RECLAMATION

Appendix C
Economics

North-of-the-Delta Offstream Storage Investigation

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Appendix C Economics

C.1 Introduction

Overview
This appendix was prepared for the North-of-the-Delta Offstream Storage (NODOS) Feasibility Study being conducted by the United States Department of the Interior, Bureau of Reclamation (Reclamation), and the California Department of Water Resources (DWR). These feasibility studies evaluate the effectiveness of offstream storage in the northern Sacramento Valley in improving water supply and water supply reliability, improving water quality in the Sacramento–San Joaquin River Delta (Delta), and enhancing the survival of anadromous fish and other aquatic species. This appendix documents the methodologies used to evaluate the economic benefits for the NODOS/Sites Reservoir Project alternatives (alternatives).

Traditionally, reservoirs are created by constructing dams on major streams (onstream storage). Offstream storage involves diverting water from a stream and transporting the water through a conveyance system to a reservoir that may be miles away from the point of diversion.

Development of the proposed offstream storage facilities would add flexibility to the State of California's water management system. The alternatives would enable Reclamation and DWR to divert water from the Sacramento River during high-flow periods, thereby avoiding adverse impacts to fish passage, and deliver water to the river as needed when flows are lower. With additional storage capacity and integrated operations coordinated with other water facilities, the alternatives' diversions and deliveries can be managed to improve systemwide responses to water demand, water quality, and reliability requirements. In addition, the alternatives would improve the State's water management system, and thus, its response to future water supply needs resulting from climate change impacts and system interruptions caused by earthquakes or flooding.

Purpose and Scope
Estimating the benefits of the potential accomplishments of the alternatives is critical to establishing economic feasibility and identifying a corresponding recommended plan. The estimated benefits are used to allocate the costs of the alternatives among the various purposes and to identify cost-sharing responsibilities among Federal and non-Federal entities. The estimates of alternatives' costs are discussed in Section B.4, Cost Estimate, of Appendix B, Engineering.

Primary Planning Objectives
The following are the primary planning objectives of the alternatives:

- Increase water supplies to meet existing contract requirements, including improved water supply reliability, and greater flexibility in water management for agricultural and municipal and industrial (M&I) users.

- Provide water supply for refuge needs to improve extent of incremental Level 4 criteria attainment.

- Increase the population of anadromous fish and other aquatic species.

- Improve the quality of water used for M&I and agricultural purposes throughout California, and environmental water quality in the Delta.

Secondary Planning Objectives

The following are the secondary planning objectives of the alternatives:

- Generate hydropower that can be integrated with the development of renewable energy.

- Develop additional recreational opportunities in the Primary Study Area.

- Provide local flood-damage reduction through the construction of new dams.

- Provide water releases for emergency response.

Alternatives

In accordance with the P&Gs, the feasibility studies for the alternatives[1] analyze proposed action alternatives and a No Action Alternative. The key components of the action alternatives relevant to the economic analysis are summarized below.

- **Alternative A:** Sites Reservoir would have a storage capacity of 1.27 million acre-feet (MAF). Water would be conveyed via the existing Tehama-Colusa (T-C) Canal (2,100 cubic feet per second [cfs]) and Glenn-Colusa Irrigation District (GCID) Canal (1,800 cfs) and a Delevan Pipeline with a diversion capacity of 2,000 cfs and release capacity of 1,500 cfs. The Delevan Pipeline would have a fish screen intake and pumping plant.

- **Alternative B:** Sites Reservoir would have a storage capacity of 1.81 MAF. Water would be conveyed via the existing T-C Canal (2,100 cfs) and GCID Canal (1,800 cfs) and a new release-only Delevan Pipeline with a release capacity of 1,500 cfs. The proposed release-only Delevan Pipeline would not have a fish screen intake or pumping plant facilities.

- **Alternative C:** Sites Reservoir would have a storage capacity of 1.8 MAF. Water would be conveyed via the existing T-C Canal (2,100 cfs) and GCID Canal (1,800 cfs) and a Delevan Pipeline with a diversion capacity of 2,000 cfs and release capacity of 1,500 cfs. The Delevan Pipeline would have a fish screen and intake pumping plant.

- **Alternative D:** The facilities for Alternative D would be similar to those for Alternative C, but this alternative would modify operations to provide greater benefits to water users in the Sacramento Valley and to anadromous fish in the Sacramento River between Keswick Dam and Red Bluff. Alternative D would also have modified recreational facilities.

All four alternatives would include pump storage hydropower facilities (see Appendix H.1) to generate dispatchable hydropower, which is easier to integrate with the grid and with the development of renewable energy resources.

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[1] Throughout the analysis, the NODOS project alternatives are generally referenced as the "alternatives."

Guidelines

The economic valuation approach for Federal water resource projects is to be consistent with the Federal Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) (WRC 1983). 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 United States 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 the USACE, United States Environmental Protection Agency, United States Department of Agriculture, U.S. Department of the Interior, National Oceanic and Atmospheric Administration, Tennessee Valley Authority, Federal Emergency Management Agency, and Office of Management and Budget.

In March 2013, the Administration released the Principles & Requirements (P&R) that lay out broad principles to guide Federal investments in water management. In addition, Final Interagency Guidelines for implementing the Principles & Requirements (PR&G) were also released in December 2014. The modernized P&R, together with the agency-specific Guidelines (PR&G), help accelerate project approvals, reduce costs, and support water infrastructure projects with the greatest economic and community benefits. They also allow agencies to better consider the full range of long-term economic, social, environmental, cultural, and other benefits.

The evaluation of benefits is consistent, when possible, with the PR&G. Efforts were also made to apply methodologies consistent with the evaluation of other CALFED storage projects to the extent practicable. Under the P&Gs, the Federal objective for water contributions is to maximize contributions to National Economic Development (NED) consistent with protection of the environment.

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 non-monetary effects, and allow for the inclusion of quantified and non-quantified 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.

Therefore, 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 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 the National Environmental Policy Act (NEPA) of 1970 (42 United States Code 4321 et seq.) and other Federal guidance.

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, should a project or program be implemented. They include increases in the net value of those goods and services that are marketed, and also 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 which occur as a result of water resources planning and development. The NED account considers the estimated benefits and costs of alternative plans. 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 under-employed 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 Shasta Lake Water Resources Investigation (SLWRI) comprehensive plans, the NED analysis considers the monetary and non-monetary 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 NED benefits 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 alternative, 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.

Based on the evaluation of the potential physical accomplishments and the benefits and costs of the alternative plans, Alternative C would achieve the highest net NED benefits while protecting the environment, and ranks the highest among the comprehensive plans in meeting the P&G criteria. Consistent with the P&Gs, since Alternative C generates maximum net NED benefits, Alternative C is identified as the NED Plan.

Regional Economic Development Account

The RED account examines and displays potential changes in 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 of the NED Plan is included to assess changes in personal income and employment.

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 are 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.

EQ benefits will be valued relative to their accomplishment levels, and corresponding policy and public laws and regulations. The anadromous fishery restoration objectives are consistent with the species recovery plan, indicating the social preference for these species and a corresponding desire for the ecosystems on which they depend, and which depend on them.

Other potential key secondary and incidental ecosystem accomplishments may include watershed protection, shoreline protection, and lake protection and quality. The need and preference for

these benefits are largely based on CALFED programs and objectives, which include ecosystem restoration, watershed management, and water management.

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. OSE also includes the effects of the displacement of people, businesses, or farms; impacts to the long-term productivity of resources, such as agricultural land, for use by future generations; and effects on energy requirements and conservation.

C.2 Economic Assessment Methods

National Economic Development Procedures
As discussed in the section titled "Guidelines," above, primary guidance for studies of Federal water projects is provided by the P&Gs (WRC 1983). Under the P&Gs, the Federal objective for water contributions is to maximize the contribution to NED consistent with protection of the environment. This section describes methods for economic assessments during the NODOS Feasibility Study. The economic analysis addresses the potential incremental economic benefits that may be provided by the NODOS project alternatives.

Potential agricultural and M&I water supply reliability, incremental Level 4 refuge supply, improved water quality (agricultural, M&I and Delta environmental), hydropower, recreational, and anadromous fish survival benefits from the NODOS project are evaluated. Alternatives' costs are documented in the Engineering Summary, Appendix B. Together, these appendices support the comparisons of comprehensive plan benefits, costs, and net benefits, which are presented in the main text of the Draft Feasibility Report.

An NED account is required for any water project study in which Federal participation is considered. The account shows changes in the net economic value of national output of goods and services. The contributions reflect the direct net benefits that would accrue to Glenn and Colusa Counties and to the rest of the Nation if an alternative were implemented. Benefit categories considered may include agricultural water supply (and the resulting net farm income); M&I water supply (and the avoided costs of the most likely alternative source); flood control (and the avoided property damages); hydropower (and the avoided costs of alternative power sources); recreation (and visitors' travel spending and user-value); and environmental enhancement.

Benefits may include both marketed and non-marketed goods and services. Marketed goods and services are those that are priced in markets or can be observed to have monetary value (e.g., water for agricultural or M&I use). Non-marketed goods and services, such as recreation, are not traded in market structures.

The NED account relates to the part of the human environment for which NEPA analyses identify beneficial and adverse effects on the economy that result from water resource planning and development. The account includes both benefits and costs of alternative development. Benefits fall into three broad categories:

- Increases in the net economic national output of goods and services

- The value of increased output arising from external economies

- Value generated by the use of otherwise unemployed or underemployed labor resources

Relevant costs in the NED account reflect the opportunities foregone because a plan is implemented; for example, reduced outputs in other sectors or employment losses. Costs fall into two categories:

- *Implementation:* Construction, operations and maintenance (O&M), planning and design, and land costs

- *Other direct costs:* Uncompensated adverse effects on third parties (e.g., increased water treatment costs for additional supplied water)

For each alternative under consideration, a "with" and "without" analysis must be applied to determine the net increase in the production of goods and services over the production that would occur in the absence of the plan.

The general measurement standard for increases in the national output of goods and services is the total value of the increase, where total value is defined by the concept of willingness to pay for each increment of output of the plan.

Willingness to pay reflects the maximum amount society would pay for a good or service. When measuring actual demand for goods and services is not possible or cost efficient, three alternative techniques can be used to estimate total value (in order of preference): change in net income, cost of the most likely alternative, and administratively established values.

The purpose of this Economics appendix is to determine the NED plan (i.e., the alternative plan with the greatest net economic benefit). The net benefit is the difference between the present value of benefits and costs, and it measures the extent to which benefits to the Nation exceed the alternatives' costs. The benefit-cost ratio (BCR) is calculated by dividing annual alternative benefits by annual alternative costs. The net benefits and costs of alternative plans are compared to identify the plan that reasonably maximizes net benefits (i.e., the NED plan). This is not necessarily the plan that results in the most benefits, but instead is the plan that reasonably maximizes net benefits while protecting the environment, given its cost to the Nation. Section 1.10.2 of the P&Gs requires that the NED plan be selected unless the Secretary of the Interior grants an exception.

Economic Concepts

Most of the goods and services purchased by individuals, businesses, or governments are traded in markets. Supplies, raw materials, food, automobiles, clothing, and utilities and other services typically are purchased at prices that are set in established markets. The benefits from the

purchases of these goods and services accrue directly to the purchaser and indirectly to other related businesses.

Natural resources can provide a variety of services or benefits, such as biological diversity, that generally are not bought or sold in markets, and therefore do not have market prices. In some cases, market values can be assigned to a natural resource; however, the societal (or economic) value of a natural resource may differ widely from its market value. For example, an acre of wetland may be traded in the market based on its appraised value for residential or commercial development. However, the full value may be much higher based on the availability of the land for mitigation purposes and for the services the land provides, such as groundwater recharge or flood control (Freeman 2003).

Market Value
The economic evaluation of water projects is difficult because it involves elements of welfare economics that are not directly observable. Each person's welfare is conceptually measurable by the utility one gains from consuming various goods and services. Utility is not measurable, however, nor is comparing utility levels among consumers. However, assuming that people are trying to maximize their utility, their utility-maximizing behavior is observable and is the basis for estimating benefits.

For purposes of the alternative evaluation, the most commonly used approach for measuring consumers' utility-maximizing behavior is to determine willingness to pay (WTP). WTP is an expression of a consumer's utility relationships. It is assumed that consumers are rational; consequently, WTP is a realistic expression of the value that a consumer places on a good, service, or resource. Minimum WTP can be approximated by estimating the dollar value of a product in a particular application. However, depending on the utility relationship, a consumer may have an actual WTP higher than the market price of the good or service (in which case an individual would gain an added "consumer surplus" benefit by the transaction, as illustrated on Figure C-1).
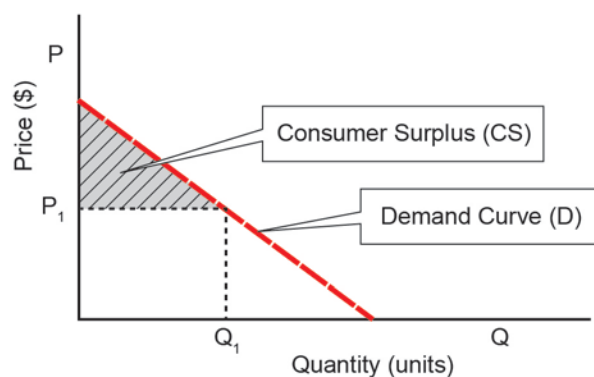
Figure C-1. Demand Curve and Consumer Surplus

For the alternatives, farmers receiving Central Valley Project (CVP) and State Water Project (SWP) water may be able to increase production and profits with increased or more reliable water supplies. This increment in profit is a benefit of an alternative and a market-based value. Similarly, for a consumer, the user value of an incremental or more reliable water supply is the

value that the consumer places (or is willing to pay) on irrigating the lawn or filling the swimming pool. In the latter case, the lower bound of the consumer's WTP is based on the water cost to irrigate the yard or fill the pool.

Non-market Value
As the name implies, non-market goods and services are those for which a price is not easily observed or determined because willing seller/willing buyer markets do not exist for the goods and services. For that reason, most activities involving most environmental resources are characterized as non-market goods. Examples include the personal utility received from scenic views or the preservation of threatened and endangered species. The costs of environmental protection or enhancement actions may be estimated using typical market-based metrics. The benefits of such actions are more difficult to quantify. Recreational activity reflects another commonly incurred market value.

Use and Non-use Values
Two main elements of value need to be distinguished: use value and non-use value. Use value accrues to those individuals who actually use an economic resource. However, there are also individuals who do not use an economic resource but still value that resource's existence. Thus, total economic value (TEV) can be defined as follows:

TEV = Use Values (market and nonmarket) + Non-use Values (nonmarket)

Non-market use values are associated with resource-related activities that have human interaction, such as fishing, hunting, and camping. In general, non-market values for *use* value are more easily determined than those for *non-use* values.

Non-use values reflect the belief that people place values on resource and environmental services that are irrespective of any use they might make of the resources (Freeman 2003). Two typical non-use values are defined: existence and bequest. Existence value relates to the value that a person places on his or her knowledge of the existence of a resource (for example, an anadromous fishery). Bequest value relates to the value that a person places on his or her ability to bequeath the availability of a resource to future generations.

Non-market Valuation Techniques
Non-market valuation (NMV) techniques are appropriate for valuation of several objectives of the alternatives. NMV techniques can be classified into two types: revealed preference (RP) techniques, and stated preference (SP) techniques. RP techniques capture primarily the use values of a resource, and SP techniques can capture both use and non-use values.

Revealed Preference Techniques
- RP techniques rely on observation of either people's actions in buying and selling goods or services or their behavior and the associated costs (e.g., travel cost method for recreation) that in some way are specifically related to the non-marketed impact under consideration. For instance, people's preferences for housing, as reflected by prices paid for property, can be used to infer the value they hold for the environmental and social factors that affect house prices but are not marketed directly themselves. Examples of these factors include pollution, scenic views, and neighborhood social facilities.

Stated Preference Techniques

- SP techniques involve asking people survey questions regarding the strength of their preferences for specified environmental or social changes. The questions are designed to focus on the trade-offs people are willing to make between the environmental and social improvements and their personal wealth and well-being.

Other Valuation Techniques

Other methods for valuing environmental attributes include benefits transfer; the cost-saving or relocation method; determination of replacement cost; interpretation of similar decisions; preventive expenditure; and threshold analysis. These techniques can be used to indicate values under certain conditions and situations at substantially less cost than the survey methods discussed above. The benefits transfer method was applied to the alternatives.

Benefits transfer is the process of taking information about economic benefits (i.e., WTP estimates) from one context (the "study site") and transferring it to another context (the "option site"). Estimates of benefit transfer can be based on RP- or SP-based value estimates for comparable economic situations. A good understanding of the quality of the original study is required when selecting the appropriate transfer value from the literature. The following criteria should be met to ensure that the original study and the new context are similar enough to ensure a valid result:

- The physical characteristics of the two sites should be similar

- Changes being valued in the study should be similar

- Policy contexts should be similar

- The cultural and socioeconomic characteristics of the affected populations should be similar

A more rigorous approach to benefit transfer involves transferring a benefit function from one context to another. The benefit function statistically relates the public's WTP for characteristics of the study site and the people whose values were elicited. When a benefit function is transferred, adjustments can be made for differences in these characteristics, thereby allowing for greater precision in transferring benefit estimates between contexts. If a previous benefit estimation study includes a variety of socioeconomic variables, physical characteristics variables, or other factors that can be input to represent a variety of sites, then the requirements for the benefit transfer become much less restrictive. In such cases, the assumption for the benefit transfer is that the relationship between WTP and the explanatory variables is consistent between the different sites (contexts). However, if the benefits transfer is based on an average value point estimate, its applicability is more limited.

When assessing a wide range of NMV techniques, Braden and Kolstad (1991) concluded that the methods being used provide reasonable estimates, and do so regularly and consistently. Other studies have shown that valuations for non-market "goods" are as reliable or unreliable as those for market-traded goods.

Economic Valuation Methods

Economic valuation methods generally fall into one of two categories: market valuation, or non-market valuation. Market values refer to conditions for which a price can be observed, such as crops for human consumptive uses. Non-market valuation methods usually apply to resources for which there are no established markets, such as ecosystem restoration or wildlife conservation. As recommended in the P&G, economic benefits may be determined by one of five valuation approaches.

- Willingness to pay

- Actual or simulated market prices

- Change in net income

- Cost of the most likely alternative

- Administratively established values

In general, the P&G recommend that the value of goods and services be measured according to WTP as a measure of demand. Revealed and stated preferences are two approaches for valuing WTP for goods and services.

RPs are based on observed behavior that reflects preferences, while SPs 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 or surveyed 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 WTP value. Other generally acceptable approaches under the P&G include cost-based approaches. Each of the valuation approaches recommended by the P&G to estimate NED economic benefits are briefly described below.

Willingness to Pay

The user value or WTP method refers to the value of the resource to the consumer. WTP refers to the value that a "seller" would obtain if able to charge each individual user a price that captures the full value to the user.

Implementation of this approach requires estimation of a demand curve. Three methods are commonly used to estimate a demand curve. The methods include: RPs, which rely on market-based data; contingent valuation, which uses surveys to directly elicit consumer benefits; and benefits transfer, which uses estimates from previously completed studies.

Determining user-benefit value through RPs can be challenging. Although the market price (if it exists) of a good/resource may demonstrate a lower-bound monetary value that consumers are willing to pay for a supply; generally, the market price will represent only a partial representation of its benefit value, because it will not include its "consumer surplus" value (i.e., user's full willingness to pay).

As an example, an agricultural producer's user value might represent the contribution of an additional water supply to their production, and ultimately, to their profits. Consequently, a user-

value approach requires understanding the output value of the agricultural users' crop production and/or their water purchase prices and transactions. A key difficulty is accurately collecting and representing such typically proprietary information, especially in the case of numerous and varied private transactions. Survey data approaches can be used, but are generally difficult and costly to administer. Also, extrapolating respondents' answers to a large user population may misrepresent the benefits.

A well-designed contingent valuation survey represents another possible method to measure WTP in a developing market. However, conducting a primary RP or contingent valuation study is often prohibitively time-consuming and expensive. Therefore, values from previous economic studies (i.e., benefit transfer approach) may be used to estimate WTP, provided their circumstances and conditions are relevant to the study area and output being valued.

Actual or Simulated Market Prices
In cases where a demand curve cannot be directly estimated, market prices may be used to estimate society's WTP for a good or service. The P&G provide some limited guidance on the use of market prices where 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, where possible, throughout the planning period to account for expected changes in demand and supply conditions.

