BUREAU OF RECLAMATION

Final Feasibility Report
Appendix C – Economics

North-of-the-Delta Offstream Storage Investigation

U.S. Department of the Interior December 2020

Mission Statements

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

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

Final Feasibility Report
Appendix C – Economics

North-of-the-Delta Offstream Storage Investigation, California
Interior Region 10 • California-Great Basin

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Cover Photo: Sites Reservoir proposed site (Sites Project Authority)

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C.1 Introduction

This technical appendix to the Feasibility Report for the North-of-the-Delta Offstream Storage Investigation (Investigation) documents National Economic Development (NED) benefit analyses to support Federal plan formulation and evaluation. The benefit analysis herein also considers economic guidance by the California Water Commission for the estimation of public benefits, in anticipation of potential funding eligibility under the State of California's Water Quality, Supply, and Infrastructure Improvement Act of 2014. The Investigation is a feasibility study evaluating alternatives to develop irrigation, municipal and industrial (M&I), and environmental water supplies, primarily through the construction of Sites Reservoir in Colusa and Glenn Counties, California.

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.

Investigation-Specific Planning Objectives

The NODOS Investigation planning objectives were developed based on identified water resources problems, needs, and opportunities in the study area and specific direction in the study authorization. Planning objectives evolved over the course of the study. The economic analysis for the initial alternatives is considered in Attachment C.1. An initial objective for improvement of Delta Environmental and Export Water Quality was used for the evaluation of initial alternatives, but later refined and replaced with CVP Operational Flexibility and Delta Ecosystem Enhancement. Similarly, an initial secondary objective for sustainable hydropower was later dropped. The objectives for the final, refined analysis of alternatives are described below.

Final Primary Objectives

- **Water Supply:** The NODOS Sites Reservoir Project would provide increased water supply and improve the reliability of water deliveries for municipal, industrial, and agricultural uses, especially during drought conditions.
- **CVP Operational Flexibility:** CVP Operational Flexibility is the benefit accruing to the Federal Government from an increased ability to allocate additional water supplies through an investment by the United States in a water supply project. The investment would enable the Federal Government to deliver benefits and better meet project purposes by increasing the efficiency, reuse, or multiple use of existing supplies or by reducing the impacts of regulatory or capacity constraints on an existing Reclamation project. The NODOS Sites Reservoir Project would provide additional water to relieve some of the existing operational constraints in the CVP system, and meet obligations under Federal and State law. This

would include providing environmental benefits to anadromous fish, refuges, and water quality, as well as providing CVP yield diversification through new facilities.

- **Anadromous Fish:** The NODOS Sites Reservoir Project would benefit anadromous fish (including endangered winter-run Chinook salmon) and other aquatic species by improving temperatures in the Sacramento, Feather, and American rivers. Conserving higher storage levels in CVP reservoirs to be used for operational flexibility provides a distinct opportunity for benefits through the preservation of coldwater pools; it also improves downstream water temperature management in Below Normal, Dry, and Critical water years.
- **IL4 Water Supply for CVPIA Refuges[1]:** The NODOS Sites Reservoir Project would provide water that is needed to meet the IL4 refuge water supply demands established in the CVPIA (P.L. 102-575, Title 34). IL4 refuge water supply obligations established by the CVPIA are not being fully met at all refuges.
- **Delta Ecosystem Enhancement[2]:** The NODOS Sites Reservoir Project would enhance the Delta ecosystem by providing water to convey food resources from the floodplain to the Delta, thereby improving the food chain and quality of the Delta's estuarine habitat for use by Delta smelt and other species.

Final Secondary Objectives

- **Flood Damage Reduction[3]:** The NODOS Sites Reservoir Project would provide an opportunity to reduce flooding in local watersheds.
- **Recreation[4]:** Recreation in the immediate vicinity of the NODOS Sites Reservoir Project would provide opportunities for hiking, fishing, camping, boating, and mountain biking.

