lnpopulation	4.13	0.29	14.46	0.00	3.57	4.70
twppercent	−2.08	0.11	−19.71	0.00	−2.29	−1.87
ag	−0.27	0.06	−4.26	0.00	−0.39	−0.14
env	−0.20	0.08	−2.56	0.01	−0.36	−0.05
dwbewa	0.28	0.09	3.22	0.00	0.11	0.45
swpseller	0.25	0.07	3.51	0.00	0.11	0.38
swpag	0.37	0.07	5.71	0.00	0.25	0.50
dytp	0.24	0.07	3.58	0.00	0.11	0.37
constant	−65.39	5.00	−13.08	0.00	−75.19	−55.58

Note:
General: Equation and variables are defined above.
Key:
RMSE = root-mean-square error

The variable twppercent is a measure of annual water availability. The amount of water available was calculated using the SWP and CVP maximum contract amounts and the percentage of the maximum contract that was delivered each year to the different contractors. The SWP and CVP allocations decrease during drought conditions. Regulatory actions such as the Delta pumping constraints could further impact water deliveries. The statistical relationship between lnadjprice and twppercent is attributable to increased demand for additional water supplies under the hydrologic and regulatory scarcity conditions that drive reduced water allocations. As an example, the coefficient value of −2.08 on the twppercent variable indicates that water transfer prices increase by approximately 52 percent in response to a decrease in percentage of total Project water allocation from 50 percent to 30 percent, all else held equal. The coefficient value on the variable lnpopulation indicates that as population grew from 29.56 million in 1990 to 40.14 million in 2019, water transfer prices increased by a factor of 3.6. The binary variables in the price equation describe conditions that influence prices but are qualitative in nature.

The coefficients for env and ag represent the influence that end-water use has on price. When these variables are zero, the model estimates prices to urban water users. Environmental water users and non-SWP agricultural water users generally paid less for water than urban users, as indicated by the negative coefficients. The results show environmental buyers have paid 20 percent less per acre-foot than urban buyers, and non-SWP agricultural buyers paid 27 percent less per acre-foot than urban buyers, with all else being equal. The variable swpag is a binary variable that captures the premium paid by agricultural SWP contractors compared to other buyers, with all else being equal. Agricultural SWP contractors have relatively unreliable surface water supplies and limited groundwater resources, causing them to pay higher prices on the spot market. The coefficient on swpag indicates these buyers pay approximately 37 percent more on average compared to other buyers.

The variable dwbewa is an indicator that the lease was either a State water lease through the Drought Water Bank of 1991, 1992, 1994, and 2009 or a lease through the EWA program. The binary variable is used to account for the price premium paid by the bank and the EWA program. The coefficient value indicates that water leased through the Drought Water Bank, and water that was purchased through the EWA program, was priced 28 percent higher than other transactions, with all else being equal. The variable dytp is an indicator that the transfer occurred as part of a dry-year transfer program in which water authorities or water associations negotiate transfers on behalf of member units. The coefficient value indicates that water transferred under a dry-year transfer program is priced 24 percent higher than other transfers, with all else being equal.

The variable nodbuyer is a binary variable measuring the difference in spot market prices between water originating and remaining North-of-Delta and water that was purchased for use South-of-Delta. Sales from North-of-Delta suppliers to North-of-Delta buyers were 36 percent lower than sales where water was purchased for use South-of-Delta, suggesting there is a higher value for water South-of-Delta. According to the coefficient estimated for scbuyer, water transactions involving buyers in the South Coast region were priced 19 percent higher than acquisitions by buyers in other regions, with all else being equal. Premium prices paid by South Coast buyers result from strong competition for water supplies in the region, and the relatively high-value water uses in the area. The variable swpseller is a binary variable measuring the premium paid for purchasing SWP water. The coefficient on swpseller indicates SWP sellers receive a premium of approximately 25 percent over CVP and non-project sellers, on average.

4.3.3.1 Future Water Market Prices

In this section, regression results are used to project water prices to 2030 for M&I buyers. For Bay Area and South Coast buyers, it is assumed that all water is purchased from sellers located both North-of-Delta and South-of-Delta using the volume-weighted proportions by water year type from the transactions include in the regression model.[9]

Future water market prices are estimated using the average value for swpseller (0.25), the average value of twppercent for each water year type, and the estimated value for lnpopulation. Table 4-3 provides the applied values for twppercent for each water year type. The values are estimated using Project water allocations from 2000 through 2019 as shown in Table 4-3. CalSim modeling indicates that future allocations will decline for each year type. To be conservative, this analysis holds future allocations constant.

Table 4-3. Value of TWPPERCENT by Water Year Type

Year Type[1]	All Years
Wet	88.8%
Above Normal	73.5%
Below Normal	62.7%
Dry	66.0%
Critical	43.6%

Note:
[1] Water year types based on the Sacramento Valley water year hydrologic classification. The values are estimated using Project water allocations from 2000–2019.

The population projection for the State of California was obtained from the California Department of Finance. Table 4-4 provides the estimated population for each year.

Table 4-4. Estimated California Population (millions)

	2020	2030
Population	40.47	43.94

Source: California Department of Finance 2018.

Table 4-5 provides estimated 2030 water market prices for Bay Area M&I buyers. Note that the estimated unit prices are somewhat higher during below-normal years than dry years owing to the lower TWPPERCENT value in below-normal years.

[9] From 1990 through 2019, North-of-Delta to South-of-Delta transfers comprised 4 percent of the total South-of-Delta purchases in wet years, 28 percent in above-normal years, 43 percent in below-normal years, 15 percent in dry years, and 43 percent in critical years.

Table 4-5. Estimated M&I Water Prices for 2030 ($/AF/yr)

Year Type Type[1]	SJ/Bay	South Coast	North-of-Delta
Wet	$257	$310	$180
Above Normal	$346	$417	$242
Below Normal	$427	$514	$298
Dry	$409	$493	$286
Critical	$634	$764	$443

Notes:
January 2020 price level.
[1] Sacramento Valley Water Year Hydrologic Classification Index used to define water year types.
Key:
AF/yr = acre-feet per year
Bay = San Francisco Bay
SBA = South Bay Aqueduct
SJ = San Jose

4.3.3.2 Estimated Conveyance Losses and Charges

Water delivery results from the CalSim II model incorporate conveyance losses. Consequently, it is necessary to estimate conveyance losses to adjust estimated water market prices according to the geographic source of the supply. For example, an estimated delivery from CalSim II of 1,000 AF to an M&I user may require the purchase of 1,111 AF at the source, if 10-percent conveyance losses apply. Conveyance losses for water supplies originating South-of-Delta are assumed to be 10 percent and 25 percent for water supply originating North-of-Delta and conveyed through the Delta to South-of-Delta M&I buyers. No conveyance losses are assigned to North-of-Delta M&I water supplies.

The power costs associated with conveying the water purchase on the spot market to the end user is added to the estimated water purchase price described above. The cost to convey water to M&I users is estimated according to the cost to move water through SWP facilities. Conveyance cost varies by location and user type. This analysis applies the forecast market power price (Pinnacle 2012) to estimate variable water conveyance costs. Fixed water conveyance charges (e.g., Delta water charge, transportation charge capital cost component) incurred by water users are not included. This section summarizes the estimated water conveyance costs by buyer location.

The amount of power required to convey water is based on DWR's estimates of power use per acre-foot for SWP power facilities (DWR 2012). A pumping plant facility is selected as a reference delivery point for each region. For example, the South Bay Pumping Plant is chosen as the facility used for buyers moving water to the South Bay Aqueduct. Table 4-6 lists the cumulative power demand and the power costs to convey water using through the South Bay Aqueduct using the forecast 2030 power price of $0.067/kWh.

Table 4-6. Estimated Power Costs by Region

Contractor Region	Pumping Plant	Cumulative Power Demand (kWh/acre-foot)	Estimated Power Cost ($/acre-foot)
South Bay Aqueduct	South Bay and Del Valle	1,165	$78
Mojave Division	Pearblossom	4.549	$304
MWD	Greenspot	5,420	$362
North Bay Aqueduct	Cordelia-Napa	786	$53
San Luis Division	Dos Amigos	434	$29
South San Joaquin Division	Teerink	971	$65
West Branch	Oso	4,126	$276

Sources: California Department of Water Resources, Management of the California State Water Project: Bulletin 132-18. Appendix B Table 7. Kilowatt-Hour Per Acre-Foot Factors for Allocating Off-Aqueduct Power Facility Costs, 2018b.

Note: January 2020 price level.

Key:

kWh= kilowatt hour

SWP= State Water Project

4.3.3.3 Market Price for Water to Municipal and Industrial Purposes

Combined water market prices, carriage losses, and conveyance costs for SWP contractors are provided in Table 4-7. The values reflect the total cost of water (water price + conveyance losses + wheeling charges) by year type in 2030. These values are applied to water deliveries by year type to estimate total M&I water supply reliability benefits.

Table 4-7. Estimated Adjusted M&I Water Prices for 2030 ($/AF/yr)

Year Type Type[1]	SJ/Bay	South Coast	North-of-Delta
Wet	$308	$367	$180
Above Normal	$422	$505	$242
Below Normal	$530	$635	$298
Dry	$486	$582	$286
Critical	$779	$934	$443

Notes:

January 2020 price level.

[1] Sacramento Valley Water Year Hydrologic Classification Index used to define water year types.

Key:

AF/yr = acre-feet per year

SBA = South Bay Aqueduct

4.3.4 M&I Water Supply Reliability Benefits

Table 4-8 presents the estimated annual M&I water supply reliability benefits for each alternative.

Table 4-8. Average Annual M&I Water Supply Economic Benefits Provided by the Dam Raise Subalternatives

Alternative	NED M&I Water Supply Reliability (AF/year)	NED M&I Water Supply Annual Benefits (million $)[1,2]
Non-Structural	0	$0.7
CVP-Only	2,870	$1.5
CVP/SWP Split Storage	–2,270	-$1.8
Investor-Directed Storage Subalternative A	3,430	$1.6
Investor-Directed Storage Subalternative B	35,740	$16.0
Investor-Directed Storage Subalternative C	1,820	$1.1
Investor-Directed Storage Subalternative D	18,050	$9.4

Note: January 2020 price levels.

[1] NED irrigation water supply reliability benefits are based on average water year type hydrologic conditions and calculated as the weighted average of five water year types and values in Table 4-1. Sacramento Valley 40-30-30 Water Year Hydrologic Classification Index used to define water year types.

[2] M&I water supply benefits have been adjusted for the structural alternatives to account for a water supply emergency's limits on the availability of this supply.

Key:

AF = acre-feet

NED = National Economic Development

CVP = Central Valley Project

SWP = State Water Project

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Chapter 5 NED Irrigation Water Supply Reliability Benefits

5.1 Introduction

The Dam Raise Alternatives affect irrigation water supplies to agricultural water users in all water year types. This chapter presents a summary of how irrigation water supply benefits were quantified and monetized, the results of that evaluation, and the potential risks and uncertainties with those results.

5.2 Physical Benefit Quantification

The incremental change in annual irrigation water supply under the alternatives relative to the No Project/No Action Alternative is the basis for irrigation water supply reliability benefits. The scenarios evaluated for the feasibility report include Future No Action Alternative (NAA), and eight policy alternatives. The CalSim modeling technical appendix (Appendix B) provides additional details regarding the development of the alternatives and the water supply delivered to agricultural users under each alternative.

The Statewide Agricultural Production (SWAP) model is used to evaluate the effects of changes in water supply to agriculture in Central Valley regions. As water supply conditions change within a region as a result of the project alternatives, growers may change the cropping pattern, fallow land, and adjust input use in the production of crops. The SWAP model evaluates these effects; results for each alternative are compared to the results of the NAA to quantify changes in agricultural production, irrigated acreage, water use, and gross farm revenues.

5.3 NED Benefit Monetization

5.3.1 Economic Method

5.3.1.1 SWAP Overview

The SWAP model is a regional agricultural production and economic optimization model that simulates the decisions of farmers in California's Central Valley. It is the most current in a series of California agricultural production models, originally developed by researchers at the University of California at Davis in collaboration with the California Department of Water Resources (DWR) with additional funding provided by the United States Bureau of Reclamation (Reclamation).

Table 5-1. Estimated Change in Annual Average Irrigation Water Supply Provided by Dam Raise Subalternatives (TAF/year)

Year Type[1]	Non-Structural Alternative	Dam Raise Alternative					
		CVP-Only	CVP/SWP Split	Investor-Directed Storage Subalternative A	Investor-Directed Storage Subalternative B	Investor-Directed Storage Subalternative C	Investor-Directed Storage Subalternative D
Wet	–78	77.55	24.03	63.06	14.45	25.71	9.62
Above Normal	–40	22.08	15.02	17.66	2.98	7.28	1.62
Below Normal	–47	38.27	18.76	30.68	4.87	9.76	2.34
Dry	–7	4.89	7.86	2.86	–3.27	11.27	–2.27
Critical	0	1.68	7.99	0.89	–1.79	7.52	–0.94
Average Annual Additional Water Quantity[2]	–39	34.58	15.62	27.65	4.65	14.46	2.93

Note:
[1] Sacramento Valley 40-30-30 Water Year Hydrologic Classification Index used to define water year types.
[2] NED irrigation water supply reliability benefits are based on average water year type hydrologic conditions and calculated as the weighted average of five water year types and values.

The SWAP model was peer-reviewed (Howitt et al. 2012) and its predecessor, the Central Valley Production Model (CVPM), was used for numerous policy analyses and impact studies over the past 20 years, including the impacts of the Central Valley Project Improvement Act (Reclamation and United States Fish and Wildlife Service 1999), Upper San Joaquin Basin Storage Investigation (Reclamation 2008), the State Water Project (SWP) drought impact analysis (Howitt et al. 2009a), and the economic implications of Delta conveyance options (Lund et al. 2007).

5.3.1.2 SWAP Model Mechanics

The SWAP model data coverage is most detailed in the Central Valley. The model assumes that farmers maximize profit subject to resource, technical, and market constraints. Farmers sell and buy in competitive markets, and no one farmer can affect or control the price of any commodity. The model selects those crops, water supplies, and other inputs that maximize profit subject to constraints on water and land, and subject to economic conditions regarding prices, yields, and costs. The competitive market is simulated by maximizing the sum of consumer and producer surplus subject to the following characteristics of production, market conditions, and available resources:

- Constant Elasticity of Substitution (CES) production functions for every crop in every region. CES has four inputs: land; labor; water; and other supplies. CES production functions allow for limited substitution between inputs, which allows the model to estimate both total input use and input use intensity. Parameters are calculated using a combination of prior information and the method of Positive Mathematical Programming (PMP) (Howitt 1995).

- Groundwater pumping cost including depth to groundwater.

- California state-wide commodity demand functions.

- Resource constraints on land, labor, water, and other input availability by region.

The SWAP model incorporates Project water supplies (SWP and CVP), other local water supplies, and groundwater. As conditions change within a SWAP region (e.g., the quantity of available Project water supply increases or the cost of groundwater pumping increases), the model optimizes production by adjusting the crop mix, water sources and quantities used, and other inputs. It also fallows land when that appears to be the most cost-effective response to resource conditions.

The SWAP model is used to compare the long-term response of agriculture to potential changes in SWP and CVP irrigation water delivery, other surface or groundwater conditions, or other economic values or restrictions.

Results from Reclamation's and DWR's operations planning model, CalSim II, are used as inputs into SWAP through a standardized data linkage tool. The CalSim II data file for each alternative includes nine water year types of which five were included in the SWAP model inputs. The water year types include: wet, above-normal, below-normal, dry, and critical conditions. For each alternative and water year type, the CalSim II model provides the SWAP model with CVP and SWP farm-gate irrigation water deliveries for each SWAP model region.

5.3.1.3 SWAP Model Theory

The SWAP model self-calibrates using a three-step procedure based on PMP (Howitt 1995) and the assumption that farmers behave as profit-maximizing agents. In a traditional optimization model, profit-maximizing farmers would simply allocate all land, up until resource constraints become binding, to the most valuable crop(s). In other words, a traditional model would have a tendency for overspecialization in production activities relative to what is observed empirically. The method of PMP incorporates information on the marginal production conditions that farmers face, allowing the model to exactly replicate a base year of observed input use and output. Marginal conditions may include inter-temporal effects of crop rotation, proximity to processing facilities, management skills, farm-level effects such as risk and input smoothing, and heterogeneity in soil and other physical capital. In the SWAP model, PMP is used to translate these unobservable marginal conditions, in addition to observed average conditions, into a cost function.

Unobserved marginal production conditions are incorporated into the SWAP model through increasing land costs. Additional land brought into production is of lower quality and, as such, requires higher production costs, captured with an exponential "PMP" cost function. The PMP cost function is both region and crop specific, reflecting differences in production across crops and heterogeneity across regions. Functions are calibrated using information from acreage response elasticities and shadow values of calibration and resource constraints. The information is incorporated in such a way that the average cost data reflected in standard crop budgets (known data) are unaffected.

PMP is fundamentally a three-step procedure for model calibration that assumes farmers optimize input use for maximization of profits. In the first step, a linear profit-maximization program is solved. In addition to basic resource availability and non-negativity constraints, a set of calibration constraints is added to restrict land use to observed values. In the second step, the dual (shadow) values from the calibration and resource constraints are used to derive the parameters for the exponential PMP cost function and CES production function. In the third step, the calibrated CES and PMP cost function are combined into a full profit maximization program. The exponential PMP cost function captures the marginal decisions of farmers through the increasing cost of bringing additional land into production (e.g., through decreasing quality). Other input costs (supplies, land, and labor) enter linearly into the objective function in both the first and third step.

The SWAP model, and calibration by PMP, is a complicated process, thus sequential testing is very useful for model validation, diagnosing problems, and debugging the model. At each stage in the SWAP model there is a corresponding model check. In other words, the calibration procedure has particular emphasis on the sequential calibration process and a parallel set of diagnostic tests to check model performance. Diagnostic tests are discussed in Howitt et al. (2012).

5.3.1.4 Constant Elasticity of Substitution Production Function

Crop production in the SWAP model is represented by a CES production function for each region and crop. In general, a production function is a mathematical specification used to capture the relationship between inputs and output. For example, land, labor, water, and other inputs are combined to produce output of any crop. CES production functions in the SWAP model are specific to each region, thus regional input use is combined to determine regional production for each crop. The calibration routine in SWAP guarantees that both input use and output exactly match a base year of observed data.

The generalized CES production function allows for limited substitution among inputs (Beattie and Taylor 1985). This is consistent with observed farmer production practices (farmers substitute among inputs to achieve the same level of production). For example, farmers may substitute labor for chemicals by reducing herbicide application and increasing manual weed control. Or, farmers can substitute labor for water by managing an existing irrigation system more intensively to increase efficiency. The CES function used in the SWAP model is non-nested, thus the elasticity of substitution is the same between all inputs.

5.3.1.5 Crop Demand Functions

The SWAP model is specified with downward-sloping California state-wide demand functions. The demand curve represents willingness-to-pay for a given level of crop production. All else constant, as production of a crop increases the price of that crop is expected to fall. The extent of the price decrease depends on the elasticity of demand or, equivalently, the price flexibility. The latter refers to the percentage change in crop price due to a percent change in production. The SWAP model is specified with linear demand functions.

Demand Shifts Crop demands are expected to shift in the future due to increased population, higher real incomes, changes in tastes and preferences, and related factors. The key changes that are included in the analysis of alternatives are population and real income. An increase in real income is expected to increase demand for agricultural products. Similarly, population increases are expected to increase crop demand. Changes in consumer tastes and preferences will have an indeterminate effect on demand and are not included in this analysis.

Increases in demand for crops produced in California may be partially offset by other production regions depending on changing export market conditions. For example, today California is the dominant producer of almonds but this may change if other regions increase production. Thus, an increase in almond demand could be partially met by other regions. However, additional demand growth from markets like China may offset this effect. The net effect is indeterminate. In the absence of data or studies demonstrating which effect would dominate, California export share is assumed to remain constant for all crops in the future. This assumption is consistent with peer-reviewed publications for the California Energy Commission (CEC) and the academic journal *Climatic Change,* in addition to the 2009 DWR Water Plan (Howitt et al. 2009a, 2009b).

Crop demands are linear in the SWAP model and population and real income changes induce a parallel shift in demand. Demand shifts are included for all of the alternative scenarios evaluated, including the No Project/No Action Alternative. Consequently, comparisons of NAA to each action alternative relates identical future market conditions.

For purposes of the demand shift analysis, a distinction is made between two types of crops grown in California, California specific crops and global commodities. Global commodity crops include grain rice and corn.[10] All other crop groups are classified as California crops. Global commodity crops are those for which there is no separate demand for California's production. For these crops, California faces a perfectly elastic demand, and is thus a price taker. For California specific crops,

[10] Rice demand is very elastic, but not perfectly elastic. For purposes of the demand shifting analysis, it is assumed to be perfectly elastic.

California faces a downward sloping demand for a market that is driven by conditions in the United States and international export markets.

5.3.1.6 SWAP Model Data

The SWAP model requires a wide range of data to simulate the supply and demand for statewide agricultural production. The necessary data are not available from a single source and are instead compiled from various publicly available sources, including state and federal agencies, academic publications, and water district reports. A SWAP model data update was completed between 2009 and 2011 under contract with Reclamation. The model data and code was updated under contract with the California Department of Food and Agriculture. The model update completed in 2011 is known as SWAP version 6.1 and this version was used for analysis of the alternatives. Importantly, SWAP version 6.1 is used because it includes a National Economic Development (NED) post-processing routine which ensures benefits are consistent with federal guidelines.

5.3.1.7 SWAP Regions and Crop Definitions

The SWAP model includes 27 base regions in the Central Valley. For this analysis, a region representing the San Felipe Unit was added to account for changes in CVP water deliveries from San Luis Reservoir. All regions are included in the analysis of the project alternatives.

Table 5-2. summarizes some of the major water users in each of the regions.

Table 5-2. SWAP Model Region Summary

Region	Major Surface Water Users
1	CVP Users: Anderson Cottonwood Irrigation District (ID), Clear Creek Community Services District, Bella Vista Water District (WD), and miscellaneous Sacramento River water users
2	CVP Users: Corning Canal, Kirkwood WD, Tehama, and miscellaneous Sacramento River water users
3a	CVP Users: Glenn Colusa ID, Provident ID, Princeton-Codora ID, Maxwell ID, and Colusa Basin Drain Municipal Water Company (MWC)
3b	Tehama Colusa Canal Service Area. CVP Users: Orland-Artois WD and Westside WD
4	CVP Users: Princeton-Codora-Glenn ID, Colusa Irrigation Company, and miscellaneous Sacramento River water users
5	Most Feather River Region riparian and appropriative users
6	Yolo and Solano Counties. CVP Users: Conaway Ranch and miscellaneous Sacramento River water users
7	Sacramento County north of American River. CVP Users: Natomas Central MWC, miscellaneous Sacramento River water users, Pleasant Grove-Verona MWC, and Placer County Water Agency
8	Sacramento County south of American River and northern San Joaquin County
9	Direct diverters within the Delta region. CVP Users: Banta Carbona ID, West Side WD, and Plainview
10	Delta Mendota service area. CVP Users: Panoche WD, Pacheco WD, Del Puerto WD, Hospital WD, Sunflower WD, and San Joaquin River Exchange Contractors
11	Stanislaus River water rights: Modesto ID, Oakdale ID, and South San Joaquin ID
12	Turlock ID

Region	Major Surface Water Users
13	Merced ID. CVP Users: Madera ID, Chowchilla WD, and Gravely Ford
14a	CVP Users: Westlands WD
14b	Southwest corner of Kings County
15a	Tulare Lake Bed. CVP Users: Fresno Slough WD, James ID, Tranquility ID, Traction Ranch, Laguna WD, and Reclamation District 1606
15b	Dudley Ridge WD and Devils Den (Castaic Lake)
16	Eastern Fresno County. CVP Users: Friant-Kern Canal, Fresno ID, Garfield WD, and International WD
17	CVP Users: Friant-Kern Canal, Hills Valley ID, Tri-Valley WD, and Orange Cove
18	CVP Users: Friant-Kern Canal, County of Fresno, Lower Tule River ID, Pixley ID, and Tulare ID
19a	SWP Service Area, including Belridge Water Storage District (WSD), Berrenda Mesa WD
19b	SWP Service Area, including Semitropic WSD
20	CVP Users: Friant-Kern Canal, Shafter-Wasco, and South San Joaquin ID
21a	CVP Users: Cross Valley Canal and Friant-Kern Canal
21b	Arvin Edison WD
21c	SWP service area: Wheeler Ridge-Maricopa WSD
22	San Felipe Unit

Note: List above does not include all water users. It is intended only to indicate the major users or categories of users. All regions in the Central Valley also include private groundwater pumpers.

Crops are aggregated into 20 crop groups which are the same across all regions. Each crop group represents a number of individual crops, but many are dominated by a single crop. Irrigated acres represent acreage of all crops within the group, production costs and returns are represented by a single proxy crop for each group. The current 20 crop groups were defined in collaboration with DWR and were last updated in 2011. Crop group definitions and the corresponding proxy crop are shown in Table 5-3.

Table 5-3. SWAP Model Crop Groups

SWAP Definition	Proxy Crop	Other Crops
Almonds and Pistachios	Almonds	Pistachios
Alfalfa	Alfalfa Hay	
Corn	Grain Corn	Corn Silage
Cotton	Pima Cotton	Upland Cotton
Cucurbits	Summer Squash	Melons, Cucumbers, Pumpkins
Dry Beans	Dry Beans	Lima Beans
Fresh Tomatoes	Fresh Tomatoes	
Grain	Wheat	Oats, Sorghum, Barley
Onions and Garlic	Dry Onions	Fresh Onions, Garlic
Other Deciduous	Walnuts	Peaches, Plums, Apples
Other Field	Sudan Grass Hay	Other Silage

SWAP Definition	Proxy Crop	Other Crops
Other Truck	Broccoli	Carrots, Peppers, Lettuce, Other Vegetables
Pasture	Irrigated Pasture	
Potatoes	White Potatoes	
Processing Tomatoes	Processing Tomatoes	
Rice	Rice	
Safflower	Safflower	
Sugar Beet	Sugar Beets	
Subtropical	Oranges	Lemons, Miscellaneous Citrus, Olives
Vine	Wine Grapes	Table Grapes, Raisins

5.3.1.8 Crop Prices and Yields

The SWAP model is designed to calibrate to the actual conditions growers faced in the calibration year. Growers make current planting decisions based on expectations of prices. The SWAP model does not attempt to model how growers form their price expectations; as an approximation, SWAP uses an average of county-level crop prices. Data for county-level crop prices are obtained from the respective County Agricultural Commissioners' annual crop reports.

5.3.1.9 Crop Yields

Crop yields for each crop group in the SWAP model correspond to the proxy crops listed in Table 2 and are based on best management practices. The corresponding costs of production, discussed in Section 3.4, are based on cost studies that also reflect best management practices. Thus, crop yields in SWAP are slightly higher than those estimated by calculating county averages but are more consistent with the production costs. Crop yield data are compiled from the University of California Cooperative Extension (UCCE) production cost budgets prepared by University of California at Davis (UC Davis) and Extension Researchers. Yields for each region are based on the most recent proxy crop cost study available in the closest region. For example, if a cost study is not available for a particular crop in the Sacramento Valley, the North San Joaquin Valley study may be used.

5.3.1.10 Crop Cost of Production Budgets

Land, labor, and other supply costs of production are obtained from the same UCCE crop budgets used to estimate crop yields. Each UCCE budget uses interest rates for capital recovery and interest on operating capital specific to the year of the study. These range from 4 percent to over 8 percent and, as such, require adjustment to a common base year interest rate. A common rate of 6 percent is used for all data.