Economic evaluation analyses performed for the feasibility studies for other major California water storage projects have collected historical data on public water sales transactions in California. These analyses of water transfer markets provide a partial but limited representation of the benefits of water supply reliability. Because they are transaction-based, the analyses do not estimate the full consumer and producer surplus associated with buyers who would have willingly paid a higher price than their seller needed to complete the deal.

In addition, the great majority of the transactions are for short-term or "spot" market sales of existing water supplies. In contrast, the alternatives represent a long-term water source that would add substantial quantities of "new" water. The alternatives' water supply may offer a far more dependable source of water with future long-term costs that are more predictable and less susceptible to future market fluctuations. Water sales to farmers and water districts may also be affected by the specifics of local land conditions, locations, and/or deal participants. It is unclear that there would be sufficient viable permanent water sellers for implementation.

Change in Net Income
When WTP 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 the project will be used as an input in a production process. One example is estimation of benefits with the Statewide Agricultural Production (SWAP) Model, which measures the change in net income to agricultural producers associated with changes in water supply conditions.

Cost of the Most Likely Alternative
For some of the purposes of the alternatives, the economic benefits can be estimated using a "cost of the most likely" approach. In situations where water supply alternatives to the proposed

project exist, the cost of the most likely alternative to obtain the same level of output can be used as a measure of NED benefits. This method assumes that if the NED Plan is not implemented, the alternative action most likely to take place provides a relevant comparison. 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.

This approach involves identifying the next best alternative project to achieve the same outcomes (i.e., increasing water supply or improving environmental conditions), and estimating the development cost of that project. The alternative project's cost can then be used to represent the purpose's benefit value. Ideally, demonstrated expenditures for similar projects would be used to estimate the benefit value for the specific purpose.

Under the P&Gs, a least-cost alternative valuation approach can be used when the outputs of the two projects are similar; the NED benefits cannot be estimated from market prices or net income changes; and the alternative project would be implemented in the absence of the multipurpose project. This method is generally considered for benefit categories that cannot be estimated through the market-based methods described above.

The 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 example, for water supply reliability, 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.

As discussed above, the "cost of the most likely alternative" approach requires identifying a feasible comparable alternative (which is limited to solely result in the same outcome for the specific purpose). The single-purpose project can then be used to determine the project's net benefit (for that specific purpose) by subtracting its development cost from the cost to develop the alternative. However, identifying a suitable, comparable single-purpose alternative project can be difficult, given the NODOS project alternatives' scale and complexity as a multiple-benefit water supply project.

Administratively Established Values
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.

NED Economic Valuation Approaches
This section briefly describes economic benefit valuation approaches used for the economic analysis of the alternatives. Valuation approaches are presented for water supply reliability, incremental Level 4 refuge supply, anadromous fish survival, water quality improvement, hydropower, recreation, and flood reduction benefit categories. Additional information describing each benefit category and the valuation approaches is presented in the second through eighth sections of this appendix.

Water Supply Reliability

Agriculture

The alternatives will improve water supply reliability to agricultural water users, particularly during dry years. Agricultural water supply reliability benefits are commonly estimated through the "change in net income" approach described in the P&G. This study estimates the NED water supply reliability benefits to agriculture through application of the SWAP model to projected changes in water supply deliveries resulting from the alternatives. SWAP is a well-accepted and frequently applied economic model of irrigated agricultural production in California, based on complex mathematical programming.

M&I

Water supplies from the alternatives will also improve water supply reliability to M&I water users, primarily south of the Delta. M&I water users have been increasingly participating in the water transfer market to augment supplies. This analysis assumes that the next increment of water supply to M&I users would likely be obtained through water transfers. This analysis relies on values estimated through application of a water transfer pricing model, and through consideration of the costs associated with conveying the water to the M&I service areas. This method is consistent with the "cost of the most likely alternative" method recommended by the P&G.

Incremental Level 4 Refuge Supplies

The alternatives provide opportunities for increase water deliveries for incremental Level 4 refuge needs. The economic benefits of the alternatives' increases in incremental Level 4 refuge water deliveries are estimated through implementation of a "cost of the most likely alternative" approach. The underlying premise for the valuation approach is that increasing incremental Level 4 refuge supplies is a socially desirable goal, as indicated by the listing of several species as threatened or endangered and the demonstrated expenditures on salmon restoration projects. The cost of the most likely alternative is based on the cost of a Shasta Lake dam raise developed and operated solely for the purpose of providing the necessary water quantities for the incremental Level 4 refuge supply purpose.

Anadromous Fish Survival

The alternatives provide opportunities for enhancing water temperature and flow conditions in the Sacramento River as a means of improving the riverine ecosystem. The economic benefits of alternatives' contributions to anadromous fish survival are estimated through implementation of a "cost of the most likely alternative" approach. The underlying premise for the valuation approach is that increasing salmon populations is a socially desirable goal, as indicated by the listing of several species as threatened or endangered and the demonstrated expenditures on salmon restoration projects. Because the increased potential to reduce water temperatures and improve flows during critical periods provided by additional surface storage is essential to increasing salmon production, the cost of the most likely alternative is based on the cost of various Shasta Lake dam raises operated solely for the purpose of increasing the number of salmon smolt in the Sacramento River.

Water Quality

M&I

The alternatives would affect the quality of M&I water supplies for many users who divert water from the Delta. Water quality in urban service areas would be affected by changes in both the amount and quality of Delta-supplied water.

Two models were used to assess the NED benefits of M&I water supplies. Each model represents a different geographic region. The Lower Colorado River Basin Water Quality Model (LCRBWQM) covers water users in the Metropolitan Water District of Southern California (MWD) service area, while the Bay Area Water Quality Economics Model (BAWQM) covers South Bay Area water users. Both models estimate the benefits of salinity reduction in terms of avoided costs and damages from water quality improvements. This approach corresponds to the "change in net income" approach described in the P&G.

Agriculture

The alternatives would affect the quality of irrigation water supplies for many users who divert water from the Delta. Water quality for agriculture would be affected by changes in both the amount and quality of Delta-supplied water. Improved water quality can increase yields and/or the variety of crops that can be cultivated. It can also reduce drainage costs and result in water use savings from producers from a reduced need to "leech" their soil to offset salt accumulation. For Central Valley agricultural producers, the SWAP model was used to estimate the unit value (or marginal value) for the projected irrigation water use savings attributable to alternatives' agricultural water quality improvements. In addition, the LCRBWQM model provides NED benefit value estimates for agricultural producers in the South Coast region. This approach corresponds to the "change in net income" approach described in the P&G.

Delta Environmental

Supplemental Delta outflow during the summer and fall months is a major water quality benefit of the alternatives. Increased flows through the Delta and out through San Francisco Bay are beneficial to numerous fish populations. The volume of water released for water quality purposes provides benefits by increasing Delta outflow, including shifting the location of X2[2] farther to the west. The economic benefits of alternatives' contributions to Delta environmental water quality are estimated through implementation of a "cost of the most likely alternative" approach. The underlying premise for the valuation approach is that increasing Delta environmental water quality is a socially desirable goal, as indicated by the listing of several species as threatened or endangered, and the demonstrated expenditures on fish restoration projects. Because the improved Delta environmental water quality provided by additional surface storage is essential for shifting X2, the cost of the most likely alternative is based on the cost of developing Auburn Dam to provide equivalent water quality improvement.

Hydropower

The proposed NODOS project alternatives will include new hydropower capacity, generation and the ability to provide ancillary services at Shasta Dam and other hydropower facilities

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[2] A Delta management tool, defined as the distance in kilometers from the Golden Gate Bridge to the location where the tidally averaged near-bottom salinity in the Delta measures 2 parts per thousand.

throughout the CVP and SWP. Estimates of net changes in hydropower capacity, generation, and ancillary services in Western Interconnection electrical power grid were estimated using both DWR's Power and Risk Office (PARO) modeling and the PLEXOS® Integrated Energy Model (PLEXOS).

The PARO model was used to estimate the costs and revenues from each Alternative's hydropower facilities' operations. Power benefits were valued by PLEXOS, a power market simulation model, to forecast energy and ancillary service power market prices for the year 2022 when the 33 percent Renewable Portfolio Standard (RPS), mandated by California law, will have been implemented. The assumption is that power market prices stabilize once the RPS is achieved.

Recreation Benefits

Development of the NODOS project would provide new recreational facilities and opportunities. Recreation benefits are quantified through application of unit values determined by a previous United States Forest Service economic study (Loomis 2005) to expected future recreation use levels. This approach corresponds to the "change in net income" approach described in the P&G.

Flood Damage Reduction

Development of the NODOS project would reduce the magnitude of flood events in the area along Funks Creek downstream of Funks Reservoir. The value of the alternatives' flood damage reduction benefits was estimated by calculating the average annual cost of flooding under No Action conditions, and the projected reduction in flooded area and costs under the alternatives. This approach corresponds to the "change in net income" approach described in the P&G.

Benefit Analysis Factors

Discount Rate

Future construction and operations for the action alternatives would generate benefits and incur costs throughout the period of alternative development and operation. Although their magnitude and timing would vary, the costs incurred (or benefits generated) in the near term would have a greater value than if the same cost were incurred at a later date. This value difference reflects the effects of the time value of money.[3]

As a result, all alternative benefits and costs must be adjusted into a common point in time (i.e., present value) to accurately represent and compare the benefits and costs that occur at different times during the alternatives' future development and operating period. The discount rate is a conversion factor used to translate the future nominal value of a benefit or expenditure into its comparable value for another time period. This creates a common basis that simplifies the comparison of the value of benefits. The future benefits (or costs) are said to be expressed in "nominal terms" when their values are stated in the actual dollar amount that would occur on that future date. Once a nominal value is adjusted into the common-time basis (e.g., 2017 dollars)

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[3] Generally, invested capital appreciates in value over its investment period. The extent of this growth is determined by the investment's interest rate. For example, $100 invested in 2017 at a 5 percent annual interest rate would be worth $105 a year later, in 2018—substantially greater than the value of a $100 investment made in 2018. One would prefer to have $100 in 2017 due to the potential to obtain $5 of interest in 2018.

using the appropriate discount rate, the adjusted benefit (or cost) is expressed in "real" terms. The higher the discount rate, the lower the present value of future cash flows.[4]

Federal regulations require economic analyses conducted for water resource planning to use the Federal discount rate, as specified by the U. S. Department of the Interior. In accordance with agency regulations, the Federal discount rate of 2.875 percent was used for fiscal year 2017 to calculate the present value of the alternatives' future benefits and costs for this study (*Federal Register* 2016). Benefits and costs are expressed in 2015 constant dollar terms and at a 2015 price level, unless stated otherwise.

Planning Horizon
Approvals and funding for an alternative are assumed to be obtained in 2018, after which the implementation of the selected alternative would begin. Construction is projected to begin in 2022, and be completed in 2030. The reservoir would continue to fill during the following 2 years. The reservoir is expected to be partially operational in 2031 (generating 50 percent benefits), and would be fully operational in 2032.

The benefits and costs of the proposed alternatives have been analyzed over a 100-year planning horizon, based on expected alternative completion by 2030, and full operation of the reservoir in 2031. Consequently, the end of the Federal planning horizon for the alternatives is 2130.

The benefit estimation analyses for most purposes projected their conditions for two future points in time (2025 and 2060). Annual benefit values were interpolated between the 2025 and 2060 to determine their values during the intervening years. The 2060 benefit values were assumed to remain constant for the period after 2060, until the end of the alternatives' time horizon in 2130. In some cases, 2030 and 2045 years were used to estimate the purposes' future points in time. In those case, interim-year values were also interpolated and held constant for years after 2045.

Presentation of Results
The economic modeling for the alternatives used a variety of models and methods, as described in the following sections. All benefits were developed using average results for the full simulation period (i.e., representing all water-year conditions weighted based on the past 1921 to 2003 hydrologic sequence). Chapter 6, Alternative Development, and Chapter 7, Alternative Evaluation, in the main text provide a discussion of the physical effects that were used to estimate the benefits. This provides a conservative estimate of the benefits, because the physical effects contributing to the benefits are greater in Dry and Critical years. For example, the increases in deliveries during Dry and Critical years are even higher than the average increases, and this occurs at a time when a premium would be paid due to the scarcity of water.

For most primary objectives, the action alternatives would enhance water supply reliability for all purposes, resulting in greater benefits during Dry and Critical water years. As identified in the respective subsections, several benefit categories lack adequate data to quantify the entire benefit. The overall total benefit value, therefore, represents a conservative estimation.

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[4] For example, if the discount rate is 5 percent, a $100 payment made in 2018 would be equivalent in present-value terms to $95.23 (i.e., $100 ÷ 1.05 = 95.23). In other words, the discounted value of a $100 payment in 2018 would have a present value of $95.23 in year 2017.

For most purposes, additional analysis was also performed using alternate valuation approaches (and/or values). The supplemental analysis was performed to provide information on the benefit findings' potential sensitivity to the analysis and assumptions. The sensitivity analysis also offers some indication of the risk and uncertainty associated with the benefit analysis. Risk and uncertainty were also further analyzed and discussed in Chapter 9, Risk and Uncertainty.

A key assumption in the quantification of benefits was assumed population growth and its impact on future water demand. Each alternative is assumed to become fully operational in 2032, with a time horizon of 100 years. In estimating benefits, two future conditions were assumed: 2025 and 2060. The 2025 and 2060 estimates of urban water demand are based on historical and projected populations; persons per household; and estimates of applied water use developed for the "current trends" future scenario in the *2005 California Water Plan Update*. Annual population growth (and consequently, growth in urban water demand) was assumed to occur at a constant rate between 2025 and 2060.

The annualized benefits calculated interpolate modeled annual benefits (reflecting urban population growth) between 2025 and 2060, and then assumed constant annual benefits from 2060 to the end of the alternatives' time horizon in 2130.[5] These benefits are shown diagrammatically on Figure C-2. Based on the annual values, their total net present value (NPV) of benefits over a 100-year period between 2031 and 2130 was calculated. The NPV total was then annualized (using the Federal discount rate of 2.875 percent) to determine the average annual benefit value for the 100-year study period.
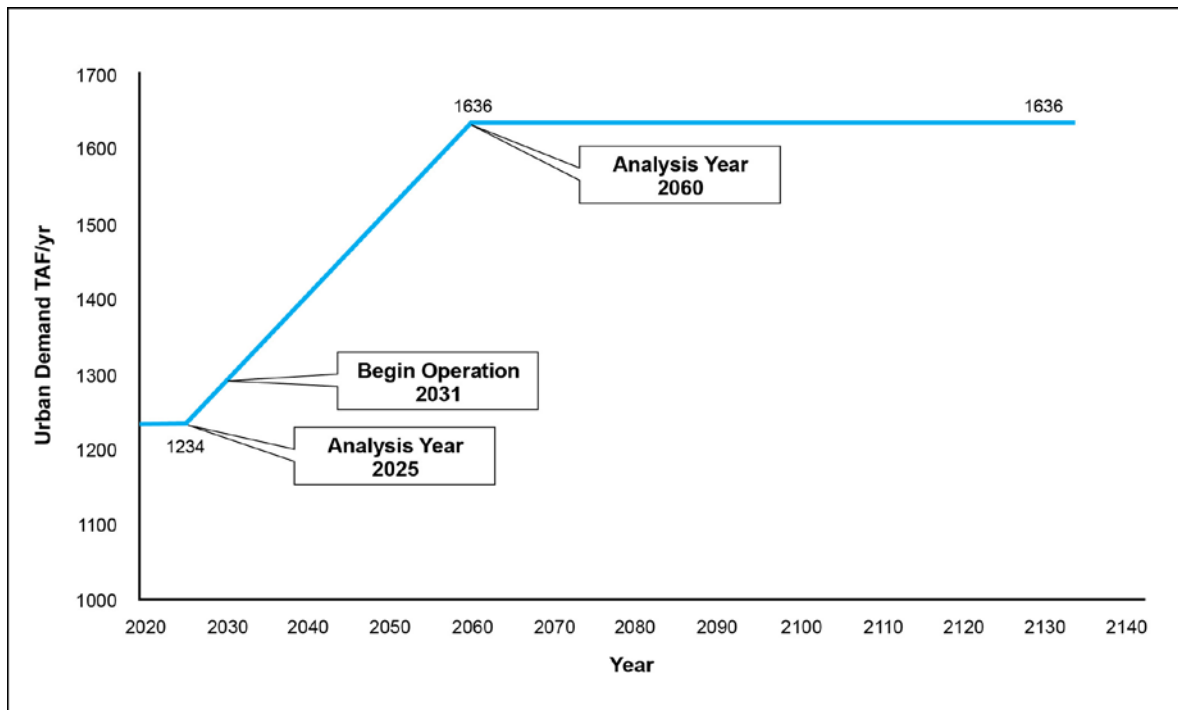
Figure C-2. Assumed Population Growth (and Associated Urban Water Demand), Interpolated between 2025 and 2060, and then Remaining Constant beyond 2060 (Example)

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[5] The constant post-2060 conditions were selected as a conservative assumption.

C.3 Water Supply Reliability Benefits

Increased water supply and water supply reliability are primary goals of the alternatives. The SWAP model was used to estimate the benefits of water allocated for agriculture and Level 2 refuge water supplies. Water transfer pricing was analyzed to estimate the benefits of water allocated for urban purposes.

Agricultural Water Supplies

The alternatives would supply water for irrigation to local and CVP users in the Sacramento Valley, and to CVP and SWP users in the San Joaquin Valley.

NED Benefit Valuation Methodology

The SWAP model was used as the agricultural economics production model to assess the agricultural and refuge benefits of the alternatives. This model is the evolution of a series of regional agricultural production models, and shares some of the basic modeling structure, data, and regional configuration used by the Central Valley Production Model. The SWAP model provides for flexibility in production technology and input substitution, and it has been extended to allow for a greater range of analyses, including interregional water transfers and climate change effects.

Description of the SWAP Model and Assumptions

The SWAP model is an agricultural production model developed specifically for large-scale analysis of agricultural water supply and cost changes. SWAP is a regional model of irrigated agricultural production and economics that simulates the decisions of agricultural producers (farmers) in California. The model's data coverage is most detailed in the Central Valley but also includes production regions for the Central Coast, South Coast, and desert areas (see Appendix 22F of the EIR/EIS for more description of the SWAP model and results).

Agricultural water sources in the SWAP model include CVP contract supply, CVP water rights and exchange supply, SWP contract supply, local surface water, and local groundwater. As conditions change in a SWAP modeling region (e.g., the available water supply for the alternatives 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 covers 27 agricultural subregions in the Central Valley. The subregions are based on water budget areas, called Detailed Analysis Units, that DWR uses for water planning.

The SWAP model is used to compare the long-term agricultural economic responses to potential changes in delivery of CVP and SWP irrigation water, other surface or groundwater conditions, or other economic values or restrictions. Results from the CALSIM II model (see Appendix 22A through 22F in the EIR/EIS for a description of the model and results) are used as inputs into the SWAP model through a standardized data linkage tool. Groundwater analysis is used to develop assumptions, estimates, and if appropriate, restrictions on pumping rates and pumping lifts for use in the model (see Appendix 22F in the EIR/EIS).

Typical output of the SWAP model includes revenues by regions and crop, land use, water use, crop stress percent, and marginal value of water. Additional post-processing analysis of the SWAP modeling results is performed to convert the results into estimates of the economic value of the various projected water supply changes to agricultural producers. In addition to aggregating the results for the numerous subregions, the post-processing analysis converts the results into a national perspective consistent with Federal P&Gs requirements for economic analysis.

SWAP Model Limitations

The SWAP model has been applied to other recent studies in the Mid-Pacific Region (e.g., SLWRI, Upper San Joaquin Storage Investigation), and is considered an appropriate and conservative approach for estimating the economic value of an alternative's future agricultural and refuge water supply benefits. The SWAP model is an optimization model that makes profit-maximizing adjustments to changes in water supply, prices, costs, or other inputs. Constraints can be imposed to simulate restrictions on the amount of adjustment possible or the speed at which the adjustment can realistically occur. Nevertheless, an optimization model can tend to overadjust and minimize costs associated with detrimental changes, or similarly, maximize benefits associated with positive changes.

The SWAP model does not explicitly account for the dynamic nature of agricultural production. To the extent that agriculture is in a "steady state" at any point in time, the calibration routine accounts for crop rotation and other intertemporal effects (Howitt 1995). In general, the model compares two conditions at a given point in time. This is consistent with the way most economic and environmental impact analysis is conducted, but it can overlook adjustment costs that may be important.