Final Alternatives

In accordance with the Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&Gs), the feasibility studies for the alternatives[5] analyze proposed action alternatives and a No Action Alternative. Attachment C.1 describes the initial alternatives and their economic evaluation.

Two alternatives (Alternatives A1 and D1) were selected as Final Alternatives. These alternatives correspond to Alternatives A and D in the initial alternatives, but without pumpback storage. These alternatives represent the range of reservoir sizes that the Authority is considering as it is "right

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[1] This objective is one of the two ecosystem benefits accepted by the California Water Commission that grants the NODOS Sites Reservoir Project the eligibility for the Water Storage Investment Program funding. The California Department of Fish and Wildlife is the authorized agency to oversee the implementation of this benefit.
[2] This objective is one of the two ecosystem benefits accepted by the California Water Commission that grants the NODOS Sites Reservoir Project the eligibility for the Water Storage Investment Program funding. The California Department of Fish and Wildlife is the authorized agency to oversee the implementation of this benefit.
[3] This objective is one of the public benefits benefits accepted by the California Water Commission under the Water Storage Investment Program funding.
[4] This objective is one of the public benefits accepted by the California Water Commission under the Water Storage Investment Program funding.
[5] Throughout the analysis, the NODOS project alternatives are generally referenced as the "alternatives."

sizing" the project for its member agencies. The key components of the action alternatives relevant to the economic analysis are summarized below.

- **Alternative A1:** 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 D1:** 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.

C.2 Economic Principles and Methods

This chapter describes Federal economic principles and methods related to plan formulation, estimation of project benefits, and derivation of total annual equivalent benefits. This chapter also describes potential economic valuation methods, and the methods applied to the Investigation.

Guidelines

The economic valuation approach for Federal water resource projects and the Investigation is consistent with the *Federal Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) (WRC 1983). In 2015, the Council on Environmental Quality completed an interagency effort to update the 1983 P&G. This effort led to the development of the *Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies* (PR&G). The PR&G apply only to plans or projects that are initiated after the PR&G take effect, therefore the P&G are the primary guidelines used for the Investigation. The approach to quantifying and monetizing benefits in the PR&G and the P&G are *not* significantly different (DOI 2015).

The P&G indicate the Federal objective of water and related land resources project planning is to contribute to national economic development consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Further, numerous Federal laws such as the Endangered Species Act (ESA) (1973) and Clean Water Act (1972) establish policy and Federal interest in the protection, restoration, conservation, and management of protecting environmental quality.

The Federal Objective, as updated and specified in the Water Resources Development Act of 2007, is that Federal water resources investments shall reflect national priorities, encourage economic development, and protect the environment by:

- Seeking to maximize sustainable economic development
- Seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used
- Protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems

In the Water Resources Development Act of 2007, Congress instructed the Secretary of the Army to develop a new P&G for the U.S. Army Corps of Engineers (USACE) to promote consistency and informed decision-making among Federal agencies. In 2009, the Obama Administration began the process of updating the P&G for Federal agencies engaged in water resources planning, including USACE, Environmental Protection Agency, Department of Agriculture, Department of the Interior, National Oceanic and Atmospheric Administration, Tennessee Valley Authority, Federal Emergency Management Agency, and Office of Management and Budget.

In consideration of the many complex water management challenges and competing demands for limited Federal resources, it is intended that Federal investments in water resources should strive to maximize public benefits, particularly in comparison to costs. Public benefits encompass environmental, economic, and social goals, include monetary and nonmonetary effects and allow for the inclusion of quantified and nonquantified measures. Stakeholders and decision makers expect the formulation and evaluation of a diverse range of alternative solutions. Such solutions may produce varying degrees of effects relative to the three goals specified above, and as a result, tradeoffs among potential solutions will need to be assessed and properly communicated during the decision-making process.