Land costs are derived from the respective UCCE crop budget and include land-related cash overhead plus rent and land capital recovery costs. Where appropriate, interest rates are adjusted as described above.

The labor cost category in the SWAP model includes both machine and non-machine labor. Labor wages per hour differ for machine and non-machine labor and, as such, are reported separately in the UCCE budgets. Both machine and non-machine labor costs include overhead to the farmer of federal and state payroll taxes, workers' compensation, and a small percentage for other benefits which varies by budget. Additionally, a percentage premium (typically 20 percent) is added to

machine labor costs to account for equipment set-up, moving, maintenance, breaks, and field repair. The sum of these components, reported on a per acre basis, is used as input data into the SWAP model.

The supply cost category in the SWAP model includes all inputs not explicitly included in the other three input categories (land, labor, and water), including fertilizers, herbicides, insecticide, fungicide, rodenticide, seed, fuel, and custom costs. Additionally, machinery, establishment costs, buildings, and irrigation system capital recovery costs are included. Each subcategory of supply costs is broken down in detail in the respective crop budget. For example, safflower in the Sacramento Valley requires pre-plant Nitrogen as aqua ammonia at 100 pounds per acre in fertilizer costs. Application of Roundup in February and Treflan in March account for herbicide costs. The sum of these individual components, on a per acre basis, is used as base supply input cost data in the SWAP model.

5.3.1.11 Surface and Groundwater

The SWAP model includes five types of surface water: SWP delivery; three categories of CVP delivery; and local surface water delivery or direct diversion. The three categories of CVP deliveries are: water service contract including Friant Class 1 (CVP1), Friant Class 2 (CL2), and water rights settlement and exchange delivery.[11] Water supply data in the calibration year for SWAP version 6.1 are derived from various sources, described below. CVP and SWP deliveries for the alternatives are from the CalSim II model.

The volume of deliveries for each water source is estimated using data from DWR, Reclamation, and water district reports. CVP water deliveries were derived from Reclamation operations data. Contract deliveries were obtained from Reclamation; the difference between total and contract deliveries indicates deliveries for water rights settlements. SWP water deliveries are obtained from DWR Bulletin 132 (DWR 2013a). Kern County Water Agency provides additional details on SWP deliveries to member agencies by region. Local surface water deliveries were obtained from individual district records and reports, DWR water balance estimates prepared for the California Water Plan Update (DWR 2009), and, where needed, data from the CVPM model. CVPM data were, in turn, provided by the Central Valley Ground-Surface Water Model.

A key source of irrigation water, and often the costliest, is groundwater pumping. The groundwater pumping capacity estimates within SWAP are from a 2014 analysis by DWR in consultation with individual districts. Groundwater pumping capacity is intended to represent the maximum that a region can pump in a year given the aquifer characteristics and existing well capacities.

Groundwater pumping costs are divided among fixed, energy, and operations and maintenance (O&M) components in the SWAP model. Energy and O&M components are variable. Energy costs depend on the price of electricity. The SWAP model version 6.1 uses the same unit cost of electricity per kilowatt-hour across all regions. Base electricity costs are derived from Pacific Gas and Electric Company (PG&E) rate books and consultation with power officials at the Fresno, California office.

[11] CVP Settlement water is delivered to districts and individuals in the Sacramento Valley based on their pre-CVP water rights on the Sacramento River, and San Joaquin River Exchange water is pumped from the Delta and delivered to four districts in the San Joaquin Valley in exchange for water rights diversion eliminated when Friant Dam was constructed. These two delivery categories are geographically distinct but for convenience are combined into one water supply category in SWAP.

Energy cost is 22 cents per kilowatt-hour, which is an average of PG&E's AG-1B and AG-4B rates (PG&E Various Years). Overall well efficiency is assumed to be 70 percent.

5.3.1.12 Crop Water Requirements

Applied water is the amount of water applied by the irrigation system to an acre of a given crop for production in a typical year. Variation in rainfall and other climate effects will alter this requirement. Additionally, farmers may stress irrigate crops or substitute other inputs to reduce applied water. The latter effect is handled endogenously by the SWAP model through the respective CES production functions. Applied water per acre (base) requirements for crops in the SWAP model are derived from DWR estimates. DWR estimates are based on Detailed Analysis Units (DAU). An average of DAUs within a SWAP region is used to generate a SWAP region specific estimate of applied water per acre for SWAP crops.

5.3.1.13 Elasticities

SWAP uses a number of economic response parameters, called elasticities, to estimate rates of change in variables. An elasticity is the percent change in a variable, per unit of percent change in another variable or parameter. Acreage response elasticity is one component of supply response. It is the percentage change in acreage of a crop from a 1-percent change in that crop's price. The SWAP model contains both long run and short run estimates, and the analyst decides which of the elasticities to use.

SWAP Model Data Sources The SWAP model version 6.1 uses a base year of 2010 for calibration. The calibration year is used to calibrate the underlying economic parameters in the model and does not represent current conditions used in the alternatives analysis. The calibration year is simply intended to represent "average" production conditions in the Central Valley. The year 2010 was neither abnormally dry nor wet, and crop markets had been relatively stable. Table 5-4 summarizes input data and sources used in the SWAP model.

Table 5-4. SWAP Model Input Data Summary

Input	Source	Notes
Land Use	DWR	Base year 2005
Crop Prices	County Agricultural Commissioners	By proxy crop using 2005–2007 average prices
Crop Yields	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Interest Rates	UCCE Crop Budgets	All interest rates normalized to year 2010
Land Costs	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Other Supply Costs	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Labor Costs	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Surface Water Costs	Reclamation, DWR, Individual Districts	By SWAP model region

Input	Source	Notes
Land Use	DWR	Base year 2005
Crop Prices	County Agricultural Commissioners	By proxy crop using 2005–2007 average prices
Crop Yields	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Groundwater Costs	PG&E, Individual Districts	Total cost per acre-foot includes fixed, O&M, and energy cost
Irrigation Water	DWR	Average crop irrigation water requirements in acre-feet per acre
Available Water	CVPM, DWR, Reclamation, Individual Districts	By SWAP model region and water supply source
Elasticities	Green et al. 2006	California estimates

5.3.1.14 Linkage to Other Models

The SWAP model has important interactions with other models. In particular, CalSim II, DWR's project operations model for the SWP and the CVP, is used to estimate SWP and CVP supplies which are inputs into SWAP. An existing linkage tool has been developed to translate CalSim II delivery output to a corresponding SWAP input (on-farm applied water) file. Changes in depth to groundwater affect pumping costs and agricultural revenues. Changes in groundwater depth and resulting changes in groundwater pumping costs can be included from other model output, such as CVHM or C2VSim, if those models are run concurrently for the project.

5.3.2 Economic Analysis

5.3.2.1 Implementing the SWAP Model for the Project Alternatives

Scenario analysis using the SWAP model can focus on a single point in time or on several future points. With reasonable interpolation, this approach will create a true time sequence to calculate net present value of a stream of costs or benefits. The alternatives for the project alternatives were evaluated using a 2030 level of development.

The SWAP model is used to compare responses to changes in irrigation water delivery under the alternatives. Results from the CalSim II model are used as inputs into SWAP through a standardized data linkage tool. This linkage tool is used for the NAA and the alternatives. The CalSim II data file for each scenario includes nine water year types, of which two are included in the SWAP model inputs. For each alternative and water year type, the CalSim II model provides the SWAP model with CVP and SWP on-farm water deliveries for each SWAP model region. Water supply for average and dry conditions are applied in this analysis.

5.3.2.2 Fixed Crop Prices Objective Function

The SWAP model can be used to estimate crop prices endogenously using the acreage response elasticities described above or a fixed crop price model can be applied. This analysis applies a fixed crop price objective function to estimate benefits given the relatively small changes in overall agricultural water supply resulting from the project alternatives.

5.3.2.3 Electricity Costs

Groundwater is typically the most expensive water supply. Real power costs are expected to increase in the future, and groundwater relies heavily on the cost of electricity for pumping. Energy pumping costs are escalated according to future marginal power cost estimates for the year 2030.

A marginal power cost escalator is determined for the year 2030 and applied to the energy cost component of groundwater costs. The cost escalator is the ratio of the expected future power cost in 2030 to the base power cost in 2010, in 2010 dollars per megawatt hour. Expected future power costs are calculated using the DWR Forward Price Projections analysis using wholesale power costs (DWR 2011). This calculates an average power cost for each month as the average of the peak (upper bound) and off-peak (lower bound) rates. An average of the monthly costs generates an average yearly cost. This cost is used to generate the power cost escalator by taking the ratio of the future year average to the current year average. The power cost escalator for 2030 is 1.51.

5.3.2.4 Groundwater Volume and Depth

As described above, the SWAP model includes groundwater pumping volume constraints that reflect aquifer conditions and well pumping capacities in 2014. For this analysis, the endogenous groundwater pumping volume for each region from the NAA was applied as the groundwater pumping limits for each of the alternatives. As such, no additional groundwater pumping is allowed to offset reductions in surface water deliveries. This approach was followed to account for the potential future limits on groundwater pumping due to the Sustainable Groundwater Management Act (SGMA). The effects of SGMA on future groundwater availability for agricultural uses are not known at this time so this approach is an approximation.

The SWAP model can be linked to a groundwater model to estimate change in depth to groundwater, both static and dynamic, to estimate the additional lift, and therefore energy cost, for water year types. Dry years can result in groundwater levels dropping by several feet in some regions of the Central Valley, depending on local aquifer conditions. The CVHM or C2VSim models were not run for the alternatives. As such, depth to groundwater is held constant at the baseline levels under all water year types and alternatives.

5.3.2.5 Other Factors

Climate change effects are held constant in the analysis of the alternatives. The SWAP model has been linked to crop models, such as LAWS, to estimate the change in crop yield and crop evapotranspiration and, therefore, applied water requirements. Climate change effects on crop growth remain highly uncertain and are consequently held constant in the analysis.

Crop yields have been increasing for most crops due to technological innovations. Innovations like hybrid seeds, better chemicals and fertilizer, improved pest management, and irrigation and mechanical harvesting advances are some examples. The expected future rate of growth in crop yields remains a contentious topic among researchers. Consequently, yield changes due to technological innovations are held constant in the analysis of the alternatives. It is important to note that the SWAP model does allow for some minor yield response to changing market conditions. This effect is referred to as endogenous yield changes. The SWAP model includes full CES production functions for each crop and region, which allow for some endogenous yield change in response to changing market conditions, but there is no exogenous technological change included in the analysis.

The SWAP model allows for deficit irrigation of crops. Agricultural producers may choose to deficit irrigated crops and incur a loss in crop yield if the strategy maximizes net returns. Deficit irrigation typically is the result of water supply shortages and high water costs. The maximum level of deficit in the SWAP model for each crop is set at 95 percent of applied water needs for each crop and region.

5.3.2.6 NED Benefits Calculations

The basic guidelines for evaluating water development projects at the federal level are specified in the "Principles, Requirements, and Guidelines for Federal Investments in Water Resources" (PR&Gs; CEQ 2014). Under the PR&Gs, the federal objective for water contributions is to maximize the contribution to NED consistent with protection of the environment. To adhere to the PR&Gs and determine the contribution to NED, a series of adjustments to the SWAP model and data are necessary. Adjustments fall into two categories, pre- and post-processing. Pre-processing adjustments are made prior to optimization with the SWAP model and include adjustments to SWAP input data and exogenous projections of future costs and demands. Post-processing adjustments are applied to SWAP output and include adjustments to prices and costs. They are adjustments needed in order for the results to comply with PR&Gs and Reclamation guidelines for NED analysis. In particular, guidelines require that certain prices be used for valuing changes in physical inputs and outputs. They do not explicitly affect farmers' decisions, so they are applied after the SWAP optimization. Post-processing adjustments include interest rates, other supply costs, fallow land costs, normalized crop prices, consumer surplus, water costs, and management charges.

All of the NED adjustments follow the SWAP NED adjustments developed in consultation with Reclamation for the North-of-Delta Offstream Storage (NODOS) feasibility study. The data have been updated to reflect current conditions (e.g., Current Normalized Prices are updated), but the fundamental method is unchanged. This section provides an overview of the approach.

Pre-processing adjustments include changes to the data that occur before SWAP model optimization. This includes demand shifts, energy pumping costs, interest rate adjustment, and other factors as described earlier in this section. These adjustments are made prior to SWAP optimization and are made regardless of whether the project is being evaluated under NED guidelines.

Post-processing adjustments take place after the SWAP model optimization. These include:

1. The PR&Gs require that the federal discount rate be used for all interest and capital recovery calculations. The current federal discount rate (FY19) is 2.75 percent. A post-processing adjustment is applied to cost data components to adjust the interest rate to 2.75 percent.
2. Machinery capital recovery costs are removed from the NED analysis under all scenarios. Additional land coming into irrigated production (with the project versus without the project) would be quite small and is therefore unlikely to require additional machinery investment. By the same logic, buildings capital recovery costs are removed from the NED analysis under all scenarios.
3. Land rent and cash overhead and land capital recovery costs are removed from the NED analysis under all scenarios. The NED analysis is adjusted to remove land costs that are included within the SWAP data file because lands being brought into irrigated production are already considered a sunk investment. Sunk investments are irrelevant to determining the economic feasibility of new project investments.

4. Interest on operating capital and capital recovery charges for permanent crop establishment and for irrigation systems are adjusted using interest factors as noted above.
5. An annual maintenance cost of $41 per acre (in 2019 dollars) is used for the NED analysis to account for fallow land costs, as required by the PR&Gs.
6. Consumer surplus is the benefit (welfare gain) that consumers realize from being able to purchase crops at less than their maximum willingness to pay. Since the changes in water supply is small and crop prices are fixed, the change in consumer surplus is negligible and is excluded from the NED benefits calculations.
7. Surface water costs are excluded from the NED benefits calculation. In a NED benefit-cost analysis of a proposed project, the incremental investment and annual costs of the new water supply are accounted for on the cost side of the ledger, so including them as water costs within the benefits analysis would effectively be double-counting.
8. Reclamation guidelines for preparing NED analysis under the PR&Gs recommend including management costs at no less than 6 percent of variable costs. A 6-percent management charge is added to the variable production costs in the SWAP model.
9. The PR&Gs state that U.S. Department of Agriculture (USDA) Current Normalized Prices (CNP) must be used for benefits calculations when available. These prices have been adjusted by USDA to remove any federal subsidies because such subsidies represent an NED cost that must be accounted for in comparing project benefits and costs. For crop groups covered by USDA's CNP estimates, SWAP prices were converted to scaled CNP. For crop groups without available CNP, the SWAP-predicted prices are used. CNP reported in dollars per ton, are as follows: corn $120.36, cotton $1,413.07, dry beans $952.00, grains (wheat) $154.00, rice $312.80, and sugar beets $41.92.

5.3.2.7 Description of Results

This section describes the SWAP model results for NAA and the alternatives. Changes in economic conditions in the Central Valley are summarized in terms of irrigated acreage, gross farm revenues, total income over expenses, groundwater use, groundwater cost, and estimated NED benefits. Water year types summarized in this section include average and dry conditions.

Tables 5-5 and 5-6 provide the SWAP model results for the average and dry water years, respectively. As shown, the total irrigated area is approximately 6.99 million acres under NAA in the average water year.

Table 5-5. SWAP Model Results Summary for Average Water Year.

Metric	NAA	*Change from NAA*					
		CVP Only Storage	CVP/SWP Split Storage	Investor-Directed Storage Subalternative A	Investor-Directed Storage Subalternative B	Investor-Directed Storage Subalternative C	Investor-Directed Storage Subalternative D
Irrigated Acres (Thousands)	6,988.1	0.8	–0.5	0.6	–2.3	–0.9	–2.4
Surface Water Use (TAF)	13,848.2	38.1	15.6	34.5	–3.3	15.0	–5.8
Groundwater Use (TAF)	8,062.0	–35.2	–17.1	–32.1	–4.9	–18.9	–3.3
Gross Revenue (millions $)	$29,740.4	$0.2	–$1.5	$0.0	–$3.4	–$0.6	–$3.5
Income Over Expenses (millions $)	$16,860.7	$1.0	$0.3	$0.9	–$0.4	$0.6	–$0.5
Groundwater Costs (millions $)	$1,016.0	–$9.0	–$4.3	–$8.2	–$1.2	–$5.0	–$0.8
Estimated NED Benefits (millions $)	N/A	$10.0	$4.6	$9.1	$0.7	$5.6	$0.2

Table 5-6. SWAP Model Results Summary for Dry Water Year.

Metric	NAA	*Change from NAA*					
		CVP Only Storage	CVP/SWP Split Storage	Investor-Directed Storage Subalternative A	Investor-Directed Storage Subalternative B	Investor-Directed Storage Subalternative C	Investor-Directed Storage Subalternative D
Irrigated Acres (Thousands)	6,795.2	5.8	2.3	5.6	–1.7	7.0	–1.4
Surface Water Use (TAF)	13,261.7	17.9	7.8	17.0	–3.0	21.3	–2.5
Groundwater Use (TAF)	8,024.4	0.0	–0.1	0.0	0.0	0.0	0.0
Gross Revenue (millions $)	$29,445.1	$13.4	$6.0	$13.2	–$2.2	$16.1	–$1.4
Income Over Expenses (millions $)	$16,792.8	$4.6	$2.2	$4.5	–$0.5	$5.6	–$0.2
Groundwater Costs (millions $)	$1,013.2	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Estimated NED Benefits (millions $)	N/A	$4.6	$2.2	$4.5	–$0.5	$5.6	–$0.3

Table 5-7. Estimated Irrigation Water Supply Reliability NED Benefits Provided by Dam Raise Subalternatives

Dam Raise Subalternatives	NED Ag Water Supply Reliability (TAF/year)	NED Ag Water Supply Annual Benefits relative to No Action Alternative (million $)[1]
Non-Structural	–39	–$10.8
CVP-Only	34.58	$7.4
CVP/SWP Split	15.62	$4.4
Investor-Directed Storage Subalternative A	27.65	$5.8
Investor-Directed Storage Subalternative B	4.65	$0.9
Investor-Directed Storage Subalternative C	14.46	$3.0
Investor-Directed Storage Subalternative D	2.93	$0.5

Notes:

[1] NED irrigation water supply reliability benefits are based on average water year type hydrologic conditions and calculated as the weighted average of five water year types and values in Table 5-1. Sacramento Valley 40-30-30 Water Year Hydrologic Classification Index used to define water year types.

[2] Irrigation water supply benefits have been adjusted for the structural alternatives to account for a water supply emergency's limits on the availability of this supply.

Key:

NED = National Economic Development

TAF= thousand acre-feet

CVP= Central Valley Project

SWP = State Water Project

Chapter 6 NED Enhanced Emergency M&I Water Supply Benefits

6.1 Introduction

The Dam Raise Alternatives provide emergency water supply benefits from increased storage. This chapter presents a summary of how these emergency water supply benefits were quantified and monetized, the results of that evaluation, and the potential risks and uncertainties with those results.

6.2 Physical Benefit Quantification

Water supply could be reduced or interrupted after an emergency such as a flood or earthquake. Conveyance of water supply through the Delta could be interrupted or reduced in the event of Delta levee failures if seawater intruded into the Delta to an extent that would make it too saline for human consumption. In such cases, the additional water available in surface and groundwater storage, the physical interconnections between groundwater and surface water system, and the operational would help to mitigate the impacts of the emergency.

Emergency storage benefits are increased supplies stored in reservoirs and underlying groundwater basins that can be delivered in the event of a major levee failure in the Delta that would significantly degrade water quality, or a major earthquake that would disrupt the ability of SLDMWA to import water into their service area. An analysis was performed to quantify and value emergency water supplies, and those available to SLDMWA M&I water users in the event of a Delta water-supply outage. These disruptions depend upon a variety of factors, including the risk of a seismic, flood or other catastrophic event, vulnerability of non-Delta water supplies, and the timing and duration of the supply disruption. Supply disruptions in an emergency that occur during prolonged periods of drought may result in significantly higher economic costs than those that coincide with wetter conditions. In addition, supply disruptions that are shorter in duration will result in lower economic costs for water users.

SLDMWA consists of 29 federal and exchange water service contractors within the western San Joaquin Valley, San Benito, and Santa Clara counties. SLDMWA's member agencies mostly receive water from the federal share of San Luis Reservoir. Emergency supplies developed at the expanded San Luis Reservoir would be available for direct delivery to Santa Clara Valley Water District (Valley Water) and the other identified south-of-Delta CVP M&I water users with the potential demand for emergency water supply[12]. The Non-Structural Alternative would not provide emergency water

[12] The South-of-Delta CVP M&I water users identified with a potential demand for emergency water supply stored in an expanded San Luis Reservoir are: the cities of Tracy, Huron, Hollister, Coalinga, and Avenal, the California Department of Fish and Wildlife, Byron-Bethany Irrigation District, Del Puerto Water District, Panoche Water District, San Luis Water District, Westlands Water District, Lemoore Naval Air Station through Westlands Water District, Fresno County and Tulare County.

supply as it could impact contractual obligations to other water users. Estimated emergency water deliveries associated with Dam Raise Alternatives are reported in Table 6-1. Refer to Appendix B of the Feasibility Report for details of the hydrologic model analysis and results.

Table 6-1. Estimated Emergency Water Supply Reliability Provided by the Dam Raise Subalternatives (TAF)

Alternative	Emergency Water Supply (TAF)
Non-Structural	--
CVP-Only	28
CVP/SWP Split	17
Investor-Directed Storage Subalternative A	31
Investor-Directed Storage Subalternative B	31
Investor-Directed Storage Subalternative C	63
Investor-Directed Storage Subalternative D	63

6.3 NED Physical Benefit Monetization

6.3.1 Economic Methods

A water supply disruption associated with flood or seismic events affecting the Delta has the potential to persist for many months. As a result, such an event is likely to lead to water shortages for South-of-Delta CVP M&I water providers and bay area water providers, as a large component of the water supply to the region consists of Delta exports. Under some circumstances it may be possible to value foregone water supplies to south-of-Delta CVP M&I water providers and bay area water providers according to the costs required to purchase water supplies from willing sellers. However, a lengthy Delta disruption is likely to result in extensive shortages to many water users that rely upon Delta exports. Under these conditions, it is unlikely that there will be adequate water supplies to purchase from potential sellers. In addition, the level and duration of water supply shortage will surpass the water supplies that can be obtained from local sources within the region. Because of these circumstances, this analysis applies a willingness to pay approach to estimate the benefits associated with emergency water supplies.

6.3.2 Economic Analysis

6.3.2.1 Previous Studies Considered

Several studies have estimated the economic impacts associated with Delta levee failures and water supply disruptions. The *Delta Risk Management Strategy* (DRMS) (DWR et al. 2009) considered seismic, high water conditions, sea level rise, and land subsidence as risks to Delta levee integrity and related Delta water exports. The study determined a seismic event as the greatest risk to levee integrity in the Delta, and Delta water exports, and estimated statewide economic costs and impacts of $15 billion (70 percent from urban user loss due to water supply disruption and about 30 percent from damaged major infrastructure) or more if a major earthquake occurs and simultaneously floods as many as 30 Delta islands. While earthquakes pose the greatest consequences to Delta levees and

water exports, winter storms and related high water conditions are the most common cause of levee failures in the Delta region. Multiple island failures caused by high water would likely lead to less severe export disruptions than failures from a major earthquake but could still be extensive.

In a study by Hanneman et al. (2006), the partial economic impacts of Delta levee failure caused by climate-change-induced sea-level rise and storm events were considered for three scenarios occurring during different months and hydrologic conditions. Estimated economic impacts to urban users in the South Coast region ranged from $10 to $14 billion. However, the study found that future development of water supplies for Southern California independent of the Delta would reduce the economic costs to urban users to between $1.8 and $4.0 billion. The analysis relied upon a short-run price elasticity of –0.05 and assumed a linear demand function to estimate the change in consumer surplus associated with the projected shortages (Hanneman et al. 2006). The analysis did not consider economic impacts of water shortages on commercial and industrial water users.

Brozovic et al. (2007) provided another estimate of the economic losses associated with water supply disruption to the Bay Area resulting from two potential earthquake scenarios affecting water supplies from the Hetch Hetchy system. Residential losses were estimated through measurement of changes in consumer surplus by applying a constant elasticity demand function to an estimate of price elasticity from empirical studies. The price elasticity used in the study (−0.41) was considerably larger than the elasticity applied in Hanneman et al. (2006) and is more representative of long-run elasticity estimates from empirical studies. The authors note that the estimates of economic losses are highly sensitive to the choice of price elasticity of demand and that the estimates should be considered a lower bound. Business losses are estimated through the use of loss functions with increasing marginal costs as shortages increase, as well as a minimum threshold water supply below which business output would cease. Study results indicated that a 60-day disruption of the Hetch Hetchy water supply would produce between $9.3 and $14.4 billion in business interruption losses and between $37 and $279 million in residential welfare losses.

Reclamation's Upper San Joaquin River Basin Storage Investigation employed the valuation approach used by Brozovic et al. (2007) to estimate economic losses from water shortages to M&I water users in California caused by seismic events and Delta levee failures. Information regarding the probabilities of Delta levee failures, potential levee failure scenarios, and associated projected shortages South-of-Delta were based on information developed for the draft DRMS (DWR et al. 2009). This analysis is limited to disruptions as characterized by scenarios under which 1, 3, 10, 20, and 30 Delta islands would become inundated because of a seismic event. The economic value of emergency water supplies potentially provided by a Temperance Flat River Mile 274 Reservoir to southern California residential users was estimated by applying a short-run price elasticity (−0.22) to a constant elasticity demand function calibrated to observed price and quantity information from southern California water providers.

In addition, the Bay Delta Conservation Plan estimated the economic value of reduced seismic risk with the Brozovic et al. (2007) approach (DWR 2013b). The analysis assumed a level of water supply availability potentially experienced from a seismic event and assumes a 2-percent probability of a seismic event occurring in any forecasted year. The Brozovic et al. (2007) approach was applied to residential, agricultural, commercial, and industrial sectors. An urban water price and consumption dataset was constructed and used to estimate individual water agency price elasticities. The economic value of water supplies after a seismic event was estimated by applying each agency's estimated

elasticity to constant elasticity demand functions calibrated to observed price and quantity information from each water provider.

Both sea level rise and Delta Island subsidence will significantly increase the risk of levee failures and flooding during the next 50 years because of higher static pressure. Delta Subventions Program funds have increased stability of levees, but more funding has been directed in some areas of the Delta than others. Historically, funding has provided about $6 million for the program annually, where typically local levee districts cost share 25 percent of the total for improvements. With funds from Proposition 84 (2006) and Proposition 1E (2007), the subventions program has expended approximately $200 million in bond funding on Delta levees in the last decade. However, with 1,100 miles of levees and worsening conditions due to sea level rise and subsidence, investments would need to increase significantly over the historical levels and land owners would have to increase their own contributions to keep pace with declining conditions. Under the right circumstances, any levee failure could usher in significant bay salinity, which is higher in bromides and severely detrimental to drinking water quality. Chain reactions of levee failures can happen because of wave erosion and tidal pumping, thus leading to extended periods of time when Delta water at the export facilities is unsuitable for drinking water use.

6.3.2.2 Benefits Estimation Method

This section describes the method applied to estimate the benefits of emergency water supplies resulting from project alternatives, beginning with key considerations and followed by the estimation procedures.

Key Considerations Key considerations in estimating the economic cost of water supply disruptions include the probability that a supply disruption would occur, level of water supply shortage, and duration and timing of the supply disruption to urban water agencies.

Probability of a Supply Disruption Supply disruptions could arise from a variety of human and natural conditions. This analysis relies on estimates of Delta levee failures due to seismic, flood, and sunny-day hazard events. No attempt was made in this analysis to estimate the probability or potential water supply effects associated with additional environmental constraints on Delta pumping.