SWAP also does not explicitly incorporate risk or risk preferences (e.g., risk aversion) into its objective function. Risk and variability are handled in two ways. First, the calibration procedure for the SWAP model is designed to reproduce the observed crop mix. The starting calibrated SWAP base condition also reproduces the observed crop mix to the extent that the crop mix incorporates risk spreading and risk aversion. Second, variability in water delivery, prices, yields, or other parameters can be evaluated by running the model over a sequence of conditions or a set of conditions that characterize a distribution, such as a set of water-year types.

CVP and SWP water costs remain at without-project prices. No additional costs are added in the model to account for costs of the alternatives. Local, non-project surface water supply is assumed to be the same for both the with-project and without-project conditions.

Groundwater is an alternative water supply source to augment CVP and SWP delivery in many subregions. Groundwater costs and availability therefore have an important effect on how the SWAP model responds to changes to surface water deliveries. The model explicitly breaks out groundwater pumping costs into fixed, variable, and O&M components. Unit pumping costs change depending on the water-year type as the depth of groundwater changes by region. Additionally, pumping costs increase over the time horizon of the study consistent with Pacific Gas and Electric Company power costs. Maximum pumping capacities, by region, in the SWAP model must rely on an accompanying groundwater analysis and carefully specified groundwater assumptions. DWR estimated groundwater pumping capacities by region for use in the model

(Howitt et al. 2009) (see Appendix 22F of the EIR/EIS for more description of the SWAP model and approach).

Modeled Results

Given the inherent difficulties of both alternative benefit evaluation approaches, the SWAP model was used to estimate the benefits of the alternatives to agricultural and Level 2 refuge water supplies. The Water Storage Investment Program (WSIP) benefit methodology and unit values have been used in the sensitivity analysis performed to evaluate the risk and uncertainty associated with the project analysis.

CALSIM II operational studies were used to estimate the increases in deliveries by the alternatives for agricultural uses (Table C-1) and the alternative source water provided for the Level 2 refuge water supplies (Table C-2). A more detailed breakdown of how deliveries are distributed is provided in Chapter 6, Alternative Development, of the main text.

Table C-1. Annual Average Volume of Increase Water Deliveries to Agricultural Users

Alternative	Annual Volume (TAF) [a]	Difference from No Project (TAF)	Difference from No Project (%)
Average Water Conditions [b]			
No Project	1,808	—	—
Alternative A	1,878	70	3.9%
Alternative B	1,845	37	2.0%
Alternative C	1,873	61	3.4%
Alternative D	1,940	132	7.3%

[a] Based on CALSIM II modeling.
[b] Average over entire hydrologic sequence (1921 to 2003).
TAF = thousand acre-feet
— = not applicable

Table C-2. Annual Average Deliveries for Level 2 Refuge

Alternative	Annual Volume (TAF) [a]	Difference from No Project (TAF)
Average Water Conditions [b]		
No Project	0	—
Alternative A	4	4
Alternative B	3	3
Alternative C	6	6
Alternative D	4	4

[a] Based on CALSIM II modeling.
[b] Average over entire hydrologic sequence (1921 to 2003).
TAF = thousand acre-feet

The modeling studies specify deliveries in the 82 years of historical hydrology under the Future No Project and with-project alternatives. Under the No Project scenario, no agricultural or Level 2 refuge water would be supplied. Therefore, differences from the No Project Alternative are equal to the annual volume under each alternative.

The alternatives would provide agricultural water users throughout the state with an increase in water supplies averaging an estimated 37 to 132 thousand acre-feet (TAF) annually (Table C-1). The alternatives would also provide the refuges with an alternative water supply estimated to average 3 to 6 TAF annually (Table C-2) (see Chapter 6, Alternative Development, of the Draft Feasibility Report for more information on agricultural deliveries).

These CALSIM II water deliveries were applied to the SWAP model. The model was then run with demands based on 2025 and 2060 levels of development for the Future No Project Alternative and the three action alternatives.

These tables show annual benefits for assumed levels of development/conditions and population growth in the years 2025 and 2060. As described in the section titled "Economic Assessment Methods,"above, the estimate of annualized benefits was calculated by interpolating these annual benefits between the years 2025 and 2060, and then keeping annual benefits constant from the year 2060 to the end of the planning horizon in year 2130. The calculation of annualized benefits in effect assumes that the alternatives' benefits would increase annually from their estimated 2025 level to their 2060 level at a constant rate. Then after 2060, the alternatives' annual benefit would remain unchanged for the rest of the analysis period (i.e., until 2130).

The average annual benefit value for each alternative during the 100-year analysis period is also converted into a net present value, using the current Federal discount rate. The weighted average appropriately balances the alternatives' long-term and near-term benefit streams. The resulting annualized benefit value represents the constant annual value, resulting in a discounted total benefit over the analysis period equivalent to that estimated from the variable-benefit stream associated with the alternatives' estimated 2025 and 2060 benefit values.

Table C-3 shows the water supply benefits to agricultural users as estimated by the SWAP model for each alternative.[6] The results show that the greatest benefits to agricultural users would result from Alternative D, and the least benefits would result from Alternative B. Alternatives A and C would have similar, more moderate annual benefits.

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[6] The SWAP model determined the combined total producer and consumer benefits of the increased agricultural production. Post-processing of the results was also performed to represent the modeling estimates of the total benefits into a NED perspective, in accordance with the P&Gs.

Table C-3. Average Annual Benefit of Increased Water Supply to Agricultural Users, as Estimated by the SWAP Model ($1,000s, 2015 Dollars)

Alternative	Annual Benefits [a, b,]		Annualized Benefit ($) [c]
	2025	2060	
Average Water Conditions [d]			
Alternative A	$11,249	$14,183	$13,162
Alternative B	$6,493	$7,722	$7,168
Alternative C	$10,327	$12,723	$11,872
Alternative D	$17,348	$21,711	$20,183

[a] Based on SWAP modeling results.
[b] Annual benefits reflect the difference between changes in agricultural production and/or groundwater supply costs under the alternatives for Future No Project conditions under year 2025 and year 2060 levels of development.
[c] Annualized benefits assume interpolated annual benefits between 2025 and 2060, and then constant annual benefits beyond 2060 (Figure C-2).
[d] Average over the entire hydrologic sequence (1921 to 2003).
SWAP   =   Statewide Agricultural Production

Table C-4 shows the benefits for Level 2 refuge water supplies. Alternative C would result in the largest annual benefits, while the benefits of the other alternatives would be approximately a third less (Alternative A), or nearly half in magnitude (Alternatives B and D).

Table C-4. Average Annual Benefit of Alternate Water Supply for Level 2 Refuge Water Supplies, as Estimated by the SWAP Model ($1,000s, 2015 Dollars)

Alternative	Annual Benefit [a]		Annualized Benefit ($) [b]
	2025	2060	
Average Water Conditions [c]			
Alternative A	$643	$810	$752
Alternative B	$526	$626	$589
Alternative C	$1,016	$1,251	$1,168
Alternative D	$560	$700	$651

[a] Based on SWAP modeling results.
[b] Annualized benefits assume interpolated annual benefits between 2025 and 2060 and then constant annual benefits beyond 2060.
[c] Average over the entire hydrologic sequence (1921 to 2003).
SWAP   =   Statewide Agricultural Production

The overall net effect of the alternatives' improved Level 2 refuge water supplies would be increased water availability for agricultural production because Level 2 refuge supplies are generally acquired from farmers. Therefore, for this analysis, the Level 2 refuge benefits are incorporated in the "agricultural water supply" purpose. Table C-5 shows the combined total estimated benefit to the agricultural water supply.

Table C-5. Average Annual Benefit of Total Increased Water Supply for Agricultural Users, as Estimated by the SWAP Model ($1,000s, 2015 Dollars)

Alternative	Annual Benefits [a]		Annualized Benefit ($) [b]
	2025	2060	
Average Water Conditions [c]			
Alternative A	$11,892	$14,993	$13,914
Alternative B	$7,020	$8,348	$7,758
Alternative C	$11,281	$13,975	$12,975
Alternative D	$17,907	$22,411	$20,834

[a] Based on SWAP modeling results, and includes both agricultural and Level 2 refuge water supplies.
[b] Annualized benefits assume interpolated annual benefits between 2025 and 2060, and then constant annual benefits beyond 2060.
[c] Average over the entire hydrologic sequence (1921 to 2003).
SWAP = Statewide Agricultural Production

For the average water conditions, the results show that Alternative D would provide the greatest total benefits to agricultural users, at more than $20.8 million per year. Alternative B would provide the least benefit ($7.8 million). Alternatives A and C would have similar annual benefits, approximately $13.9 million and $13.0 million, respectively.

Municipal and Industrial Water Supplies

M&I water uses include water for municipal, domestic, commercial and industrial, school, public safety, and other applications. Development of an alternative would increase M&I water supplies in the long term, with a greater change in supplies during Dry and Critical periods.

NED Benefit Valuation Methodology

M&I benefits can be estimated based on consumers' WTP, measured by estimating demand functions and using existing estimates of price elasticity. Such an approach generally would be expected to provide a higher total benefit value because it would represent the higher consumer surplus value that many consumers obtain from their M&I water use. More specifically, a Water Transfer Pricing Analysis was used as a cost-based approach to estimate the NED benefit values of the alternative's future increases in M&I water deliveries and reliability.

Water Transfer Pricing Analysis

A cost-based approach has been used to determine a conservative benefit value for the M&I water supplies based on the assumption that a cost-based approach for M&I water does not include the additional consumer surplus values that many M&I users place on marginal changes in water supply. Cost-based methods are based on actual, lower water supply costs and prices, because most utilities are regulated and use average cost pricing to set water prices. Nonetheless, the NED analysis used data on water transfer prices as the primary approach to determining the estimated benefit values for the alternatives' M&I water supply increases.

Economic evaluation analyses performed for the feasibility studies for other major California water storage projects have collected and analyzed historical data on public water sales transactions in California to develop approaches to estimating benefits and findings for NED analyses.

The SLWRI recently developed a database of California water market sales and a model for water transfer pricing (Reclamation 2015). The SLWRI collected data for sales of permanent water rights, long-term transfers, and the (short-term) spot market for both north- and south-of-Delta transactions occurring from 1990 through 2013.

The SLWRI also performed a regression analysis on the water transfers to estimate the level of water trading activity and unit prices for water trades. In its analysis, the SLWRI expanded on its previous studies by forecasting future agricultural and M&I water prices. The analysis focused on transactions involving water considered comparable to water supplied from Shasta Lake. As a result, sales from water sources with significantly different water quality and reliability were excluded.

The analysis of water transfer pricing relied in part on market prices paid to purchase water on an annual basis from willing sellers. The market prices were reported according to the payments made directly to the sellers. The buyers incurred additional costs to convey the water to their M&I service areas. These costs included both conveyance losses (which diminish the volume of water delivered to end users) and wheeling and power charges. Conveyance costs were estimated for M&I water users expected to receive future supplied water from the reservoir, and were added to the estimated market prices of acquiring the water to develop an estimate of the full cost of the additional water supply obtained in the transfer market.

These analyses of water transfer markets provide a partial but limited representation of the benefits of water supply reliability. Because they are transaction based, the analyses do not estimate the full consumer and producer surplus associated with buyers who would have willingly paid a higher price than their seller needed to complete the deal. In addition, the great majority of the transactions are for short-term or "spot" market sales of existing water supplies. In contrast, the alternatives represent a long-term water source that would add substantial quantities of "new" water. The alternatives' water supply may offer a far more dependable source of water with future long-term costs that are more predictable and less susceptible to future market fluctuations. If this increase in supply is able to address local demand shortages, lower prices could occur.

In addition, the scale and long-term nature of the alternatives' water supply are substantially greater than most successful water sale agreements. Between 1990 and 2007, the total estimated volume of annual market transactions for the State of California varied from 56,775 acre-feet (AF) to a high of 883,989 AF (Reclamation 2008). During the same period, the number of market transactions varied from a low of 4 to a high of 46, with an average size of 18,410 AF per year. The alternatives would provide an average annual volume of between 212 and 236 TAF of water for agriculture, M&I, and water quality purposes.[7] Therefore, on their own, these alternatives would represent a major proportion of statewide total water sales transactions.

Water sales between farmers and water districts may also be affected by the specifics of local land conditions, locations, and/or deal participants. It is unclear that there would be sufficient viable, permanent water sellers; particularly because the transaction costs (legal, administrative,

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[7] The project would also result in up to 242 TAF of increased water outflows to the Delta (especially between June and September), which would greatly improve the Delta and upstream fish habitat conditions. These benefits are analyzed in Sections C.5 and C.6.

and wheeling)—and if necessary—costs of developing new infrastructure for implementation could be substantial and possibly prohibitive.

Modeled Results

CALSIM II operational studies were used to estimate the additional water provided by the alternatives for M&I use. Other water demands and supplies were estimated using data from DWR, as well as local agencies' planning studies and urban water management plans.

The alternatives would increase water supplies to M&I water users across the state, especially during Dry and Critical water years (see Chapter 6, Alternative Development, in the main text). The M&I water supply benefits would accrue largely to SWP contract holders south of the Delta. Table C-6 shows estimates for the average water conditions year of deliveries to M&I water users under the alternatives. On average, the alternatives would provide an estimated 89 to 103 TAF of additional water supplies to urban users annually. Increases in M&I water delivery generate economic benefits in the form of avoided water supply costs.

Table C-6. Average Annual Volume of Increased Water Supply to Municipal and Industrial Water Users under the Alternatives

Alternative	Average Annual Volume (TAF)[a]	Difference from No Project	Difference from No Project (%)
Average Water Conditions[b]			
No Project	2,487	—	—
Alternative A	2,580	93	3.7%
Alternative B	2,584	97	3.9%
Alternative C	2,590	103	4.1%
Alternative D	2,576	89	3.6%

[a] Based on CALSIM II modeling.
[b] Average over the entire hydrologic sequence (1921 to 2003).
TAF = thousand acre-feet
— = not applicable

Table C-7 presents the M&I water supply benefits for the alternatives, as estimated based on the SLWRI's methodology for modeling water transfer pricing and projected 2030 transfer water values. The transfer model only provides projected water values for 2030. Therefore, it was conservatively assumed that future M&I water values would remain constant in the subsequent years. Consequently, the annualized benefit value over the future 100-year study period would be the same as the 2030 estimated values.

Table C-7. Municipal and Industrial Water Supply Benefits—Transfer Model Values ($1,000s, 2015 Dollars)

	Annual Benefit [a]	
Alternative	**2030**	**Annualized ($)** [b]
Average Water Conditions [c]		
Alternative A	$121,581	$121,581
Alternative B	$128,822	$128,822
Alternative C	$136,234	$136,234
Alternative D	$117,096	$117,096

[a] Based on SLWRI water transfer modeling results.
[b] Annualized benefits assume constant annual benefits beyond 2030.
[c] Average over entire hydrologic sequence (1921 to 2003).
SLWRI = Shasta Lake Water Resources Investigation

The results show that Alternative C would provide the greatest projected total benefits to M&I users, at more than $136 million per year. Alternative D would provide the least M&I benefits, at $117 million. Alternatives A and B are expected to result in annual benefits of approximately $121.6 million and $128.8 million, respectively.

Sensitivity

Sensitivity analyses were conducted to evaluate the risk and uncertainty associated with the water supply benefit estimates, as discussed briefly below. These sensitivity analyses are provided solely for informational purposes, and are not included in the calculation of total benefits, NED benefits, or BCRs.

Agricultural Water Supplies

The *Draft Technical Reference*, published by the WSIP of the California Water Commission (CWC) (CWC 2016), compared the results of SWAP modeling to transfer analysis. The CWC concluded that combining the two approaches would improve a project's values for future conditions and the safe-yield limits imposed by the Sustainable Groundwater Management Act. This suggests that the NED benefits estimates using the SWAP model are likely conservative. WSIP recommends instead using a methodology that combines the results of SWAP modeling with transfer price data to develop unit values for estimating agricultural supply benefits.

- The sensitivity analysis for agricultural water supply was based on the CWC WSIP's valuation approach and unit values (CWC 2016). The WSIP unit values were developed by combining a statistical analysis of water transfer prices from 1992 through 2015 with SWAP analysis results. CWC's valuation analysis includes assumptions related to future Sustainable Groundwater Management Act (SGMA) mandates that require management for a sustainable yield from groundwater pumping in affected groundwater basins by either 2040 or 2042.

- Table C-8 shows the averaged CWC unit values used to estimate the alternatives' future agricultural benefits. The unit values vary between alternatives due to differences in the location and quantities of their agricultural water deliveries.

Table C-8. Average Unit Agricultural Benefit Values by Alternative—WSIP Estimated Values ($1,000s, 2015 Dollars)

Alternative	WSIP Unit Benefits Value		Annualized Benefit
	2030	2045	
Alt A	$241	$429	$390
Alt B	$251	$452	$411
Alt C	$246	$441	$401
Alt D	$236	$319	$300

WSIP = Water Storage Investment Program

Table C-9 shows the total estimated benefit to the agricultural water supply (adjusted to account for Level 2 refuge water supplies) using the WSIP's benefit valuation approach unit values and the CALSIM II agricultural water supply quantities (Table C-1 and Table C-2).

Table C-9. Average Annual Benefit of Total Increased Water Supply to Agricultural Users—WSIP Estimated Values ($1,000s, 2015 Dollars)

Alternative	Annual Benefits [a]		Annualized Benefit ($) [b]
	2030	2045	
Average Water Conditions [c]			
Alternative A	$17,863	$31,725	$28,886
Alternative B	$10,801	$19,427	$17,665
Alternative C	$16,460	$29,531	$26,860
Alternative D	$31,901	$43,105	$40,552

[a] Based on WSIP modeling results.
[b] Annualized benefits assume interpolated annual benefits between 2030 and 2045 and then constant annual benefits beyond 2045.
[c] Average over the entire hydrologic sequence (1921 to 2003).
WSIP = Water Storage Investment Program

The results show that Alternative D would provide the greatest total benefits to agricultural users, at more than $40.6 million per year, and Alternative B would provide the least ($17.7 million). Alternatives A and C would have similar, more limited annual benefits of approximately $28.9 million and $26.9 million, respectively. These results are approximately twice the magnitude of the benefits estimates obtained using the SWAP values (Table C-5). The two benefit valuation approaches result in very similar rankings and comparative values for the alternatives.

The results from the agricultural water supply sensitivity analysis suggest that the NED benefit estimates are conservative and could underestimate the alternatives' benefits to agricultural uses.

Municipal and Industrial Water Supplies
The sensitivity analysis for M&I water supply used Least-Cost Planning Simulation Model (LCPSIM) and Other Municipal Water Economics Model (OMWEM) modeling analyses. The results of LCPSIM and OMWEM modeling differ from the water transfer pricing approach applied to estimate NED benefits in that they incorporate conservation, groundwater banking, and other water management actions to address urban water shortages. A comparison of the

results from the two models more completely shows the degree to which the benefits estimates are sensitive to the inclusion of these different water management actions.