Thus, in addition to traditional, monetized economic development, projects that contribute to Federal ecosystem and species' restoration goals, public health and safety, environmental justice, community benefits, and support recreation opportunities are relevant components of water project planning and development.

Economic evaluation provides a way to understand and evaluate trade-offs that can be quantified and monetized and that must be made between alternatives with respect to objectives, investments, and other social goals. It also provides a means to identify the plan that is acceptable, effective, efficient, and complete, and contributes most favorably to national priorities. The Federal P&G established four main accounts for organizing, displaying, and analyzing project alternatives:

- NED
- Regional Economic Development (RED)
- Environmental Quality (EQ)
- Other Social Effects (OSE)

The above accounts encompass all significant effects of a plan, consistent with NEPA of 1970 (42 United States Code 4321 et seq.) and other Federal guidance. The NED account is the only required account under the 1983 P&Gs, although information that could affect Federal decision-making should be presented in the other accounts. Only the NED benefits are quantified in this appendix.

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 NODOS alternatives, 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 D1 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, because Alternative D1 generates maximum net NED benefits, Alternative D1 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.

Other Considerations

Authorization for Federal financial participation in implementing Sites Reservoir is established by the Water Infrastructure Improvements for the Nation (WIIN) Act, 2015-2016 (Public Law 114-322). The Investigation is a State-led storage project as defined in Section 4007 (a)(2).

A major constraint on Federal cost-sharing is provided in subsection 4007(c)(1) of the WIIN Act:

> (1) In General.—Subject to the requirements of this subsection, the Secretary of the Interior may participate in a State-led storage project in an amount equal to not more than 25 percent of the total cost of the State-led storage project.

Further, WIIN Act Section 4007(c)(2)(C) specifies water supply to Federal wildlife refuges as an example of an authorized Federal benefit under the WIIN Act:

> (C) the Secretary of the Interior determines that, in return for the Federal cost-share investment in the State-led storage project, at least a proportional share of the project benefits are the Federal benefits, including water supplies dedicated to specific purposes such as environmental enhancement and wildlife refuges;

The WIIN Act defines the scope for Federal interest in State-led storage projects as: (1) providing Federal benefits in accordance with the Reclamation laws, and/or (2) providing a benefit in meeting obligations under Federal law. Section 4007(c)(2)(C) further reinforces Refuge water supplies as a Federal benefit under the WIIN Act.

Although all of the final benefits contribute to Federally authorized purposes, CVP Operational Flexibility and Anadromous Fish are considered Federal benefits for this Investigation, consistent with WIIN Act defined scope for Federal interest in State-led storage projects.

In addition to following Federal guidelines in development of economic analysis methods and procedures for the Investigation, consideration was given to economic guidance being developed by the California Water Commission (specifically the Draft Working Paper for Water Storage Investment Program Common Assumptions – Economics [July 29, 2015], available at: https://cwc.ca.gov/Pages/DocumentLibrary.aspx) related to the distribution of Water Storage Investment Program funding available through the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1). This bond initiative dedicated $2.7 billion for investments in water storage projects and designated the California Water Commission as the agency responsible for allocating these funds based on specific criteria (Proposition 1 funding criteria for investments in water storage projects is discussed further in Appendix G - Cost Allocation, and in Chapter 6 of the main body of the Feasibility Report). The California Water Commission may fund portions of project costs that contribute to the public benefits of these projects, which must also provide measurable benefits to the Delta ecosystem or its tributaries.