Information regarding the probabilities of Delta levee failures, potential levee failure scenarios, and associated projected Bay Area shortages was based on information developed for the DRMS (DWR et al. 2009). The annual probabilities associated with seismic, flood, and all hazard events for Delta island inundation scenarios considered in this analysis are listed in Table 6-1. Because sunny-day hazard events are only considered to occur one island at a time, the annual probability of occurrence for all hazards only includes the probability of a sunny-day occurrence in the 1-island breach scenario. This analysis assumes that seismic and flood events that result in a small number of levee breaches do not result in significant water shortages to M&I water suppliers. This analysis is limited to longer disruptions as characterized by the 20 and 30 Delta island inundation scenarios. The annual probabilities associated with the 20 and 30 Delta island inundation scenarios for all hazards applied in this analysis are 0.055 and 0.029, respectively. Annual emergency water supply benefits were estimated using an annual probability of occurrence of 0.042, which was derived by averaging the 20-island probability (0.055) and the 30-island probability (0.029) listed under the "All Hazards" column in Table 6-2. A sensitivity analysis was developed using the 20-island probability and the 30-island probability.

Table 6-2. Probabilities of Delta Island Breach Scenarios

Delta Island Breach Scenario	Annual Probability of Occurrence[1]		
	Seismic	Flood	All Hazards[2]
1-island	0.107	0.205	0.420
3-island	0.082	0.138	0.220
10-island	0.051	0.051	0.102
20-island	0.032	0.023	0.055
30-island	0.019	0.010	0.029

Notes:
[1] Probabilities of occurrence were developed by the Delta Risk Management Strategy (DWR, USACE, and DFG 2009).
[2] All hazards include the probability of seismic, flood, and sunny-day Delta island breach scenarios. Because sunny-day failures are considered to occur one island at a time, the all hazards probability of occurrence only includes the probability of a sunny-day occurrence in the 1-island breach scenario.

Level of Water Supply Shortage South-of-Delta CVP M&I water providers and bay area water providers rely on a variety of water sources to satisfy M&I water demand, including local surface water and groundwater, stored water, recycled water, desalination, and imported supplies. The diversity in potential water sources is indicative of the need to address the potential for an individual source to be affected by drought, poor water quality, or damages to conveyance infrastructure. Despite this, South-of-Delta water providers along with water providers in the Bay Area are particularly susceptible to a hazard event that would restrict water supplies from the Delta because of heavy reliance on water supplies upstream from the Delta. Imported water supplies susceptible to Delta disruptions comprise an estimated 45 percent of total water supplies to Valley Water, an emergency water supply beneficiary, during an average water year (2030 future conditions) and 31 percent during dry and critical years (DWR 2015). In addition, imported water supplies susceptible to Delta disruptions comprise an estimated 90 percent of total water supplies to the other South-of-Delta CVP M&I water user beneficiaries. Groundwater banking agreements that may be exercised in dry and critical years are susceptible to Delta disruptions because they generally involve in-lieu deliveries of SWP water. This analysis assumes longer water export disruptions (0.9 to 1.9 years) characterized by 20- and 30-island breach scenarios (DWR et al. DFG 2007) would result in a shortage level of 45 percent of the forecast 2030 water demand without additional groundwater pumping and 28 percent of the forecast 2030 water demand with additional groundwater pumping.

Duration and Timing of Supply Disruption The economic effects of a water supply disruption would vary according to the length of time that water supplies from the Delta are shut down or curtailed, the season during which the disruption occurs, and the hydrologic conditions that exist at the time. For example, a Delta water supply disruption that occurs during or immediately following drought conditions would result in larger economic losses than a disruption that occurs during or immediately following a wetter period. Similarly, a disruption that occurs during the winter may have different effects than one occurring in the spring or summer, depending upon the duration of the water supply disruption. In this analysis, it was assumed that the disruption occurs during hydrologic conditions that would have resulted in water deliveries that meet demand to South-of-Delta CVP M&I water users. As a result, the water supply shortage and associated economic value can be fully attributed to the reduction in Delta water supplies.

Analyses summarized in the DRMS phase 1 Risk Analysis Summary Report (2007) determined that pumping from the Delta would be disrupted for extended periods as a result of the breach scenarios

considered. According to the seismic hazard analysis, partial export pumping could resume in 0.9 to 1.8 years under the "20-island breach" scenario and 1.3 to 1.9 years under the "30-island breach" scenario. Depending on the number of flooded islands, timing and size of flood, and Delta salinity conditions, export disruptions under flood hazard conditions could be less significant than under seismic hazard conditions. It is assumed that under larger Delta island breach scenarios (i.e., 20- and 30-island breach scenarios) export disruptions could extend greater than one year. Based on these findings, this analysis assumed a Delta water supply disruption of 12 months.

Estimation Methodology Economic benefits from emergency water supplies are measured according to water users' willingness-to-pay to avoid interruptions in water deliveries. The value of emergency supplies to M&I users was estimated by applying an estimated short-run price elasticity to a constant elasticity demand function calibrated to observed price and quantity information from South-of-Delta CVP M&I water providers. This valuation approach was used by Jenkins et al. (2003) and Brozovic et al. (2007) to estimate economic losses from water shortages to M&I water users in California. Estimated benefits were weighted according to the probability of a Delta water supply disruption (DWR et al. 2009). Demand, price, price elasticity, and the demand function used in the analysis are discussed below.

Demand The alternatives would provide emergency water supply benefits to Valley Water, as summarized in Table 6-3, and South-of-Delta CVP M&I water providers, as summarized in Table 6-4.

Table 6-3. Estimated North County Santa Clara Subbasin Population and Water Demands 2030 Conditions

Population/Demands	2017[3]	2030[2]
Population[1]	1,895,211	2,115,128
Water Demands (acre-feet)		
Water Retailer Potable Demands	291,335	293,086
Treatment Plant Losses	2,993	2,940
Other Demands	–	1,652
Total Demands	**294,328**	**297,678**

Notes:

[1] Population estimates are based on estimated population for North County Santa Clara Subbasin, based on population estimates from the California Department of Finance Demographic Research Unit (February 2017).

[2] Based upon San Luis Low Point Improvement Project WEAP input data.

[3] Based on projections in Valley Water's WSIP Application for Pacheco Reservoir Expansion, Attachment G1: Economics for Emergency Response – Delta Outage (Valley Water 2018). Numbers have been rounded for display purposes and may not sum to totals.

Table 6-4. Estimated South-of-Delta CVP M&I Water Demands 2030 Conditions

South-of-Delta CVP M&I Water Provider	Projected 2030 Demand	Source
City of Tracy	31,000	City of Tracy 2014 Water Supply Assessment
City of Huron	823	City of Huron Municipal Service Review and Sphere of Influence 2019 Update
City of Hollister	8,840	2015 Hollister Urban Area Urban Water Management Plan
City of Coalinga	6,683	City of Coalinga Draft 2015 Urban Water Management Plan
City of Avenal	2,776	City of Avenal USBR Water Management Plan (2014 Criteria)
California Department of Fish and Wildlife	10	Final Environmental Assessment Central Valley Project Interim Renewal Contracts for Cities of Avenal, Coalinga, Huron and the California Department of Fish and Wildlife 2017-2019
Byron-Bethany Irrigation District	3,000	Byron Bethany Irrigation District Agricultural Water Management Plan October 2017
Del Puerto Water District	34	Del Puerto Water District Water Management Plan 2008 Criteria
Panoche Water District	134	Finding of No Significant Impact Central Valley Project Interim Renewal Contracts for Panoche Water District and San Luis Water District 2019-2021
San Luis Water District	1,649	Finding of No Significant Impact Central Valley Project Interim Renewal Contracts for Panoche Water District and San Luis Water District 2019-2021
Lemoore Naval Air Station	2,849	Environmental Assessment for Strike Fighter Realignment at Naval Air Station Lemoore, California October 2011
Fresno County	828	2015 Final Environmental Impact Statement for the Central Valley Project Municipal and Industrial Water Shortage Policy
Tulare County	877	2015 Final Environmental Impact Statement for the Central Valley Project Municipal and Industrial Water Shortage Policy
Total	59,503	

Price The water price used in this analysis is based on reported charges for Santa Clara County water providers (M. Cubed 2016). The price used in this analysis is the volume weighted average price charged by water providers in 2015 ($1,694/AF), adjusted to 2019 price levels ($1,841/AF). The water price used for the other South-of-Delta CVP M&I water providers is based on the weighted average water service price in 2015 for each provider.

Price Elasticity M&I demand for water has been shown by most studies to be inelastic. A survey of previous economic literature by Dalhuisen et al. (2003) found a mean price elasticity of demand of −0.41 and a median of −0.35 for 268 individual estimates. Previous studies have shown that the price elasticity of demand varies throughout the year. In general, price elasticity is higher in the

summer when water use is at its peak and lowest during the winter when water use is lower. Similarly, price elasticity is lower in the short term than the long term because water users are less able to alter water demand through conservation. However, most of the previous studies estimated long-term price elasticities of demand. Economic losses from an unexpected water supply outage are most appropriately measured through application of a short-term price elasticity. Estimates of economic losses increase with application of lower price elasticities. Table 6-5 provides price elasticity estimates from water demand studies in California.

Seasonal variation in price elasticity was not considered in this analysis because of the uncertainty regarding potential timing of a Delta water supply disruption. In addition, as described above, the duration of the event is expected to last nearly a year, thereby limiting the usefulness of considering seasonal demand patterns. This analysis applies an elasticity estimated from a recently completed California urban water demand study (DWR 2013b). The study used panel data from 127 California water retailers and estimated an elasticity −0.189 for Valley Water, which is applied in this analysis.

Table 6-5. Estimated Price Elasticities of Water Demand in California

Study	Location	Sector	Season	Elasticity	
				Low	High
Howe 1982	Western U.S.	Residential, single family	summer	−0.43	
Weber 1989	Bay Area	Residential	winter	−0.08	−0.2
			annual	−0.1	−0.2
CCWD 1989	Bay Area	Residential	annual	−0.2	−0.4
			summer	−0.35	
DWR 1991	California	Residential	annual	−0.2	−0.5
Dziegielewski & Optiz 1991	Southern California	Residential, single family	winter	−0.24	
			summer	−0.39	
		Residential, multiple family	winter	−0.13	
			summer	−0.15	
		Urban	annual	−0.22	
Renwick, 1996	California	Residential	annual	−0.33	
Renwick and Archibald 1998	Bay Area and Southern California	Residential, single family	average	−0.16	
			summer	−0.2	
Metzner 1989[1]	San Francisco	Residential	annual	-0.25	
Metropolitan Water District of Southern California 1990[1]	South Coast	Residential, single family	summer	−0.29	−0.36
			winter	−0.03	−0.16
DWR 1998	California	Residential, single family	annual	−0.16	
Espey et al. 1997	U.S.	Residential	annual	−0.64	
			annual	−0.38	
			annual	−0.51	
Dalhuisen et al. 2003	U.S.	Residential	annual	−0.41	

Study	Location	Sector	Season	Elasticity	
				Low	High
Olmstead and Stavins 2006	U.S. and Canada	Residential, uniform marginal prices	annual	−0.33	
		Residential, increasing block rates	annual	−0.064	
California Climate Change Center 2009	El Dorado County, California	Residential, increasing block rate structure	annual	−0.2198	
Gleick et al. 2005	U.S.	Residential, single family	annual	−0.16	
		Residential, multiple family	annual	−0.05	
Upper San Gabriel Valley Municipal Water District, 2012	Upper San Gabriel Valley	Residential, single family	annual	−0.13	
		Residential, multiple family	annual	−0.11	
Metropolitan Water District of Southern California, 2010	Southern California	Residential, single family	annual	−0.1947	
		Residential, multiple family	annual	−0.1626	
Jenkins et al. 2003	Santa Clara Valley	Residential	(average of summer and winter)	−0.25	
Bay Delta Conservation Plan (DWR 2013b)	California	Residential	Annual	−0.146	−0.324

Note:
[1] Cited in California Water Plan Update (DWR 1998)
Key:
CA = California
CCWD = Contra Costa Water District
DWR = California Department of Water Resources

Demand Function This analysis assumes a constant price elasticity of demand over the changes in water delivery considered. The demand function is calibrated to 2030 water demand levels by adjusting 2017 prices and quantities according to water demand projections. The demand function applied in this analysis is as follows:

$$P = e^{\frac{\ln(D)}{\eta}+C}, \quad \text{or} \quad P = D^{\frac{1}{\eta}} e^{C} \qquad (1)$$

Where

- P is the observed price ($/AF) of water to South-of-Delta CVP M&I water users
- D is the estimated volume of M&I water use for South-of-Delta CVP water users under 2030 conditions
- e is a mathematical constant approximately equal to 2.71828
- η is the short-run price elasticity of demand
- C is the integration constant (k=e^{C}).

The integration constant is calculated according to equation 2 using the observed water price (P2017) and level of water use (D2017). The integration constant is then scaled to 2030 according to the ratio of population in 2030 to population in 2017 (N2017 / N2030) as shown in equation 3.

$$k_{2017} = P_{2017} * D_{2017}^{\frac{-1}{\eta}} \quad (2)$$

$$P_{2030} = k_{2017} * \left(D_{2030} * \frac{N_{2017}}{N_{2030}}\right)^{\frac{1}{\eta}} \quad (3)$$

The economic benefits of emergency water supplies are calculated according to equation 4.

$$Benefits\,(Q_E) = \mathrm{k}_{2030}\frac{\eta}{1+\eta}\left[(D_{2030} - Q_R + Q_E)^{\left\{\frac{1+\eta}{\eta}\right\}} - (D_{2030} - Q_R)^{\left\{\frac{1+\eta}{\eta}\right\}}\right] - c * Q_E \quad (4)$$

Where,

- Q_E is the Project emergency water supply yield
- Q_R is the level of disrupted through-Delta water deliveries
- c is the avoided marginal cost of water delivery and treatment during a shortage

The estimation method described above was used to generate an estimate of the economic losses associated with a 12-month Delta outage to develop a dollar per acre-foot benefit for emergency water supplies. The average value was then multiplied by the volume of emergency supplies available from the alternatives, and the expected annual benefit is calculated by multiplying by the probability of a Delta water export disruption. The estimation method described above was used to generate an estimate of the economic losses associated with a 29-percent shortage level in 2030 to develop a dollar per acre-foot benefit for emergency water supplies. The average value was then multiplied by the volume of emergency supplies available from the alternatives, and the expected annual benefit is calculated by multiplying by the probability of a Delta water export disruption. The expected annual emergency water supply benefit is then reduced by the avoided marginal cost of emergency water delivery and treatment to M&I customers (c). This analysis applies a fixed per unit cost of $277/AF/year (DWR 2013b). Table 6-6 and Table 6-7 summarize the parameters applied in this analysis.

Table 6-6. Summary of Key Assumptions and Parameters for Valley Water

Variable	Value	Description	Source
P_{2017}	$1,841/acre-foot	Weighted average service rate (2019 dollars) for water providers in Santa Clara County	M. Cubed (2016)
D_{2017}	294,328 acre-feet	Estimated 2017 annual M&I water demand for North County Santa Clara Subbasin	Valley Water WEAP model
D_{2030}	297,678 acre-feet	Forecast 2030 annual M&I water demand in North County Santa Clara Subbasin	Valley Water WEAP model

Variable	Value	Description	Source
Q_E	31,997 acre-feet	Average emergency water supply yield in 2030 under each alternative	Valley Water WEAP model
η	–0.189	Short-term price elasticity of demand	Bay Delta Conservation Plan (DWR 2013b)
Shortage Level	29%	Level of shortage to M&I users as a percentage of 2030 water demand	San Luis Low Point Draft Feasibility Report
Shortage Duration	12 months	Duration of the Delta water supply disruption	San Luis Low Point Draft Feasibility Report
Probability	0.042[1]	Annual probability of a Delta water supply export disruption during the planning period[1]	DRMS (DWR, USACE, and DFG 2009)
c	$277/ acre-foot	Marginal cost of delivery	Bay Delta Conservation Plan (DWR 2013b)

Notes:

[1] The annual probability of a Delta water supply export disruption applied in this analysis is the average annual all hazards probabilities for the 20- and 30-island breach scenarios identified for the Delta Risk Management Strategy (DWR et al. 2009).

Key:

Delta = Sacramento-San Joaquin Delta

DRMS = Delta Risk Management Strategy

M&I = municipal & industrial

Valley Water = Santa Clara Valley Water District

WEAP = Water Evaluation and Planning

Table 6-7. Summary of Key Assumptions and Parameters for South-of-Delta CVP M&I Water Users

Water Provider	Elasticity Estimate	Probability of Delta Failure[1]	2015 Retail Price ($/acre-feet)	2015 Demand (acre-feet)	2030 Demand (acre-feet)	2030 Average Emergency Water Supply (acre-feet)	2030 Shortage Level
City of Avenal	–0.189	0.042	$1,266	2,435	2,776	1,388	50%
City of Hollister	–0.189	0.042	$1,156	6,820	8,840	3,271	37%
City Coalinga	–0.189	0.042	$965	5,563	6,683	3,342	50%
City of Tracy	–0.189	0.042	$1,186	23,000	31,000	6,786	22%
City of Huron	–0.189	0.042	$895	743	823	412	50%
San Luis Water District	–0.189	0.042	$895	200	276	138	50%
Lemoore Naval Station	–0.189	0.042	$895	2,499	2,849	1,425	50%
Fresno County	–0.189	0.042	$895	726	828	414	50%
Tulare County	–0.189	0.042	$739	769	877	439	50%

Notes:

[1] The annual probability of a Delta water supply export disruption applied in this analysis is the average annual all hazards probabilities for the 20- and 30-island breach scenarios identified for the Delta Risk Management Strategy (DWR et al. 2009).

Key:

Delta = Sacramento-San Joaquin Delta

DRMS = Delta Risk Management Strategy

M&I = municipal & industrial

Valley Water = Santa Clara Valley Water District

WEAP = Water Evaluation and Planning

Valley Water Supplies The available supplies accessible to areas overlying the North Area Santa Clara Subbasin during a Delta outage for 2030 future conditions include:

- Natural groundwater recharge
- Local surface water supplies
- Recycled water
- SFPUC Hetch Hetchy
- Groundwater extraction in excess of natural groundwater recharge

Delta conveyed supplies (i.e., CVP and SWP deliveries) were not included because of the assumed Delta outage. Estimated quantities of available supplies, including natural groundwater recharge, local surface water supplies, recycled water, and SFPUC Hetch Hetchy, were based on long-term averages (i.e., 1922–2003) for the without-project conditions from Valley Water's WEAP model and are shown in Table 6-8.

Table 6-8. Summary of Valley Water's North Basin 2030 Demands and Available Water Supplies During Delta Outage

Demand	Value
Demand (acre-feet)[1]	297,678
Available Supplies During Outage Prior to Additional Groundwater Pumping	
Natural Groundwater Recharge/Sustainable Groundwater Use (acre-feet) [1]	36,586
Surface Water (acre-feet)[1]	39,052
Recycled Water (acre-feet)[1]	26,733
SFPUC Hetch Hetchy (acre-feet)[1]	57,596
Total Available Supplies (acre-feet)[1]	159,966
Shortage (acre-feet)	137,712
Water Availability (%)	54%
Shortage (%)	46%
Available Supplies During Outage with Additional Groundwater Pumping	
Shortage Quantity prior to Groundwater Pumping (acre-feet)	137,712
Additional Groundwater Pumping during Outage (acre-feet)[2]	49,912
Shortage with Additional Groundwater Pumping (acre-feet)	87,800
Total Available Supplies with Additional Groundwater Pumping (acre-feet)	209,878
Water Availability (%)	71%
Shortage (%)	29%

Notes:

[1] Based upon WEAP output for No Action Alternative.

[2] Assumed additional groundwater pumping above natural groundwater recharge rates/sustainable groundwater yield of the basin. The North County Santa Clara Subbasin reaches the "severe" stage, as defined in the Water Shortage Contingency Plan, at 232,000 AF. The long-term average storage in the North County Santa Clara Subbasin, based on the WEAP output for the No Action Alternative, is 316,340 AF. The difference between the long-term average storage and the Water Shortage Contingency Plan "severe" stage is 84,340 AF. For the purposes of this analysis, it is assumed that 49,912 AF of additional groundwater pumping would occur during the initial 12 months of an outage, allowing for a limited of groundwater (approximately 34,428 AF) to be available to help meet shortages in the event that a Delta outage lasted beyond 12 months.

The ability to pump groundwater in response to shortages is limited by Valley Water thresholds established to ensure sustainable groundwater conditions. Santa Clara County has historically experienced land subsidence caused by groundwater pumping and overdraft. It is assumed that additional groundwater pumping from North County Santa Clara Subbasin, beyond natural groundwater recharge rates and sustainable groundwater yield of the basin, would be used to help meet demands during the outage. For this analysis, limitations on additional groundwater pumping was limited by the severe stage of the Water Shortage Consistency Plan (WSCP) and considerations for maintaining minimal quantities of groundwater supplies above the severe stage if a Delta outage lasted beyond 12 months. Valley Water's WSCP is included in Valley Water's 2015 Urban Water Management Plan as Chapter 8. The WSCP stages represent countywide values; in the North County Santa Clara Subbasin, the severe stage of the WSCP corresponds to 232,000 AF of storage.

Table 6-9 shows the values for groundwater and surface water outage supplies for Valley Water. The total was then multiplied by the annual probability of occurrence to obtain the expected annual benefit for each alternative.

Table 6-9. Average Annual NED Benefits for Enhanced M&I Emergency Water Supply: Delta Outage for 2030 Future Conditions

Alternative	Outage Volume (acre-feet)	Value[1] ($)	Emergency Water Supply (TAF)	Annual Benefit[1] (million $)
Non-Structural	–	–	–	–
CVP-Only	87,800	$1,841	28	$12.5
CVP/SWP Split Storage	87,800	$1,841	17	$4.4
Investor-Directed Storage Subalternative A	87,800	$1,841	31	$14.7
Investor-Directed Storage Subalternative B	87,800	$1,841	31	$14.7
Investor-Directed Storage Subalternative C	87,800	$1,841	63	$27.8
Investor-Directed Storage Subalternative D	87,800	$1,841	63	$27.8

Notes:
[1]Based on January 2020 price levels.
Key:
AF = acre-feet

South-of-Delta CVP Supplies The available supplies accessible to the other South-of-Delta CVP M&I water users during a Delta outage for 2030 future conditions are limited. Groundwater in the cites of Avenal, Coalinga, and Huron is not used because of poor quality and it is not suitable for M&I purposes in these areas. These cities rely solely on imported CVP M&I water deliveries. The California Department of Fish and Wildlife, San Luis Water District, Lemoore Naval Station, Fresno County, and Tulare County also rely on imported CVP M&I water deliveries. It is estimated that for 2030 future conditions 100 percent of supplies to these users would be CVP M&I deliveries and depended on the Delta.

The City of Tracy received water supplies from surface water from CVP M&I deliveries, Surface water from the Stanislaus River via the South County Water Supply Project, and groundwater pumped from nine groundwater wells located within the city. Historically, groundwater has accounted for approximately 40 to 50 percent of the City's annual water supply (City of Tracy 2014). The remaining annual water supply is imported CVP M&I deliveries. It is estimated for 2030 future conditions that 44 percent of future supplies would be CVP M&I deliveries and depended on the Delta.

The City of Hollister relies on both local groundwater and imported water from the CVP for its M&I water supply. The city's management has resulted in a reliable groundwater resource, but levels have declined locally due to pumping and prolonged drought. However, due to groundwater quality concerns groundwater use is expected to decrease in the future (City of Hollister 2016). It is estimated for 2030 future conditions that 66 percent of future supplies would be CVP M&I deliveries and depended on the Delta.

6.3.3 Results

Table 6-8 shows the estimated NED benefits for emergency response under 2030 future conditions. The total groundwater and surface water volumes were multiplied by the annual probability of occurrence (0.042) and value (Table 6-6) to obtain the expected total and annual benefit for each alternative.

Table 6-8. Estimated NED Benefits for Enhanced M&I Emergency Water Supply

Alternative	NED Emergency Response Annual Benefits (million $)[1]
Non-Structural	–
CVP-Only	$12.5
CVP/SWP Split	$4.4
Investor-Directed Storage Subalternative A	$14.7
Investor-Directed Storage Subalternative B	$14.7
Investor-Directed Storage Subalternative C	$27.8
Investor-Directed Storage Subalternative D	$27.8

Notes:

[1] Total economic losses were multiplied by the annual probability of occurrence of 0.042 to obtain the emergency response annual benefits.

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Chapter 7 NED Transportation Safety Benefits

7.1 Introduction

The Dam Raise Alternative includes modifications along SR 152 at the Cottonwood Bay crossing. This alternative would provide benefits to public safety by preventing inundation of the roadway when the enlarged reservoir is filled to capacity and reducing current seismic risk at the SR 152 Cottonwood Bay crossing. This chapter presents a summary of how these public safety benefits were quantified and monetized and the results of that evaluation.

7.2 Physical Benefit Quantification

SR 152 is a state highway that runs east from near the middle of California SR 1 in Watsonville to SR 99 southeast part of Merced County. Its western portion (which is also known as Pacheco Pass Road and Pacheco Pass Highway) provides access to and from Interstate 5 toward Southern California for motorists in or near Gilroy, and Hollister in the Silicon Valley. In absence of this highway, motorists from Gilroy and Hollister area in the Silicon Valley would be routed through SR 130 north of SR 152 to access Interstate 5. The SR 130 route would add approximately 80 miles and 2 hours to motorist commute.

In the vicinity of San Luis Reservoir, SR 152 is a four-lane divided expressway that extends along the northern and eastern shore of the reservoir. The route then passes between the San Luis Dam and the O'Neill Forebay at the eastern base of the dam. A portion of SR 152 at the northern edge of the reservoir crosses Cottonwood Creek with a fill embankment that creates Cottonwood Bay to the north.

San Luis Reservoir is in a seismically active area and is close to several faults and fault systems. The Ortigalita fault passes under the reservoir in two locations, one is along the western shore of the reservoir crossing over Lone Oak Bay to the east and the other runs from Cottonwood Bay close to the eastern shore of the reservoir on the eastern side of Basalt Hill (Reclamation and CDPR 2013 and USGS 2011). A detailed geologic study to characterize all the potential seismic sources[1] in the area of B.F. Sisk and O'Neill Forebay dams was conducted by Reclamation in 1999 and 2000. That study identified nine faults as being potentially significant sources of seismic shaking, including:

- Strike-slip faults of the Ortigalita and San Andreas faults

[1] CGS describes seismic sources (faults) as (1) Active, which describe historical and Holocene faults with displacements within the past 11,000 years, (2) Potentially Active, which describes faults with evidence of displacements during the Quaternary (the past 1.6 million years), (3) Inactive, which are pre-Quaternary age. Seismic events and displacements may still take place along an inactive fault; however, the chance of that happening are considered low.

- West-dipping, bedding-plane, reverse faults within the Great Valley Sequence
- West-dipping, blind thrust faults along the uplift margin of the Diablo Range (Reclamation 2009)

Located in the eastern part of the San Andreas Fault system, the Ortigalita Fault in the vicinity of the reservoir has two sections, the Los Banos Valley section and the Cottonwood Arm section (roughly corresponding to the locations described above [USGS 2011 and Bryant and Cluett 2000a]). The Los Banos Valley section is in Merced County. Bryant and Cluett (2000b) do not report any recent (historic) earthquakes and the most recent prehistoric deformation (defined as the most recent prehistoric surface rupturing or surface deforming earthquake) was the latest Quaternary (around 15,000 years ago). The Cottonwood Arm section is in Merced and Stanislaus Counties. There are no records of recent earthquake activity along this section of the Ortigalita fault zone. The most recent prehistoric deformation was around 15,000 years ago (Bryant and Cluett 2000a). Based on the information available from the USGS, the Ortigalita Fault Zone's Ortigalita-Cottonwood Arm Section traverses through the SR 152 embankment foundation. For the return period of 975 years, the seismicity at the SR 152 embankment section is high with the peak ground acceleration (PGA) of 0.77 g as obtained from the Caltrans ARS 3.0.1 tool.