Least-Cost Planning Simulation Model: The LCPSIM is a simulation/optimization model for urban water service systems that operates on an annual time step. As shown on Figure C-3, the objective of the LCPSIM is to find the least-cost water management strategy for a region, given the mix of demands and available supplies. The model uses shortage management measures, including regional carryover storage, water market transfers, contingency conservation, shortage allocation, and operating requirements to reduce regional costs and losses associated with water shortages. It also considers the adoption of long-term measures for regional demand reduction and supply augmentation to reduce the frequency, magnitude, and duration of shortage events. For more information on LCPSIM assumptions, refer to DWR (2010) and Appendix 22D in the EIR/EIS.
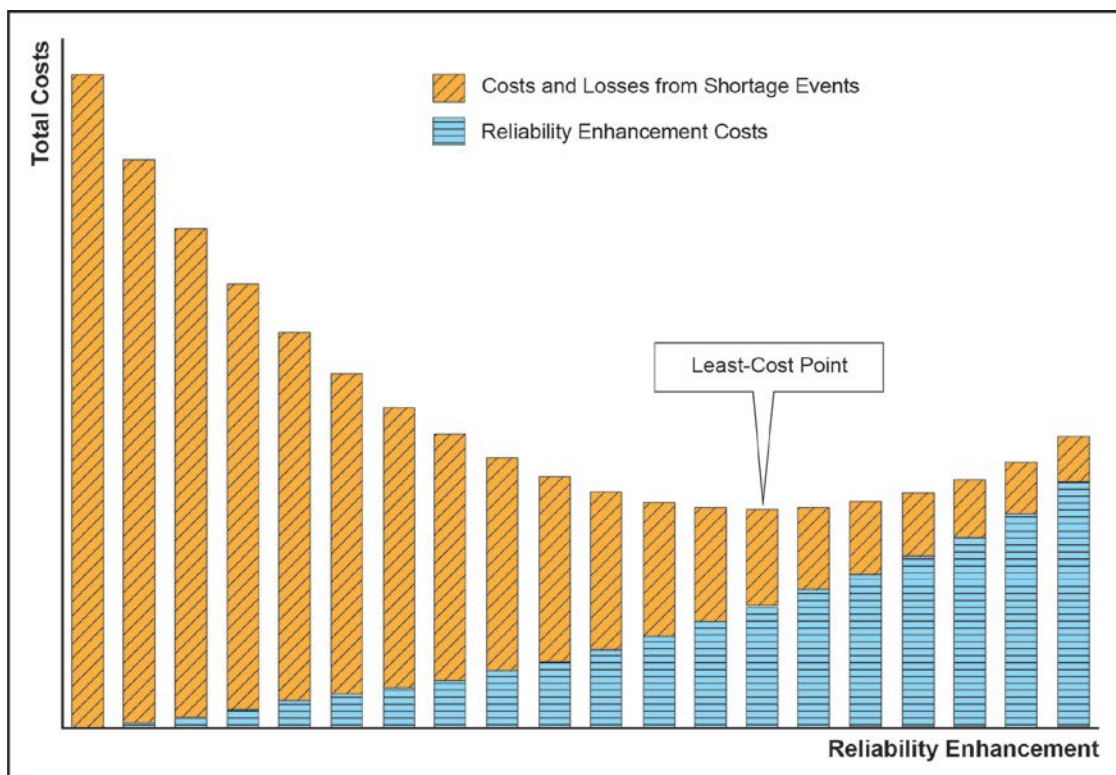
Figure C-3. The Effect of Increasing Reliability on Total Costs

Other Municipal Water Economics Model: A number of relatively small M&I water providers receive CVP or SWP water, but are not covered by the LCPSIM. A set of individual spreadsheet calculations, collectively called OMWEM, can be used to estimate the economic benefits of changes in CVP or SWP supplies for these potentially affected M&I water providers. The OMWEM model includes CVP M&I supplies north of the Delta, and CVP and SWP supplies to the Central Valley and the Central Coast. In addition, the model includes SWP supplies or supply exchanges to the desert regions east of the LCPSIM's South Coast region. The model estimates the economic value of M&I supply changes in these areas as the change in the cost of shortages

and alternative supplies (such as groundwater pumping or transfers). For more information on OMWEM assumptions, refer to Appendix 22D in the EIR/EIS.

LCPSIM and OMWEM Limitations: Both the LCPSIM and the OMWEM assume that regions being evaluated have the facilities and institutional agreements in place to move water in the region as needed to minimize the economic effect of shortage events.

The models do not include the full level of detail that may exist in local water providers' plans. The results produced by the models are useful for comparing alternatives, and they provide an approximate estimate of avoided costs. However, the results should not be viewed as precise representations of individual water providers' costs or options.

The following potential limitations to the LCPSIM have been identified:

- The LCPSIM is not appropriate for management decisions by individual water agencies and its results may not reflect agency decisions that are based on their cost perspective.

- The model determines its estimates of reliability benefits based on a risk-neutral view, not from risk minimization. Risk minimization would likely result in considerations outside of cost effectiveness and result in more conservative water management practices.

- The LCPSIM relies on base estimates of urban quantity demand/use and functions that are not responsive to the higher water prices for urban users.

- The LCPSIM uses studies of regional operations to obtain annual delivery information for local supplies. Other water supply sources are assumed to be available at their average-year values.

- The model does not simulate seasonal water decisions.

Generally, the OMWEM has the same limitations as the LCPSIM. In addition, decision rules about water supply costs and shortages are relatively simplistic.

Other urban areas across the state are not covered by either model; however, M&I water supplies delivered to these areas are negligible individually, and collectively they account for less than 5 percent of the average total urban supplies. These benefits have not been quantified.

Table C-10 presents the benefits of the alternatives to the urban M&I water supply as estimated by the LCPSIM and OMWEM.

Table C-10. M&I Water Supply Benefits—LCPSIM/OMWEM Modeled Values ($1,000s, 2015 Dollars)

Alternative	Annual Benefits [a, b, c]		Annualized Benefit [d]
	2025	2060	
Average Water Conditions [e]			
Alternative A	$87,169	$231,416	$188,130
Alternative B	$89,425	$236,172	$192,125
Alternative C	$95,784	$242,532	$198,391
Alternative D	$53,670	$165,947	$132,465

[a] Based on LCPSIM modeling results (South Coast and San Francisco Bay–South regions) and OMWEM modeling results (Sacramento River, San Francisco Bay–North, Central Coast, Tulare Lake, and South Lahontan regions).
[b] These figures do not account for the increased power costs attributable to additional conveyance of SWP deliveries.
[c] Annual benefits reflect the difference between shortage, conservation, and other supply costs under the alternatives for Future No Project conditions, based under year 2025 and 2060 levels of development.
[d] Annualized benefits represent the average benefit values for the planning horizon (2031 to 2130).
[e] Average over the entire hydrologic sequence (1921 to 2003).

LCPSIM	=	Least Cost Planning Simulation Model
M&I	=	municipal and industrial
OMWEM	=	Other Municipal Water Economics Model
SWP	=	State Water Project
TAF	=	thousand acre-feet

Annualized M&I benefits are estimated to range between approximately $132.5 million and $198.4 million.[8] Alternative C would generate the greatest benefits. Alternatives A and B would result in slightly less annual benefits, and Alternative D would result in substantially less annual benefits than the other alternatives. As estimated by the LCPSIM, most of the urban water supply benefits are concentrated in the South Coast region, and to a lesser extent, the San Francisco Bay–South region.

The LCPSIM-estimated benefits represent the upper estimates of the alternatives' potential M&I benefits. Future conveyance costs for water supply deliveries for the alternatives were estimated to range from $28.2 million (Alternative D) to $34.8 million (Alternative C). Under most alternatives, M&I supplies can be expected to incur a majority of these costs due to the supply quantities and delivery locations. Consequently, the net benefits estimated by the LCPSIM would be more comparable to Water Transfer Pricing Model results (Table C-7). Nonetheless, even if all conveyance costs were attributed to M&I, the LCPSIM benefit estimate would generally remain $36 million to $40 million higher than the benefit estimated by the water transfer pricing analysis. Only Alternative D's water transfer pricing estimate would be expected to be greater than the corresponding adjusted LCPSIM estimated benefit value. These results generally support the view that the Water Transfer Pricing Model likely provides conservative benefit valuations, especially when representing urban water use south of the Delta.

C.4 Incremental Level 4 Refuge Supply Benefits

The alternatives would provide an alternate source of water for incremental Level 4 refuge supplies (see Chapter 6, Alternative Development, for more background information). incremental Level 4 refuge supplies would otherwise most likely be acquired from existing

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[8] The annual benefit calculation method is the same as that used for the refuge supply's annual benefit calculation.

agricultural users. Therefore, obtaining incremental water from an alternative would reduce some of the cost of water acquisition and associated costs.

NED Benefit Valuation Methodology

The economic value of incremental Level 4 refuge water supply benefits were estimated using a "least-cost alternative" approach. This approach involves identifying the next best alternative project to achieve the same outcomes (i.e., delivering incremental Level 4 refuge water supplies to refuges) and using that project's development cost to represent the alternatives' benefits. The alternatives would substantially increase the reliability of incremental Level 4 refuge water supplies. Securing an increase of this magnitude without a dedicated, long-term water supply would be difficult. This makes the least-cost alternative approach especially relevant to securing the long-term benefit.

Under the P&Gs, a least-cost alternative valuation approach can be used when the outputs of two projects are similar; the NED benefits cannot be estimated from market prices or net income changes; and the alternative project would be implemented. For the alternatives' incremental Level 4 refuge water supply benefits, the most comparable approach to obtaining the necessary quantity of reliable water supplies is a single-purpose raise of Shasta Dam. As an alternative to constructing Sites Reservoir, additional surface storage could be developed at Shasta Lake to provide an increased water supply to meet the refuges' incremental Level 4 refuge water supply needs.

Modeled Results

CALSIM II operational studies were used to estimate the additional water provided by the alternatives for incremental Level 4 refuge supplies (Table C-11).

Table C-11. Average Annual Volume of Incremental Level 4 Refuge Water Supplies for Average Water Conditions

Alternative	Annual Volume (TAF) [a]
Average Water Conditions [b]	
No Project	0
Alternative A	44
Alternative B	71
Alternative C	74
Alternative D	48

[a] Based on CALSIM II modeling.
[b] Average over the entire hydrologic sequence (1921 to 2003).
TAF = thousand acre-feet

Table C-12 shows the alternatives' incremental Level 4 refuge water supply benefits, as estimated based on the least-cost alternative of expanding Shasta Lake's storage with a 6.5-foot raise of Shasta Dam as a single-purpose water storage project that would provide 72 TAF. The base construction cost for the Shasta raise was obtained from the 2015 Shasta Lake Water Resource Investigation Feasibility Study. The costs were adjusted into current dollar terms and annualized using the current Federal discount rate of 2.875 percent. The benefits for each alternative were then determined on a pro-rata basis.

Table C-12. Estimated Annual Benefits of Alternative Water Supply to Incremental Level 4 Refuges—Least-Cost Alternative ($1,000s, 2015 Dollars)

Alternative	Supply Quantity (TAF)	Annual Cost (Est.) ($)	Annualized Benefit ($) [a]
Average Water Conditions [b]			
Alternative A	44	$22,205	$22,205
Alternative B	71	$35,831	$35,831
Alternative C	74	$37,345	$37,345
Alternative D	48	$24,223	$24,223

[a] Based on CALSIM II modeling.
[b] Average over the entire hydrologic sequence (1921 to 2003).
TAF   =   thousand acre-feet

The results project that the future incremental Level 4 refuge benefits would range between $22.2 million and $37.3 million annually. Alternative C would have the greatest benefits, followed closely by Alternative B ($35.8 million). Alternatives D and A would result in much lower incremental Level 4 refuge water supply benefits of $22.2 million and $24.2 million per year, respectively.

Sensitivity

A sensitivity analysis was conducted to evaluate the risk and uncertainty associated with the estimates of incremental Level 4 refuge water supply benefits. The sensitivity analysis for incremental Level 4 refuge water supplies was based on the CWC WSIP's valuation approach and unit values. As discussed in the section titled "Water Supply Reliability Benefits," above, the WSIP unit values were developed by combining a statistical analysis of past water transfer prices with the results from the SWAP model. CWC's valuation analysis includes assumptions related to future SGMA mandates that require management for a sustainable yield from groundwater pumping.

Table C-13 shows the total estimated benefit to incremental Level 4 refuge water supplies based on CALSIM II water supply quantities (Table C-11), and using the WSIP's benefit valuation approach and unit values.

Table C-13. Estimated Annual Benefit of Increased Water Supply to Incremental Level 4 Refuges for Average Water Conditions—WSIP Values ($1,000s, 2015 Dollars)

Alternative	Annual Benefits [a]		Annualized Benefit ($) [b]
	2030	2045	
Average Water Conditions [c]			
Alternative A	$11,577	$27,197	$24,141
Alternative B	$18,681	$43,886	$38,954
Alternative C	$19,470	$45,740	$40,600
Alternative D	$12,630	$29,669	$26,335

[a] Based on WSIP modeling results.
[b] Annualized benefits assume interpolated annual benefits between 2030 and 2045, and then constant annual benefits beyond 2045.
[c] Average over the entire hydrologic sequence (1921 to 2003).
WSIP   =   Water Storage Investment Program

The results show that Alternative C would provide the greatest future benefits of increased incremental Level 4 refuge water supplies, more than $40.6 million per year; and Alternative A would provide the least, $24.1 million. Alternatives B and C would have similar, more limited annual benefits of approximately $38.9 million and $26.3 million, respectively. These results are approximately twice the magnitude of the NED benefit estimates obtained using the SWAP values (Table C-5). The two benefit valuation approaches result in very similar ranking and comparative values for the alternatives.

These results suggest that the NED benefit values are conservative and could underestimate the alternatives' benefits to incremental Level 4 refuge water supplies.

C.5 Water Quality Benefits

M&I Water Quality

The alternatives would affect the quality of urban water supplies for many users who divert water from the Delta. The major diversion points for urban use that would be affected are the CVP Tracy Pumping Plant, SWP Banks Pumping Plant, Contra Costa Water District intakes, North Bay Aqueduct, and urban and industrial diversions in Contra Costa County.

Water quality in urban service areas would be affected by changes in both the amount and quality of Delta-supplied water. Many water quality constituents would be affected. Salinity and disinfection byproduct precursors are among the most economically important constituents, but nutrients, pathogens, and a range of other pollutants are also important. Only changes in salinity are evaluated in this analysis. Consequently, the estimates of water quality benefits presented should be considered conservative.

NED Benefit Valuation Methodology

Two models were used to assess the economic benefits of M&I water supplies. Each model represents a different geographic region. The LCRBWQM covers water users in the MWD service area, while the BAWQM covers South Bay Area water users. Both models estimate the benefits of salinity reduction in terms of avoided costs and damages from water quality improvements.

Lower Colorado River Basin Water Quality Model: The LCRBWQM, developed by Reclamation and MWD, covers nearly the entire urban coastal region of Southern California. This model divides MWD's service area into 15 subareas to reflect each subregion's unique water supply conditions and benefit factors. These regions include the Northwest, San Fernando Valley–West, San Fernando Valley–East, San Gabriel, Central Los Angeles, Central and West Basins, Coastal Plain, North West Orange County, South East Orange County, Western MWD, Eastern MWD, Upper Chino, Lower Chino, North San Diego, and South San Diego. The salinity model is designed to assess average annual salinity benefits or costs based on demographic data, water deliveries, total dissolved solids (TDS) concentrations, and cost relationships for typical household, agricultural,[9] industrial, and commercial water uses. It uses mathematical functions

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[9] As described below, for reporting purposes, LCRBWQM-estimated agricultural water quality benefits are presented with the other south-of-the-Delta agricultural water quality benefits.

that define the relationship between TDS and key items in each affected category, such as the useful life of appliances, specific crop yields, and costs to industrial and commercial customers.

The LCRBWQM calculates the economic benefits or costs of SWP and Colorado River Aqueduct salinity changes compared to a selected baseline condition. The modeling inputs from the CALSIM II model and the DWR Simulation Model (DSM2) are SWP East and West Branch deliveries and TDS of these deliveries, respectively, in milligrams per liter (mg/L). A separate modeling routine is available to estimate the salinity of urban water supplies delivered to the South Coast, based on the timing of urban deliveries, mixing in San Luis Reservoir, and salinity estimates at Edmonston Pumping Plant. LCRBWQM outputs are used to compare changes in average salinity and annual salinity costs.

Bay Area Water Quality Economics Model: The BAWQM includes the portion of the Bay Area from Contra Costa County south to Santa Clara County. The model was developed and used for the economic evaluation of a proposed expansion of Los Vaqueros Reservoir (Reclamation 2006a). The BAWQM uses relationships between salinity and damage to residential appliances and fixtures to estimate the benefits of salinity reductions. Specific modeling outputs compare changes in average salinity and changes in annual salinity costs.

Updates to the LCRBWQM and BAWQM: To properly reflect the changes between without-project and with-project conditions under the alternatives, several updates were made to the water quality economics models after preparation of the *North-of-the-Delta Offstream Storage Investigation Plan Formulation Report* (Reclamation 2008). The updates included indexing all prices to 2015 dollars; developing the LCRBWQM to include 2009, 2025, and 2060 levels of development; and updating the BAWQM to include 2009, 2025, and 2060 levels of development.

LCRBWQM and BAWQM Model Limitations: Although the LCRBWQM and BAWQM are the best available models for determining the alternatives' future water quality benefits, a key limitation is that they consider economic benefits only for salinity improvements, not other water quality constituents. Research has shown that consumers are willing to pay to avoid many other water quality constituents, so valuing only salinity will underestimate the water quality benefit. These "other" constituents include many human-made chemicals, pathogens, and byproducts that may have health implications.

The models use somewhat dated information about current ownership patterns and the costs of modern water-using appliances. The BAWQM does not include commercial, industrial, or public users, or costs to utility infrastructure.

An input to the models is the average expected water quality of water supplies over the full hydrologic period. This simplification could result in errors in estimates of economic benefits. Providing more detail regarding the quality of supplies used over the hydrologic period might result in a different expected value, and could improve insights about water management during Dry and Critical periods.

Lastly, the models do not cover all regions south of the Delta where water quality benefits would be realized as a result of the alternatives. Therefore, the modeling results from the LCRBWQM and BAWQM were extrapolated to represent benefits for these "other" regions.[10]

Modeled Results

Table C-14 presents benefits to urban M&I water quality, as estimated based on the LCRBWQM and BAWQM modeling analysis.

Table C-14. Estimated Annual M&I Water Quality Benefits Based on Estimated Salinity ($1,000s, 2015 Dollars)

Alternative	Annual Benefits [a, b]		Annualized Benefit [d]
	2025	2060 [c]	
Average Water Conditions [e]			
Alternative A	$16,233	$20,366	$18,922
Alternative B	$17,549	$22,485	$20,788
Alternative C	$21,063	$27,405	$25,246
Alternative D	$10,932	$15,556	$14,048

a   Based on LCRBWQM modeling results (South Coast region, excluding agricultural benefits), BAWQM modeling results (San Francisco Bay region), and extrapolated results for areas south of the Delta (San Joaquin River, Central Coast, Tulare Lake, and South Lahontan regions). Excludes the Sacramento River region.
b   Annual benefits reflect the difference in water quality damages expected under the project alternatives and No Project conditions based on year 2025 and year 2060 levels of development.
c   Excludes benefits to south-of-the-Delta water users.
d   Annualized benefits represent avoided costs for Future No Project conditions over the planning horizon (2031 to 2130).
e   Average over the entire hydrologic sequence (1921 to 2003).
BAWQM   =   Bay Area Water Quality Economics Model
Delta   =   Sacramento–San Joaquin River Delta
LCRBWQM =   Lower Colorado River Basin Water Quality Model
M&I   =   municipal and industrial

Annualized benefits range between $14.0 million and $25.2 million for average years.[11] Alternative C would offer the greatest water quality benefits. Alternative D would result in the least M&I water quality benefits, largely because of the smaller quantity of water it would supply for M&I use.

Irrigation Water Quality

Changes to irrigation water quality as a result of the alternatives could affect crop production in both the short- and long-term. These effects are based largely on the overall salinity of the irrigation water and the resulting salinity in the crop's root zone. Salinity is measured as TDS (parts per million, mg/L) or electrical conductivity (EC) (decisiemens per meter). Specific constituents, such as boron, can also limit crop yields and are particularly costly if they are present above tolerance threshold concentrations.

Potential benefits of improved irrigation water quality for agriculture can be categorized according to specific crop and/or irrigation management effects, such as:

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10   Water quality benefits for other south-of-the-Delta users are available for the 2025 level of development only. Accordingly, estimated benefits in 2060 and annualized benefits over the planning horizon (2031 to 2130) are understated.
11   The annual benefit calculation method is the same approach as that used to calculate the water supply's annual benefit.

- Increased yield of existing crops

- Ability to grow more salt-sensitive crops

- Reduced leaching requirements and other irrigation management costs

- Reduced drainage and disposal costs

- Avoided losses in crop acreage

The first three benefits on this list are near-term effects of reducing TDS in irrigation water. Near-term effects include lower TDS in root-zone moisture, lower required leaching fractions, higher crop yield, and the ability to grow a wider range of crops. Growers can take advantage of some or all of these benefits, depending on their irrigation and cropping decisions. For example, if the salinity of irrigation water were to improve, a grower could maintain the current cropping and reduce leaching. Alternatively, a grower could continue to leach at the same rate and potentially get a better crop yield from the resulting lower soil salinity (assuming that the initial water quality exceeds the crop salinity thresholds).

Near-term water quality effects can be estimated using standard relationships between crop yield and salinity. For example, the well-known Maas-Hoffman relationship can be used to evaluate the effects of changes in Delta water salinity on crop yield.[12] This relationship shows little or no effect on crop yield if a sufficient leaching fraction is provided during irrigation to prevent salts from accumulating in the root zone. Therefore, as the EC or TDS increases in irrigation water, the leaching fraction required also increases.