Projects that may receive State funding under Proposition 1 will be selected by the California Water Commission through a competitive public process based on a project's expected return on the public investment as measured by the magnitude of the public benefits provided. The public benefits categories defined by Proposition 1 include:

> (1) Ecosystem improvements, including changing the timing of water diversions, improvement in flow conditions, temperature, or other benefits that contribute to restoration of aquatic ecosystems and native fish and wildlife, including those ecosystems and fish and wildlife in the Delta.
>
> (2) Water quality improvements in the Delta, or in other river systems, that provide significant public trust resources, or that clean up and restore groundwater resources.
>
> (3) Flood control benefits, including, but not limited to, increases in flood reservation space in existing reservoirs by exchange for existing or increased water storage capacity in response to the effects of changing hydrology and decreasing snow pack on California's water and flood management system.
>
> (4) Emergency response, including, but not limited to, securing emergency water supplies and flows for dilution and salinity repulsion following a natural disaster or act of terrorism.
>
> (5) Recreational purposes, including, but not limited to, those recreational pursuits generally associated with the outdoors.

In recognition that the Investigation is a potentially eligible project to receive funding, economic guidance by the California Water Commission, related to the estimation of public benefits, was considered as part of the Investigation. The California Water Commission's proposed methods for estimating benefits are generally consistent with Federal guidelines in general. The California Water Commission guidelines were considered, to ensure consistency in approach and 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.

As described in the P&G, water resources project plans shall be formulated to alleviate problems and take advantage of opportunities in ways that contribute to NED. The alternative plan with the greatest net NED economic benefit is identified as the NED Plan and often has the greatest potential for Federal investment. The NED account includes the following categories of goods and services: (1) M&I water supply; (2) agricultural floodwater, erosion, and sediment reduction; (3) agricultural drainage; (4) agricultural irrigation; (5) urban flood damage reduction; (6) power (hydropower); (7) transportation (inland navigation); (8) transportation (deep draft navigation); (9) recreation; (10) commercial fishing; and, (11) other categories of benefits for which procedures are documented in the planning report and are consistent with the general measurement standard in the P&Gs. While multipurpose projects may provide additional types of benefits, these categories coincide with project purposes in which an established Federal financial interest exists. Other categories of benefits may be allowed, or may be included in, congressional authorization for a specific project.

Environmental benefits, including fisheries and ecosystem resources, are typically included in the EQ account if monetary units cannot be attributed to these benefits. However, in some cases, environmental benefits may be developed as monetary units, and be included in the NED account under "other categories of benefits." For this analysis, benefits were monetized for Anadromous Fish, IL4 Water Supply for CVPIA Refuges, and Delta Ecosystem Enhancement.

NED costs are the opportunity costs of resource use and require consideration of the private and public uses that producers and consumers are making of available resources, now and in the future. For goods and services produced in a competitive market, price is often used to reflect opportunity cost. Consequently, market prices should be used to determine NED costs, provided market prices reflect the full economic value of a resource to society. The market price approach should reflect the interaction of supply and demand. If market prices do not reflect total resource values, surrogate values may be used that approximate opportunity costs based on an equivalent use or condition.

The two primary decision criteria used in a Federal economic analysis are net benefits and the benefit-cost ratio. The net benefit is the difference between the net present value of benefits and costs, and it measures the extent to which benefits to the nation exceed project costs. The benefit-cost ratio is calculated by dividing annual project benefits by annual project costs. The net benefits and costs of alternative plans are compared to identify the plan that reasonably maximizes net benefits, or the NED Plan. The NED Plan is not necessarily the plan with the greatest benefits, but rather the plan that maximizes benefits given the cost to the nation. Section 1.10.2 of the P&G requires that the NED Plan be selected unless the Secretary of the Interior grants an exception.

The alternatives' costs are documented in the Engineering Summary, Appendix B. Together, Appendices B and C 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.

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 (WTP) 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.

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 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).