The PR&G's identify public safety as one of the overarching concepts the federal government seeks to promote through federal investments in water development project (CEQ 2014). Public safety benefits are identified in actions that include reducing threats to people, including both loss of life and injury, from natural events. As noted previously, the Ortigalita Fault passes under the SR 152 embankment that crosses Cottonwood Bay. The Dam Raise Alternative includes modifications to SR 152 with three design actions: (1) raising the SR 152 embankment at the Cottonwood Bay crossing by 11 feet to prevent inundation of the roadway when the enlarged reservoir is filled to capacity; (2) flattening the side slopes from 2:1 to a 3:1 slope to increase seismic stability of the embankment at Cottonwood Bay; and (3) slope protection of the East Overlook Parking Area located approximately half a mile southeast from the SR 152 Cottonwood Bay crossing. The modifications to the Cottonwood Bay SR 152 embankment to increase seismic stability and reduce current seismic risk would be a public safety benefit as described in the PR&G's.

Failure of the existing SR 152 embankment during a seismic event is given the fault potential on site estimated to generate a significant slumping of the embankment core that would during period of high reservoir storage put the SR 152 under water. In periods of lower water storage levels in the reservoir this significant slumping is anticipated to generate buckling and failure of the roadway surface. In either condition this impact to the roadway would present significant safety risk to motorists crossing the embankment at highway speeds. In addition to this direct safety impact to motorists, failure of the roadway would generate a long-term public safety effect by inhibiting access for emergency vehicles needing to respond not only to the seismic event that generated the embankment failure but also generate significant interruptions for emergency response to potential wildfires or other natural disasters in the region, transit of emergency vehicles accessing medical facilities in communities along the US 101 corridor to the west and Interstate 5 and SR 152 corridors to the east. It is assumed that repair of this embankment following a seismic failure would take approximately 2 years, however the highway would be fully closed to traffic during the 2-year period. During this outage, the fastest potential detour would rely on existing SR 130. This alternate route would add an additional 2 hours of travel time and significantly inhibit emergency access.

7.3 NED Benefit Monetization

7.3.1 Economic Methods

7.3.1.1 Approach 1: Value of lost time approach

The approach builds on estimates for the value of lost time and is consistent with the methodology applied by the U.S. Department of Transportation (DOT). This approach assumes, the SR 152 embankment would be fully closed to traffic for a 2-year period following a seismic failure. During this outage, the fastest potential detour would add an additional 2 hours of travel time. This approach monetizes the potential trip delay of 2 hours to commercial and personal passengers due to the closure of SR-152 Highway.

This method distinguishes between business or commercial travel time and personal and recreational time. While commercial travel time is reimbursed at 100 percent of the wage rate, the DOT values personal travel time (including commute time) at 50 percent of the wage rate (FHWA 2007). The full wage rate is not typically used to measure personal travel because it is assumed that individuals benefit from the travel (e.g., a scenic drive), or they are willing to accept the travel time in order to gain something (e.g., a higher paying job).

According to the National Household Travel Survey (DOT 2006), 82 percent of vehicles on the road are personal passenger vehicles, with the remaining 18 percent being commercial vehicles. This survey also determined that the average number of persons per vehicle is 2.3. Employing the national average hourly wage of $43.35 and DOT's methodology for per-hour value of time, the equation below was used to determine the hourly value of time per vehicle:

$$((\%personal_passenger * (wage_rate * 0.5)) + \%commercial * wage_rate)) * persons_per_vehicle$$

The value from this formula was then applied to annual traffic count data collected for SR 152 for both years of the assumed outage following a seismic failure to account for the lost time. Finally, the benefit identified was adjusted by 0.001 to account for the assumed probability of a seismic event large enough to generate roadway failure.

This evaluation approach does not however quantify all potential economic benefits to the nation from the avoidance of seismic failure at the embankment including impacts to emergency response times during the two-year highway outage including response times to emergencies at the San Luis Reservoir State Recreation Area.

7.3.1.2 Approach 2: Least-cost most likely alternative approach

The least-cost most likely alternative formulated to reduce seismic risk at the existing embankment considered flattening the slope of existing embankment from 2:1 to a 3:1 slope. This alternative would maintain the current crest elevation (El. 555), add a 90-foot-wide riprap buttress from the toe of the slopes to an elevation of El. 499, and add riprap reinforcement to the upper portion of the embankment ranging from 40 feet wide to 10 feet wide. The single purpose alternative would also introduce a 50-foot-wide bench at El. 499 and a 10-feet-wide bench at El. 550. The design slopes for the lower buttress and the upper reinforcement would be 2H:1V and 2.4H:1V, respectively. All the additional material would consist of riprap for this single purpose alternative, which includes adding about 513,000 cy of riprap for slope protection, 3,500 cy of embankment.

As part of this approach other alternative solutions including structural and non-structural elements to avoid, reduce and mitigate threat to motorists from the seismic risk associated with the SR 152 embankment were evaluated. The potential nonstructural alternative that was identified and evaluated would decommission the existing embankment. Under this alternative motorists would need to rely on existing SR 130 to connect between the US 101 corridor to the west and Interstate 5 corridor to the east. However, the SR 130 route would add an additional 2 hours of travel time which would cause a significant impact to motorists and it was screened from further consideration.

Other structural options evaluated included numerous potential configurations including replacement of the existing embankment with a bridge, rerouting of the state route around Cottonwood Bay, and modification of the existing embankment to address the seismic risk. The option of replacing the existing embankment with a bridge was evaluated and given the increased length of the span when compared to the existing embankment, the need to construct this new bridge in the reservoir without impacting its operation, and the active fault line that it would need to cross, it was estimated to increase its potential cost higher than modifying the existing embankment. Similarly, rerouting the roadway around Cottonwood Bay was also screened given the complexity of procuring privately owned lands that the new roadway would traverse along with mapped active landslides throughout its potential alignment.

7.3.2 Economic Analysis

It is assumed that modifications at multiple locations along SR 152 would improve transportation safety to the surrounding areas and provide benefits to public safety by reducing threats to people, including both loss of life and injury, from future seismic events. The least-cost and most likely alternative is based on the cost of upgrades to SR 152 solely for the purpose of reducing seismic risk and increasing public safety. The value of lost time approach is based on the cost incurred by personal and commercial vehicles from the trip delay due to closure of SR-152 Highway.

7.3.3 Results

Table 7-1 shows the estimated benefits for performing modification to SR 152 using the value of lost time approach. As discussed in Section 7.3.1.2, this approach evaluates the value of reductions in lost time, and the cost from road facility closures and outages.

Table 7-1. Estimated Benefits for Modification to SR 152 using the Value of Lost Time Approach

Alternative Plan[1]	Benefit based on lost time to commercial and personal vehicles only (million $)[2]	Annual Benefits (million $)
Lost Time to Commercial and Personal Vehicles Only	$9.1	$0.3

Notes:
[1] All operational configurations of the Dam Raise Alternative include the full SR 152 upgrade which would provide this transportation safety benefit
2 Based on January 2020 price levels.

Table 7-2 shows the estimated public safety benefits for performing modifications to SR 152 using the least-cost most likely alternative approach.

Table 7-2. Estimated Public Safety Benefits for Modification to SR 152 using the Least-Cost Most Likely Alternative Approach

Alternative Plan[1]	Public Safety Benefit based on Seismic Upgrade Only (million $)[2]	Public Safety Annual Benefits (million $)
Seismic Upgrade Only	$256.0	$7.6

Notes:
[1] All operational configurations of the Dam Raise Alternative include the full SR 152 upgrade which would provide this transportation safety benefit
2 Based on January 2020 price levels.

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Chapter 8 NED Refuge Water Supply Benefits

8.1 Introduction

The Dam Raise Alternative would be the only alternative evaluated that would provide benefits to San Joaquin Valley wildlife refuges. This chapter presents a summary of how these refuge water supply benefits were quantified and monetized, the results of that evaluation, and the potential risks and uncertainties with those results.

8.2 Physical Benefit Quantification

Through the passage of the CVPIA in 1992, fish and wildlife were given equal priority as other water uses in the CVP service area. As a result, the federal government was required to provide a clean and reliable supply of water to wetland habitats in these refuges in support of fish and wildlife species. This is being accomplished through the Refuge Water Supply Program (Reclamation and USFWS 2009). Reclamation delivers water to wildlife refuges in the Central Valley as a requirement of the CVPIA, as Level 2 supply (firm supply) and Incremental Level 4 supply (purchased from willing sellers). Currently, Incremental Level 4 refuge demands are not being fully met.

An environmental benefit of the B.F. Sisk Dam Raise Project would be the increased deliveries of Incremental Level 4 water supplies to the Refuge Water Supply Program. The B.F. Sisk Dam Raise Project would transfer 2,000 AF of SLDMWA's CVP water supply, during below-normal water years, to the Incremental Level 4 Refuge Water Supply Pool, which is managed by Reclamation and USFWS. SLDMWA has requested that Reclamation dedicate this supply to the Grasslands Resource Conservation District (GRCD), which provides water to the largest contiguous block of wetlands remaining in California's Central Valley. The increased supply would provide habitat and food for migratory birds of the Pacific Flyway, resident bird species, and many wildlife species. Additionally, purchases on the spot market by Reclamation to meet Incremental Level 4 refuge demands may be avoided.

An analysis was performed to estimate the benefit of improved environmental water-supply reliability under 2030 future conditions. The CalSim II model was used to estimate increases in environmental water supplies available to the Incremental Level 4 Refuge Water Supply Pool, between with- and without-Project for 2030 future conditions over an 82-year simulation period (1922–2003). These CalSim II simulations specifically targeted improving deliveries for GRCD. Increased environmental water supplies for San Joaquin River watershed wildlife refuges are summarized in Table 8-1.

Table 8-1. Estimated Change in Annual Average Irrigation Water Supply Provided by Dam Raise Subalternatives (TAF/year)

Year Type[1]	Non-Structural Alternative	Dam Raise Alternative					
		CVP-Only[3]	CVP/SWP Split[3]	Investor-Directed Storage Subalternative A	Investor-Directed Storage Subalternative B	Investor-Directed Storage Subalternative C	Investor-Directed Storage Subalternative D
Wet	–	–	–	13.1	–	4.4	–
Above Normal	–	–	–	4	–	1.5	–
Below Normal	–	–	–	6.6	–	2	–
Dry	–	–	–	1.8	–	3.7	–
Critical	–	–	–	0.7	–	2.3	–
Average Annual Additional Water Quantity[2]	–	–	–	6	–	3	–

Notes:
[1] Sacramento Valley 40-30-30 Water Year Hydrologic Classification Index used to define water year types.
[2] Average calculated as the weighted average of five water year types and values in
[3] Refuge deliveries are minimal with an average annual increase of approximately 1 TAF/year.

8.3 NED Benefit Monetization

8.3.1 Economic Methods

The economic value of improvements in water deliveries to refuges and the associated improvements in wetland functions and wildlife habitat can be measured in a variety of ways. Applicable valuation methods generally include revealed preferences, surveys, and alternative costs. As described above, Reclamation has an ongoing program to purchase water supplies to benefit refuges in the Central Valley from willing sellers. Given the existence of the program, the costs associated with purchasing water supplies from willing sellers is considered to be the most applicable for valuing the improved water supplies for refuges.

8.3.2 Economic Analysis

This section addresses the refuge water supply benefits that may be realized by providing additional refuge water supplies to help meet Incremental Level 4 refuge water needs. The quantification of refuge water supply benefits considers the estimated short-term water market purchase price as the most likely alternative in the absence of firm water supply from the B.F. Sisk Dam Raise and Reservoir Expansion Project.

8.3.2.1 Market Price for Water to Refuges

Historically, Incremental Level 4 water supplies have been primarily obtained through single-year water purchase agreements. In this analysis, the benefits of refuge water supply are measured

according to the estimated cost of obtaining the water supply through continued spot market leases. The water transfer pricing model is applied to estimate the benefits of improved refuge water supply. The economic model consists of a statistical analysis of documented spot market water transactions in California. The model seeks to explain the factors that influence California water market prices and is used to forecast 2030 prices under a variety of conditions including seller and buyer location, buyer type, and hydrologic conditions.

Table 8-2 provides the estimated 2030 water market prices assuming:

- The water is being leased for environmental purposes. As shown by the coefficient value for model variable *env* (presented in Table 6-3 in Chapter 6 of this document) environmental buyers are typically able to acquire water for a lower price than urban buyers.
- Water is leased from lower priced North-of-Delta sources during below-normal, dry, and critical years when Sacramento-San Joaquin River Delta (Delta) conveyance capacity is available. During above-normal and wet year types water is leased from South-of-Delta sources.
- A 25-percent conveyance loss factor is applied to water leased from North-of-Delta sources and 10 percent to water leased from South-of-Delta sources.

Table 8-2. Estimated 2030 Refuge Water Prices

Year Type	Water Transfer Price[1] ($/AF/yr)
Wet	$212
Above Normal	$236
Below Normal	$337
Dry	$377
Critical	$628

Notes:
[1] Dollar values are expressed in January 2020 price levels.
Key:
AF/yr = acre-feet per year

In addition to the market price for water, buyers incur conveyance costs that vary with location and infrastructure. This analysis assumes that the refuge water delivered to the DMC is estimated at the Banks Pumping Plant and is approximately $20/AF.[13] Combined water market prices, carriage losses, and conveyance costs for refuge water supplies are provided in Table 8-3. The values reflect the total cost of water (water price + conveyance losses + conveyance charges) to environmental water users by location and year type in 2030. These values are applied to the subalternative of the Dam Raise Alternative water deliveries year type to estimate total refuge water supply reliability benefits displayed in Table 8-4. While water transfer costs are expected to continue to increase in the future, the estimated values are not increased beyond the 2030 levels in this analysis because of the

[13] Sources: California Department of Water Resources, Management of the California State Water Project: Bulletin 132-18. Appendix B Table 7. Kilowatt-Hour Per Acre-Foot Factors for Allocating Off-Aqueduct Power Facility Costs, 2018b.

limited set of willingness-to-pay based estimates that can be applied as a constraint on future water values.

Table 8-3. Estimated 2030 Refuge Water Supply Costs

Year Type[1]	Total Water Cost ($/AF/yr)
Wet	$256
Above Normal	$293
Below Normal	$410
Dry	$463
Critical	$773

Notes:
[1] Sacramento Valley Water Year Hydrologic Classification Index used to define water year types.

Table 8-4 provides a summary of the estimated benefits for subalternatives of the Dam Raise Alternative. As shown, the estimated annual benefits are approximately $0.14 million in 2030. Table 8-4 presents annual benefits for incremental environmental water supplies to San Joaquin River Valley wildlife refuges under 2030 future conditions.

Table 8-4. Average Annual Refuge Water Supply Economic Benefits Relative to No Action Alternative

Alternative	NED Refuge Water Supply Reliability (TAF/year)	NED Refuge Water Supply Annual Benefits (million $)[1]
Non-Structural	–	–
CVP-Only	–	–
CVP/SWP Split	–	–
Investor-Directed Storage Subalternative A	6.2	$1.8
Investor-Directed Storage Subalternative B	–	–
Investor-Directed Storage Subalternative C	3.2	$1.1
Investor-Directed Storage Subalternative D	–	–

Notes: Based on January 2020 price levels.
[1] Refuge water supply benefits have been adjusted for the structural alternatives to account for a water supply emergency's limits on the availability of this supply.
Key:
NED = National Economic Development

Chapter 9 Other NED Benefits

9.1 Introduction

The Dam Raise Alternative would provide other economic benefits that are not quantified for this analysis. This chapter describes these benefits qualitatively.

9.2 Long-Term Operational Flexibility and Water Supply Reliability to SLDMWA Member Agencies

The Dam Raise Alternative would increase operational flexibility and allow SLDMWA member agencies to manage water supplies efficiently by increasing supply and storage management options.

The Dam Raise Alternative would improve long-term water supply reliability to SLDMWA member agencies. In years when CVP contractors choose to conserve portions of their allocation for use in a subsequent dry year, those contractors can choose to leave that unused supply in San Luis Reservoir as carried-over water. The contractors, in storing this carried-over supply in San Luis Reservoir, take on a risk of potentially losing it if San Luis Reservoir fills the next year and that supply is "spilled" (converted to CVP supplies for following year's allocation). The CVP contractors also store their supplemental supply (non-Project water) such as transfer water or conserved water into a subsequent year. The contractors also risk losing this water if San Luis Reservoir fills. Implementing the Dam Raise Alternative and Reservoir Expansion Project could increase storage capacity and reduce the likelihood of carried-over supply and other water being lost to CVP contractors. Additionally, the contractors could also capture more Project water if excess flows become available.

This increased operational flexibility and reliability could change cropping decisions and generate increased revenues in the long term.

9.3 Reduced Reliance on Groundwater

Increasing reliability of surface water deliveries would decrease the use of groundwater. Groundwater levels would be drawn down at slower rates and the aquifer storage would increase over time. This would contribute to objectives of California's Sustainable Groundwater Management Act (SGMA), which is focused on addressing groundwater overdraft and ensuring sustainable management of groundwater basins throughout the State. SGMA requires agencies to develop projects to create a water balance in the groundwater basins. The Dam Raise Alternative would be a project to achieve this objective.

Increased groundwater pumping during recent droughts has resulted in land subsidence, which has reduced the freeboard and flow capacity of the Delta-Mendota Canal, requiring costly repairs. Reduced groundwater pumping as a result of the Dam Raise Alternative would result in a decreased rate of subsidence along the Delta-Mendota Canal and less costly canal repairs.

9.4 Increased Recreation Opportunity at San Luis Reservoir

Increased water storage at San Luis Reservoir level would increase water levels and the surface water area of the reservoir. Increased surface water area would provide additional access to recreation opportunities and increase recreational use and visitation at the reservoir. Increased recreation days at the reservoir provides economic benefits that represent the value of the recreation resource to the user. The recreation value considers accessibility, environmental quality, recreation experience, availability of opportunity, and carrying capacity.

The Dam Raise Alternative would provide recreation economic benefits by providing additional surface area through increased reservoir storage and increased average water levels throughout the year when compared to the No Project/No Action Alternative.

Chapter 10 NED Benefits Summary

This economic analysis appendix presents estimates of the economic benefits associated with the Dam Raise Alternatives. Table 10-1 summarizes the estimated benefits according to each of the alternatives and benefit categories. Benefit categories include M&I water supply reliability, irrigation water supply reliability, refuge water supply, enhance emergency M&I water supply, and transportation safety.

M&I water supply reliability was valued according to the estimated costs of water transfers. Economic benefits of irrigation water supply reliability value was determined by comparing the results for each alternative to the results of the NAA to quantify changes in agricultural production, irrigated acreage, water use, and gross farm revenue. The value of emergency water supplies from the alternatives was estimated through measurement of the consumer's willingness to pay to avoid water supply shortages. During emergency supply periods, it was assumed that all available water would be used to alleviate shortages to urban water users in the Valley Water district. Economic benefits associated with transportation safety were evaluated using the "least cost" most likely alternative approach. Refuge water (Incremental Level 4) supply was evaluated using an econometric model of water market prices that estimated the costs of alternative water supplies in the absence of the alternatives. The water pricing model considered region and source of water supply, water year type, and population growth, among other factors, to predict water market prices over the planning period. To avoid double-counting, total benefits were weighted according to the estimated probability of an emergency water supply disruption during the planning period.

Table 10-1 summarizes the estimated annual economic benefits for the proposed project alternatives. The economic benefits estimated in this analysis rely on a set of assumptions. Changes in these assumptions will change the estimated benefits and could affect the applicability of the methods applied to estimate the benefits.

Table 10-1. Summary of Estimated Economic Benefits by Alternative, Adjusted for Delivery of Emergency Supplies ($ millions)

Benefit Category	Non-Structural	CVP-Only	CVP/SWP Split	Investor Directed Storage Subalternative A	Investor Directed Storage Subalternative B	Investor Directed Storage Subalternative C	Investor Directed Storage Subalternative D
Annual M&I Water Supply Benefits (Million $)[1,2]	$0.7	$1.5	–$1.8	$1.6	$16.0	$1.1	$9.4
Annual Agricultural Water Supply Benefits (Million $)[2,3]	–$5.7	$7.4	$4.4	$5.8	$0.9	$3.0	$0.5
Enhanced Emergency M&I Water Supply (Million $)[2]	–	$12.5	$4.4	$14.7	$14.7	$27.8	$27.8
Transportation Benefit – Approach 1[4]	–	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3
Transportation Benefit – Approach 2[4]	–	$7.6	$7.6	$7.6	$7.6	$7.6	$7.6
Annual San Joaquin Refuge Water Supply (Million $)[5]	–	–	–	$1.8		$1.1	–
Total Annual Economic Benefits	–$5.0	$32.6	$21.1	$34.4	$41.9	$39.1	$43.7

Notes:

General: January 2020 price levels. All values are rounded for display purposes; as a result, not all totals may sum. Emergency M&I benefits and Transportation Public Safety benefits were not adjusted.

[1] Market-based estimates of the cost of water transfers to Bay Area M&I agencies.

[2] Non-emergency water supply benefits have been adjusted for the structural alternatives to account for a water supply emergency's limits on the availability of this supply.

[3] Based on SWAP Modeling results

[4] Transportation Benefit – Approach 1 presents estimated benefits generated by avoidance of transportation delays, Transportation Benefit – Approach 2 presents economic benefits estimated using the "least cost" most likely alternative approach.

[5] Market-based estimates of the cost of water transfers to wildlife Refuges in the San Joaquin Valley.

Key:

M&I = municipal and industrial

Chapter 11 Regional Economic Development Account

11.1 Introduction

Regional economic impacts are concerned with the effects of changes in the economy of a region. The magnitudes of the economic impacts are determined by the interactions between linkages within the local/regional economy and the leakages from this economy to the larger economy. Economic linkages are the relationships between industries, businesses, factors of production (e.g., labor and capital), and government created by trade and other exchange, such as taxes, within and among regions. Economic linkages create multiplier effects in a regional economy as money is circulated by trade. The magnitudes of impacts resulting from economic linkages are limited by the amount of leakage that occurs within the region. Economic leakages are a measure of the income shares spent outside of the region. Thus, the more the economic leakage, the less the multiplier effect. Generally, the smaller the regional economy, the higher the economic leakage. For example, the economic leakages for a county are larger than those for the state, which are larger than those for the nation.

11.2 RED Benefit Monetization

11.2.1 Economic Methods

Several regional economic analysis modeling systems (consisting of data and analytical software) are available for use in regional economic analysis, such as Regional Economic Models Inc. (REMI), Regional Industrial Multiplier System II (RIMS II), and IMPLAN. The regional economic modeling for this project was completed using IMPLAN.

11.2.1.1 IMPLAN Model Assumptions

The IMPLAN model is the most widely used input-output (I-O) impact model system in the United States. IMPLAN is an I-O database and modeling software used to estimate economic impacts of changes in final demand or spending associated with the project alternatives. An I-O analysis describes and analyzes the relationship among industries.

IMPLAN analyzes the relationship among industries. IMPLAN is a static model that estimates impacts for a snapshot in time when the impacts are expected to occur, based on the makeup of the economy at the time of the underlying IMPLAN data. IMPLAN measures the initial impact to the economy but does not consider long-term adjustments as labor and capital move into alternative uses. This approach is used to compare the alternatives. Realistically, the structure of the economy will adapt and change; therefore, the IMPLAN results can only be used to compare relative changes between alternatives and cannot be used to predict or forecast future employment, labor income, or output (sales).

Any given industry typically purchases goods and services from, and sells goods and services to, another industry within a given geographic area, which in turn, sells to or buys from other industries or supplies final consumers. Figure 11-1 shows the general flows of money between industries and consumers that is captured by IMPLAN.

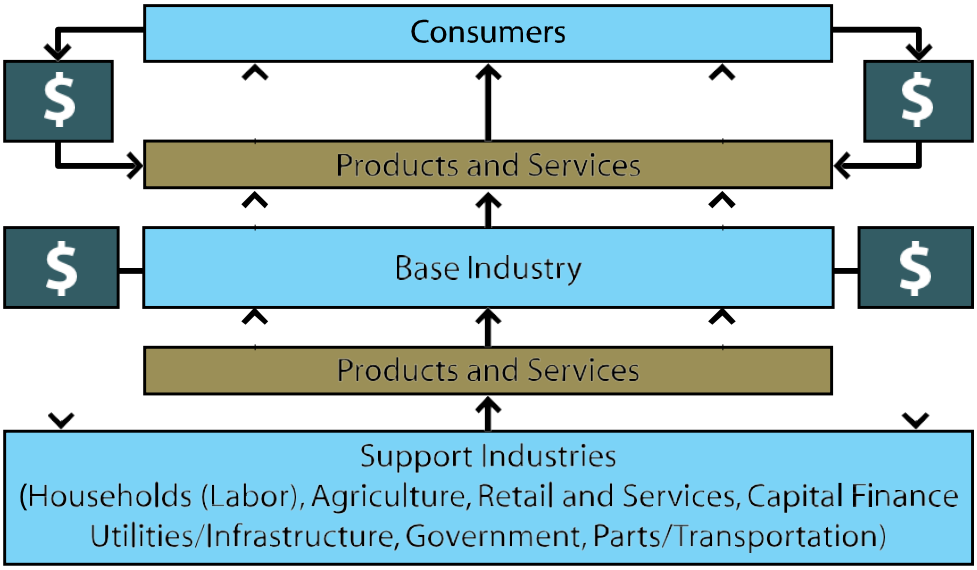


Figure 11-1. Economic Linkages in a Hypothetical Industry

IMPLAN uses these interindustry linkages and provides a tool to estimate the total economic effects within a region from a change in final demand to one economic sector. The industry linkages are estimated by economic multipliers (e.g., a multiplier of 2.0 indicates that each dollar of direct sale generates another dollar of secondary sales in the regional economy; a multiplier of 3.0 indicates that each dollar of direct sale generates an additional $2 of secondary sales in the regional economy, and so on).

Total economic effects include:

- **Direct effects** – changes in final demand
- **Indirect effects** – changes in expenditures within the region in industries supplying goods and services
- **Induced effects** – changes in expenditures of household income

IMPLAN estimates impacts on an annual basis. If the project effects occurred over a shorter time period, there would be fewer economic effects. This analysis presents estimates of impacts to value of output, labor income, and employment. The 2017 IMPLAN datasets were used for this analysis.

11.2.1.2 IMPLAN Data

As discussed previously, the 2017 IMPLAN dataset was used in this analysis. IMPLAN develops and releases data each year. IMPLAN data are developed from the system of national accounts for the United States based on data collected by the U.S. Department of Commerce's Bureau of Economic Analysis, U.S. Department of Labor's Bureau of Labor Statistics, and other federal and state government agencies. The 2017 dataset used in this analysis, uses the 15th comprehensive, or benchmark update of the National Income and Product Accounts (NIPAs) (IMPLAN 2018).

Data are collected for 536 distinct producing industry sectors of the national economy corresponding to the 2017 North American Industry Classification System (NAICS). Industry sectors are classified based on the primary commodity or service produced. Corresponding datasets are produced for each county in the United States, allowing analyses at the county level and for geographic aggregations such as clusters of contiguous counties, individual states, or groups of states. Initially, MIG Inc., and now the IMPLAN Group LLC, provide annual IMPLAN I-O datasets representing the state of the economy for any region. Since these data rely on the release of federal economic data, the release of the IMPLAN I-O dataset typically lags by a year or two.