Rhoades (1974) developed an empirical relationship between the EC of irrigation water (EC_w) and the EC of a saturation-soil extract (EC_e) that a grower needs to maintain to avoid or minimize salt damage to crop yields. These relationships form the standard approach for evaluating the near-term effect of changes in irrigation water salinity (Ayers and Westcot 1985, 1989, 1994; Hoffman 2009).

NED Benefit Valuation Methodology
The economic benefit assessment of reduced irrigation water salinity depends on the range of water quality changes under evaluation. If salinity in the soil and/or irrigation water is currently high and yield limiting, the benefits of reducing salinity in the irrigation water can include improved crop yields, wider crop selection, and reduced irrigation management. On the other hand, if salinity levels are below crop thresholds, irrigation management focuses on preventing salt accumulation in the crop's root zone, and the reduced salinity may allow growers to reduce the leaching fractions that are currently applied.

Estimates of the current salinity of delivered CVP and SWP water are below the tolerance threshold for even the most salt-sensitive crops, and the changes in salinity from implementing the alternatives would be relatively small. Therefore, this analysis is based on the latter scenario, in which benefits are attributed to reduced leaching fractions.

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[12]   An example of the application of crop yield/salinity relationships can be found in the *Delta Risk Management Strategy, Phase 1 Report and Technical Memoranda* (DWR 2009).

Ayers and Westcot (1985, 1989, 1994) cite Rhoades' work to calculate the leaching fraction required for applied water salinity and target root-zone salinity, based on crop tolerance. The reduction in the rate of applied water, times the area receiving the water, results in a volume of water that is available for use elsewhere in the region. The value of this water can be estimated using the same approach used to value any direct changes in CVP or SWP deliveries of irrigation water.

The SWAP model was used to estimate the unit value (or marginal value) of an additional unit of water available for irrigation (Table C-15). Because the saved water would have been delivered to farms anyway, neither the Project (CVP or SWP) nor the local district would incur any additional water delivery costs.

Table C-15. Estimated Value of Irrigation Water Savings—SWAP Model Values ($/AF, 2015 Dollars)

Alternative	Annual Values [a, b]		Annualized Value (2031 to 2130) [c]
	2025	2060	
Average Water Conditions [d]			
Alternative A	$158	$200	$185
Alternative B	$158	$188	$177
Alternative C	$159	$196	$183
Alternative D	$131	$164	$153

[a] Annual values are based on SWAP modeling results.
[b] Annual values represent the marginal value of water used in agriculture. Not including any transaction costs, the values represent the value at which water would trade to other uses (e.g., M&I use).
[c] Annualized values assume interpolated annual benefits between 2025 and 2060, and then constant annual benefits beyond 2060 (Figure C-2).
[d] Average over the entire hydrologic sequence (1921 to 2003).
AF = acre-foot
SWAP = Statewide Agricultural Production

Model Limitations

A more comprehensive analysis of water quality benefits would consider the complex relationships among irrigation, crop use, soil salinity, and groundwater conditions. The following major qualifications apply to this analysis:

- Assumes that growers are actively managing their leaching requirement to avoid salt accumulation in the soil and its effects on crops, and that growers have enough control over irrigation application rates to make small adjustments in leaching.

- Assumes that growers are currently applying water using an optimum leaching fraction for each type of crop grown.

- Assumes that CVP and SWP water salinity reductions would not directly affect lands that are irrigated by other sources (e.g., groundwater).

- Uses a steady-state calculation based on irrigation water as the only important source of salts introduced into the root zone.

- In certain situations where soils have high proportions of sodium relative to other base conditions, irrigation with extremely low TDS water can lead to soil dispersion, loss of

structure, and impaired drainage. The approach used here assumes that reducing TDS in irrigation water would not have a detrimental effect on soil structure.

These qualifications suggest that the analysis may overestimate, or at least provide an upper bound for, the near-term benefit of small reductions in irrigation water salinity. The assumptions may not be valid in all locations in the study area; however, they are expected to provide a reasonable basis for the analysis described below.

This approach does not capture the long-term benefit of reducing the salt load added to the soil and groundwater. Estimating long-term benefits requires a more complex evaluation of groundwater conditions and trends. The magnitude of the benefits of water quality improvements to irrigation water deliveries will depend on the supply, cost, and quality of alternative groundwater supplies. If future groundwater availability and/or quality decrease, then the value of higher-quality surface deliveries would potentially increase in value.

Therefore, although the approach likely overstates the near-term benefits, it excludes any estimate of the long-term benefit. The net effect is unclear, but is more likely to provide a conservatively low estimate of the total benefits. Furthermore, as discussed above under "Planning Horizon," the NED benefit analysis conservatively assumes that benefits after 2060 would remain constant.

Modeled Results

The CALSIM II model and DSM2 were used to estimate the TDS in and EC of water pumped by the CVP and SWP facilities under the 2025 level of development.[13] The Jones Pumping Plant supplies water to the Delta-Mendota Canal, the primary source of CVP water delivered into the Grasslands salinity analysis area (Table C-16). The Banks Pumping Plant supplies water to the California Aqueduct, which either delivers it directly to contractors or conveys it to San Luis Reservoir, from which the water is delivered to contractors (Table C-17). The results shown are pumping-weighted averages simulated monthly over the hydrologic period October 1921 to September 2003. The DSM2 values should not be considered absolute, but the model does indicate a trend toward slight decreases in salinity for all of the alternatives. This decrease can then be used to determine the water quality benefit.

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[13] No separate water quality modeling for the NODOS project was conducted at the 2060 level of development.

Table C-16. Salinity at Jones Pumping Plant, by Alternative

Alternative	Average TDS (mg/L) [a]	Difference from No Project (mg/L)	Difference from No Project (%)
Average Water Conditions [b]			
No Project	268.0	—	—
Alternative A	261.4	-6.6	-2%
Alternative B	261.7	-6.3	-2%
Alternative C	258.8	-9.2	-3%
Alternative D	264.2	-3.8	-1%

[a] Based on DSM2 modeling.
[b] Average over the entire hydrologic sequence (1921 to 2003).
mg/L = milligrams per liter
TDS = total dissolved solids

Table C-17. Salinity at Banks Pumping Plant, by Alternative

Alternative	Average TDS (mg/L) [a]	Difference from No Project (mg/L)	Difference from No Project (%)
Average Water Conditions [b]			
No Project	239.8	—	—
Alternative A	234.3	-5.6	-2%
Alternative B	233.9	-5.9	-2%
Alternative C	232.0	-7.8	-3%
Alternative D	237.1	-2.7	-1%

[a] Based on DSM2 modeling.
[b] Average over the entire hydrologic sequence (1921 to 2003).
mg/L = milligrams per liter
TDS = total dissolved solids

Table C-18 shows the estimated irrigation water "saved" by reduced leaching requirements resulting from lower salinity in irrigation water. These physical benefits are translated into economic benefits by applying irrigation water values to the quantity of saved water.[14]

Table C-19 shows the estimated benefit value for the irrigation water quantities saved under each alternative.

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[14] The benefits described for agricultural water users are in addition to the agricultural water quality benefits in the South Coast region, estimated using the LCRBWQM as described above.

Table C-18. Estimated Savings in Irrigation Water for Leaching, by Salinity Analysis Area

Alternative/Benefit [a]	Grasslands	Westlands	Tulare	Kern	San Felipe	Total
Average Water Conditions						
Alternative A						
Percent Savings [b]	0.13%	0.10%	0.10%	0.12%	0.23%	0.12%
Volume Saved (AF/year)	1,328	548	128	654	83	2,741
Alternative B						
Percent Savings [b]	0.13%	0.10%	0.11%	0.13%	0.24%	0.13%
Volume Saved (AF/year)	1,276	569	136	700	86	2,768
Alternative C						
Percent Savings [b]	0.19%	0.14%	0.14%	0.17%	0.32%	0.17%
Volume Saved (AF/year)	1,849	769	181	934	117	3,850
Alternative D						
Percent Savings [b]	0.08%	0.05%	0.05%	0.06%	0.11%	0.07%
Volume Saved (AF/year)	775	261	62	317	40	1,455

[a] Irrigation water savings do not vary under the 2025 and 2060 levels of development.
[b] Estimated reduction in existing irrigation water use based on deliveries of improved water quality supplies and reducing leaching needs.
AF = acre-feet

Table C-19. Benefits from Water Use Savings from Irrigation Water Quality Improvements—SWAP Model Values ($1,000s, 2015 Dollars)

Alternative	Annual Benefits [a, b]		Annualized Benefit [c]
	2025	**2060**	
Average Water Conditions [d]			
Alternative A	$469	$590	$548
Alternative B	$476	$565	$532
Alternative C	$664	$787	$741
Alternative D	$251	$303	$284

[a] Based on results of the agricultural salinity model (for irrigation water export areas served by CVP/SWP facilities) and LCRBWQM (for the South Coast region).
[b] Benefits attributed to salinity reductions only under 2025 and 2060 level of development using SWAP values.
[c] Annualized benefits represent avoided costs relative to the Future No Project conditions over the planning horizon (2032 to 2131).
[d] Average over the entire hydrologic sequence (1921 to 2003).
CVP = Central Valley Project
LCRBWQM = Lower Colorado River Basin Water Quality Model
SWAP = Statewide Agricultural Production
SWP = State Water Project

The alternatives would also improve water quality for agricultural users in the South Coast region. The LCRBWQM analysis estimated the annual value of the agricultural water quality benefits, and Table C-20 shows its findings by alternative. The analysis conservatively assumes that the future quantity of irrigation water savings would remain unchanged over the entire 100-year study period. However, based on past trends and increased water demand, the water quality of other supplies might reasonably be expected to decline further, which would correspondingly increase the alternatives' water quality benefits.

Table C-20. Irrigation Water Quality Benefits—South Coast Region ($1,000s, 2015 Dollars)

Alternative	Annual Benefits [a, b]		Annualized Benefit [c]
	2025	2060	
Average Water Conditions [d]			
Alternative A	$737	$698	$699
Alternative B	$852	$842	$832
Alternative C	$897	$906	$890
Alternative D	$643	$634	$627

[a] Based on LCRBWQM results (for the South Coast region).
[b] Benefits attributed to salinity reductions only under 2025 and 2060 levels of development.
[c] Annualized benefits represent avoided costs relative to the Future No Project conditions over the planning horizon (2031 to 2130). Annual average is less than 2025 and 2060 values due to initial ramp-up of benefits.
[d] Average over the entire hydrologic sequence (1921 to 2003).
LCRBWQM = Lower Colorado River Basin Water Quality Model

These benefits are added to the benefit estimates for salinity analysis areas (i.e., water use savings) to estimate the total agricultural water quality benefits shown in Table C-21.

The benefits to irrigation water quality are substantially lower than the benefits to M&I water quality (Table C-14), and range between approximately $0.9 million (Alternative D) and $1.6 million (Alternative C).

Table C-21. Total Agricultural Water Quality Benefits—SWAP Model Values ($1,000s, 2015 Dollars)

Alternative	Annual Benefits [a, b]		Annualized Benefit [c, d]
	2025	2060	
Average Water Conditions [e]			
Alternative A	$1,205	$1,289	$1,246
Alternative B	$1,328	$1,407	$1,364
Alternative C	$1,561	$1,693	$1,631
Alternative D	$894	$937	$911

[a] Based on results of the agricultural salinity model (for irrigation water export areas served by CVP/SWP facilities) and the LCRBWQM (for the South Coast region).
[b] Benefits attributed to salinity reductions only under 2025 and 2060 level of developments using SWAP modeling values.
[c] Annualized benefits represent avoided costs relative to the Future No Project conditions over the planning horizon (2031 to 2130).
[d] Adjusted for Level 2 supply quantities.
[e] Average over the entire hydrologic sequence (1921 to 2003).
CVP = Central Valley Project
LCRBWQM = Lower Colorado River Basin Water Quality Model
SWAP = Statewide Agricultural Production
SWP = State Water Project

Delta Environmental Water Quality

A major water quality benefit of the alternatives is the supplemental Delta outflow during the summer and fall months. Increased flows through the Delta and out through San Francisco Bay are beneficial to numerous fish populations. These flows increase estuarine habitat, reduce entrainment, and improve food availability for anadromous fish and other estuarine-dependent species (e.g., Delta smelt, longfin smelt, Sacramento splittail, starry flounder, and California bay shrimp).

The State Water Resources Control Board (SWRCB) concluded that the best available science suggests that current flows in the Delta are insufficient to protect public-trust resources, including fish populations (State Water Resources Control Board 2010). In determining the extent of protection to be afforded public-trust resources through development of the flow criteria, the SWRCB considered the broad goals of the planning efforts that the criteria are intended to inform, including restoring and promoting viable, self-sustaining populations of aquatic species. The SWRCB stated that flow modification is one of the immediate actions available, although linkages between flows and fish response are often indirect and have not been fully determined.

The volume of water released for water quality purposes provides benefits by increasing Delta outflow, including shifting the location of X2 farther to the west. It is also possible to value the increase in Delta outflow directly. Table C-22 shows the estimated volumes of water that would be released to the Delta under each alternative. These quantities exclude water entering the Delta for water supply export (these are accounted for in the volumes used to quantify water supply benefits and water quality benefits to M&I and agricultural users only). These releases are solely releases from the Delevan Pipeline to improve X2 conditions, and not to meet existing compliance obligations. Additional discussion on water rights is included in the section titled "Water Rights" in Chapter 6, Alternative Development, in the main text of the report. Additional discussion on water quality is included in the section titled "Proposed Operations" of Chapter 6, Alternative Development, of the main text of the report.

Table C-22. Total Releases to the Delta Specifically for Water Quality Improvement (TAF)

Alternative	Difference from No Project (TAF) over the Average Water Conditions Period [a]
Average Conditions [b]	
No Project	—
Alternative A	212
Alternative B	216
Alternative C	242
Alternative D	174

[a] Based on CALSIM II modeling.
[b] Average over the entire hydrologic sequence (1921 to 2003).
Delta = Sacramento–San Joaquin River Delta
TAF = thousand acre-feet

NED Benefit Valuation Methodology

The NED benefit valuation analysis for Delta environmental water quality used SWAP unit values to estimate benefit value of the water quantity required to achieve the Delta environmental water quality improvement. This benefit valuation represents an "opportunity cost" for the necessary water supply.

Table C-23 shows the estimated total benefit to Delta Environmental Water Supply based on SWAP values. However, given the large quantity of supply necessary for the Delta improvements, it is likely not feasible to secure this water from existing users on even a short-term basis. As a result, this approach may result in findings that understate the actual project benefits.

Modeled Results

Table C-23 shows the estimated benefits for Delta environmental water quality improvement by alternative.

Table C-23. Delta Environmental Water Quality Improvement
Benefits—SWAP Values ($1,000s, 2015 Dollars)

Alternative	Annualized Benefit ($1,000s, 2015 Dollars) [a, b]
Average Condition [c]	
Alternative A	$39,301
Alternative B	$37,765
Alternative C	$44,202
Alternative D	$26,605

[a] Annual benefits are based on CALSIM II water volumes and the estimated average SWAP values.
[b] Based on June through September increases in outflow.
[c] Average over the entire hydrologic sequence (1921 to 2003).
Delta   =   Sacramento–San Joaquin River Delta
SWAP   = Statewide Agricultural Production

Alternative C is projected to generate the greatest benefits to Delta environmental water quality, at more than $47.1 million per year. Alternative D would result in the least benefits, at $26.6 million. Alternative D operations would emphasize benefits to agricultural water supply and anadromous fish more than benefits to Delta environmental water quality. Alternative D could be adaptively managed to closely match the benefits achieved under Alternative C. Alternatives A and B are expected to result in similar, more moderate annual benefits of approximately $39.9 million and $41.8 million, respectively.

Sensitivity Analysis

Sensitivity analyses were conducted to evaluate the risk and uncertainty associated with the estimates of the alternatives' water quality benefits. The approaches to and findings of the sensitivity analyses are discussed briefly below. The sensitivity analyses are provided solely for informational purposes, and are not included in the calculation of total benefits, NED benefits, or BCRs.

M&I Water Quality

No sensitivity analysis was performed for M&I water quality because no suitable alternative analysis approach was identified.

Irrigation Water Quality

The sensitivity analysis for agricultural water quality used the CWC WSIP's valuation approach and unit values to estimate the future benefit value of the saved quantity of irrigation water. As discussed in the section titled "Water Supply Reliability Benefits," above, the WSIP unit values were developed from a statistical analysis of past water transfer prices, combined with application of the SWAP model.

Table C-24 shows the estimated total benefit to agricultural water supply, based on CALSIM II-generated water supply quantities (Table C-11) and use of the WSIP benefit valuation approach and unit values for the projected improvements to irrigation water salinity and water use savings.

Table C-24. Total Agricultural Water Quality Benefits—WSIP Unit Values ($1,000s, 2015 Dollars)

	Annual Benefits [a, b]		
Alternative	**2030**	**2045**	**Annualized Benefit [c]**
Average Water Conditions [d]			
Alternative A	$1,390	$1,860	$1,744
Alternative B	$1,543	$2,062	$1,941
Alternative C	$1,838	$2,532	$2,378
Alternative D	$993	$1,242	$1,179

[a] Based on the results of the agricultural salinity model (for irrigation water export areas served by CVP/SWP facilities) and the LCRBWQM (for the South Coast region).
[b] Annualized values for South Coast benefits interpolated for 2030 and 2045, but continuing to increase until 2060, after which they are assumed to remain constant. Irrigation water savings benefits are assumed to remain unchanged after 2045.
[c] Annualized benefits represent avoided costs relative to Future No Project conditions over the planning horizon (2031 to 2130). Annualized benefits are greater in some cases because of projected continued increases in water quality benefits for South Coast after 2045.
[d] Average over the entire hydrologic sequence (1921 to 2003).
CVP = Central Valley Project
LCRBWQM = Lower Colorado River Basin Water Quality Model
SWP = State Water Project
WSIP = Water Storage Investment Program

The results of the sensitivity analysis for agricultural water quality benefits are 40 to 45 percent (approximately $0.3 million to $0.75 million) higher in magnitude than the NED results from the SWAP model. Consequently, the NED and sensitivity analyses result in similar rankings and comparative values for the alternatives.

Delta Environmental Water Quality

The sensitivity analysis for Delta environmental water quality used A "least-cost alternative" approach was used to estimate benefits to the Delta's environmental water quality. The alternatives would release a substantial quantity of water to the Delta specifically for environmental purposes (i.e., excluding water released for export, including carriage water). Securing a long-term increase in Delta inflow of this magnitude without a dedicated water supply would be difficult.

The least-cost alternative approach would secure the same long-term benefit. Under such an approach, the alternative project chosen to secure 174 to 242 TAF per year and achieve the same outcome (i.e., improved water quality in the Delta) is the construction of Auburn Dam. No other potential projects were identified with suitable cost information and operations analysis that would provide a similar volume of inflow into the Delta from the Sacramento River. For this analysis, the costs for the Auburn Dam project (Reclamation 2006c) were adjusted to remove the separable costs of hydropower generation to estimate the cost for a single-purpose water supply project. Both the operations and potential deliveries from Auburn Dam were modeled using CALSIM II in the *Folsom South Unit Special Report Benefits and Cost Update*, December 2006.

Table C-25 shows the estimated total benefit to Delta Environmental Water Supply based on Least Cost Alternative values. The sensitivity analysis projected that Alternative C would result in the greatest future benefits to Delta environmental water quality at more than $232.1 million per year. Alternative D would result in the least benefits, at $166.9 million. Alternative D operations would emphasize benefits to agricultural water supply and anadromous fish more than

benefits to Delta environmental water quality. Alternative D could be adaptively managed to closely match the benefits achieved under Alternative C. Alternatives A and B are expected to result in similar, more moderate annual benefits, approximately $203.3 million and $207.2 million, respectively.

Table C-25. Estimated Delta Environmental Water Quality Improvement Benefits—WSIP Values ($1,000s, 2015 Dollars)

Alternative	Annualized Benefit ($1,000s, 2015 Dollars) [a, b]
Average Condition [c]	
Alternative A	$203,340
Alternative B	$207,170
Alternative C	$232,110
Alternative D	$166,890

[a] Annual benefits are based on CALSIM II water volumes and the estimated annual cost for construction of Auburn Dam as a single-purpose water supply project.
[b] Based on June through September increases in outflow.
[c] Average over the entire hydrologic sequence (1921 to 2003).
Delta = Sacramento–San Joaquin River Delta
WSIP = Water Storage Investment Program

The sensitivity analysis's Least Cost Alternatives benefit valuation approach result in similar rankings of the alternatives. For Alternatives A, B, and C, its results are approximately 5 times higher the NED benefit values estimated using the SWAP water value approach (Table C-23). The sensitivity analyses results are more than 6 times higher for Alternative D than its estimated value using the NED valuation approach. The difference in the benefit valuations suggests that the NED benefit estimates for Delta environmental water quality may be very conservative, and underestimate its actual benefit value.