Data provided for each industry sector include outputs and inputs from other sectors, value added, employment, wages and business taxes paid, imports and exports, final demand by households and government, capital investment, business inventories, marketing margins, and inflation factors (deflators). These data are provided both for the 536 producing sectors at the national level and for the corresponding sectors at the county level. Data on the technological mix of inputs and levels of transactions between producing sectors are taken from detailed I-O tables of the national economy. National and county level data are the basis for IMPLAN calculations of I-O tables and multipliers for local areas.

11.2.2 Economic Analysis

Construction expenditures would create jobs and generate additional economic activity within the region during the period of construction. The regional economic analysis was conducted using engineering estimates of total project costs, including materials and labor costs. IMPLAN is then used to determine indirect and induced effects of construction work.

11.2.2.1 Modeling Objectives

IMPLAN modeling was conducted to evaluate regional economic impacts from construction expenditures. Modeling objectives included the evaluation of the following potential impacts:

- Effects on regional employment
- Effects on regional labor income
- Effects on regional total economic output

11.2.2.2 Study Areas

Models of the multicounty regions were used to measure impacts in terms of total changes in employment, income, and economic output in these regions. Construction would be experienced in Merced County

11.2.2.3 Modeling and Assumptions

Construction impacts over the period of construction were analyzed using Analysis-by-Parts. Direct construction impacts included direct construction employment and labor income based on engineering estimates developed for the alternatives, as well as the direct input into the four IMPLAN sectors to account for nonfield expenditures (see Table 11-1).

Indirect and induced impacts are analyzed using default IMPLAN industry spending patterns in the construction sector, listed in Table 11-1. Additionally, income spending by construction workers is evaluated as a labor income event. Induced impacts are analyzed as employee compensation of change in construction income for construction workers.

Table 11-1. Mapping Construction Expenditures to IMPLAN Sectors

IMPLAN Sector
INDUSTRY CHANGE
Sector 449 – Architectural, engineering, and related services
Sector 455 – Environmental and other technical consulting services
Sector 438 – Insurance agencies, brokerages, and related activities
Sector 62 – Maintenance and repair construction of nonresidential structures
INDUSTRY SPENDING PATTERN
Sector 58 – Construction of other new nonresidential structure
Sector 445 – Commercial and Industrial machinery and equipment rental and leasing
LABOR INCOME CHANGE
Sector 5001 – Employee Compensation

11.2.2.4 Modeling Results

Table 11-2 and Table 11-3 summarize direct, indirect, induced, and total employment and output effects of construction expenditures for the Dam Raise Alternative. Since there are no construction actions associated with the Non-Structural Alternative, it is not discussed in table below.

Table 11-2. Direct, Indirect, Induced Employment and Output Effects of Construction Expenditures – Most Probable Construction Cost

	Dam Raise Alternative		
	Dam Raise Action	**SR 152 Modification Action**	**Total**
Construction Duration	**8 years**	**2 years**	**--**
Employment Direct Effect (# jobs)	3,451	1,116	4,567
Employment Indirect Effect (# jobs)	719	555	1,274
Employment Induced Effect (# jobs)	558	242	800
Total Employment Effect (# jobs)	**4,729**	**1,912**	**6,641**
Output Direct Effect ((million $)	$506.0	$362.3	$868.3
Output Indirect Effect (million $)	$92.6	$74.5	$167.1
Output Induced Effect (million $)	$79.7	$34.5	$114.2
Total Output Effect (million $)	**$678.3**	**$471.3**	**$1,149.6**

Key:
Direct effects – changes in final demand
Indirect effects – changes in expenditures within the region in industries supplying goods and services
Induced effects – changes in expenditures of household income

Table 11-3. Direct, Indirect, Induced Employment and Output Effects of Construction Expenditures – Probable Low Cost Construction Cost

	Dam Raise Alternative	**SR 152 Modification Action**	**Total**
Construction Duration	**8 years**	**2 years**	--
Employment Direct Effect (# jobs)	3,079	843	3,922
Indirect Effect (# jobs)	557	387	944
Induced Effect (# jobs)	479	176	655
Total Employment Effect (# jobs)	4,115	1,405	5,520
Output Direct Effect (million $)	**$427.5**	**$253.8**	**$681.30**
Output Indirect Effect (million $)	$71.0	$51.9	$122.90
Output Induced Effect (million $)	$68.3	$25.1	$93.40
Total Output Effect (million $)	**$566.9**	**$330.7**	**$897.60**

Key:
Direct effects – changes in final demand
Indirect effects – changes in expenditures within the region in industries supplying goods and services
Induced effects – changes in expenditures of household income
Based on January 2020 price levels.

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Chapter 12 Environmental Quality Account

The EQ account is a means of integrating information about the EQ resources and NEPA human environment effects (as defined in 40 Code of Federal Regulations 1507.14) of the Project alternatives into water resources planning. These include ecological, cultural, and aesthetic properties of natural and cultural resources that sustain and enrich human life. The EQ account includes nonmonetized positive and negative benefits, while the NED account includes monetized positive and negative benefits.

An evaluation of the ecological, cultural, and aesthetic properties of EQ resources was performed as part of the NEPA environmental review and documentation process. A detailed discussion of possible effects of the alternatives and proposed mitigation measures is included in the Final EIR/SEIS. These documents provide details on methods, process, procedures, and assumptions used in evaluating environmental effects associated with the projects with each project alternative. All phases of the proposed project, including construction and operation, were evaluated in the analysis. The impacts were organized by environmental resource or issue area. Significance criteria were used to define the level at which an impact would be considered significant, per NEPA and California Environmental Quality Act (CEQA). Impacts were identified as beneficial, where appropriate. Each impact was categorized as follows:

- No Impact – An impact that would cause no adverse change in the environment, as measured by the applicable significance criterion.
- Beneficial Impact – An impact that would cause a beneficial change to the environment, as measured by the applicable significance criterion.
- Less than Significant Impact – An impact that would cause no substantial adverse change in the environment, as measured by the applicable significance criterion; therefore, no mitigation would be required.
- Less than Significant Impact with Mitigation – A significant or potentially significant impact that would be a less than significant level if mitigation measures are implemented. Mitigation measures are applied where feasible to avoid, minimize, rectify, reduce, or compensate for significant impacts of the project, per NEPA regulations (40 Code of Federal Regulations 1508.20) and California State CEQA Guidelines (Section 15126.4).
- Significant and Unavoidable Impact – An impact that is a substantial adverse change in the environment that cannot be avoided or mitigated to a less than significant level if the project is implemented.

The alternatives would be similar in the types of environmental effects, although the level of some effects would vary across different portions of the extended study area. Generally, the adverse effects would be mitigated to less than significant levels with prescribed mitigation measures. Based on environmental resources studies to date, the alternatives were projected to be environmentally feasible.

12.1 No-Impacts and Less than Significant Impacts

The Public Draft EIR/SEIS has identified the following resource or issue areas as having either no impact or a less than significant impact on resources for all the alternatives:

- Flood Control
- Indian Trust Assets
- Public Utilities, Services, and Power
- Population and Housing

12.2 Significant and Unavoidable Impacts

The Public Draft EIR/SEIS has identified the following impacts in Table 12-1, which, even after mitigation measures are implemented, may remain significant and unavoidable for the action alternatives.

Table 12-1. Summary of Significant and Unavoidable Impacts

Impact	Alternative	Mitigation
Surface Water Supply		
Operational impacts on water supply would be considered significant if the alternative would substantially reduce the annual supply of water available to CVP, SWP, refuges, or other water users during the long-term operation of the alternative.	2	None
Air Quality		
Conflict with or obstruct implementation of the applicable air quality plan.	3	AQ-11, AQ-21, AQ-3, AQ-4
Noise and Vibration		
Expose sensitive receptors to noise levels in excess of standards established in the local general plan or noise ordinance.	1	NOI-1, NOI-2, NOI-3[2]
	3- Dam Raise	None
Cause a substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project.	1	NOI-1, NOI-2, NOI-3[2]
	3- Dam Raise	None
Traffic and Transportation		
Cause a substantial increase in traffic in relation to the existing traffic load and capacity of the street system.	3	None

Impact	Alternative	Mitigation
Recreation		
Project construction could result in temporary closure to recreation facilities, resulting in a substantial loss of recreation opportunities.	3	REC-1[2]
Cultural Resources		
Project construction and operation could result in adverse effects to historic properties and/or substantial adverse changes to historical resources, unique archaeological resources, or tribal cultural resources or result in the disturbance of human remains.	3	CR-1, CR-2, CR-3

Notes:

[1] Indicates measures carried forward from the B.F. Sisk Dam SOD Modification Project and implemented under Alternative 3. Description of measures provided in Section 4.15 of the B.F. Sisk Dam Raise and Reservoir Expansion Project Environmental Impact Report/Supplemental Environmental Impact Statement.

[2] Indicates Mitigation Measures implemented under the B.F. Sisk Dam SOD Modification Project. Section B.1.1.1 in Appendix B of the B.F. Sisk Dam Raise and Reservoir Expansion Project Environmental Impact Report/Supplemental Environmental Impact Statement includes full mitigation measure descriptions.

Key: CEQA = Alternative 1 – No Action/No Project Alternative; Alternative 2 – Non-Structural Alternative; Alternative 3 – Dam Raise Alternative; California Environmental Quality Act; CRHR = California Register of Historical Resources; NEPA = National Environmental Policy Act; NRHP = National Register of Historic Places

12.3 Less than Significant Impacts with Mitigation

Several resource areas would be affected by the alternatives. However, these impacts would be reduced to less than significant with mitigation. These less than significant impacts with mitigation are summarized in Table 12-2.

Table 12-2. Summary of Less than Significant with Mitigation Impacts

Impact	Alternative	Significance Determination (W/O Mitigation, W Mitigation)	Mitigation
Air Quality			
Conflict with or obstruct implementation of the applicable air quality plan.	1	S, LTS	AQ-1, AQ-2. AQ-3[1]
Greenhouse Gases			
Generate greenhouse gas emissions, either directly or indirectly, that could have a significant impact on the environment.	1	S, LTS	GHG-1[1]
	3	S, LTS	AQ-1[2], AQ-2[2], GHG-1, GHG-2
Conflict with an applicable plan, policy, or regulation adopted for the purpose of reducing the emissions of greenhouse gases.	3	S, LTS	AQ-1[2], AQ-2[2], GHG-1, GHG-2

Impact	Alternative	Significance Determination (W/O Mitigation, W Mitigation)	Mitigation
Visual Resources			
Have a substantial adverse effect on a scenic vista.	1	S, LTS	VIS-1[1]
Substantially damage scenic resources within a State scenic highway corridor.	1	S, LTS	VIS-1[1]
	3	S, LTS	VIS-2
Substantially degrade the existing visual character or quality of public views of the site and its surroundings or conflict with applicable regulations governing scenic quality.	1	S, LTS	VIS-1[1]
Create a new source of substantial light or glare, which would adversely affect day or nighttime views in the area.	1	S, LTS	VIS-1[1]
	3	S, LTS	VIS-1
Traffic and Transportation			
Substantially increase traffic hazards due to a geometric design feature or incompatible uses.	1	S, LTS	TR-1[1]
	3	S, LTS	TR-1
Result in inadequate emergency access.	1	S, LTS	TR-1[1]
	3	S, LTS	TR-1
Hazards and Hazardous Materials			
During construction activities, there is potential to encounter contaminated soil and/or groundwater, which could result in an accidental release of hazardous materials and pose a threat to the public and the environment.	1	S, LTS	HAZ-1[1]
Construction activities at San Luis Reservoir could conflict with seaplane maneuvers on San Luis Reservoir and operations at the San Luis Reservoir Seaplane Base, resulting in safety hazards for pilots and people working and residing in the area.	1	S, LTS	HAZ-2, HAZ-3[1]
During construction activities use of Basalt Road and SR 152 for site access could temporarily interfere with an emergency response plan or emergency evacuation plan for the State Responsibility Area.	1	S, LTS	TR-1[1]
	3	S, LTS	TR-1
The use of mechanical equipment during construction could increase the risk of wildfire within the vicinity of the study area.	1	S, LTS	HAZ-4[1]
	3	S, LTS	HAZ-1[4]

Impact	Alternative	Significance Determination (W/O Mitigation, W Mitigation)	Mitigation
Terrestrial Resources			
Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as an endangered, threatened, candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by the CDFW, NMFS, or USFWS.	1	S, LTS	TERR-1 through TERR-16[1]
	3	Construction – S, LTS	TERR-1,2,3,8,10,11,12,14; TERR-15: Species-specific mitigation measures; TERR-4,5,6,7,9 and 13[2]
Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations, or by the CDFW, NMFS, or USFWS.	1	S, LTS	TERR-16[1]
	3	Construction – S, LTS	TERR-16: Jurisdictional wetlands or waters, and streambeds and streambank mitigation
Have a substantial adverse effect on federally or state protected wetlands (including, but not limited to, marsh, vernal pool, coast, etc.) through direct removal, filling, hydrological interruption, or other means.	1	LTS	TERR-16[1]
	3	Construction – S, LTS	TERR-16: Jurisdictional wetlands or waters, and streambeds and streambank mitigation
Conflict with any local policies or ordinances protecting biological resources, or adopted Habitat Conservation Plan (HCP), Natural Community Conservation Plan (NCCP), or other approved local, regional, or State conservation plan.	3	S, LTS	TERR-1,2,3,8,10,11,12,14; TERR-15: Species-specific mitigation measures; TERR-16: Jurisdictional wetlands or waters, and streambeds and streambank mitigation TERR-4,5,6,7,9 and 13[2]
Recreation			
Project construction could result in temporary closure to recreation facilities, resulting in a substantial loss of recreation opportunities.	1	S, LTS	REC-1[1]
	3	S, LTS	REC-1[1]

Impact	Alternative	Significance Determination (W/O Mitigation, W Mitigation)	Mitigation
Operational changes to water levels in recreational water bodies could affect recreational uses.	3	S, LTS	REC-1, REC-2
Cultural Resources			
Project construction and operation could result in adverse effects to historic properties and/or substantial adverse changes to historical resources, unique archaeological resources, or tribal cultural resources or result in the disturbance of human remains.	1	S, LTS	CR-1[1]
Geology, Seismicity, and Soils			
Construction activities could directly or indirectly destroy a unique paleontological resource or site or unique geologic feature.	3	S, LTS	GEO-1

Notes:

[1] Indicates Mitigation Measures implemented under the B.F. Sisk Dam SOD Modification Project. Section B.1.1.1 in Appendix B of the B.F. Sisk Dam Raise and Reservoir Expansion Project Environmental Impact Report/Supplemental Environmental Impact Statement includes full mitigation measure descriptions.

[2] Indicates measures carried forward from the B.F. Sisk Dam SOD Modification Project and implemented under Alternative 3. Description of measures provided in Section 4.15 of the B.F. Sisk Dam Raise and Reservoir Expansion Project Environmental Impact Report/Supplemental Environmental Impact Statement.

Key: Alt = alternative; Alternative 1 – No Action/No Project Alternative; Alternative 2 – Non-Structural Alternative; Alternative 3 – Dam Raise Alternative; CDFW = California Department of Fish and Wildlife; HCP = Habitat Conservation Plan; LTS = less than significant; NCCP = Natural Communities Conservation Plan; NI = no impact; NMFS = National Marine Fisheries Service; S = Significant; USFWS = United States Fish and Wildlife Service; W = with; WO = without

12.4 Beneficial Impacts

As shown in Table 12-3, the four alternatives were identified to have beneficial impacts on water quality, surface water supply, and groundwater.

Table 12-3. Summary of Beneficial Impacts

Significance Criteria	Alternative	Significance Determination
Surface Water Supply		
Operational impacts on water supply would be considered significant if the alternative would substantially reduce the annual supply of water available to CVP, SWP, refuges, or other water users during the long-term operation of the alternative.	3	CVP Only Storage: South-of-Delta CVP - B
		CVP/SWP Split Storage: South-of-Delta CVP - B
		Investor-Directed Storage: South-of-Delta CVP - B
Geology, Seismicity, and Soils		
Maintenance activities during operations could expose people or structures to adverse effects related to the rupture of a known earthquake fault.	1	B
	3	B

Key: Alternative 1 – No Action/No Project Alternative; Alternative 3 – Dam Raise Alternative; B = beneficial; Valley Water = Santa Clara Valley Water District; CVP = Central Valley Project; SWP = State Water Project

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Chapter 13 Other Social Effects Account

The OSE account measures effects to the social well-being of a community from implementing an alternative. This OSE account analysis uses a series of criteria to assist in identifying relevant social effects. These criteria consider social well-being factors, including health and safety, economic vitality, social connectedness and identity, social vulnerability, public participation, and leisure and recreation. The OSE account evaluation is qualitative and describes potential social effects related to the change in water supply deliveries under the alternatives relative to the No Project/No Action Alternative. Table 13-1 summarizes OSE account evaluation for the alternatives.

Table 13-1. OSE Account Evaluation

OSE Account Criteria	Alternative Evaluation
Health and Safety	Non-Structural Alternative would reduce water supply deliveries and would not provide any improvement to health and safety. The Dam Raise Alternative would increase water supply reliability for South-of-Delta contractors and reduce potential water shortages, which would improve long-term health and safety. The Dam Raise Alternative would also provide social health and safety benefits relative to the No Project/No Action Alternative, including emergency response to natural hazards.
Economic Vitality	Economic vitality relates to employment opportunities, business development, and population growth. The Non-Structural Alternative would reduce water supply deliveries and would not provide any improvement to economic vitality. The Dam Raise Alternative would provide a local, more reliable water supply for businesses, which would support employment and economic activity. A reliable municipal and industrial water supply would support projected increase in population and long-term economic vitality. Water provided for agricultural uses under the Dam Raise Alternative would support the agricultural economy in the Central Valley, including jobs.
Social Connectedness and Identity	Social connectedness and identity consider how residents connect to and view their community. The change in San Luis Reservoir operations under the Non-Structural Alternative would not affect residents' view of their community. In Merced County, San Luis Reservoir is one of the top three community assets (Merced County 2013). The Dam Raise Alternative would affect recreation at San Luis Reservoir for 3 or between 8 and 12 years, respectively. Effects could affect Merced County residents' social connectedness with the reservoir.

OSE Account Criteria	Alternative Evaluation
Social Vulnerability	Social vulnerability refers to the capacity for being adversely affected by hazards or other impacts and disproportionate effects to vulnerable populations in the ability to prepare for and respond to impacts. The alternatives would rely on imported CVP supplies from San Luis Reservoir, which could have reliability issues in case of a natural disaster if infrastructure or conveyance is damaged. Additional water supply under the Dam Raise Alternative could help alleviate effects of climate change, such as extreme heat or increased wildfires. Water supplies would be delivered within all areas and to all customers within a contractor service area; therefore, there would be no disproportionate effects on vulnerable populations.
Leisure and Recreation	The Dam Raise Alternative could adversely affect recreation opportunities at San Luis Reservoir in Merced County during the construction period. Two main use areas, Basalt and Dinosaur Point, would be closed to the public because of construction activities.
Participation	Participation means being able to interact with others to influence social outcomes. Reclamation and SLDMWA are pursuing this project in an open and transparent process allowing participation by all stakeholder groups. Reclamation and SLDMWA have and will provide opportunities for public participation throughout the planning process. All affected stakeholder groups would have the same opportunities to participate in this process. All alternatives would have the same opportunities for participation.

Key:
OSE = Other Social Effects
SLDMWA = San Luis & Delta-Mendota Water Authority
CVP = Central Valley Project

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Final Feasibility Report

Appendix D: Preliminary Cost Allocation



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RECLAMATION



December 2020

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List of Acronyms

AF	acre-feet
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
Delta	Sacramento-San Joaquin Delta
IDC	interest during construction
M&I	municipal and industrial
NED	National Economic Development
NMFS	National Marine Fisheries Service
O&M	operations and maintenance
OM&R	operations, maintenance, and replacement
Reclamation	United States Department of the Interior, Bureau of Reclamation
SBCWD	San Benito County Water District
SCRB	Separable Cost-Remaining Benefits
SGMA	Sustainable Groundwater Management Act
SLDMWA	San Luis & Delta-Mendota Water Authority
SR	State Route
TAF	thousand acre-feet
U.S.	United States
USEPA	U.S. Environmental Protection Agency
Valley Water	Santa Clara Valley Water District
Westlands	Westlands Water District
WIIN	2016 Water Infrastructure Improvements for the Nation Act
YR	year

Appendix D Cost Allocation

This appendix documents cost allocation terminology and methods, and an initial cost allocation and apportionment for the Dam Raise Alternative Plan. Chapters 1 and 4 of the Feasibility Report present the project background, objectives, and alternatives evaluated. The cost allocation is applied to the configurations of the Dam Raise Alternative Plan with National Economic Development (NED) benefits that exceeded the NED costs as described in Chapter 5 of the Feasibility Report. .

D.1 Process Overview, Terms, and Potential Methods

D.1.1 Process Overview and Terms

Allocation of federal water resources project costs is conducted to derive an equitable distribution of costs among the authorized project purposes, or those purposes proposed for authorization, in accordance with existing law. This initial analysis provides an indication of the cost implications of constructing the NED Plan for each authorized purpose.

Three basic steps are associated with cost allocation and apportionment:

- Identify costs to be allocated
- Allocate costs to project purposes
- Apportion costs to beneficiaries

The cost allocation process provides an important intermediary step towards evaluating the financial feasibility of potential alternatives, as illustrated in Figure D-1.

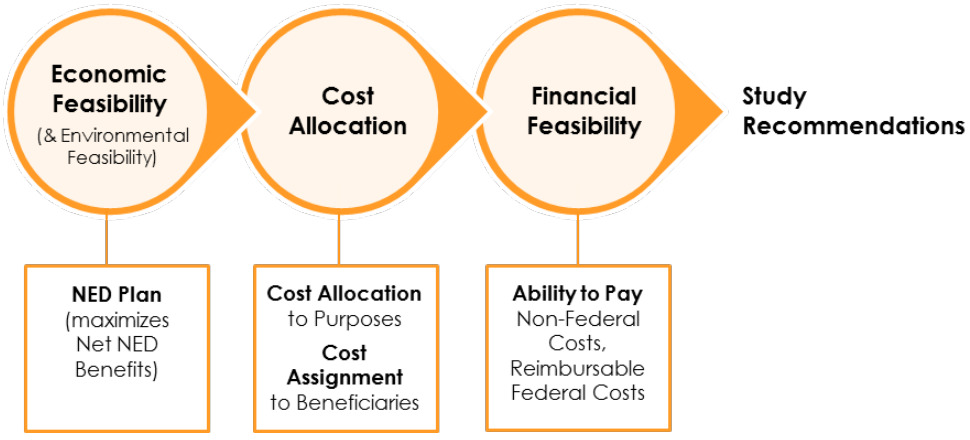


Figure D-1. Process for Evaluating Financial Feasibility

D.1.2 Costs Allocated

Total project costs allocated include construction costs, interest during construction (IDC), and annual operations, maintenance, and replacement (OM&R) costs. These costs are summarized below:

- Construction costs – Include field costs and noncontract costs to implement all elements of the project necessary to achieve the associated benefits.
- Interest during construction (IDC) – Accounts for the financial cost of project expenditures during the period between when construction begins and benefits are derived.
- Annual operation, maintenance, and replacement costs (OM&R) – Costs required to assure continued benefits over the life of the project.

It should be noted that cost allocation is a financial exercise rather than an economic evaluation; consequently, project costs may be presented differently in a cost allocation than in an economic analysis.

D.1.3 Allocating Costs to Project Purposes

Once all project costs are identified, they are allocated to the project purposes. Specific costs are for project components that contribute to a single purpose. For each purpose, separable costs are the costs of the portion of multipurpose facilities due to the inclusion of the purpose in question. Separable costs include specific costs and may include a portion of joint costs. They are estimated as the reduction in financial costs that would result if a purpose were excluded from an alternative. Joint costs are the costs remaining after specific and separable costs are removed.

Methods for allocating joint costs generally fall into two categories depending on how benefits are considered. Benefits are derived in the economic analysis. Methods that do not consider benefits may divide joint costs between beneficiaries equally or based on beneficiaries' share of separable costs. Methods that are based on benefits divide joint costs among beneficiaries proportional to the benefits each receives. Among these, the separable costs-remaining benefits (SCRB) method has historically been used to allocate Central Valley Project (CVP) facility costs. Other methods for allocating joint costs based on benefits include the Alternative Justifiable Expenditure method and the share of Total Benefits Method.

D.1.4 Apportioning Costs to Beneficiaries

The cost allocation process is designed so that costs associated with project purposes can be apportioned to beneficiaries for repayment. Once costs are allocated to the appropriate purpose, costs can be assigned to federal and/or state taxpayers and project beneficiaries based on specific project authorization, existing federal law, existing cost-sharing requirements, and laws and objectives of non-federal entities, including states, counties, and nonprofit organizations.

Reimbursable costs are those that, through some form of up-front cost sharing, repayment, or other financial agreement, are repaid to the government. Nonreimbursable costs are those borne entirely by the government.

D.1.5 Potential Cost Allocation Methods

This section discusses two potential cost allocation methods for multipurpose projects.

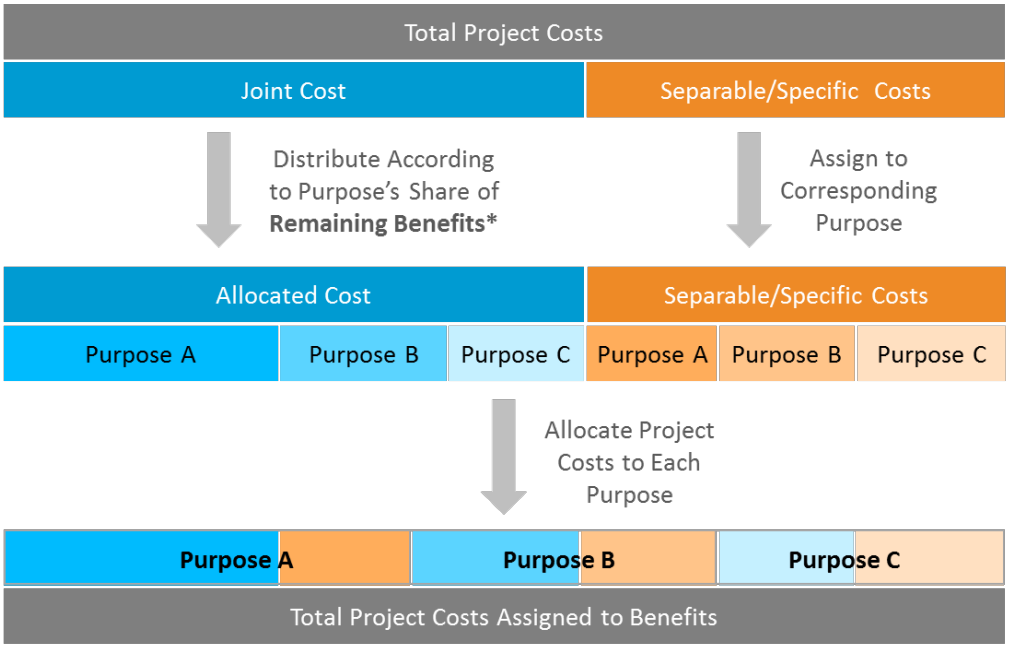
D.1.5.1 Separable Costs-Remaining Benefits Method

Distribution of project cost considers both the elements of the project that are directly tied to a project purpose, as well as the elements tied to multiple project purposes. A widely used method for cost allocation in federal water resources projects is the SCRB method, which distributes costs among the project purposes by identifying separable costs and allocating joint costs in proportion to each purpose's remaining benefits. Project costs (e.g., construction costs, operations and maintenance costs, and indirect costs) can be grouped, with respect to project purposes, into separable and joint costs. Separable costs are the incremental costs of adding a purpose to a multipurpose project. Separable costs for a project purpose are estimated as the reduction in project costs that would result if that purpose is excluded. Joint costs are the remaining project costs after all separable costs are subtracted.