Both the NED opportunity cost and sensitivity analysis's Least Cost Alternative valuation presumes that—at least in theory—the necessary quantity of water supplies could be obtained to achieve the improvement in Delta water quality. However, it is unlikely that it would be possible to obtain, reallocate, or redirect existing water agricultural supplies to such an extent that a similar long-term water supply for Delta environmental water quality could be achieved; in which case, identification and use of a least-cost alternative would likely provide a more accurate and realistic benefit valuation.

However, given its high development cost and permitting challenges, it is considered unlikely that Auburn Dam would be constructed and sustainably operated to achieve and maintain the benefits to Delta environmental water quality at the same level as the alternatives would achieve.

C.6 Anadromous Fish and Other Aquatic Species

The alternatives would enable changes to the volume and timing of environmental flows at critical times throughout the year. These flow changes would create benefits for anadromous fish. The section titled "Water Quality Benefits" in this appendix describes improvements to Delta water quality that could improve conditions for anadromous fish as they pass through the

Delta, in addition to providing benefits for Delta smelt and other estuary-dependent species. This section describes benefits of the alternatives to anadromous fish between Keswick Dam and Red Bluff. Habitat in this reach of the Sacramento River is critical to the spawning and rearing of anadromous fish, including endangered winter-run Chinook salmon (see Aquatic Resources Chapter of the EIR/EIS for more information).

The following types of economic benefits could be quantified:

- Increases in consumptive-use values for commercial and recreational fisheries or nonconsumptive-use values for recreation

- Non-use values that people place on the fishery or ecosystem enhancement, even though they may never fish or see the improvement

- Reduced costs for recovery and management of the ecosystem and/or fishery species

The benefits of the alternatives extend beyond the projected increased-use values for recreational and commercial catches of salmonids. A substantial benefit is also attributable to the species' listed statuses and the value that society places on preserving the species. This distinction has important implications for the methods used to value the alternatives' benefits and allocated costs.

Recovery planning is under way for Endangered Species Act–listed Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead to return them to viable status in the Central Valley. Initial cost estimates for recovery plans range from $1.1 billion to $1.4 billion over the next 5 years, and up to $11.5 billion over 50 years in 2015 dollars (National Marine Fisheries Service 2009). With a Federal discount rate of 2.875 percent, the annualized value of $11.5 billion over 50 years is $436 million.

NED Benefit Valuation Methodology

As discussed above in the section titled Economic Assessment Methods," numerous techniques are potentially available for quantifying NMVs, including RP, SP, and most likely least-cost techniques.[15] However, no recent SP or RP studies are available specifically for the fisheries restoration and environmental enhancement benefits that the alternatives would provide.

The economic value of the ecosystem enhancement accomplishments of the alternatives can also be estimated using a "least-cost alternative" approach. This approach involves identifying the next-best alternative project to achieve the same outcomes (i.e., increasing salmon habitat), and using its development cost to represent the alternatives' benefits.

Under the P&Gs, a least-cost alternative valuation approach can be used when the outputs of two projects are similar; the NED benefits cannot be estimated from market prices or net income changes; and the alternative project would be implemented.

For the alternatives' cold-water benefits, the most comparable approach to reducing water temperatures in the Sacramento River between Keswick Dam and Red Bluff is a raise of Shasta Dam. As an alternative to constructing Sites Reservoir, additional surface storage could be

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[15] Note that mixing and matching WTP and avoided cost estimates could double-count the restoration benefits.

developed at Shasta Lake to ensure the availability of a greater supply of cold water to reduce downstream water temperatures, thereby achieving the same benefit. Fisheries modeling was undertaken using two models: the Winter-Run Chinook Interactive Object-oriented Salmon Simulation/Delta Passage Model, developed by Cramer Fish Sciences; and the Salmonid Population Model (SALMOD), developed by CH2M Hill for Reclamation. For more information about the assumptions, limitations, and outputs of these models, see the modeling appendix to the EIR/EIS.

Over the full hydrological simulation period, Alternative A would generate an increase in salmon production (all species) totaling approximately 936 habitat units.[16] Alternative B is projected to create 683 habitat units, and Alternative C would create 756 habitat units. The greatest increase in salmon production is projected to occur under Alternative D, which would create 986 new habitat units.

Modeled Results

Increasing the cold-water pool improves operational flexibility to provide suitable water temperatures year-round at levels suitable for all species and life stages of Chinook salmon and steelhead. The most important benefits are associated with the increase in the cold-water pool at Shasta Lake; however, similar benefits occur to a lesser degree in the cold-water pools for Folsom Lake, Lake Oroville, and Trinity Lake. There is an opportunity cost associated with maintaining a greater cold-water pool at these facilities.

Table C-26 lists the projected increases in end-of-May storage for the four reservoirs associated with the alternatives and the No Project scenario. Additional information on temperature modeling is provided in Appendices 7E and 12E in the EIR/EIS.

Preliminary design and cost analyses for multiple raise scenarios were developed as part of the SLWRI. Corresponding increases in the salmon population for the three dam raise scenarios were also projected using the CALSIM and SALMOD models. Table C-27 shows estimated annual costs and salmon production for the six Shasta Dam raise scenarios based on the habitat units achieved. Additional information on SALMOD results is provided in Appendix 12K of the EIR/EIS.

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[16] Each habitat unit is equivalent to 1,000 additional salmon produced.

Table C-26. Projected Increases in End-of-May Storage for Shasta Reservoir, Trinity Lake, Lake Oroville, and Folsom Lake (TAF)

Alternative	Average Annual Volume (TAF) [a]	Difference from No Project (TAF)	Difference from No Project (%)
Average Water Conditions [b]			
No Project	9,596	—	—
Alternative A	9,722	126	1.3%
Alternative B	9,737	141	1.5%
Alternative C	9,739	143	1.5%
Alternative D	9,696	100	1.0%

[a] Based on CALSIM II modeling.
[b] Average over the entire hydrologic sequence (1921 to 2003).
TAF = thousand acre-feet

Table C-27. Salmon Production and Annual Costs for Shasta Dam Raise Scenarios (2015 Dollars)

Dam Raise (feet)	Habitat Units [a]	Annual Cost ($1,000s) [b]	Cost per Habitat Unit ($) [c]
0.5	63	$37,070	$588,414
1.7	212	$37,926	$178,896
3.2	381	$39,348	$103,275
6.5	684	$42,535	$62,185
12.5	988	$48,227	$48,813
18.5	975	$53,921	$55,304

Source: Reclamation 2015.
[a] Each habitat unit equals 1,000 additional salmon produced.
[b] Costs have been adjusted into 2015 dollars and are based on a 2.875 percent annual discount rate.
[c] Unit cost values have been rounded.

As shown in Table C-27, the minimum average annual equivalent cost per habitat unit was estimated to be $48,813 for a dam raise of 12.5 feet.

Table C-28 shows the annual benefits of each alternative to anadromous fish by applying the cost per habitat unit from the SLWRI to each alternative's projected increase in habitat units.[17]

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[17] The annualized benefit estimate based on the $48,813 minimum alternative cost per habitat unit is likely conservative, because the actual cost of creating 756 new habitat units (i.e., equal to Alternative C's outcome) is most similar to the 6.5-foot dam raise scenario, which has a $51,248 cost per habitat unit (Table C-26). It might therefore be expected that Alternative C's benefits would be closer to $38.7 million. Similarly, Alternative B habitat outcomes could be secured from a 6.5-foot raise, although at a greater expense.

Table C-28. Estimated Benefits of Alternatives to Anadromous Fish,
Based on Habitat Improvement from the Least-Cost Alternative (2015 Dollars)

Alternative	Projected Habitat Units [a]	Annualized Benefit ($1000s, 2015 Dollars) [b, c]
Alternative A	936	$45,689
Alternative B	683	$33,339
Alternative C	756	$36,902
Alternative D	986	$48,129

[a] Each habitat unit equals 1,000 additional salmon produced.
[b] Annual benefits are based on an average annual equivalent cost per habitat unit of $48,813.
[c] Annualized value from Shasta adjusted for a 2.875 percent discount rate.

Alternative D would generate annual benefits to anadromous fish of approximately
$48.1 million, based on a "least-cost alternative" approach to raising Shasta Dam. Alternative A
would result in slightly lower benefits, at $45.7 million. The annual benefits to anadromous fish
under Alternative B and Alternative C are projected to be up to $33.3 million and $36.9 million,
respectively.

C.7 Generation of Hydropower to Support Sustainable Energy

Hydropower generation by the alternatives' facilities is a potential benefit of the alternatives. The
seasonal water diversions for the alternatives would require power, and the seasonal water
releases under the alternatives would generate power. A pump-back component of the
alternatives' operations has been modeled separately, and pump-back operations would occur
throughout the year as conditions allow (see Appendix H, Hydropower, for more information).

The three new pumping/generating facilities envisioned for the alternatives would be located at
Holthouse Reservoir, adjacent to Sites Reservoir; at the Terminal Regulating Reservoir,
connecting the GCID Canal to Funks Reservoir; and at the Sacramento River diversion point,
connecting the Sacramento River to Holthouse Reservoir.

The different facilities for the alternatives would result in the following hydropower benefits:

- Revenues from generated energy incidental to water deliveries to downstream
  agricultural and urban water users[18]

- Net revenues resulting from an optimized pump-back operation at Sites Reservoir[19]

- Net revenues/costs associated with delivering additional water to CVP and SWP water
  customers

- Revenues from selling ancillary services (AS) and capacity products, and potentially
  selling renewable-energy firming services

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[18] The O&M costs for Sites Reservoir include pumping costs to fill the reservoir and energy generation revenues
from releases.
[19] This net benefit includes both pumping and generation.

NED Benefit Evaluation Methodology

DWR's PARO has developed an optimization scheme for the alternatives' operations to take advantage of opportunities and price differentials offered by the energy market. The optimization scheme maintains the alternatives' operations, constraints, and assumptions as envisioned by the water operations modeling team, but optimizes operations to maximize the Power Portfolio value of the alternatives' assets. A pump-back operation has been superimposed on the alternatives' operation modes (diversion and release modes) to the extent that the pumping, generation, and storage assets are simultaneously available to complete pump-back operations. The premise is that optimizing the alternatives' operations can translate the inherent excess design capacities (resulting from hydrology swings) of the alternatives' components into operational flexibility and minimize net O&M costs.

Three operation modes are identified for the modeling of the alternatives' power operations:

- Diversion mode (pumping) from the Sacramento River to fill up Sites Reservoir

- Release mode (generation) from Sites Reservoir to meet the alternatives' objectives for water releases

- A pump-back mode to better use the residual capacities of the different alternatives' components

The alternatives' pump-back operations are designed to enhance the alternatives' economic performance by capturing opportunities offered by the energy market (energy price differentials between on-peak and off-peak hours), and to provide the support and products needed to integrate renewable energy (e.g., wind and solar).

Power portfolio models available to DWR PARO have been used in the analysis of the alternatives. Specifically, the analysis uses the Electric Power Research Institute (EPRI) Energy Portfolio Model (EPM), Version 5. The EPM is a computer software model designed to help businesses manage value and risk in the power and energy markets. EPM has been used to value the alternatives' energy assets and contract needs, and to assess the exposure of its energy portfolio to major sources of risk.

The EPM requires the user to describe the intended operations of project assets and underlying commodity prices. For the alternatives, the intended operations are the results of the optimization scheme developed and executed for the alternatives by DWR PARO. Operations of the alternatives' assets are translated to a representative set of financial instruments and incorporated into the EPM. The model determines the probabilistic monetary value of the power portfolio under each alternative and operational scenario used in the study.

The EPM provides a set of templates to facilitate describing and evaluating common types of power and fuel contracts (supply contracts, standard and customized forward, and option contracts). The model characterizes each commodity market by a forward price curve and a term volatility structure. The model also uses a correlation matrix to characterize the behavior of pairs of commodity markets.

EPRI's Fast Fit model, Version 2.5, is used to describe the needed power, fuel price volatilities, pricing structures, and the correlations between the different energy markets in which the alternatives would participate, or with which the alternatives would compete.

Appendix H, Hydropower, provides additional details on the optimization modeling scheme developed by DWR PARO, as well as its analysis and findings.

Modeling Results

Expected power generation and use were estimated using the EPM and Fast Fit models, and the resulting net revenue was calculated based on forecasted energy costs for 2025 and 2060. The results are presented below for all three alternatives under two different operational scenarios.

The first is an incidental scenario that assumes that the alternatives would be operated for purposes other than optimal power generation. Therefore, this scenario does not consider the peak and off-peak timing of the resulting power use and generation. Instead, the incidental scenario assumes that pumping and generation are scheduled according to expected demand for water deliveries. This scenario further assumes that pump-back operation would not occur at the alternatives' facilities (flat operations would limit the availability of the alternatives' components).

The second is an optimized scenario that assumes that the alternatives would be operated to achieve optimal power generation and usage (with no impact on water objectives), with pumping during off-peak periods and generation during peak (or super-peak) periods, to the extent possible. In addition, this scenario assumes that the residual pumping, generating, and storage capacities at Sites and Holthouse Reservoirs would be used to superimpose a pump-back operation cycle, and to provide a reliability reserve for renewable-energy integration needs.

The results from the two aforementioned approaches were merged (integrated) to produce the study results presented in Table C-29. The alternatives' power optimization analysis (performed by DWR) shows that the alternatives, as stand-alone projects, would have a negative cash flow. However, optimizing operations and superimposing pump-back operations on the water diversion and release modes greatly enhance the economics of the alternatives.

Table C-29 provides the average annual power generation and use results for the four alternatives under both the incidental and optimized scenarios. The table also shows that, under the incidental production scenario, each alternative is a net power user systemwide.

Overall, the power modeling shows that if the alternatives' pumping and generation operations are shifted to address peak demand and energy pricing considerations, the optimized costs and revenues have a substantial beneficial impact on the alternatives' economics.

Table C-29. Estimated Net Revenue from NODOS Power Use and Generation ($1,000s, 2015 Dollars)

Pumping-Generation Site								
Planning Alternative	Alternative A		Alternative B		Alternative C		Alternative D	
Operations Strategy	Incidental	Optimized	Incidental	Optimized	Incidental	Optimized	Incidental	Optimized
Pumping	Annual Revenues							
T-C Canal Pumping	($289)	($289)	($347)	($347)	($272)	($272)	($309)	($309)
GCID Pumping	($462)	($462)	($525)	($525)	($453)	($453)	($496)	($496)
Delevan Pipeline Intake Facilities	($2,551)	($2,551)	$0	$0	($2,783)	($2,783)	($1,661)	($1,661)
TRR Pumping	($484)	($484)	($760)	($760	($554)	($554)	($615)	($615)
Sites Pumping	($7,296)	($6,711)	($6,854)	($6,370)	($8,244)	($7,634)	($8,852)	($8,137)
Subtotal	**($11,082)**	**($10,497)**	**($8,486)**	**($8,001)**	**($12,306)**	**($11,695)**	**($11,932)**	**($11,218)**
Generation	Annual Revenues							
Sites Generation	$4,950	$5,786	$4,897	$5,526	$6,122	$6,745	$6,081	$6,565
TRR Generation	$836	$836	$285	$285	$884	$884	$474	$474
Sacramento River Generation	$1,894	$1,894	N/A	N/A	$2,181	$2,181	$2,058	$2,058
Subtotal	**$7,680**	**$8,516**	**$5,182**	**$5,182**	**$9,187**	**$9,811**	**$8,613**	**$9,097**
Pump-Back Operations	Annual Revenues							
Pump-Back during Diversion Cycle	N/A	$155	N/A	$227	N/A	$137	N/A	$129
Pump-Back during Release Cycle	N/A	$65	N/A	$46	N/A	$155	N/A	$68
Pure Pump-Back Operations Cycle	N/A	$175	N/A	$175	N/A	$201	N/A	$159
Subtotal		**$394**		**$447**		**$,493**		**$356**
Total Net Revenues	**($3,402)**	**$(1,587)**	**($3,304)**	**$1,742**	**($3,119)**	**$(1,391)**	**($3,319)**	**($1,766)**
Project Optimization Potential		**$1,815**		**$1,562**		**$1,728**		**$1,553**

GCID = Glenn-Colusa Irrigation District
N/A = not applicable
NODOS = North-of-the-Delta Offstream Storage
T-C = Tehama-Colusa
TRR = Terminal Regulating Reservoir

Table C-29 also shows the cost and revenue effects of pump-back operations on the alternatives. Under Alternative C, future optimized pumping and generation at Sites Reservoir would reduce the alternatives' power cost from $3.1 million to $1.9 million, a savings of $1.2 million. In addition, future pump-back hydropower operations are estimated to generate $0.5 million in revenue. Consequently, the total revenue impact of the optimized and pump-back operations under Alternative C is estimated at $1.7 million per year. The annual net pumping cost for Sites Reservoir is estimated to be $1.4 million per year.

Under all the Alternatives, the combined hydropower and pump-back operations are projected to result in net pumping costs. Consequently, the alternatives would have annual net energy cost charge ranging between approximately $1.4 million (Alternative C) and up to $1.8 million (Alternative D).

The combined pumping and generation operations are incorporated as O&M components for the economic feasibility analysis and are projected to operate on a net cost basis. Hydropower NED benefits are based on the projected ancillary and capacity benefits.

Additional Hydropower Facility and Operational Benefits
In addition to supporting its water operations, the alternatives' power facilities (pumping and generating) may participate in three additional power markets: AS, capacity markets, and renewable integration.

Ancillary Services Benefits
Ancillary services benefits consist of the power facility functions that support the power system's generating capacity, energy supply, and power delivery services. Ancillary services include improved capabilities for the power "grid" to respond to electricity system demand, supply, or other market imbalances.

The California Independent System Operator (CAISO) procures AS to ensure that it has adequate reserve generation capacity to maintain the electrical system's reliability and frequency, by matching generation and load at all times under both normal and abnormal operating conditions. In its restructured electricity market (i.e., post-Market Redesign and Technology Upgrade conditions), CAISO obtains AS through competitive bidding. CAISO procures four primary AS services daily (regulation, spinning reserves, nonspinning reserves, and replacement reserves), in a day-ahead market. The two additional AS procured by CAISO are black-start and voltage support services, which are procured on a long-term basis.

For the alternatives' pumping/generating facilities, if interconnected to the CAISO grid, AS would be a substantial concern related to operations and costs/revenues. The CAISO Tariff requires a participating generator, potentially including the alternatives, to undergo a certification process before participating in the CAISO AS market. The details of the process are beyond the scope of this study.

The CAISO Tariff states that a participating generator is a generator or other seller of energy or AS that:

- Operates through a scheduling coordinator over the CAISO grid from a generating unit with a rated capacity of 1 megawatt or greater; and/or

- Provides AS and/or imbalance energy from a generating unit through an aggregation arrangement approved by the CAISO.

The alternatives would clearly meet the second criterion listed above. The CAISO accepts market bids for energy and AS only from scheduling coordinators on behalf of the participating generator.

In general, participation in the AS market is an opportunity to translate inherent operational flexibilities and excess capacities into revenue opportunities. For the alternatives, the highest priority is to supply the intended seasonal water cycle (diversions/deliveries) that the alternatives were designed to provide. Therefore, the alternatives' revenue opportunities from AS market participation would have to result from incidental activity occurring after the alternatives have achieved their primary operational responsibilities related to water supply.

During their pumping cycle, the alternatives would have the opportunity to sell Nonspinning Reserve AS into the CAISO market as a participating load (meeting the CAISO Tariff's definition). However, AS participation would be limited to the Sites Reservoir pumping plant so that Sacramento River water diversions could be maintained at all times. The assumption is that if the pumping load at Sites Reservoir Pumping Plant were dropped by CAISO, water diversions from the Sacramento River could be stored in Holthouse Reservoir for the period of time CAISO needs the service. Currently, the maximum period for a Nonspinning Reserve AS is 2 hours.

During their generation cycle, the alternatives would have the opportunity to sell Regulation Down Reserve AS into the CAISO market. In this analysis, the alternatives' water release cycle is optimized to capture the most value of the associated energy (generation cycle). Therefore, water releases from Sites Reservoir are designed to occur during on-peak periods. Accordingly, the alternatives' generation facilities are assumed to sell Regulation Down Reserve AS mostly during on-peak periods, and to a lesser extent during off-peak periods. The assumption is that if called on, the alternatives' Regulation Down Reserve AS may necessitate a temporary delay in water releases that could be rectified within a few hours. Also, it is assumed that the alternatives' facilities would be equipped with an automatic generation control system that could be ramped down to satisfy CAISO requirements for providing AS power supplies. Participating in the Regulation Down Reserve AS market may cause the alternatives to temporarily forgo some of the on-peak generation revenues.

Another ancillary service benefit of hydropower can be its potential ability to rapidly ramp up and down to meet short-term energy needs, and thereby provide operating reserves in case of high peak-period demand. A peaking plant may operate for many hours, a day, or as little as a few hours per year, depending on the region. In California, peaking plants are generally gas turbines that burn natural gas. Peaking plants are essential, given the growth of alternative renewable energies such as solar and wind, where production fluctuates throughout the day and throughout the year.

Gas turbine plants dominate the peaking plant category, but hydroelectric facilities, with the capacity for pumped storage, can be used as a source for peak-load power. The value of the

alternatives as a peaking plant can be estimated as the avoided cost of investing in development of an alternative peaking plant.

To quantify this avoided cost, it is necessary to understand the current and predicted use of peaking plants, and the planned future capital investments in new peaking plants. The benefit of the alternatives' facilities from their use as a "peaking plant" would be the change in the present value of the currently planned new investment that would otherwise be necessary. However, these data were not available, and consequently, no benefits are quantified for the alternatives at this time.

Planning Capacity Market

CAISO is charged, both under California law and by the Federal Energy Regulatory Commission (FERC), with the responsibility of maintaining and operating a reliable grid system (transmission system), a system that is under its operational control. System reliability is a complex subject, as it is inextricably intertwined with market economics, a subject that is beyond the scope of this analysis. Nevertheless, resource adequacy (RA) is a crucial element of reliable grid operations and relevant to the alternatives' operations. CAISO (through its FERC-approved Tariff) and the RA requirements adopted in California Public Utilities Commission (CPUC) mandates are intended to establish a process ensuring that capacity procured for RA purposes is available whenever and wherever needed. For the alternatives, RA obligations are a pseudo-financial obligation in the diversion (pumping) mode (self-provided), and a revenue opportunity in release (generation) mode.

The capacity value of a power asset can be harnessed in several ways. One way is to consider the value of RA capacity. The State of California has embraced an RA mandate/regime (Assembly Bill 380, enacted in 2005) to make power resources available when and where they are needed, and to promote investment in new resources and maintenance of existing facilities. CPUC governs the RA program for entities under its jurisdiction, and CAISO monitors implementation of the RA program by publicly owned utilities and government agencies. Currently, RA capacity is being traded bilaterally through a solicitation and bidding process, and the price of capacity negotiation is opaque. However, the CAISO Tariff requires CAISO to procure capacity as a backstop, should a load-serving entity fail to meet its RA obligation showings. RA obligation showings take place annually and monthly. FERC has authorized CAISO to charge or pay the default RA capacity procurement price of $69 per kilowatt per year.

It is assumed that the alternatives would offer capacity in the CAISO market to participants that need to secure capacity to meet their RA obligations. CAISO's capacity market has two different levels of participation for a generation asset, local RA and system RA, based on the location of that specific asset relative to pre-established zones in the CAISO grid. The alternatives' facilities and the location of their potential connection to the CAISO grid do not fall in one of the congested CAISO zones, where generation assets can sell local RA products. Moreover, the current CAISO market has sufficient system RA, with very little monetary value for assets to capture from capacity offerings. However, system RA needs, system configuration, and the geographical distribution of assets change all the time. Consequently, as the CAISO market evolves, opportunities for the alternatives to participate in the RA market may become available in the future.

Renewable Integration

The California Renewable Energy Resources Act, signed by Governor Brown on April 12, 2011, substantially increased the State's renewable portfolio standard targets from 20 percent to 33 percent by 2020. This law also expanded compliance obligations to include virtually all retail sales of electricity in California.

In September 2010, CAISO undertook a multiphase stakeholder process, the Renewable Integration Market and Product Review Initiative. The goal of the initiative was to identify changes to the energy market structure and introduce new market products to reliably mitigate the impact of renewable generation (intermittent generation) as it penetrates the market. Recently, CAISO has refocused the Renewable Integration Market and Product Review Initiative from an expansive market to a more incremental, phased approach. CAISO is focusing on developing a high-level road map to enhance short-, medium-, and long-term markets to integrate renewable energy.

Improved energy storage technologies for hydroelectric pumping/storage facilities are a promising area for technological improvement that could greatly improve their role in power generation and delivery. The conventional role of energy storage facilities is to store off-peak energy for use during on-peak periods, or to provide AS. New roles for energy storage include converting intermittent renewable-energy facilities into dispatchable resources, and enhancing both grid reliability and power quality.

Great potential exists for the alternatives' generation and pumping assets to participate in providing renewable integration services as market needs evolve. Hydropower assets have a unique feature that is not available from other energy storage technologies: fast ramping that can provide high capacity and energy simultaneously. Although the alternatives' potential benefits related to renewable energy integration are certain, monetizing that potential is difficult, given the absence of a clear tradable market for these services.

Renewable Energy—Green Power

Hydropower is the primary source of renewable energy in the United States.[20] In 2010, hydropower accounted for 60 percent of all renewable-energy generation and 6 percent of overall electricity consumption (EIA 2011). It is a clean, reliable, and extremely efficient source of energy that can be ramped up and down quickly at any time of the day. As demonstrated by the CPUC, which sets a market price reference for qualifying green power that exceeds the market price for non-renewable energy sources, hydropower is a valuable source of renewable energy.

However, the alternatives' facilities would not be typical of most hydropower plants in that they would be offstream storage facilities. Unlike onstream storage reservoirs, the alternatives would require using power to pump water into storage before any hydroelectric power could be generated. With seasonal releases, 143 to 353 gigawatt-hours of energy would be generated. Consequently, the alternatives' facilities would be a net user of energy.

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[20] However, under circumstances (such as the NODOS project) in which applied energy is necessary for its water storage, specific hydropower facilities may not operate as a source of renewable energy.

NED and Total Hydropower Benefits, Including Capacity and Ancillary Services

Additional hydropower analysis has been performed for the proposed configuration of Alternative C (Toolson and Zhang 2013). Appendix H provides additional information on the hydropower analysis and findings.

The additional hydropower analysis confirmed DWR's direct net energy benefits, and estimates annual AS benefits of approximately $2.6 million and systemwide capacity benefits of $19.4 million per year. The resulting ancillary services and systemwide capacity NED benefits potentially attributable to the hydropower facilities would be $22.0 million per year. Combined with its estimated direct net pumping cost of nearly $1.4 million, Alternative C would be expected to result in total net hydropower benefits of $20.6 million per year. However, as previously discussed, for the purposes of the feasibility analysis, the net hydropower cost is recognized as an OM&R cost for the reservoir. Consequently, the corresponding hydropower benefit value for the feasibility study is the full value of Alternative C's $22.0 million in projected annual ancillary and systemwide service benefits.

The supplemental hydropower analysis projected benefits only for Alternative C. However, given the similarity of its proposed hydropower facilities, Alternative A would likely generate comparable AS and systemwide capacity benefits. Based on the DWR analysis, Alternative B's future annual hydropower generation is projected to be approximately 61 percent of Alternative C's annual power generation. Assuming that Alternative B's potential AS and systemwide capacity benefits are similarly proportional, Alternative B would be expected to result in approximately $13.4 million in ancillary services and systemwide capacity NED benefits annually. Alternative B is estimated to have a direct net pumping cost of approximately $1.6 million. Consequently, Alternative B would be expected to result in total hydropower net benefits of $11.8 million per year.

Alternative A is projected to generate approximately 87 percent of the power revenue benefits of Alternative C. Applying the same benefit approximation approach, Alternative A would be expected to result in approximately $19.0 million annually in ancillary services and systemwide capacity NED benefits. Combined with estimated direct net hydropower costs of nearly $1.6 million per year, Alternative A would be expected to generate total hydropower net benefits of approximately $17.4 million per year.

Alternative D is projected to generate approximately 92 percent of the power revenue benefits of Alternative C. As a result, Alternative D is expected to generate ancillary services of approximately $2.4 million and systemwide capacity NED benefits of $17.8 million, which results in estimated combined total NED benefits of $20.2 million per year. However, given its projected $1.8 million net power cost, Alternative D's total hydropower net benefits are estimated to be $18.4 million per year.

C.8 Flood Damage Reduction

The area along Funks Creek downstream of Funks Reservoir is subject to flooding. Under current No Project conditions, Funks Reservoir is not a flood control reservoir. Therefore, it can be overwhelmed with runoff and still send peak flows downstream on Funks Creek. The

alternatives would reduce the flooding risk of Funks Creek, Stone Corral Creek, and various other unnamed streams. Additional reductions in flooding would be realized in some portions of the downstream Colusa Basin.

NED Benefit Valuation Methodology

The reduction of flood damage was estimated by calculating the average annual cost of flooding under No Project conditions and the projected reduction in flooded area and costs under the alternatives.

The average annual cost of flooding was estimated by assessing expected annual damages to property and infrastructure in the floodplain area. Flood risk analysis using economic models such as USACE's Hydrologic Engineering Center assessment tools was not performed due to the expected limited nature, area, and magnitude of the NODOS project alternatives' expected flood risk reduction.

Instead, the benefit value of the project-related flood damage reduction was estimated based on the average annual net cost savings of flood damages for the future "with Project" conditions compared to the existing "No Action" conditions. The resulting Expected Annual Damages savings was estimated based on hydraulic analysis that quantified the project-related reduction in flood-impacted areas and flooding severity for six different flood event types (ranging from 5-year to 500-year flood events). Geographic information system (GIS) land use analysis inventoried the impacted areas.

For each year flood event, expected flooding condition and damage estimates (for both the No Action and action alternatives) were developed. The flood damage estimates were based on the current land uses, existing structures, and property values. Standard damage estimation approaches and data were used for the area flood risk and damage assessment. Flood-related data sources include previous USACE analyses and DWR's Flood Rapid Assessment Model (F-RAM).[21]

No differences in the alternatives' flood reduction performance were expected. Because of the relatively small proportion of benefits associated with flood damage reduction and the limited amount of hydrology and hydraulic data, damages and resulting benefits were annualized based solely on the 100-year flood event. It is assumed that all alternatives would provide the same level of flood risk mitigation.

Modeled Results

Agricultural

Figure C-4 shows the land uses of parcels in the 100-year floodplain for Funks and Stone Corral Creeks. Rice production is the primary crop in the area, followed by dryland pasture. Irrigated production in the area is predominantly tomatoes (for processing), wheat, or alfalfa. Wheat and alfalfa crops are generally followed by a second planting of seed crops such as cucumbers and watermelons (Azevedo 2012).

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[21] F-RAM is an economic analysis tool for assessing the flood reduction benefits of floodplain management measures.

Orchards
1%

Irrigated*

20%

Rice 58%

21% Dryland Pasture

Percentage by Crop Type of Agricultural Land within the 100 Year Floodplain
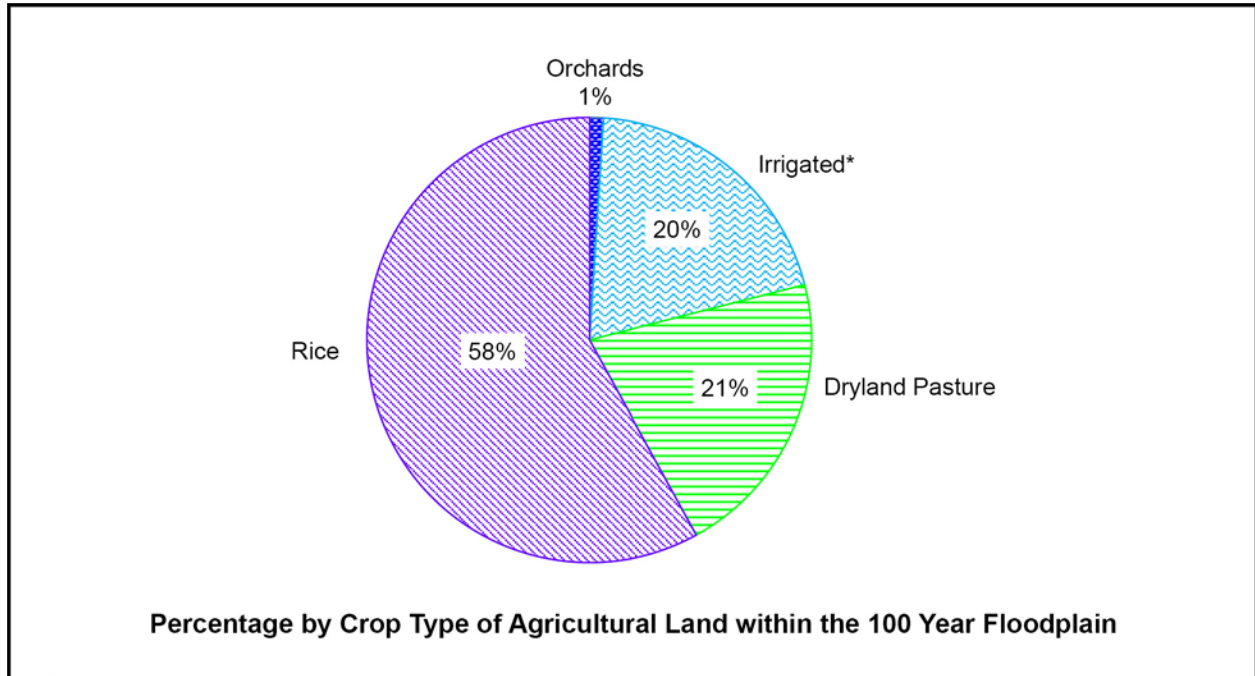
* Irrigated production in the floodplain area predominantly consists of tomatoes, wheat, and alfalfa.

Source: County parcels intersecting the 100-year floodplain (data compiled by URS).

Figure C-4. Agricultural Land Use in the Affected Floodplain

Where flood risks are reduced, an opportunity exists to develop the land for higher-value uses, and therefore, increased economic value. Opportunities for land use changes resulting from changes in flood risk have not been modeled in the Draft Feasibility Report.

In 2008, agricultural flood damages per acre were estimated for typical land uses in the Central Valley, based on initial losses estimated for the USACE Comprehensive Study (DWR 2008b). Crop budget data were used to calculate a weighted-average annual flood damage estimate for each crop type. The weighted average included probability of flooding in each month, expected crop income losses, and variable costs not expended if a flood were to occur for each major crop type. Establishment costs represent the agricultural producer's costs typically incurred and invested before crop production begins (e.g., cultivation activities during maturation period for orchard crops). Land cleanup and rehabilitation costs were added to each estimate as a fixed cost. As shown in Table C-30. the study estimated that flood damages per acre ranged from less than zero for pasture to approximately $3,500 for wine grapes.[22]

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[22] The negative damages (i.e., benefit) to pasture from flooding reflect the expected yield gains from the additional water content in the soils.

Table C-30. Per Acre Losses and Estimated Damages,100-Year Flood Event (2015 Dollars)

Product	Average Annual Damages ($/acre) [a]	Land Cleanup and Rehabilitation ($/acre)	Total Damage Per Acre ($/acre) [b]	Reduced Flood Area [c]	Total Damages ($1,000s) [d]
Rice	$245	$262	$508	6,035	$3,066
Almonds	$1,746	$262	$2,008	266	$534
Tomatoes	$1,096	$253	$1,349	731	$986
Wine grapes	$3,498	$253	$3,751	15	$55
Alfalfa	$269	$262	$532	731	$389
Pasture	($16)	$293	$277	1,779	$493
Other	$0	$265	$265	15	$4
Total				**9,570**	**$5,526**

Source: DWR 2008a.
[a] Based on expected crop income losses, variable costs not expended, and probability of flooding on a monthly basis.
[b] Costs typically incurred and invested before crop production begins (e.g., cultivation activities during orchard crop maturation).
[c] Represents a short-term flood event, which typically results in only limited damages to perennial crops.
[d] Represents a flood event that will likely result in major damage to perennial crops and require their subsequent reestablishment.

Under the alternatives, up to 9,570 acres of farmland would experience a reduction in flood-related damages.[23] Apart from irrigated production in the floodplain, most of the land uses shown in Table C-30. would not be substantially affected by the short-term flooding (i.e., less than 5 days) that the area periodically experiences. In addition, approximately the northern quarter of the town of Maxwell is in the 100-year floodplain; consequently, this area might benefit from alternative-related reductions in area flooding.

Based on the area's general agricultural production and on additional GIS analysis of the likely affected areas, approximately 6,035 acres of rice and 1,780 acres of dryland pasture would benefit from reduced flooding as a result of the alternatives. Based on USACE's total damage estimates of $508 per acre of rice and $277 for pasture,[24] their reduced farmland flood damages would be approximately $3.56 million. Conservatively assuming a 50:50 split between tomato and alfalfa production on the 1,462 acres of irrigated production that could benefit from reduced flooding, the average avoided damage would be approximately $940 per acre. The total damages to irrigated production would be $1.38 million.

The GIS analysis also indicated that approximately 266 acres of orchard production might be in the reduced floodplain area. Because almonds are Colusa County's primary orchard crop (Colusa County 2016), an avoided flood event of 5 days or less would result in approximately $0.53 million in flood damage savings.

Consequently, the total estimated agricultural flood reduction benefit would be $5.53 million for a 100-year flood event. Similar agricultural damage analysis was performed for the other flood events to develop a more comprehensive representation of the future project-related flood damage reduction.

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[23] The specific locations and related agricultural production in the floodplain that would be less affected by flood events are not known.

[24] It is conservatively assumed that the avoided flood event would last 5 days or less.

Structures and Contents

The alternatives could reduce the likelihood of flood damage to some of the homes and other structures in the northern portion of Maxwell. The most recent census information reports that Maxwell has 378 housing units.

Staff from the USACE Sacramento District provided region-specific damage curves by structural and content stage for short-duration flood events. According to this set of damage curves, a 5-foot flood above the first-floor elevation is assumed to result in structural and content damage equivalent to 90 percent of the structure's replacement value. Census data on the median age and size of single-family homes in the area were applied to estimated replacement values based on Marshall & Swift cost estimates. The estimated average full-structure replacement value for single-family homes in the area is $175,000.

Indirect damages to account for cleanup costs, temporary housing, relocation assistance, and other potential emergency costs were modeled as a proportion of direct damages, in this case 25 percent, according to estimates provided in the F-RAM model documentation.

Damages to structures and contents represent full replacement value, not depreciated value. Full replacement value, which is used by the Federal Emergency Management Agency (FEMA), more accurately reflects the true cost to replace damaged assets.

Only structures in the town of Maxwell were included in this assessment of flood damages. There are additional structures scattered across the agriculturally zoned parcels outside of the town center that would also be subject to damage. Table C-31 illustrates the flood depth damage functions, indirect cost assumptions, square footage of residential and non-residential structures that avoid damage in the 100-year flood event from the without-project conditions compared to the with-project conditions, and the estimated avoided damage. Corresponding estimates were developed for the other flood events to determine their expected avoided damage costs.

Table C-31. Avoided Cost Assumptions and Estimates for 100-Year Flood Event (2015 Dollars)

Structure Type	Structure [a]	Contents [a]	Indirect [b]	Square Feet [c]	Avoided Damage
Residential one-story	53%	29%	25%	76,584	$11,701
Non-residential one-story	31%	100%	25%	52,666	$12,470
Total Avoided Costs				129,250	**$24,171**

Sources: DWR 2008b; USACE 2010, 2013.
[a] Assumes 5-foot flood depth based on USACE 2013.
[b] F-RAM indirect cost factor.
[c] The difference in square feet of the structures exposed to the 100-year event for the period between the without-project condition and the with-project condition.

Transportation and Other Flood Reduction Benefits

Interstate 5 passes through a short section of the 100-year floodplain near Maxwell. It is not expected that the alternatives would substantially reduce the potential for flood-related highway closure, because other sections of the highway (e.g., near the city of Williams) would remain more vulnerable to closure under potential flood events. Nonetheless, State Route 20 between Interstate 5 and the city of Colusa would likely experience flood damage reduction benefits.