The SCRB method starts by identifying the separable costs for each project purpose. Separable costs are subtracted from the lesser of benefits or single-purpose alternative project costs to derive remaining benefits. Next, joint costs are allocated in proportion to the distribution of remaining benefits. Joint project costs are then assigned to a project purpose based on the proportion of their remaining benefits (i.e., total benefits less the separable costs of each project purpose). Total cost allocated to a project purpose is the sum of its separable and apportioned joint costs. This is illustrated in Figure D-2.

D.1.5.2 Alternative Justifiable Expenditure

The Alternative Justifiable Expenditure method is a modified SCRB method used in situations when derivation of the separable costs is not feasible. Cost allocation under the Alternative Justifiable Expenditure method is the same as under the SCRB method, except that specific costs (i.e., costs for project components that contribute to a single purpose and exclude the costs of a change in project design due to inclusion) replace separable costs. The remaining (joint) costs are apportioned among project purposes based on their total benefits. However, if no specific or separable costs can be identified, cost allocation can be directly carried out based on the distribution of benefits between project purposes.



* **Remaining Benefit** for each Purpose = Justifiable Expenditure - Separable Costs

Justifiable Expenditure = Minimum of: (1) Estimated Benefit, or (2) Single Purpose Alternative Cost

Figure D-2. Separable Cost-Remaining Benefit Method

D.2 Authorization for Financial Participation

This section discusses existing federal authorities for financial participation for benefits for the proposed project alternatives.

Authorization for federal financial participation in implementing B.F. Sisk Dam Raise and Reservoir Expansion is established by the *Water Infrastructure Improvements for the Nation Act*, 2015–2016 (Public Law 114-322). Public Law 114-322, Section 4007 (a)(1) establishes B.F. Sisk Dam Raise and Reservoir Expansion as a qualified federally owned storage project:

(1) Federally owned storage project.—The term "federally owned storage project" means any project involving a surface water storage facility in a Reclamation State—

> *(A) to which the United States holds title; and*
>
> *(B) that was authorized to be constructed, operated, and maintained pursuant to the reclamation laws.*

Further guidance is provided in Public Law 114-322, Section 4007(b):

(1) Agreements. - On the request of any State, any department, agency, or subdivision of a State, or any public agency organized pursuant to State law, the Secretary of the Interior may negotiate and enter into an agreement on behalf of the United States for the design, study, and construction or expansion of any federally owned storage project in accordance with this section.

(2) Federal cost share. - Subject to the requirements of this subsection, the Secretary of the Interior may participate in a federally owned storage project in an amount equal to not more than 50 percent of the total cost of the federally owned storage project.

(3) Commencement. - The construction of a federally owned storage project that is the subject of an agreement under this subsection shall not commence until the Secretary of the Interior—

> *(A) determines that the proposed federally owned storage project is feasible in accordance with the reclamation laws;*
>
> *(B) secures an agreement providing upfront funding as is necessary to pay the non-Federal share of the capital costs; and*
>
> *(C) determines that, in return for the Federal cost-share investment in the federally owned storage project, at least a proportionate share of the project benefits are Federal benefits, including water supplies dedicated to specific purposes such as environmental enhancement and wildlife refuges.*

(4) Environmental laws. - In participating in a federally owned storage project under this subsection, the Secretary of the Interior shall comply with all applicable environmental laws, including the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.).

Therefore, Section 4007(a)(1) and Section 4007(b)(3)(A) define the scope for federal interest in federally owned storage projects as providing federal benefits in accordance with the Reclamation laws. The Dam Raise Alternative's multiple operational configurations are formulated to provide a range of quantifiable benefits that include the following:

1. Support for Reclamation's delivery of contractually obligated M&I and irrigation water supplies through increased CVP yield and improvements in the security of rescheduled water supply stored in the enlarged reservoir.

2. Enhanced M&I emergency water supply available to South-of-Delta CVP contractors by increasing storage.

3. Refuge water supply, through increased reliability and deliveries of Incremental Level 4 water.

4. Safety improvements to State Route (SR) 152 generated by correction of an existing seismic deficiency at its crossing of Cottonwood Bay.

The Dam Raise Alternative Plan, Investor-Directed Storage Subalternative D, that is the NED Plan, would provide increased M&I and irrigation water supply, additional M&I emergency water supply, and the safety improvements to SR 152.

In addition to these quantifiable benefits, numerous additional benefits that cannot be quantified but remain important to the non-federal partner (the San Luis & Delta-Mendota Water Authority [SLDMWA] member agencies) include:

1. Improved certainty of long-term water supply to safely support the development of higher value permanent crops.

2. Access to additional surface water supply to offset potential expansion in limits on SLDMWA member agencies' access to groundwater as a part of their water supply portfolio with implementation of the Sustainable Groundwater Management Act (SGMA).

3. Improvements in recreational opportunity at San Luis Reservoir with increased opportunity for recreationists to access its water surface at higher storage levels.

Costs allocated to each purpose are assigned to federal taxpayers and project beneficiaries based on the specific project authorization, existing federal law, existing cost-sharing requirements, and laws and objectives of non-federal entities, including states, counties, and nonprofit organizations. Applicable federal authorities are summarized in Table D-1. Note that non-federal partners are not seeking federal up-front financing for the implementation of this project.

All these benefits contribute to federally authorized purposes and are considered federal benefits for this feasibility investigation, consistent with WIIN Act defined scope for federal interest in federally owned storage projects.

D.2.1 Applicable Authorities for Cost Assignment

Costs allocated to each purpose are assigned to federal taxpayers and project beneficiaries based on the specific project authorization, existing federal law, existing cost sharing requirements, and laws and objectives of non-federal entities, including states, counties, and nonprofit organizations. Applicable federal authorities are summarized in Table D-1. Note that non-federal partners are not seeking federal up-front financing in the form of reimbursable federal funding for the implementation of this project.

Table D-1. Existing Authorities for Federal Financial Participation for Monetized Benefit Categories

Purpose	Pertinent Federal Legislation	Description
Federal Cost Share for a Federally Owned Storage Project	Water Infrastructure Improvements for the Nation Act, 2015–2016 (Public Law 114-322)	Provides authorization for federal funding in federally owned surface storage projects and limits federal participation to not more than 50 percent of the total cost of the federally owned storage project.[1]
M&I Water Supply (Including Emergency Water Supply)	Reclamation Act of 1939, as amended	Provides for up-front Federal financing of M&I water supply purposes, with 100% repayment of capital costs (including interest during construction and interest over the repayment period); 100% of OM&R costs are non-Federal.

Purpose	Pertinent Federal Legislation	Description
Irrigation Water Supply	Reclamation Act of 1902, as amended	Provides for up-front Federal financing of irrigation water supply purposes, with 100% repayment of construction costs, without interest, and OM&R costs by beneficiaries.
State Route 152 Improvements	Reclamation Project Act, 1939 (43 U.S.C. § 485)	Provides authorization for road improvements, maintenance, reconstruction, or relocation of existing public roads when deemed necessary for the construction of any authorized project for the development of water resources.
State Route 152 Improvements	River and Harbor Act, 1962 (Public Law 87-874)	Provides for Federal financing for the replacement of public roads, consistent with design standards established by the State, that would be taken in order for a water resources project to be constructed. Federal costs under this authority are non-reimbursable.

Notes:
[1] Total cost interpreted as total capital cost.
Key:
M&I = municipal and industrial
U.S.C. = United States Code
OM&R = operations, maintenance, and replacement

D.3 Initial Cost Allocation

A single-purpose alternative cost is the cost of the most probable alternative providing the same level of benefit for that purpose as the entire multipurpose project. The single-purpose project cost is used to determine the justifiable expenditure for any given purpose by comparing it to its respective purpose's benefits.

D.3.1 Screening and Selection of Single-Purpose Alternatives

Single-purpose alternatives were evaluated for the Dam Raise Alternative Plan for each of the project purposes for which costs could be allocated—emergency water supply, M&I water supply, irrigation water supply, and transportation improvements on SR 152. The sections below summarize the screening and selection process for single-purpose alternatives for the Dam Raise Alternative Plan.

D.3.1.1 Emergency Water Supply

The Dam Raise Alternative Plan would provide emergency M&I water supplies in the event of a Delta water supply outage through providing additional stored water in San Luis Reservoir for delivery of emergency supplies to two potential recipient groups. As described in Appendix C, emergency water supply could be delivered to Santa Clara County, which is the Valley Water service area, Avenal and the Lemoore Naval Air Station in Kings County, Coalinga in Fresno County, the City of Tracy in San Joaquin County, the City of Huron in Fresno County, which include the M&I water users in the Westlands Water District Service Area, and Hollister in San Benito County, which is the SBCWD service area.r.

The measures identified to address water supply reliability, including emergency water supply, are presented in Table 3-1 of Chapter 3 – Plan Formulation. Many of these measures were identified during the initial alternative formulation and screening process for inclusion in the multi-objective project alternatives. These measures were revaluated for their potential to provide emergency water supplies in the context of the single-purpose alternative. These include expansion of San Luis Reservoir to provide only emergency supply, non-structural measures (including use of the existing San Luis Reservoir), and increased M&I water transfers (e.g., spot market purchases). As a part of this evaluation, other potential measures that could provide emergency water supply were considered (e.g., other local surface storage projects and increased San Joaquin Valley groundwater banking). In formulating/screening single-purpose alternatives for emergency water supply, it was assumed that, at a minimum, the single-purpose alternative would need to be capable of providing:

- Emergency M&I water supplies for south-of-Delta CVP M&I water users in the event of a Delta water supply outage.

During an initial screening of alternatives, several options for the emergency water supply single-purpose alternative were removed (based on the above criteria) and not evaluated further.

- Several local surface storage alternatives in the Valley Water service area, with the exception of expanding the existing Pacheco Reservoir, were screened out of consideration in the April 2019 Draft San Luis Low Point Improvement Project Feasibility Report given concerns with their technical or institutional viability (Reclamation 2019). Given these previously determined viability issues, these measures were screened out of this analysis.

- Increased use of San Joaquin Valley groundwater banking was screened out because it would have limited ability to provide water to Valley Water or SBCWD during Delta water supply outages. Recovery of banked water, which is downstream of both districts' service areas on the California Aqueduct, would require exchanges with Delta diversions at the head of the California Aqueduct. Lack of these diversions during Delta outages would curtail the ability of groundwater bank to provide stored water to agencies upstream from the location of these banks.

- Design capacity of the existing Pacheco Reservoir is 6,000 AF with an operational capacity of 5,500 AF. The earthen dam is 100-feet tall and collects rainfall from a 75-square-mile watershed. The North Fork Dam is currently under restricted-operation criteria through an April 5, 2017 order of the California Department of Water Resources Division of Safety of Dams (DSOD), as a result of existing spillway deficiencies. The existing operation capacity of Pacheco Reservoir and the operational restrictions limit the reservoir in providing emergency storage; thus, this measure was screened out.

- Increasing M&I water supply transfers were screened out because water transfers would not be available on the spot market during Delta water supply outages, as most transfers are purchased from North-of-Delta sources.

- Local groundwater supplies are already relied on in the Valley Water and SBCWD service areas as a part of normal operations and their availability to fully offset interrupted supplies during an emergency outage would be limited.

Two potential emergency water supply single-purpose alternatives were evaluated in more detail, including the following:

- Expansion of Pacheco Reservoir – This option, similar to the single-purpose alternative evaluated in the 2019 Draft San Luis Low Point Improvement Project Feasibility Report (Reclamation 2019), would scale-down the Pacheco Reservoir Expansion Alternative based on providing only emergency water supplies. However, this alternative would be unable to reliably deliver emergency water supply to south-of-Delta CVP M&I water users outside of the San Felipe Division and would need to rely on potentially complex South-of-Delta water exchanges in an emergency Delta outage condition. This alternative would also only be available for implementation in the event that Valley Water is unable to move forward with the Pacheco Reservoir Expansion proposed under the San Luis Low Point Improvement Project where it is currently identified as the NED Plan.

- Expansion of San Luis Reservoir – This option would be similar to the current Dam Raise Alternative Plan but scaled down based on providing only emergency water supplies. The smaller expanded reservoir would be operated to reserve additional storage in the expanded San Luis Reservoir to provide for deliveries to Valley Water or SBCWD in the event of a Delta outage. This option was retained as the emergency water supply single-purpose alternative. Under this option, San Luis Reservoir would be expanded to provide 63,000 acre-feet in additional storage capacity to provide for the delivery of emergency water supplies.

D.3.1.2 M&I Water Supply

The Dam Raise Alternative Plan would provide increased M&I water supply reliability to south-of-Delta CVP M&I water users through improvements in the availability of CVP supply in an expanded San Luis Reservoir when compared to existing conditions.

Numerous measures to address South-of-Delta CVP M&I water supply reliability issues are presented in Table 3-1 of Chapter 3 – Plan Formulation. Although a number of these measures were screened out for inclusion in the project alternatives, key measures with potential to provide South-of-Delta CVP M&I water supplies were reevaluated in the context of the single-purpose alternative. These include other local surface storage projects, expansion of the existing Pacheco Reservoir, and increased M&I water transfers (i.e., spot market purchases). In formulating/screening single-purpose alternatives for M&I water supply, it was assumed that, at a minimum, the single-purpose alternative would need to be capable of providing:

- Additional M&I water supplies at a level comparable to that provided under the Dam Raise Alternative Plan.

During an initial screening of alternatives, several options for the M&I water supply single-purpose alternative were screened out based on the above criteria and not evaluated further.

- Several local surface storage alternatives in the Valley Water service area, with the exception of expanding the existing Pacheco Reservoir, were screened out of consideration in the April 2019 Draft San Luis Low Point Improvement Project Feasibility Report given concerns with their technical or institutional viability (Reclamation 2019). Given these previously determined viability issues, these measures were screened out of this analysis.

- Increased use of San Joaquin Valley groundwater banking was screened out because of both the lack of availability of an existing groundwater bank with sufficient capacity or, alternatively, the complexity of securing land and groundwater rights in sufficient quantity to develop a new groundwater bank capable of fully replacing the M&I water supply generated by the Dam Raise Alternative Plan.

- Local groundwater supplies are already relied on in the Valley Water, Westlands, and SBCWD service areas as a part of normal operations; their availability to provide additional supply comparable to the Dam Raise Alternative Plan would be limited.

Three potential M&I water supply single-purpose alternatives were evaluated in more detail, including the following:

- Increasing purchases of M&I water supply on the spot market for delivery to Valley Water or Westlands Water District and SBCWD – This non-structural alternative would be the least costly. Because of timing (i.e., water year types) and quantity of increased M&I water supplies under the NED Plan, it was determined that increased purchases of M&I water supplies on the spot market could be a feasible single-purpose alternative. Although spot market purchases would be a less reliable source of M&I water supplies than expansion of San Luis Reservoir, this option is included as a potential single-purpose alternative to provide a conservative estimate of the least costly single-purpose alternative.

- Expansion of Pacheco Reservoir – This option would scale down the Pacheco Reservoir Expansion Alternative identified as the NED Plan in the 2019 Draft San Luis Low Point Improvement Project Feasibility Report (Reclamation 2019) to only provide M&I water supplies. This alternative would, however, be unable to deliver M&I water supply directly to either Coalinga or Avenal under the second emergency water supply configuration and would need to rely on potentially complex South-of-Delta water. This alternative would also only be available for implementation in the event that Valley Water is unable to move forward with the Pacheco Reservoir Expansion proposed under the San Luis Low Point Improvement Project where it is currently identified as the NED Plan.

- Expansion of San Luis Reservoir – This option would be similar to the current Dam Raise Alternative Plan but scaled down based on providing only M&I water supplies. This option was screened out as a single-purpose alternative for M&I water supply primarily because it would have either higher or comparable costs for each acre-foot of increased M&I water supply compared to the spot market purchase option described above.

D.3.1.3 Irrigation Water Supply

The Dam Raise Alternative Plan would provide increased irrigation water supply reliability to South-of-Delta CVP contractors through improvements in the availability of CVP supply in an expanded San Luis Reservoir when compared to existing conditions.

Numerous measures to address South-of-Delta CVP agricultural water supply reliability issues are presented in Table 3-1 of Chapter 3 – Plan Formulation. Although a number of these measures were screened out for inclusion in the project alternatives, key measures with potential to provide South-of-Delta CVP agricultural water supplies were reevaluated in the context of the single-purpose alternative. These include other local surface storage projects and increased agricultural water

transfers (i.e., spot market purchases). In formulating/screening single-purpose alternatives for agricultural water supply, it was assumed that, at a minimum, the single-purpose alternative would need to be capable of providing:

- Additional irrigation water supplies at a level comparable to that provided under the Dam Raise Alternative Plan.

During an initial screening of alternatives, several options for the agricultural water supply single-purpose alternative were screened out based on the above criteria and not evaluated further.

- Several local surface storage alternatives in the Valley Water service area, with the exception of expanding the existing Pacheco Reservoir, were screened out of consideration in the April 2019 Draft San Luis Low Point Improvement Project Feasibility Report, given concerns with their technical or institutional viability (Reclamation 2019). Given these previously determined viability issues, these measures were screened out of this analysis. In addition, inclusion of expanding Pacheco Reservoir was also screened out, given the technical challenges associated with delivering water supply stored in that reservoir to the majority of the South-of-Delta agricultural water supply users.

- Increased use of San Joaquin Valley groundwater banking was screened out because of both the lack of availability of an existing groundwater bank with sufficient capacity or, alternatively, the complexity of securing land and groundwater rights in sufficient quantity to develop a new groundwater bank capable of fully replacing the agricultural water supply generated by the Dam Raise Alternative Plan.

- Local groundwater supplies are already relied on in the South-of-Delta CVP agricultural water supply users service areas as a part of normal operations and their availability provide additional supply comparable to the Dam Raise Alternative Plan would be limited.

Two potential irrigation water supply single-purpose alternatives were evaluated in more detail, including the following:

- Increasing purchases of agricultural water supply on the spot market for delivery to South-of-Delta CVP Agricultural Water Supply Users — This non-structural alternative would be the least costly. Because of the timing (i.e., water year types) and quantity of increased agricultural water supplies under the Dam Raise Alternative Plan, it was determined that increased purchases of agricultural water supplies on the spot market could be a feasible single-purpose alternative. Although spot market purchases would be a less reliable source of agricultural water supplies than expansion of San Luis Reservoir, this option is included as a potential single-purpose alternative to provide a conservative estimate of the least costly single-purpose alternative.

- Expansion of San Luis Reservoir – This option would be similar to the current Dam Raise Alternative Plan but scaled down based on providing only agricultural water supplies. This option was screened out as a single-purpose alternative for agricultural water supply primarily because it would have either higher or comparable costs for each acre-foot of increased agricultural water supply compared to the spot market purchase option described above.

D.3.1.4 Transportation Safety and Reliability

The Dam Raise Alternative Plan would provide increased safety levels for SR 152 as it crosses Cottonwood Bay on San Luis Reservoir. As it is currently configured, SR 152 does not meet Caltrans or Federal Highway Design Manual standards for safety against potential seismic failure. In formulating/screening single-purpose alternatives for providing this same transportation safety and reliability benefit, it was assumed that, at a minimum, the single-purpose alternative would need to be capable of providing:

- Modification to the existing road embankment at SR 152, replacement with a new structure crossing SR 152 or rerouting SR 152 to provide compliance with Caltrans and Highway Design Manual at a level comparable to that provided under the Dam Raise Alternative Plan.

Multiple configurations of a SR152 single-purpose project were identified including the modification of the existing embankment to upgrade its strength against seismic shaking, replacement of the embankment with a bridge, and rerouting of the state route north of the reservoir to avoid the need for an embankment. The replacement of the SR 152 embankment with a bridge would, given the need to allow SR 152 to remain operational during construction, require a substantially longer crossing (in excess of 5,000 feet) of an active seismic fault and was determined to cost significantly more than modifications to the existing embankment. The rerouting of SR 152 north to bypass San Luis Reservoir would require significant private land acquisition and significant slope modification along the steep hillsides surrounding Cottonwood Bay to protect the new roadway against existing landslides in the area as well as avoid roadway curves that would require modifications to the roadway's existing speed limits.

One transportation safety and reliability single purpose alternative was evaluated in detail:

- Modifications to Existing SR 152 Embankment – This option would modify the existing roadway embankment's potential for failure in a seismic event by developing new stability berms. The stability berms would be placed on the downstream and upstream toes of the embankment and would prevent embankment settling during seismic shaking that could result in embankment failure.

D.3.2 Description of Single-Purpose Alternative Costs

Single-purpose alternatives are described for the configurations of the Dam Raise Alternative Plan with NED benefits that exceeded the NED costs. As is indicated in Chapter 5, this includes Investor-Directed Storage Subalternative C and Investor-Directed Storage Subalternative D when compared against transportation safety benefits estimated using the value of lost time approach detailed in Appendix C, and the Investor-Directed Storage Subalternative B when compared against the least cost most likely alternative approach to estimate transportation safety benefits detailed in Appendix C. The evaluation presented in Chapter 5 also identifies the most probable low cost estimate for the project which when compared against the benefits generated by the CVP Only Storage Subalternative and the Investor-Directed Storage Subalternative A identifies NED benefits that exceed NED costs. Estimates of costs for the single purpose alternatives identified for each of these configurations of the Dam Raise Alternative Plan are shown in Table D-2, Table D-3, Table D-4, Table D-5 and Table D-6.

- Emergency Water Supply – This single-purpose alternative would consist of an increase in storage capacity for San Luis Reservoir by 63 TAF. This would provide sufficient carryover

capacity required to provide the long-term emergency water supply benefits equivalent to the Dam Raise Alternative Plan.

- M&I Water Supply – This single-purpose non-structural alternative would consist of increased purchases of M&I water supplies on the spot market for delivery to CVP M&I water users.
- Irrigation Water Supply – This single-purpose non-structural alternative would consist of increased purchases of irrigation water supplies on the spot market for delivery to CVP agricultural water users.
- Refuge Water Supply - This single-purpose non-structural alternative would consist of increased purchases of refuge water supplies on the spot market for delivery to refuge water users.
- Transportation Safety and Reliability – This single-purpose alternative would consist of modifications to the SR 152 embankment to provide improvements in the existing embankment's noncompliance with Caltrans and Federal Highway Design Manual Requirements.

Table D-2. Summary of Estimated Costs of Single-Purpose Alternatives, CVP Only Storage Subalternative

Item[1]	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Transportation Safety and Reliability
Alternative	Expand San Luis Reservoir (63 TAF)	Water transfers	Water transfers	SR 152 Modifications
Total Capital Cost (million $)[2]	$583.3	--	--	$259.0
Total Annual Cost (million $/year)[3]	**$17.2**	**$1.6**	**$7.7**	**$7.6**

Notes:
[1] Refuge Water Supply benefits are not included because the Investor Directed Subalternative D does not provide benefits to refuge water supply reliability.
[2] January 2020 price level.
[3] Annual costs include interest and amortization and annual OM&R. Interest and amortization based on a 2.75 percent federal discount rate over 100 years.
Key:
M&I = municipal and industrial
TAF = thousand acre-feet
SR = State Route
NED = National Economic Development
OM&R = operations, maintenance, and replacement

Table D-3. Summary of Estimated Costs of Single-Purpose Alternatives, Investor-Directed Storage Subalternative A

Item	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability
Alternative	Expand San Luis Reservoir (63 TAF)	Water transfers	Water transfers	Water transfers	SR 152 Modifications
Total Capital Cost (million $)[1]	$583.30	--	--	--	$259
Total Annual Cost (million $/year)[2]	**$17.18**	**$1.70**	**$6.10**	**$1.90**	**$7.63**

Notes:
[1] January 2020 price level.
[2] Annual costs include interest and amortization and annual OM&R. Interest and amortization based on a 2.75 percent federal discount rate over 100 years.
Key:
M&I = municipal and industrial
TAF = thousand acre-feet
SR = State Route
NED = National Economic Development
OM&R = operations, maintenance, and replacement

Table D-4. Summary of Estimated Costs of Single-Purpose Alternatives, Investor-Directed Storage Subalternative B

Item[1]	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Transportation Safety and Reliability
Alternative	Expand San Luis Reservoir (63 TAF)	Water transfers	Water transfers	SR 152 Modifications
Total Capital Cost (million $)[2]	$583.3	--	--	$259.0
Total Annual Cost (million $/year)[3]	**$17.2**	**$16.7**	**$0.9**	**$7.6**

Notes:
[1] Refuge Water Supply benefits are not included because the Investor Directed Subalternative D does not provide benefits to refuge water supply reliability.
[2] January 2020 price level.
[3] Annual costs include interest and amortization and annual OM&R. Interest and amortization based on a 2.75 percent federal discount rate over 100 years.
Key:
M&I = municipal and industrial
TAF = thousand acre-feet
SR = State Route
NED = National Economic Development
OM&R = operations, maintenance, and replacement

Table D-5. Summary of Estimated Costs of Single-Purpose Alternatives, Investor-Directed Storage Subalternative C

Item	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability
Alternative	Expand San Luis Reservoir (63 TAF)	Water transfers	Water transfers	Water transfers	SR 152 Modifications
Total Capital Cost (million $)[1]	$583.30	--	--	--	$259
Total Annual Cost (million $/year)[2]	**$17.18**	**$1.10**	**$3.10**	**$1.20**	**$7.63**

Notes:
[1] January 2020 price level.
[2] Annual costs include interest and amortization and annual OM&R. Interest and amortization based on a 2.75 percent federal discount rate over 100 years.
Key:
M&I = municipal and industrial
TAF = thousand acre-feet
SR = State Route
NED = National Economic Development
OM&R = operations, maintenance, and replacement

Table D-6. Summary of Estimated Costs of Single-Purpose Alternatives, Investor-Directed Storage Subalternative D

Item[1]	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Transportation Safety and Reliability
Alternative	Expand San Luis Reservoir (63 TAF)	Water transfers	Water transfers	SR 152 Modifications
Total Capital Cost (million $)[2]	$583.3	--	--	$259.0
Total Annual Cost (million $/year)[3]	**$17.2**	**$9.8**	**$0.5**	**$7.6**

Notes:
[1] Refuge Water Supply benefits are not included because the Investor Directed Subalternative D does not provide benefits to refuge water supply reliability.
[2] January 2020 price level.
[3] Annual costs include interest and amortization and annual OM&R. Interest and amortization based on a 2.75 percent federal discount rate over 100 years.
Key:
M&I = municipal and industrial
TAF = thousand acre-feet
SR = State Route
NED = National Economic Development
OM&R = operations, maintenance, and replacement

D.3.3 Separable Costs

The separable costs of each project purpose are the difference between the cost of the multipurpose project and the cost of the project with the purpose omitted. The separable costs are subtracted from the specific project purpose benefit to determine the remaining benefit in the SCRB cost allocation process. Following is a summary of each specific cost with the project purpose omitted. Specific costs are summarized in Table D-7.

D.3.3.1 Without Emergency Water Supply

Without the emergency water supply purpose, the project would still require the expanded reservoir to provide for M&I water supply, agricultural, and refuge water supply benefits. Hence, there would be no separable costs for the emergency water supply purpose.

D.3.3.2 Without M&I Water Supply

Without the M&I water supply purpose, the project would still require the expanded reservoir to provide for emergency water supply, agricultural water supply, and refuge water supply benefits. Hence, there would be no separable costs for the M&I water supply purpose.

D.3.3.3 Without Agricultural Water Supply

Without the agricultural water supply purpose, the project would still require the expanded reservoir to provide for emergency water supply, M&I water supply, and refuge water supply benefits. Hence, there would be no separable costs for the agricultural water supply purpose.

D.3.3.4 Without Refuge Water Supply

Without the agricultural water supply purpose served, the project would still require the expanded reservoir to provide for emergency water supply, M&I water supply, agricultural water supply, and refuge water supply benefits. Hence, there would be no separable costs for the refuge water supply purpose.

D.3.3.5 Without Transportation Safety and Reliability

Modifications to the SR 152 embankment are required to support increased water levels to provide an expansion of storage capacity within San Luis Reservoir and the associated emergency water supply, M&I water supply, agricultural water supply, and refuge water supply benefits. Traffic safety and reliability benefits are a result of the seismic improvements within the design of the proposed embankment modification. The costs within the design specific to the embankment modification for water supply and the costs specific to seismic improvements for transportation safety have been identified. While the embankment modification for only increased water surface levels would not be technically feasible without correction of the embankment's existing noncompliance with Caltrans and Federal Highway Design Manual Requirements, correction of the seismic risk could be completed independent of the dam raise and reservoir expansion.

D.3.4 Joint Costs

The joint cost is the cost of facilities that serve two or more project purposes. The cost is the difference between the cost of the multipurpose project and the sum of the separable costs, as shown above. The joint cost is allocated to each purpose based on remaining benefits, which are the justifiable expenditure minus the separable costs. Most of the project costs are joint costs, as shown in Table D-7 for the Dam Raise Alternative Plan.

Table D-7. Summary of Estimated Separable and Joint Costs for the Dam Raise Alternative Plan

Item	Separable Costs						Joint Cost[1]	Total Cost
	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability	Total		
Capital Cost (million $)								
Construction Cost	$0.0	$0.0	$0.0	$0.0	$259.0	$259.0	$663.1	$922.1
IDC	$0.0	$0.0	$0.0	$0.0	$26.9	$26.9	$68.8	$95.7
Total Capital	$0.0	$0.0	$0.0	$0.0	$285.9	$285.9	$732.0	$1,017.9
Annual Cost (million $/yr)								
Interest and Amortization on Capital Costs[2]	$0.0	$0.0	$0.0	$0.0	$7.6	$7.6	$19.6	$27.2
Annual IDC[2]	$0.0	$0.0	$0.0	$0.0	$0.8	$0.8	$2.0	$2.8
Annual OM&R	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.7	$0.7
Total Annual Cost	$0.0	$0.0	$0.0	$0.0	$8.4	$8.4	$22.3	$30.7

Notes:
General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals.
[1] Joint costs are total costs minus total separable costs.
[2] Interest and amortization on construction costs and annual IDC are based on a 2.75-percent federal discount rate over a 100-year period analysis.
Key:
NED = National Economic Development
IDC = interest during construction
M&I = municipal and industrial
OM&R = operation, maintenance, and replacement
AF = acre-feet

D.3.5 Initial Cost Allocation

The following provides an illustration of how costs for the Dam Raise Alternative Plan could be allocated to project purposes. A SCRB analysis was performed to equitably allocate costs to the project purposes for all configurations of the Dam Raise Alternative Plan with NED benefits that exceeded the NED costs. As described above in Section 3.3.2, this includes the CVP Only Storage Subalternative, Investor-Directed Storage Subalternative A, Investor-Directed Storage Subalternative B, Investor-Directed Storage Subalternative C and Investor-Directed Storage Subalternative D.

In the SCRB analysis, annual separable costs (calculated in Table D-8, Table D-10, Table D-12, Table D-14 and Table D-16) are subtracted from the total annual cost to determine the total annual joint cost. The resulting allocated joint cost is based on the percentage of the remaining benefits of each project purpose. The total allocated costs are the sum of the separable annual costs and the allocated annual joint costs. This approach can be used for developing allocated annual OM&R, annual capital, annual total, total construction, total IDC, and total capital costs.

Table D-8, Table D-10, Table D-12, Table D-14 and Table D-16 display the step-by-step process used to determine the annual cost to be allocated to each project purpose. Table D-9, Table D-11, Table D-13, Table D-15 and Table D-17 provide the results for the total cost allocation by each project purpose.

Table D-8. Initial SCRB Analysis and Annual Cost Allocation Summary for the Dam Raise Alternative Plan, CVP Only Storage Subalternative (million $/year)

Item	Calculation	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability[1]	Total
		A	B	C	D	E	F
Annual Construction and OM&R Costs							
1 Average Annual Benefits		$12.50	$1.50	$7.40	$0.00	$7.60	$29.00
2 Single-Purpose Projects		$17.18	$1.60	$7.70	$0.00	$7.63	$34.11
3 Justifiable Expenditure	minimum of (1) or (2)	$12.50	$1.50	$7.40	$0.00	$7.60	$29.00
4 Separable Annual Costs		$0.00	$0.00	$0.00	$0.00	$8.40	$8.40
5 Remaining Benefits/ Justifiable Expenditure	(3) – (4)	$12.50	$1.50	$7.40	$0.00	$0.00	$21.40
6 Percentage of Remaining Benefits	(A5 to E5) ÷ (F5)	58.4%	7.0%	34.6%	0.0%	0.0%	100.0%
7 Allocated Joint Costs	(A6 to E6) × (F7)	$13.03	$1.56	$7.71	$0.00	$0.00	$22.30
8 Total Allocated Costs	(4) + (7)	$13.03	$1.56	$7.71	$0.00	$8.40	$30.70
OM&R Annual Costs							
9 Separable OM&R Cost[1]		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
10 Percentage of Remaining Benefits	(6)	58.4%	7.0%	34.6%	0.0%	0.0%	100.0%
11 Allocated Joint OM&R Cost	(A10 to E10) × (F11)	$0.41	$0.05	$0.24	$0.00	$0.00	$0.70
12 Total OM&R Allocated Costs	(9) + (11)	$0.41	$0.05	$0.24	$0.00	$0.00	$0.70
Annual Capital Cost[1]							
13 Separable Capital Cost[2]		$0.00	$0.00	$0.00	$0.00	$8.40	$8.40
14 Percentage of Remaining Benefits	(6)	58.4%	7.0%	34.6%	0.0%	0.0%	100.0%
15 Allocated Joint Capital Cost	(A14 to E14) × (F15)	$17.52	$2.10	$10.37	$0.00	$0.00	$30.00
16 Total Capital Allocated Costs	(13) + (15)	$17.52	$2.10	$10.37	$0.00	$8.40	$38.40

Notes:

General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals. Interest and amortization based on a 2.75-percent federal discount rate over a 100-year period analysis. Benefits, except emergency water supply, were adjusted according to the probability of a Delta water supply disruption (4.2 percent per year) to avoid double-counting of benefits. For this alternative, no replacement costs are assumed to be incurred over the 100-year period of record

[1] Transportation safety benefits estimated using the least cost most likely alternative approach.

[2] Capital costs include construction and interest during construction.

Key:

NED = National Economic Development; M&I = municipal and industrial; OM&R = operations, maintenance, and replacement
SCRB = separable costs-remaining benefits

Table D-9. Initial Total Cost Allocation Summary for the Dam Raise Alternative Plan, CVP Only Storage Subalternative (million $)

Item	Calculation	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability	Total
		A	B	C	D	E	F
Allocation of Capital Cost (Construction + IDC)							
1 Separable Capital Cost[1]		$0.00	$0.00	$0.00	$0.00	$285.90	$285.90
2 Percentage of Remaining Benefits	(6) of Table D-5	58.4%	7.0%	34.6%	0.0%	0.0%	100.0%
3 Allocated Joint Capital Cost	(A2 to E3) × (F3)	$427.51	$51.30	$253.09	$0.00	$0.00	$731.90
4 Total Allocated Capital Cost	(1) + (3)	$427.51	$51.30	$253.09	$0.00	$285.90	$1,017.80
Allocated IDC Costs							
5 Separable IDC Costs		$0.00	$0.00	$0.00	$0.00	$26.90	$26.90
6 Percentage of Remaining Benefits	(6) of Table D-5	58.4%	7.0%	34.6%	0.0%	0.0%	100.0%
7 Allocated Joint IDC Costs	(A6 to E6) × (F7)	$55.90	$6.71	$33.09	$0.00	$0.00	$95.70
8 Total Allocated IDC Costs	(5) + (7)	$32.65	$0.47	$11.44	$0.00	$0.00	$95.70
Allocated Construction Costs							
9 Separable Construction Costs		$0.00	$0.00	$0.00	$0.00	$259.00	$259.00
10 Percentage of Remaining Benefits	(6) of Table D-5	58.4%	7.0%	34.6%	0.0%	0.0%	100.0%
11 Allocated Joint Construction Cost	(A10 to E10) × (F11)	$387.32	$46.48	$229.30	$0.00	$0.00	$663.10
12 Total Allocated Construction Cost	(9) + (11)	$387.32	$46.48	$229.30	$0.00	$259.00	$922.10

Notes:
General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals. Interest and amortization based on a 2.75-percent federal discount rate over a 100-year period analysis.
Key:
NED = National Economic Development
IDC = Interest During Construction
M&I = municipal and industrial

Table D-10. Initial SCRB Analysis and Annual Cost Allocation Summary for the Dam Raise Alternative Plan, Investor-Directed Storage Subalternative A (million $/year)

Item	Calculation	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability[1]	Total
		A	B	C	D	E	F
Annual Construction and OM&R Costs							
1 Average Annual Benefits		$14.70	$1.70	$5.90	$1.80	$7.60	$31.70
2 Single-Purpose Projects		$17.18	$1.70	$6.10	$1.90	$7.63	$34.51
3 Justifiable Expenditure	minimum of (1) or (2)	$14.70	$1.70	$5.90	$1.80	$7.60	$31.70
4 Separable Annual Costs		$0.00	$0.00	$0.00	$0.00	$8.40	$8.40
5 Remaining Benefits/ Justifiable Expenditure	(3) – (4)	$14.70	$1.70	$5.90	$1.80	$0.00	$24.10
6 Percentage of Remaining Benefits	(A5 to E5) ÷ (F5)	61.0%	7.1%	24.5%	7.5%	0.0%	100.0%
7 Allocated Joint Costs	(A6 to E6) × (F7)	$13.60	$1.57	$5.46	$1.67	$0.00	$22.30
8 Total Allocated Costs	(4) + (7)	$13.60	$1.57	$5.46	$1.67	$8.40	$30.70
OM&R Annual Costs							
9 Separable OM&R Cost[1]		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
10 Percentage of Remaining Benefits	(6)	61.0%	7.1%	24.5%	7.5%	0.0%	100.0%
11 Allocated Joint OM&R Cost	(A10 to E10) × (F11)	$0.43	$0.05	$0.17	$0.05	$0.00	$0.70
12 Total OM&R Allocated Costs	(9) + (11)	$0.43	$0.05	$0.17	$0.05	$0.00	$0.70
Annual Capital Cost[1]							
13 Separable Capital Cost[2]		$0.00	$0.00	$0.00	$0.00	$8.40	$8.40
14 Percentage of Remaining Benefits	(6)	61.0%	7.1%	24.5%	7.5%	0.0%	100.0%
15 Allocated Joint Capital Cost	(A14 to E14) × (F15)	$18.30	$2.12	$7.34	$2.24	$0.00	$30.00
16 Total Capital Allocated Costs	(13) + (15)	$18.30	$2.12	$7.34	$2.24	$8.40	$38.40

Notes:

General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals. Interest and amortization based on a 2.75-percent federal discount rate over a 100-year period analysis. Benefits, except emergency water supply, were adjusted according to the probability of a Delta water supply disruption (4.2 percent per year) to avoid double-counting of benefits. For this alternative, no replacement costs are assumed to be incurred over the 100-year period of record

[1] Transportation safety benefits estimated using the least cost most likely alternative approach.

[2] Capital costs include construction and interest during construction.

Key:

NED = National Economic Development; M&I = municipal and industrial; OM&R = operations, maintenance, and replacement
SCRB = separable costs-remaining benefits

Table D-11. Initial Total Cost Allocation Summary for the Dam Raise Alternative Plan, Investor-Directed Storage Subalternative A (million $)

Item	Calculation	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability	Total
		A	B	C	D	E	F
Allocation of Capital Cost (Construction + IDC)							
1 Separable Capital Cost[1]		$0.00	$0.00	$0.00	$0.00	$285.90	$285.90
2 Percentage of Remaining Benefits	(6) of Table D-5	61.0%	7.1%	24.5%	7.5%	0.0%	100.0%
3 Allocated Joint Capital Cost	(A2 to E3) × (F3)	$446.43	$51.63	$179.18	$54.66	$0.00	$731.90
4 Total Allocated Capital Cost	(1) + (3)	$446.43	$51.63	$179.18	$54.66	$285.90	$1,017.80
Allocated IDC Costs							
5 Separable IDC Costs		$0.00	$0.00	$0.00	$0.00	$26.90	$26.90
6 Percentage of Remaining Benefits	(6) of Table D-5	61.0%	7.1%	24.5%	7.5%	0.0%	100.0%
7 Allocated Joint IDC Costs	(A6 to E6) × (F7)	$58.37	$6.75	$23.43	$7.15	$0.00	$95.70
8 Total Allocated IDC Costs	(5) + (7)	$35.61	$0.48	$5.74	$0.53	$0.00	$95.70
Allocated Construction Costs							
9 Separable Construction Costs		$0.00	$0.00	$0.00	$0.00	$259.00	$259.00
10 Percentage of Remaining Benefits	(6) of Table D-5	61.0%	7.1%	24.5%	7.5%	0.0%	100.0%
11 Allocated Joint Construction Cost	(A10 to E10) × (F11)	$404.46	$46.77	$162.34	$49.53	$0.00	$663.10
12 Total Allocated Construction Cost	(9) + (11)	$404.46	$46.77	$162.34	$49.53	$259.00	$922.10

Notes:
General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals. Interest and amortization based on a 2.75-percent federal discount rate over a 100-year period analysis.
Key:
NED = National Economic Development
IDC = Interest During Construction
M&I = municipal and industrial

Table D-12 Initial SCRB Analysis and Annual Cost Allocation Summary for the Dam Raise Alternative Plan, Investor-Directed Storage Subalternative B (million $/year)

Item	Calculation	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability[1]	Total
		A	B	C	D	E	F
Annual Construction and OM&R Costs							
1 Average Annual Benefits		$14.70	$16.00	$0.90	$0.00	$7.60	$39.20
2 Single-Purpose Projects		$17.18	$16.70	$0.90	$0.00	$7.63	$42.41
3 Justifiable Expenditure	minimum of (1) or (2)	$14.70	$16.00	$0.90	$0.00	$7.60	$39.20
4 Separable Annual Costs		$0.00	$0.00	$0.00	$0.00	$8.40	$8.40
5 Remaining Benefits/ Justifiable Expenditure	(3) – (4)	$14.70	$16.00	$0.90	$0.00	$0.00	$31.60
6 Percentage of Remaining Benefits	(A5 to E5) ÷ (F5)	46.5%	50.6%	2.8%	0.0%	0.0%	100.0%
7 Allocated Joint Costs	(A6 to E6) × (F7)	$10.37	$11.29	$0.64	$0.00	$0.00	$22.30
8 Total Allocated Costs	(4) + (7)	$10.37	$11.29	$0.64	$0.00	$8.40	$30.70
OM&R Annual Costs							
9 Separable OM&R Cost[1]		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
10 Percentage of Remaining Benefits	(6)	46.5%	50.6%	2.8%	0.0%	0.0%	100.0%
11 Allocated Joint OM&R Cost	(A10 to E10) × (F11)	$0.33	$0.35	$0.02	$0.00	$0.00	$0.70
12 Total OM&R Allocated Costs	(9) + (11)	$0.33	$0.35	$0.02	$0.00	$0.00	$0.70
Annual Capital Cost[1]							
13 Separable Capital Cost[2]		$0.00	$0.00	$0.00	$0.00	$8.40	$8.40
14 Percentage of Remaining Benefits	(6)	46.5%	50.6%	2.8%	0.0%	0.0%	100.0%
15 Allocated Joint Capital Cost	(A14 to E14) × (F15)	$13.96	$15.19	$0.85	$0.00	$0.00	$30.00
16 Total Capital Allocated Costs	(13) + (15)	$13.96	$15.19	$0.85	$0.00	$8.40	$38.40

Notes:

General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals. Interest and amortization based on a 2.75-percent federal discount rate over a 100-year period analysis. Benefits, except emergency water supply, were adjusted according to the probability of a Delta water supply disruption (4.2 percent per year) to avoid double-counting of benefits. For this alternative, no replacement costs are assumed to be incurred over the 100-year period of record

[1] Transportation safety benefits estimated using the least cost most likely alternative approach.

[2] Capital costs include construction and interest during construction.

Key:

NED = National Economic Development; M&I = municipal and industrial; OM&R = operations, maintenance, and replacement
SCRB = separable costs-remaining benefits

Table D-13. Initial Total Cost Allocation Summary for the Dam Raise Alternative Plan, Investor-Directed Storage Subalternative B (million $)

Item	Calculation	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability	Total
		A	B	C	D	E	F
Allocation of Capital Cost (Construction + IDC)							
1 Separable Capital Cost[1]		$0.00	$0.00	$0.00	$0.00	$285.90	$285.90
2 Percentage of Remaining Benefits	(6) of Table D-5	46.5%	50.6%	2.8%	0.0%	0.0%	100.0%
3 Allocated Joint Capital Cost	(A2 to E3) × (F3)	$340.47	$370.58	$20.85	$0.00	$0.00	$731.90
4 Total Allocated Capital Cost	(1) + (3)	$340.47	$370.58	$20.85	$0.00	$285.90	$1,017.80
Allocated IDC Costs							
5 Separable IDC Costs		$0.00	$0.00	$0.00	$0.00	$26.90	$26.90
6 Percentage of Remaining Benefits	(6) of Table D-5	46.5%	50.6%	2.8%	0.0%	0.0%	100.0%
7 Allocated Joint IDC Costs	(A6 to E6) × (F7)	$44.52	$48.46	$2.73	$0.00	$0.00	$95.70
8 Total Allocated IDC Costs	(5) + (7)	$20.71	$24.53	$0.08	$0.00	$0.00	$95.70
Allocated Construction Costs							
9 Separable Construction Costs		$0.00	$0.00	$0.00	$0.00	$259.00	$259.00
10 Percentage of Remaining Benefits	(6) of Table D-5	46.5%	50.6%	2.8%	0.0%	0.0%	100.0%
11 Allocated Joint Construction Cost	(A10 to E10) × (F11)	$308.47	$335.75	$18.89	$0.00	$0.00	$663.10
12 Total Allocated Construction Cost	(9) + (11)	$308.47	$335.75	$18.89	$0.00	$259.00	$922.10

Notes:
General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals. Interest and amortization based on a 2.75-percent federal discount rate over a 100-year period analysis.
Key:
NED = National Economic Development
IDC = Interest During Construction
M&I = municipal and industrial

Table D-14. Initial SCRB Analysis and Annual Cost Allocation Summary for the Dam Raise Alternative Plan, Investor-Directed Storage Subalternative C (million $/year)

Item	Calculation	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability[1]	Total
		A	B	C	D	E	F
Annual Construction and OM&R Costs							
1 Average Annual Benefits		$27.80	$1.00	$3.00	$1.20	$0.30	$33.30
2 Single-Purpose Projects		$17.18	$1.10	$3.10	$1.20	$7.63	$30.21
3 Justifiable Expenditure	minimum of (1) or (2)	$17.18	$1.00	$3.00	$1.20	$0.30	$22.68
4 Separable Annual Costs		$0.00	$0.00	$0.00	$0.00	$8.40	$8.40
5 Remaining Benefits/ Justifiable Expenditure	(3) – (4)	$17.18	$1.00	$3.00	$1.20	$0.00	$22.38
6 Percentage of Remaining Benefits	(A5 to E5) ÷ (F5)	76.8%	4.5%	13.4%	5.4%	0.0%	100.0%
7 Allocated Joint Costs	(A6 to E6) × (F7)	$17.12	$1.00	$2.99	$1.20	$0.00	$22.30
8 Total Allocated Costs	(4) + (7)	$17.12	$1.00	$2.99	$1.20	$8.40	$30.70
OM&R Annual Costs							
9 Separable OM&R Cost[1]		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
10 Percentage of Remaining Benefits	(6)	76.8%	4.5%	13.4%	5.4%	0.0%	100.0%
11 Allocated Joint OM&R Cost	(A10 to E10) × (F11)	$0.54	$0.03	$0.09	$0.04	$0.00	$0.70
12 Total OM&R Allocated Costs	(9) + (11)	$0.54	$0.03	$0.09	$0.04	$0.00	$0.70
Annual Capital Cost[1]							
13 Separable Capital Cost[2]		$0.00	$0.00	$0.00	$0.00	$8.40	$8.40
14 Percentage of Remaining Benefits	(6)	76.8%	4.5%	13.4%	5.4%	0.0%	100.0%
15 Allocated Joint Capital Cost	(A14 to E14) × (F15)	$23.03	$1.34	$4.02	$1.61	$0.00	$30.00
16 Total Capital Allocated Costs	(13) + (15)	$23.03	$1.34	$4.02	$1.61	$8.40	$38.40

Notes:

General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals. Interest and amortization based on a 2.75-percent federal discount rate over a 100-year period analysis. Benefits, except emergency water supply, were adjusted according to the probability of a Delta water supply disruption (4.2 percent per year) to avoid double-counting of benefits. For this alternative, no replacement costs are assumed to be incurred over the 100-year period of record

[1] Transportation safety benefits estimated using the value of lost time approach.

[2] Capital costs include construction and interest during construction.

Key:

NED = National Economic Development; M&I = municipal and industrial; OM&R = operations, maintenance, and replacement
SCRB = separable costs-remaining benefits

Table D-15. Initial Total Cost Allocation Summary for the Dam Raise Alternative Plan, Investor-Directed Storage Subalternative C (million $)

Item	Calculation	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability	Total
		A	B	C	D	E	F
Allocation of Capital Cost (Construction + IDC)							
1 Separable Capital Cost[1]		$0.00	$0.00	$0.00	$0.00	$285.90	$285.90
2 Percentage of Remaining Benefits	(6) of Table D-5	76.8%	4.5%	13.4%	5.4%	0.0%	100.0%
3 Allocated Joint Capital Cost	(A2 to E3) × (F3)	$561.85	$32.70	$98.11	$39.24	$0.00	**$731.90**
4 Total Allocated Capital Cost	(1) + (3)	$561.85	$32.70	$98.11	$39.24	$285.90	$1,017.80
Allocated IDC Costs							
5 Separable IDC Costs		$0.00	$0.00	$0.00	$0.00	$26.90	$26.90
6 Percentage of Remaining Benefits	(6) of Table D-5	76.8%	4.5%	13.4%	5.4%	0.0%	100.0%
7 Allocated Joint IDC Costs	(A6 to E6) × (F7)	$73.46	$4.28	$12.83	$5.13	$0.00	**$95.70**
8 Total Allocated IDC Costs	(5) + (7)	$56.40	$0.19	$1.72	$0.28	$0.00	$95.70
Allocated Construction Costs							
9 Separable Construction Costs		$0.00	$0.00	$0.00	$0.00	$259.00	$259.00
10 Percentage of Remaining Benefits	(6) of Table D-5	76.8%	4.5%	13.4%	5.4%	0.0%	100.0%
11 Allocated Joint Construction Cost	(A10 to E10) × (F11)	$509.03	$29.63	$88.88	$35.55	$0.00	**$663.10**
12 Total Allocated Construction Cost	(9) + (11)	$509.03	$29.63	$88.88	$35.55	$259.00	$922.10

Notes:
General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals. Interest and amortization based on a 2.75-percent federal discount rate over a 100-year period analysis.
Key:
NED = National Economic Development
IDC = Interest During Construction
M&I = municipal and industrial

Table D-16. Initial SCRB Analysis and Annual Cost Allocation Summary for the Investor-Directed Storage Subalternative D (million $/year)

Item	Calculation	Emergency Water Supply A	M&I Water Supply B	Agricultural Water Supply C	Refuge Water Supply D	Transportation Safety and Reliability[1] E	Total F
Annual Construction and OM&R Costs							
1 Average Annual Benefits		$27.80	$9.40	$0.50	$0.00	$0.27	$37.97
2 Single-Purpose Projects		$17.18	$9.80	$0.50	$0.00	$7.60	$35.08
3 Justifiable Expenditure	minimum of (1) or (2)	$17.18	$9.40	$0.50	$0.00	$0.27	$27.35
4 Separable Annual Costs		$0.00	$0.00	$0.00	$0.00	$8.40	$8.40
5 Remaining Benefits/ Justifiable Expenditure	(3) – (4)	$17.18	$9.40	$0.50	$0.00	$0.00	$27.08
6 Percentage of Remaining Benefits	(A5 to D5) ÷ (F5)	63.4%	34.7%	1.8%	0.0%	0.0%	100.0%
7 Allocated Joint Costs	(A6 to D6) × (E7)	$14.15	$7.74	$0.41	$0.00	$0.00	$22.30
8 Total Allocated Costs	(4) + (7)	$14.15	$7.74	$0.41	$0.00	$8.40	$30.70
OM&R Annual Costs							
9 Separable OM&R Cost[1]		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
10 Percentage of Remaining Benefits	(6)	63.4%	34.7%	1.8%	0.0%	0.0%	100.0%
11 Allocated Joint OM&R Cost	(A10 to D10) × (E11)	$0.44	$0.24	$0.01	$0.00	$0.00	$0.70
12 Total OM&R Allocated Costs	(9) + (11)	$0.44	$0.24	$0.01	$0.00	$0.00	$0.70
Annual Capital Cost[1]							
13 Separable Capital Cost[2]		$0.00	$0.00	$0.00	$0.00	$8.40	$8.40
14 Percentage of Remaining Benefits	(6)	63.4%	34.7%	1.8%	0.0%	0.0%	100.0%
15 Allocated Joint Capital Cost	(A14 to D14) × (E15)	$19.03	$10.41	$0.55	$0.00	$0.00	$30.00
16 Total Capital Allocated Costs	(13) + (15)	$19.03	$10.41	$0.55	$0.00	$8.40	$38.40

Notes:

General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals. Interest and amortization based on a 2.75-percent federal discount rate over a 100-year period analysis. Benefits, except emergency water supply, were adjusted according to the probability of a Delta water supply disruption (4.2 percent per year) to avoid double-counting of benefits. For this alternative, no replacement costs are assumed to be incurred over the 100-year period of record

[1] Transportation safety benefits estimated using the value of lost time approach.

[2] Capital costs include construction and interest during construction.

Key:

NED = M&I = municipal and industrial; OM&R = operations, maintenance, and replacement; SCRB = separable costs-remaining benefits

Table D-17. Initial Total Cost Allocation Summary for the Investor-Directed Storage Subalternative D (million $)

Item	Calculation	Emergency Water Supply	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability	Total
		A	B	C	D	D	E
Allocation of Capital Cost (Construction + IDC)							
1 Separable Capital Cost[1]		$0.00	$0.00	$0.00	$0.00	$285.90	$285.90
2 Percentage of Remaining Benefits	(6) of Table D-12	63.4%	34.7%	1.8%	0.0%	0.0%	100.0%
3 Allocated Joint Capital Cost	(A2 to E3) × (F3)	$464.34	$254.05	$13.51	$0.00	$0.00	**$731.90**
4 Total Allocated Capital Cost	(1) + (3)	$464.34	$254.05	$13.51	$0.00	$285.90	$1,017.80
Allocated IDC Costs							
5 Separable IDC Costs		$0.00	$0.00	$0.00	$0.00	$26.90	$26.90
6 Percentage of Remaining Benefits	(6) of Table D-12	63.4%	34.7%	1.8%	0.0%	0.0%	100.0%
7 Allocated Joint IDC Costs	(A6 to E6) × (F7)	$60.71	$33.22	$1.77	$0.00	$0.00	**$95.70**
8 Total Allocated IDC Costs	(5) + (7)	$38.52	$11.53	$0.03	$0.00	$0.00	$95.70
Allocated Construction Costs							
9 Separable Construction Costs		$0.00	$0.00	$0.00	$0.00	$259.00	$259.00
10 Percentage of Remaining Benefits	(6) of Table D-12	63.4%	34.7%	1.8%	0.0%	0.0%	100.0%
11 Allocated Joint Construction Cost	(A10 to E10) × (F11)	$420.69	$230.17	$12.24	$0.00	$0.00	**$663.10**
12 Total Allocated Construction Cost	(9) + (11)	$420.69	$230.17	$12.24	$0.00	$259.00	$922.10

Notes:
General: January 2020 price levels. All values are rounded for display purposes; therefore, line items may not sum to totals. Interest and amortization based on a 2.75-percent federal discount rate over a 100-year period analysis.
Key:
IDC = Interest During Construction
M&I = municipal and industrial

D.3.6 Initial Cost Assignment

D.3.6.1 Methodology

The assignment of costs includes costs to accomplish all purposes consistent with the planning objectives. Cost assignment was conducted on a purpose-by-purpose basis, based off relevant authorities. The process is illustrated in Figure D-3.