Default cost-per-mile damage estimates from the Flood Rapid Assessment Model (F-RAM) were escalated to 2015 values and applied to the approximately 8 miles of State Route 20 that would be assumed to no longer be vulnerable to flooding after construction of any of the alternatives. The direct benefits of flood damage reduction to roads are estimated to be $1. 55 million for a single 100-year flood event. Corresponding estimates were developed for the other flood events to determine their expected avoided damage costs.

Additional roadway repair damages were estimated using assumptions concerning the amount of roadway exposed and cost-per-mile factors for different roadway classifications. Indirect damages to account for cleanup costs, emergency costs, and losses from disruption to employment and commerce were modeled as a proportion of direct damages, in this case 50 percent. Both repair and indirect damages were informed by estimates provided in the F-RAM model documentation.

Total

Table C-32 presents the estimated avoided costs across the primary damage categories for the six flood events modeled.

Table C-32. Flood Benefits by Event and Impact Category (2015$, 1,000s)

Flood Type	Agricultural	Structures and Contents	Transportation	Total
500-year	$4,856	$10,199	$1,365	$16,420
100-Yyear	$5,526	$24,171	$1,552	$31,249
50-year	$5,959	$23,337	$1,690	$30,986
25-year	$6,323	$11,472	$1,767	$19,562
10-year	$5,829	$7,912	$1,570	$15,311
5-year	$5,211	$24,546	$1,410	$31,167

Source: DWR 2008b; USACE 2010, 2013.

After applying applicable frequency and interval factors to account for each flood event's projected future occurrence, flood reduction benefits were estimated to be approximately $4.4 million in 2030. It was conservatively assumed that 2025 benefit values would remain constant throughout the future. As a result, the annualized flood reduction benefits for the alternatives are estimated to be $4.3 million.

C.9 Recreational Benefits

The alternatives would directly provide recreational benefits at Sites Reservoir by establishing a new venue for recreational activity in the alternatives' area. The alternatives operations could also indirectly affect other existing recreational opportunities in the Sacramento River, and facilities connected throughout the CVP and SWP systems, by causing changes in downstream flows.

Sites Reservoir Recreation

At maximum capacity, Sites Reservoir would be the seventh largest reservoir in California, with a storage volume of approximately 1.81 MAF, and surface area of approximately 14,000 acres. The reservoir would provide new opportunities for surface-water recreation, such as boating, fishing, and swimming. In addition, new facilities would be developed to support other recreational activities like camping, hiking, picnicking, and sightseeing. Potential recreation development for the facility has been previously evaluated,[25] and an updated analysis of recreational opportunities and constraints has been prepared as part of this Draft Feasibility Report (see Appendix E, Recreation).

Alternatives A, B, and C will provide developed access and facilities at three recreation areas: Stone Corral, Lurline Headwaters, and Antelope Island. Alternative D would provide two recreation areas: Stone Corral and Peninsula Hills. Facilities for Alternative D are being sized to provide a similar level of recreation as the other alternatives. The proposed facilities include boat launch sites, picnic areas and tables, developed campsites, restrooms, trails, designated swimming areas, and parking. Additional information on the facilities for each recreation area is provided in Appendix E. All alternatives would provide comparable levels of recreational development and types of recreational opportunities at Sites Reservoir.

NED Benefit Evaluation Methodology

The Travel Cost Method (TCM) and Contingent Valuation Method (CVM) are the most common NMV techniques used to determine the economic value of outdoor recreational activities. TCM is a "revealed preference" economic valuation method based on the time and travel expenses that users incur for their recreational activity. CVM is a "stated preference" economic valuation method based on the reported WTP (or less commonly willingness to accept) information obtained through public surveys or interviews.

Both approaches are recommended by the P&Gs for use in valuing outdoor recreational activities. However, no original NMV studies have been conducted for the alternatives. Consequently, the benefits-transfer approach has instead been used to estimate the value of new recreation at Sites Reservoir.

The analysis of economic benefits attributed to full development of surface-water recreation at Sites Reservoir considers several factors: the physical characteristics of the recreational facilities; recreational levels and use patterns at similar facilities; and the operational parameters for the reservoir that would affect the surface area available for recreation under the various alternatives. The economic benefits are based on estimated visitation levels and representative consumer surplus values across anticipated recreational activities. The analysis also accounts for substitution effects of recreation relocating from other reservoirs.

Modeled Assumptions

Potential visitation to Sites Reservoir would be "several hundred thousand recreation-days per year" (CALFED 2000). Previous planning estimates indicated that the reservoir has the potential to support an average of 410,000 recreation user-days annually (Reclamation 2006b). However, this analysis conservatively assumes that the planned recreation areas at Sites Reservoir will

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[25] See CALFED (2000).

support a maximum of 200,000 visitor-use days per year. Visitor-use days would likely decline when alternatives' operations reduce the reservoir's surface area during the peak recreation months. This recreational use adjustment is discussed below.

The value of recreation at Sites Reservoir is based in part on anticipated recreation patterns at the facility, which are assumed to follow typical patterns of recreational activity in the region. It is expected that future recreation at Sites Reservoir would be comparable to current recreational use at nearby Black Butte and East Park Reservoirs. Consequently, Black Butte Reservoir's activity patterns have been used to project the expected distribution of activity types across the estimated 200,000 visitor-use days at Sites Reservoir, as presented in Table C-33 (Reclamation 2006b). The recreational use activities have been matched with planned recreational facilities to ensure that the projected recreational use could be supported at Sites. Appendix E provides more detailed discussion of the recreation facilities currently planned and budgeted for development under each Alternative.

Table C-33 also presents the economic values (as measured by consumer surplus) of the different recreational activities anticipated at Sites Reservoir. These benefit values are derived from published estimates for specific outdoor activities across distinct regions of the United States, and represent average values from individual studies conducted between 1967 and 2015, stated in 2015 dollars (Rosenberger 2016). The weighted-average value per activity expected at Sites Reservoir is $50.41 per day. Based on a maximum of 200,000 visitor-days per year across a range of activities, the maximum annual value of recreation is nearly $10.1 million.

Table C-33. Estimated Maximum Annual Visitation and Value by Activity, Based on Local Reservoir Activity Patterns

Activity	Maximum Number of Visitor-Days [a]	Value per Visitor-Day ($2015) [b]	Maximum Economic Value ($2015)
Shore fishing	17,400	$87.05	$1,514,692
Boat fishing	9,000	$87.05	$783,462
Picnicking	46,000	$21.69	$997,912
Sightseeing	39,600	$51.78	$2,050,360
Swimming/beach use	45,200	$44.53	$2,012,862
Walking	5,800	$73.02	$423,496
Bicycling/motorcycling	2,600	$195.30	$507,787
Off-road vehicle use	200	$52.05	$10,411
Horseback riding	800	$22.37	$17,893
Boating/waterskiing	31,200	$52.98	$1,653,003
Hunting	600	$72.98	$43,786
Other	1,600	$41.16	$65,851
Total	200,000	$87.05	$10,081,515

Source: Rosenberger 2016.
[a] Based on activity patterns at Black Butte Reservoir.
[b] Visitor-day values based on Loomis 2005 and updated into 2015 dollars.

The alternatives' operations under the various alternatives would likely affect recreational use and values at Sites Reservoir by causing changes in the surface area available for recreation. The CALSIM II modeling has projected the end-of-month storage volumes and surface areas for each

alternative. For some alternatives, water storage and surface area would be considerably below maximum levels during the summer months—the peak recreation season, in many years. In these conditions, the ability to use the facilities would be limited, crowding would occur, and the overall recreation experience would be impaired. Such effects can reduce visitation levels and/or diminish the economic value of recreational activities.

Table C-34 shows assumptions regarding the share of maximum economic value that could be obtained under other future conditions. It is assumed that full economic value would be obtained in any month when the reservoir's end-of-month surface area is more than 10,000 acres. Estimates of end-of-month surface area for May, June, and July are weighted equally in the quantification of recreation values.

Table C-34. Share of Maximum Economic Value Obtained for Ranges of Surface Areas

End-of-Month Surface Acreage	Percent of Maximum Recreation Value
More than 10,000 acres	100%
8,000 to 10,000 acres	80%
6,000 to 8,000 acres	60%
4,000 to 6,000 acres	40%
2,000 to 4,000 acres	20%
Less than 2,000 acres	0%

The potential substitution effects of merely relocating existing recreational activities from other nearby reservoirs to Sites Reservoir must also be considered to quantify net NED recreation benefits accurately. To the extent that substitution would occur, it would not necessarily represent a change in NED benefits. Based on data compiled by Reclamation, recreational use at reservoirs in the market area that would be served by Sites Reservoir is apparently less than capacity.[26] Specifically, current regional recreational use (demand) is approximately 64 percent of annual capacity. Although Sites Reservoir could offer capacity benefits during peak periods (e.g., weekends and holidays), even accounting for future population growth and related increases in recreation demand, existing facilities likely could accommodate most demand. Therefore, the addition of Sites Reservoir would likely cause some recreational visitors to simply shift their trips from other reservoirs in the region, and therefore may not contribute appreciably to additional recreational use in the region.

However, the market area for reservoir recreation in the region may not be as large as assumed in the analysis outlined above. If Sites Reservoir were to serve a smaller geographic market (for example, because of rising transportation costs), it could be argued that the region's existing facilities would not be adequate to meet its recreation demand. For example, overcrowding is a concern at nearby Black Butte Reservoir, where visitation levels are approximately 127 percent of capacity. Such overcrowding can deter recreational use in the region, and can cause visitors to value their experience less.

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[26] The reservoirs considered include Englebright Reservoir, Lake Pillsbury, Lake Mendocino, Camp Far West Reservoir, Rollins Reservoir, Collins Lake, Berryessa Reservoir, Folsom Lake, Lake Oroville, Indian Valley Reservoir, Stony Gorge Reservoir, Black Butte Reservoir, and East Park Reservoir.

Development of new recreational opportunities at Sites Reservoir may enable local residents to participate in reservoir-based recreation when they would not have done so otherwise. In addition, even for those people who have recreated elsewhere (particularly at overcrowded facilities), the quality of the recreational experience at Sites Reservoir may be higher, thereby generating incremental recreation benefits.

Based on these considerations, this analysis conservatively assumes that most recreational use (75 percent) at Sites Reservoir would represent substitution from other reservoirs, and therefore, would not generate any new "net" recreation benefits. Only the remaining 25 percent of visitation would represent new and/or enhanced recreational activity that would generate NED benefits. Given the projections of future visitation to the reservoir and the comparatively low share (25 percent) of this total visitation that would be expected to represent new and/or enhanced recreation activity generating NED benefits, the estimates of recreational benefits for Sites Reservoir are considered conservative.

Modeled Results
Table C-35 presents the results of the recreation benefits analysis.

Table C-35. Estimated Annual Recreation Benefits ($1,000s, 2015 Dollars)

Alternative	Annual Benefits [a]		Annualized Benefit [b]
	2025	2060	
Average Conditions [c]			
Alternative A	$2,472	$2,472	$2,241
Alternative B	$2,452	$2,452	$2,223
Alternative C	$2,558	$2,558	$2,319
Alternative D	$2,558	$2,558	$2,319

[a] Annual benefits reflect consumer surplus value for various recreational activities supported by Sites Reservoir and water operation scenarios under year 2025 and year 2060 levels of development. Benefits are attributed only to the 25 percent of future visitation expected to be from new recreational use.

[b] Annualized benefits represent avoided costs relative to the Future No Project conditions over the planning horizon (2031 to 2130), and are adjusted for expected variations in surface area conditions. Annual average is less than 2025 and 2060 values due to initial short ramp-up period before full benefits are generated.

[c] Average over the entire hydrologic sequence (1921 to 2003).

As shown in Table C-35, annualized recreational benefits under average conditions are estimated to be between approximately $2.2 million and $2.3 million, depending on the alternative's typical drawdown conditions. The greatest benefits are anticipated under Alternatives C and D.

The extent of recreational benefits is not expected to change over the planning horizon. It is assumed that recreation visitation would be determined primarily by water management scenarios (i.e., level of drawdown during the peak recreation season) rather than by long-term population growth in the region.

Other Reservoir Recreation
Recreation at other reservoirs in the CVP and SWP water systems was evaluated based on the effect of the alternatives on operational changes in these systems. Operational effects were evaluated at San Luis Reservoir, Folsom Lake, Lake Oroville, Shasta Reservoir, and Trinity Lake.

The alternatives would affect the long-term average water storage, elevation, and surface area of these other reservoirs, thereby resulting in potential effects on recreation. Overall, the alternatives would be expected to result in minor increases in storage, reservoir levels, and surface areas at the Shasta, Trinity, Oroville, and Folsom facilities. A minor decrease in these parameters at San Luis Reservoir would also be expected. Assuming that recreation is positively correlated to surface area, the alternatives would have a net positive impact on recreation at other lakes and reservoirs that are part of the CVP and SWP supply systems. These minor beneficial impacts were not quantified for the Draft Feasibility Report.

River Recreation

The alternatives would also change the flows and temperature in the Sacramento River system and connected Delta. These effects could alter the suitability of these waterways for river-based recreation, such as boating—including kayaking and canoeing. Because of the inherent difficulty translating flow and fishery effects into related changes in recreational benefits, these benefits are acknowledged here, but not quantified for the Draft Feasibility Report. Appendix E presents more details regarding the potential physical benefits to recreational resources.

C.10 Summary of Benefits

Table C-36 presents the total NED benefits for the alternatives.

Using the Federal discount rate of 2.875 percent over 100 years, the total annual benefits for the alternatives would range from $278.6 million for Alternative D, to $323.2 million for Alternative C. Based on the estimated total annual costs for the alternatives, Alternative C was identified as the NED plan, with projected net benefits of $135.8 million, and a BCR of 1.72. Alternative D had both the lowest net benefits ($90.4 million) and the lowest BCR (1.48).

Table C-36. Summary of Estimated Annual NED Benefits for the Alternatives ($M, 2015 Dollars)

Beneficiary	Alternative A [a]	Alternative B [a]	Alternative C [a]	Alternative D [a]
Water Supply				
Agricultural	$13.9	$7.7	$13.0	$20.8
M&I	$121.6	$128.8	$136.2	$117.1
Total	$135.5	$136.6	$149.3	$137.9
Incremental Level 4 Refuge	$22.2	$35.8	$37.3	$24.2
Anadromous Fish	$45.7	$33.3	$36.9	$48.1
Water Quality				
Agricultural	$1.2	$1.4	$1.6	$0.9
Urban	$18.9	$20.8	$25.2	$14.0
Delta Environmental	$39.3	$37.8	$44.2	$26.6
Total	$59.5	$59.9	$71.1	$41.6
Hydropower (system) [b]	$19.0	$13.4	$22.0	$20.2
Recreation	$2.2	$2.2	$2.3	$2.3
Flood Damage Reduction	$4.3	$4.3	$4.3	$4.3
Total	**$288.4**	**$285.5**	**$323.2**	**$278.6**

[a] Discounted at the Federal discount rate of 2.875 percent over 100 years. May not total exactly due to rounding.
[b] Ancillary and capacity benefits are approximated for Alternatives A and B.
M&I   =   municipal and industrial
NED   =   National Economic Development
$M   =   dollars in millions

Table C-37 shows the sensitivity results by purpose and alternative.

Table C-37. Sensitivity Analysis Summary of Estimated Federal Annual NED Benefits for the Alternatives ($M, 2015 Dollars)

Beneficiary	Lowest Value (NED Method in Bold) [a]				Highest Value (NED Method in Bold) [a]			
	Alternative A	Alternative B	Alternative C	Alternative D	Alternative A	Alternative B	Alternative C	Alternative D
Water Supply								
Agricultural	$13.9	$7.7	$13.0	$20.8	$28.2	$17.2	$25.9	$56.8
M&I	$121.6	$128.8	$136.2	$117.1	$188.1	$192.1	$198.4	$132.5
Conveyance	N/A	N/A	N/A	N/A	($31.1)	($32.0)	($34.2)	($27.7)
Total	$135.5	$136.5	$149.3	$137.9	$185.3	$177.4	$190.1	$161.5
Incremental Level 4 Refuge	$22.2	$35.8	$37.3	$24.2	$24.1	$39.0	$40.6	$26.3
Anadromous Fish [b]	$29.1	$32.6	$33.0	$23.1	$45.7	$33.3	$36.9	$48.1
Water Quality								
Agricultural	$1.2	$1.4	$1.6	$0.9	$1.8	$2.1	$2.6	$1.2
Urban	$18.9	$20.8	$25.2	$14.0	$18.9	$20.8	$25.2	$14.0
Delta Environmental	$39.3	$37.8	$44.2	$26.6	$203.3	$207.2	$232.1	$166.9
Total	$59.5	$59.9	$71.1	$41.6	$224.1	$230.0	$260.0	$188.2
Hydropower (system) [b, c]	$19.0	$13.4	$22.0	$20.2	$19.0	$13.4	$22.0	$20.2
Recreation [b]	$2.2	$2.2	$2.3	$2.3	$2.2	$2.2	$2.3	$2.3
Flood Damage Reduction [b]	$4.3	$4.3	$4.3	$4.3	$4.3	$4.3	$4.3	$4.3
Total	**$271.8**	**$284.8**	**$319.3**	**$253.6**	**$504.8**	**$499.6**	**$556.2**	**$444.9**

[a] Discounted at the Federal discount rate of 2.875 percent over 100 years.
[b] No sensitivity analysis alternative values determined.
[c] Ancillary and capacity benefits are approximated for Alternatives A , B and D.
M&I = municipal and industrial
N/A = not applicable
NED = National Economic Development
$M = dollars in millions

The greatest difference between the NED benefit approach and the sensitivity analysis occurs in the benefit valuations for M&I water, anadromous fish, and Delta environmental water quality. The NED approaches generally result in more conservative benefit valuations than the alternate valuation methodologies that are used for the sensitivity analyses.

For the NED plan (Alternative C), combining its lower valuation approaches would result in a minimum potential annual NED benefit totaling $319.3 million, which would correspond to an annual net benefit of $131.9 million and a BCR of 1.7. Conversely, using the higher valuation approaches, the maximum annual NED benefit would total $556.2 million, which would correspond to an annual net benefit of $368.8 million and a BCR of 2.97.

For Alternative D, combining its lower valuation approaches would result in a minimum annual NED benefit totaling $253.6 million, which would correspond to an annual net benefit of $64.9 million and a BCR of 1.34. Conversely, using the higher valuation approaches, the maximum annual NED benefit would total $444.9 million, which would correspond to an annual net benefit of $256.3 million and a BCR of 2.36.

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Acronyms and Other Abbreviations

AF	acre-feet
AS	ancillary services
BAWQM	Bay Area Water Quality Economics Model
BCR	benefit-cost ratio
CAISO	California Independent System Operator
cfs	cubic feet per second
CPUC	California Public Utilities Commission
CVM	Contingent Valuation Method
CVP	Central Valley Project
CWC	California Water Commission
Delta	Sacramento–San Joaquin River Delta
DSM2	DWR Simulation Model
DWR	California Department of Water Resources
EC	electrical conductivity
EPM	Energy Portfolio Model
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
F-RAM	Flood Rapid Assessment Model
GCID	Glenn-Colusa Irrigation District
GIS	geographic information system
LCPSIM	Least-Cost Planning Simulation Model
LCRBWQM	Lower Colorado River Basin Water Quality Model
M&I	municipal and industrial
MAF	million acre-feet
mg/L	milligram(s) per liter
MWD	Metropolitan Water District of Southern California
NED	National Economic Development
NMV	nonmarket valuation

NODOS   North-of-the-Delta Offstream Storage
NPV   net present value

O&M   operations and maintenance
OMWEM   Other Municipal Water Economics Model

P&Gs   Principles and Guidelines
PR&G   Guidelines for implementing Principles & Requirements
PARO   Power and Risk Office

RA   resource adequacy
Reclamation   United States Department of the Interior, Bureau of Reclamation
RP   revealed preference
RPS   Renewable Portfolio Standard

SALMOD   Salmonid Population Model
SGMA   Sustainable Groundwater Management Act
SLWRI   Shasta Lake Water Resources Investigation
SP   stated preference
SWAP   Statewide Agricultural Production
SWP   State Water Project
SWRCB   State Water Resources Control Board

TAF   thousand acre-feet
T-C   Tehama-Colusa
TCM   Travel Cost Method
TDS   total dissolved solids
TEV   total economic value

USACE   United States Army Corps of Engineers

WSIP   Water Storage Investment Program
WTP   willingness to pay
X2   A Delta management tool, defined as the distance in kilometers from the
               Golden Gate Bridge to the location where the tidally averaged near-bottom
               salinity in the Delta measures 2 parts per thousand.