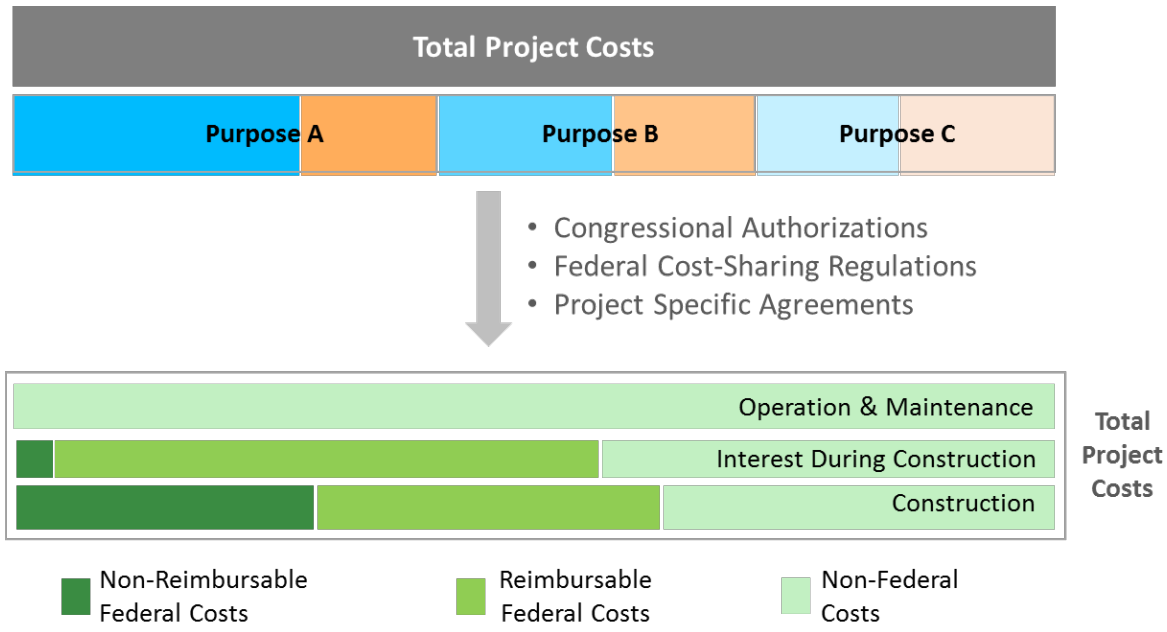


Figure D-3. Cost Assignment Process

The assignment percentages used as the basis for assigning costs are based on existing federal authorities and are summarized in Table D-18. After a first iteration based on these percentages, federal costs were limited to 50 percent (based on stipulation of the WIIN Act [Public Law 114-322]). Any excess cost was assigned to non-federal beneficiaries.

Table D-18. Initial Cost Assignment Percentages

Cost Type	Cost Category	Emergency Water Storage	M&I Water Supply	Agricultural Water Supply	Refuge Water Supply	Transportation Safety and Reliability
Construction[1]	Federal Costs	0%	50%	50%	75%	100%
	Non-federal Costs	100%	50%	50%	25%	0%
OM&R	Federal Costs	0%	0%	0%	75%	0%
	Non-federal Costs	100%	100%	100%	25%	100%

Notes:
[1] The WIIN Act (Public Law 114-322) limits federal participation to not more than 50 percent of the total cost of a federally owned storage project.
Key: M&I = municipal and industrial; OM&R = operations, maintenance, and replacement; WIIN = Water Infrastructure Improvements for the Nation

D.3.6.2 Initial Cost Assignment

The assignment of costs includes costs to accomplish all purposes consistent with the planning objectives. Table D-19, Table D-20, Table D-21, Table D-22, and Table D-23 show estimates of construction costs assigned to beneficiaries for each project purpose for the configurations of the Dam Raise Alternative Plan with NED benefits that exceeded the NED costs. As described above in Section 3.3.3, this includes the CVP Only Storage Subalternative, Investor-Directed Storage Subalternative A, Investor-Directed Storage Subalternative B, Investor-Directed Storage Subalternative C and Investor-Directed Storage Subalternative D. It is anticipated that federal funding for the project will be provided via the WIIN Act, which caps federal funding participation at 50 percent of the total project cost; the initial allocations presented in Table D-19, Table D-20, Table D-21, Table D-22, and Table D-23 meet this requirement. As shown in Table D-19, the federal construction costs for the Dam Raise Alternative Plan, CVP Only Storage Subalternative would be $461.1 million, for the Investor Subalternative A they would be $461.1 million (Table D-20), for the Investor Subalternative B they would be $461.1 million (Table D-21), for the Investor Subalternative C they would be $413.07 million (Table D-22),and for the Investor Subalternative D they would be $461.1 million (Table D-23).

Table D-19. Initial Construction Cost Assignment for the CVP Only Storage Subalternative by Project Purpose (million $)

Purpose/Action	Non-federal Assigned Percentage	Cost	Federal Assigned Percentage	Cost	Total Cost
Emergency Water Supply	100%	$387.3	0%	$0.0	$387.3
M&I Water Supply	27%	$12.4	73%	$34.1	$46.5
Irrigation Water Supply	27%	$61.3	73%	$168.0	$229.3
Refuge Water Supply	25%	$0.0	75%	$0.0	$0.0
Transportation Safety and Reliability	0%	$0.0	100%	$259.0	$259.0
Total	**50%**	**$461.1**	**50%**	**$461.1**	**$922.1**

Notes:
General: January 2020 price levels. Federal funding for the NED Plan will be provided via the WIIN Act, which limits federal funding participation at 50 percent of the total project cost. Values may not add due to rounding. Cost assignment does not include IDC.
Key:
M&I = municipal and industrial
NED = National Economic Development
WIIN = Water Infrastructure Improvements for the Nation

Table D-20. Initial Construction Cost Assignment for the Investor-Directed Storage Subalternative A by Project Purpose (million $)

Purpose/Action	Non-federal Assigned Percentage	Cost	Federal Assigned Percentage	Cost	Total Cost
Emergency Water Supply	100%	$404.5	0%	$0.0	$404.5
M&I Water Supply	21%	$9.9	79%	$36.9	$46.8
Irrigation Water Supply	21%	$34.3	79%	$128.0	$162.3
Refuge Water Supply	25%	$12.4	75%	$37.1	$49.5
Transportation Safety and Reliability	0%	$0.0	100%	$259.0	$259.0
Total	**50%**	**$461.1**	**50%**	**$461.1**	**$922.1**

Notes:
General: January 2020 price levels. Federal funding for the NED Plan will be provided via the WIIN Act, which limits federal funding participation at 50 percent of the total project cost. Values may not add due to rounding. Cost assignment does not include IDC.
Key:
M&I = municipal and industrial
NED = National Economic Development
WIIN = Water Infrastructure Improvements for the Nation

Table D-21. Initial Construction Cost Assignment for the Investor-Directed Storage Subalternative B by Project Purpose (million $)

Purpose/Action	Non-federal Assigned Percentage	Cost	Federal Assigned Percentage	Cost	Total Cost
Emergency Water Supply	100%	$308.5	0%	$0.0	$308.5
M&I Water Supply	43%	$144.5	57%	$191.3	$335.7
Irrigation Water Supply	23%	$8.13	77%	$10.76	$18.9
Refuge Water Supply	25%	$0.0	75%	$0.0	$0.0
Transportation Safety and Reliability	0%	$0.0	100%	$259.0	$259.0
Total	**50%**	**$461.1**	**50%**	**$461.1**	**$922.1**

Notes:
General: January 2020 price levels. Federal funding for the NED Plan will be provided via the WIIN Act, which limits federal funding participation at 50 percent of the total project cost. Values may not add due to rounding. Cost assignment does not include IDC.
Key:
M&I = municipal and industrial
NED = National Economic Development
WIIN = Water Infrastructure Improvements for the Nation

Table D-22. Initial Construction Cost Assignment for the Investor-Directed Storage Subalternative C by Project Purpose (million $)

Purpose/Action	Non-federal Assigned Percentage	Cost	Federal Assigned Percentage	Cost	Total Cost
Emergency Water Supply	100%	$509.0	0%	$0.0	$509.0
M&I Water Supply	0%	$0.0	100%	$29.6	$29.6
Irrigation Water Supply	0%	$0.0	100%	$88.88	$88.9
Refuge Water Supply	0%	$0.0	100%	$35.6	$35.6
Transportation Safety and Reliability	0%	$0.0	100%	$259.0	$259.0
Total	**55%**	**$509.03**	**45%**	**$413.07**	**$922.1**

Notes:
General: January 2020 price levels. Federal funding for the NED Plan will be provided via the WIIN Act, which limits federal funding participation at 50 percent of the total project cost. Values may not add due to rounding. Cost assignment does not include IDC.
Key:
M&I = municipal and industrial
NED = National Economic Development
WIIN = Water Infrastructure Improvements for the Nation

Table D-23. Initial Construction Cost Assignment for Investor-Directed Storage Subalternative D by Project Purpose (million $)

Purpose/Action	Non-federal Assigned Percentage	Cost	Federal Assigned Percentage	Cost	Total Cost
Emergency Water Supply	100%	$420.7	0%	$0.0	$420.7
M&I Water Supply	17%	$38.3	83%	$191.8	$230.2
Irrigation Water Supply	17%	$2.0	83%	$10.2	$12.2
Transportation Safety and Reliability	0%	$0.0	100%	$259.0	$259.0
Total	**50%**	**$461.1**	**50%**	**$461.1**	**$922.1**

Notes:
General: January 2020 price levels. Federal funding for the NED Plan will be provided via the WIIN Act, which limits federal funding participation at 50 percent of the total project cost. Values may not add due to rounding. Cost assignment does not include IDC.
Key:
M&I = municipal and industrial
NED = National Economic Development
WIIN = Water Infrastructure Improvements for the Nation

Table D- 24, Table D- 25, Table D- 26, Table D- 27 and Table D-28 present estimates of the annual OM&R costs assigned to beneficiaries for each project purpose for the Dam Raise Alternative Plan configurations with NED benefits that exceeded the NED costs.

Table D-24. Initial OM&R Cost Assignment for the CVP Only Storage Subalternative by Project Purpose (million $/year)

Purpose/Action	Non-federal Assigned Percentage	Cost	Federal Assigned Percentage	Cost	Total Cost
Emergency Water Supply	100%	$0.41	0%	$0.00	$0.41
M&I Water Supply	100%	$0.05	0%	$0.00	$0.05
Irrigation Water Supply	100%	$0.24	0%	$0.00	$0.24
Refuge Water Supply	25%	$0.00	75%	$0.00	
Transportation Safety and Reliability	100%	$0.00	0%	$0.00	$0.00
Total	**100%**	**$0.70**	**0%**	**$0.00**	**$0.70**

Key:
M&I = municipal and industrial
OM&R = operations, maintenance, and replacement
NED = National Economic Development

Table D-25. Initial OM&R Cost Assignment for the Investor-Directed Storage Subalternative A by Project Purpose (million $/year)

Purpose/Action	Non-federal Assigned Percentage	Cost	Federal Assigned Percentage	Cost	Total Cost
Emergency Water Supply	100%	$0.43	0%	$0.00	$0.43
M&I Water Supply	100%	$0.05	0%	$0.00	$0.05
Irrigation Water Supply	100%	$0.17	0%	$0.00	$0.17
Refuge Water Supply	25%	$0.01	75%	$0.04	$0.05
Transportation Safety and Reliability	100%	$0.00	0%	$0.00	$0.00
Total	**94%**	**$0.66**	**6%**	**$0.04**	**$0.70**

Key:
M&I = municipal and industrial
OM&R = operations, maintenance, and replacement
NED = National Economic Development

Table D-26. Initial OM&R Cost Assignment for the Investor-Directed Storage Subalternative B by Project Purpose (million $/year)

Purpose/Action	Non-federal Assigned Percentage	Cost	Federal Assigned Percentage	Cost	Total Cost
Emergency Water Supply	100%	$0.33	0%	$0.00	$0.33
M&I Water Supply	100%	$0.35	0%	$0.00	$0.35
Irrigation Water Supply	100%	$0.02	0%	$0.00	$0.02
Refuge Water Supply	25%	$0.00	75%	$0.00	$0.00
Transportation Safety and Reliability	100%	$0.00	0%	$0.00	$0.00
Total	**100%**	**$0.70**	**0%**	**$0.00**	**$0.70**

Key:
M&I = municipal and industrial
OM&R = operations, maintenance, and replacement
NED = National Economic Development

Table D-27. Initial OM&R Cost Assignment for the Investor-Directed Storage Subalternative C by Project Purpose (million $/year)

Purpose/Action	Non-federal Assigned Percentage	Cost	Federal Assigned Percentage	Cost	Total Cost
Emergency Water Supply	100%	$0.54	0%	$0.00	$0.54
M&I Water Supply	100%	$0.03	0%	$0.00	$0.03
Irrigation Water Supply	100%	$0.09	0%	$0.00	$0.09
Refuge Water Supply	25%	$0.01	75%	$0.03	$0.04
Transportation Safety and Reliability	100%	$0.00	0%	$0.00	$0.00
Total	**96%**	**$0.67**	**4%**	**$0.03**	**$0.70**

Key:
M&I = municipal and industrial
OM&R = operations, maintenance, and replacement
NED = National Economic Development

Table D-28. Initial OM&R Cost Assignment for Investor-Directed Storage Subalternative D by Project Purpose (million $/year)

Purpose/Action	Non-federal Assigned Percentage	Cost	Federal Assigned Percentage	Cost	Total Cost
Emergency Water Supply	100%	$0.44	0%	$0.00	$0.44
M&I Water Supply	100%	$0.24	0%	$0.00	$0.24
Irrigation Water Supply	100%	$0.01	0%	$0.00	$0.01
Transportation Safety and Reliability	100%	$0.00	0%	$0.00	$0.00
Total	**100%**	**$0.70**	**0%**	**$0.00**	**$0.70**

Key:
M&I = municipal and industrial
OM&R = operations, maintenance, and replacement
NED = National Economic Development

D.3.6.3 Potential Impact of State Funding

In addition to federal funding, non-federal funding for a majority of the construction costs of a Dam Raise Alternative Plan would need to be identified and secured for the Secretary of the Interior to recommend funding for construction. Financing arrangements are being actively explored by SLDMWA for the remainder of non-federal costs.

D.3.7 Payment Capacity and Ability to Pay

D.3.7.1 M&I Water Supply Ability to Pay Analysis

The financial feasibility analysis for M&I water supply benefits assesses how much water users can afford to pay for water supply improvements (i.e., payment capacity) and provides the basis to determine if their payment capacity is sufficient to pay for the allocated project costs (Reclamation 2009). Of a number of accepted methods to estimate payment capacity for M&I water supplies, the following two approaches are most commonly applied:

- **Affordability Threshold Approach** – The most common measures of ability to pay for municipal water supply are the percent of water costs relative to median household income and other socioeconomic measures. For potential municipal water supply beneficiaries of the Dam Raise Alternative Plan, ability to pay and payment capacity of potential beneficiaries is estimated with an "affordability threshold" represented as a percent of median household income. Under this approach, the threshold is applied to median household income for all households within the water service area to arrive at the total payment capacity.

- **Payment Capacity Ratios Approach** – This approach estimates M&I payment capacity by assessing actual water payments relative to net household income for households in the region outside the service area of project beneficiaries. The resulting ratios can be used to approximate payment capacity for the households that will benefit from the project. The payment capability ratios represent the proportion of discretionary income that households served by various utilities spend for domestic water supplies. Therefore, they are a measure of dollars spent on water service per dollar of discretionary household income. This methodology provides an estimate of ability to pay that accounts for variation in household

income, household expenses, and costs of living that are not considered when using set percentages of household income (Piper and Martin 1999).

Each of these approaches will generally produce similar results depending on the selection of the affordability threshold percentage. The affordability threshold approach is used in this analysis to estimate the ability to pay of potential M&I water supply beneficiaries of the Dam Raise Alternative Plan. This analysis applies the affordability threshold established by the EPA. In 1980, the EPA Office of Drinking Water completed a study to assess the costs of complying with new drinking water regulations. The study determined that costs of water service exceeding 2.5 percent of household income were not affordable (EPA 1980).

For municipal water supply beneficiaries, ability to pay and payment capacity of potential beneficiaries is estimated with an "affordability threshold" represented as a percent of median household income. This analysis applies the affordability threshold established by the U.S. Environmental Protection Agency (USEPA). In 1980, the EPA Office of Drinking Water completed a study to assess the costs of complying with new drinking water regulations. The study determined that costs of water service exceeding 2.5 percent of household income were not affordable (Reclamation 2014). For this analysis, the EPA affordability threshold of 2.5 percent of median income is applied to estimate payment capacity. The Dam Raise Alternative Plan, Investor Directed Subalternative D generates the largest M&I water supply reliability benefit. This improved water supply reliability would be provided to Santa Clara County, which is the Valley Water service area, Avenal and the Lemoore Naval Air Station in Kings County, Coalinga in Fresno County, the City of Tracy in San Joaquin County, the City of Huron in Fresno County, which include the M&I water users in the Westlands Water District Service Area, and Hollister in San Benito County, which is the SBCWD service area.

In this analysis, the number of households (U.S. Census Bureau 2020) within Santa Clara County, the City of Avenal, the City of Coalinga, and the City of Hollister is used to estimate payment capacity. Table D-14 provides the average payment capacity analysis results for Valley Water, Westlands Water District and SBCWD. As described above, emergency water supplied by the Dam Raise Alternative Plan Investor Directed Subalternative D would be delivered to a number of other communities but the payment capacity for this subset of water users was used to demonstrate the capacity of the overall group. The payment capacity for water supply is estimated as 2.5 percent of median household income. To account for existing water payments, an average annual water charge for residential customers, (obtained from Raftelis Financial Consultants, Inc. and American Water Works Association 2013) is subtracted from the estimate to arrive at the estimated additional payments that are available to support new water projects. As shown in Table D-29, the estimated annual unused payment capacity in the Valley Water service area is approximately $1.5 billion and in the Westlands Water District and SBCWD service areas is approximately $28 million.

Table D-29. Payment Capacity Results

County/City	Households, 2014–2018[1]	Median Household Income, 2014–2018[1]	Estimated Current Water Rates, 2013[2,3] ($1/hhld/yr)	Household Payment Capacity ($1/hhld/yr)	Estimated Total Payment Capacity ($/yr)
Santa Clara	635,525	$116,178	$490	$2,414	$1,534,443,336
Avenal	2,323	$41,097	$615	$412	$958,063
Coalinga	4,490	$59,535	$528	$960	$4,312,084
Hollister	15,356	$82,434	$594	$1,467	$22,524,949

Source: [1]U.S. Census Bureau 2020, [2]Raftelis Financial Consultants, Inc. and American Water Works Association 2013, [3]Value for Santa Clara County includes rates reported by the City of Morgan Hill, the City of Mountain View, and the City of Santa Clara
Key: hhld = household, yr = year

Financial feasibility was assessed by comparing the representative M&I beneficiaries' ability to pay with their allocated annualized costs (construction costs, interest during construction, and OM&R costs) for the project (Table D-30).

Table D-30. Dam Raise Alternative Plan Investor Directed Subalternative D Allocated Municipal and Industrial Water Supply Costs

Item	Unit	Allocated M&I Water Supply Costs
Allocated Capital (Construction and IDC) Costs	million $	$718.39
Annual Repayment of Allocated Capital Costs (40-years, 2.75-percent interest)	million $/yr	$29.84
Non-Federal OM&R Costs	million $/yr	$0.70
TOTAL Annual Payment for the NED Plan	million $/yr	**$30.54**
Annual Repayment Capacity	million $/yr	$1,562.20
TOTAL Annual Payment as Percentage of Repayment Capacity	%	**2.0%**

Key:
% = percent
NED = National Economic Development
M&I = municipal and industrial
IDC = interest during construction
OM&R = operations, maintenance, and replacement

The estimated average annual ability to pay of M&I users is large in comparison to the estimated total annual M&I water supply cost, as shown in Table D-30, which indicates that the potential M&I partners that would benefit from the Dam Raise Alternative Plan Investor Directed Subalternative D will be able to repay their allocated annualized costs. In addition, expected increases in population and related regional income beyond 2030 will increase regional ability to pay and further support potential SLDMWA and its member agencies' ability to pay allocated project costs, including construction and OM&R costs.

D.3.7.2 Irrigation Water Supply Ability to Pay Analysis

The financial feasibility analysis for irrigation water supply benefits assesses agricultural water users' ability to pay. Typically, agricultural water users' ability to pay is defined as the farm-level payment capacity aggregated to the entire district, less district existing obligations, operations and maintenance costs, power costs, and reserve fund requirements.

The Dam Raise Alternative Plan Investor Directed Subalternative C will provide increased water supply reliability to members of SLDMWA. This analysis provides a preliminary estimate of the ability to pay for one of the SLDMWA member agencies. Investors for the Dam Raise Alternative Plan will be confirmed in future agreements. This analysis may be expanded in the future to include other SLDMWA member agencies that may benefit from the Dam Raise Alternative Plan.

For irrigation water supply beneficiaries, ability to pay begins with a payment capacity analysis. Payment capacity is the estimated residual net farm income of irrigators available for payment of both federally and non-federally assessed water costs, after deduction for on-farm production and investment expenses, as well as appropriate allowances for management, equity, and labor. Nonfarm revenues are not included in the payment capacity assessment.

The estimation of payment capacity normally begins with the identification of "representative farms" that are constructed to emulate typical agricultural operations within each region affected by the Dam Raise Alternative Plan. However, more than 60 different crops are grown within the representative SLDWMA district. As a result, it is necessary to limit the number of crops and farm types considered in the payment capacity analysis. This analysis applies available crop budgets to the crops that comprise 5 percent or more of the average harvested acreage within the representative SLDMWA district (see Table D-31). The estimated payment capacity is then aggregated to the representative SLDMWA district according to the proportion of the district's total water deliveries.

Table D-31. Selected Crops and Average Acres for Payment Capacity Analysis

Selected Crop	Representative Water District Average Acres (2017 – 2019)
Almonds	89,582
Cotton	39,334
Pistachios	49,757
Tomatoes	60,685
Wheat	17,756
Total Selected Crop Acreage	257,115
Total Harvested and Non-Bearing Trees and Vines Acreage	416,741

Source: WWD 2017-2019.

Recent crop budgets for each of the five selected crops were obtained from the University of California. All production costs were converted to 2020 dollars using the Implicit Gross Domestic Product Price Deflator. The applied crop budgets are reported in Table D-32.

Table D-32. Applied Recent Crop Budgets for Selected Crops

Selected Crop	Recent Crop Budgets
Almonds	Sample Costs to Establish an Orchard and Produce Almonds, North San Joaquin Valley, 2019
Cotton	Sample Costs to Produce Cotton (Pima), South San Joaquin Valley, 2012
Pistachios	Sample Costs to Establish an Orchard and Produce Pistachios, South San Joaquin Valley, 2015
Tomatoes	Sample Costs to Produce Processing Tomatoes, Sacramento Valley and North Delta, 2017
Wheat	Sample Costs to Produce Wheat, Sacramento Valley, 2016

Source: UCCE 2012, 2016, 2017, 2019

The production costs from each budget were applied after conversion into 2020 dollars. However, district provided water costs were removed from the crop budgets. In addition, the costs of farms supplied groundwater in the representative SLDWMA district was estimated and added to each of the crop budgets. Based on the representative SLDMWA districts agricultural water management plan, groundwater pumped by individual farms represents approximately 26 percent of the total water available for irrigation on an annual basis. This analysis assumed that each crop received 26 percent of its applied water requirement from groundwater. Groundwater costs for the representative SLDWMA district were obtained from estimates contained within the Statewide Agricultural Production Model that include both capital and O&M cost components. Crop prices and yields were obtained from Fresno County and Kings County agricultural commissioner reports for 2014 through 2018. The representative SLDWMA district is located within both counties. Therefore, the crop yields and prices applied in the payment capacity analysis are the five-year averages for both counties. Table D-33 reports the applied crop yields and prices.

Table D-33. Applied Crop Yields and Prices

Selected Crop	Units	Crop Price (price/unit)	Crop Yield (unit/acre)
Almonds	lbs	$3.06	2,138.0
Cotton	lbs	$1.53	1,562.0
Pistachios	lbs	$2.69	2,388.0
Tomatoes	tons	$80.31	55.0
Wheat	tons	$227.38	2.6

Source: Fresno County 2014-2018, Kings County 2014-2018 Key: lbs = pounds

Table D-34 provides the estimated payment capacity for each of the selected crops and the acres-weighted average payment capacity for the representative SLDWMA district is located within both counties. The weighted average payment capacity includes the estimated negative payment capacity for wheat which is set to $0/acres. As shown, the estimated payment capacity ranges from -$402/acre for cotton to $1,361/acre for pistachios. The weighted average payment capacity is $697/acre.

Table D-34. Estimated Payment Capacity for Selected Crops

Selected Crop	Estimated Payment Capacity ($/acre)[1]
Almonds	$549
Cotton	$402
Pistachios	$1,361
Tomatoes	$614
Wheat	$0[2]
Weighted Average Payment Capacity	$697

Notes:
[1] Includes non-project water costs, return to management estimate of 10% of net income, return to equity estimate of 3% of operating costs, return to labor from the crop budgets. Adjusted for applies groundwater available for irrigation annually. Project water costs are not included.
[2] Crops with negative payment capacities are set to $0

The weighted average payment capacity is applied to average irrigated and harvested acres for the representative SLDWMA district from 2017 through 2019 (see Table D-35). This analysis excludes fallowed acres and nonharvested acres. It also includes nonbearing trees and vines acres as the almond and pistachio crop budgets applied in this analysis include establishment costs. The total estimated payment capacity for the representative SLDWMA district is approximately $290.5 million (see Table D-35). District costs and revenues were obtained from district financial statements and represent averages from 2016 through 2019. Average revenues not associated with water sales were added to the estimated total payment capacity. Average total expenses and debt obligations were deducted from the estimated payment capacity to estimate ability to pay. As shown, the estimated ability to pay is approximately $85.1 million, annually.

Table D-35. Estimated Annual Ability to Pay

Category	Annual Ability to Pay
District Crop Acres	416,741
Total Payment Capacity ($ million)	$290.5
Other District Revenues ($ million)	$12.6
Reserve Funds ($)	$0
District Operation and Maintenance ($ million)	$207.3
Debt Repayment ($ million)	$10.6
Ability to Pay ($ million)	**$85.1**

Notes:
General: April 2020 price levels.

Irrigation water supply beneficiaries could be assigned annual repayment costs of approximately $4.0 million. This assumes that they will also receive the project's CVP water supply benefits, under the NED Plan. Therefore, under this scenario, the representative SLDWMA district would have the ability to pay its assigned share of annual costs.

D.4 References

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