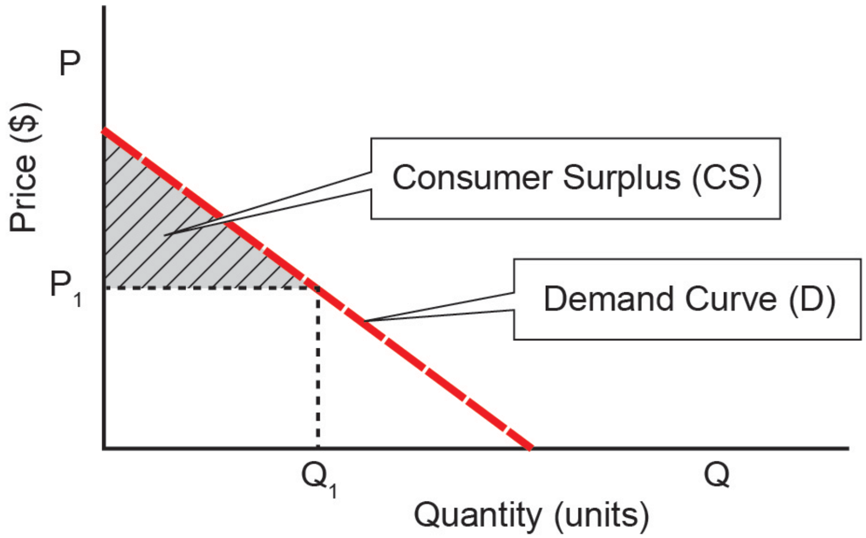

Figure C-1. Demand Curve and Consumer Surplus

For the alternatives, farmers receiving 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 benefits of such actions are often difficult to quantify. The costs of environmental protection or enhancement actions may be estimated using typical market-based metrics. Recreational activity reflects another commonly incurred market value that can be used to estimate benefit value for some environmental resources.

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. Therefore, 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 primarily capture 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 NMV. Market values refer to conditions for which a price can be observed, such as crops for human consumptive uses. NMV 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 four valuation approaches:

- Actual or simulated market prices
- Change in net income
- Cost of the most likely alternative
- Administratively established values

In general, the P&G 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. Revealed preferences are based on observed behavior that reflects preferences, while stated preferences are based on directly asking individuals to indicate preferences in a hypothetical setting. Demand functions cannot always be estimated for many goods and services due to a lack of observed market 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. In addition, benefits transfer, which uses values from previous economic studies (developed with any of the four valuation approaches indicated by the P&G), may be used to estimate willingness to pay, provided they are relevant to the study area and output being valued. Each of the valuation approaches recommended by the P&G to estimate NED economic benefits is briefly described below.

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

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 proxy 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 analysis parameters and benefit valuation approaches used for the economic analysis of the alternatives. Valuation approaches are presented for water supply reliability, CVP operational flexibility, Incremental Level 4 refuge supply, anadromous fish survival, Delta ecosystem enhancement, 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.

Economic Analysis Parameters

Economic parameters and future without-project conditions form the basis for the economic analysis presented in this report. The economic analysis assumptions outlined in the P&G include those related to full employment, risk neutrality, and others. Parameters specific to the Investigation include period of analysis and discount rate, summarized below.

- **Period of analysis** – The period of analysis is the anticipated period over which project effects are likely to accumulate. The P&G allow for a period of analysis for up to 100 years based on anticipated project life. A 100-year period of analysis is believed appropriate for the Investigation because of the anticipated longevity of a dam and reservoir project. The economic benefits of the project would begin to accrue the year construction is completed. In this analysis, annual benefits are estimated for the year 2030 for all purposes. Future benefit projections are also estimated for later years for some purposes. More specifically M&I water use benefits are estimated for 2070 and other water supply purposes (e.g. agricultural and IL4 Water Supply for CVPIA Refuges) were estimated for 2040 values. The 2040 model year benefits also incorporate projected effects on agricultural and environmental-related benefits values of the future groundwater use constraints resulting from Sustainable Groundwater Management Act (SGMA). For the M&I and non-M&I water purposes their interim-year values were interpolated on a straight-line basis and then subsequently held constant after their latter model year (i.e. 2040 or 2070) until the end of period of analysis in 2129.

- **Discount rate** – The discount rate is the rate at which society is willing to trade off present benefits for future benefits. NED impacts are compared at a common point in time in average annual equivalent terms. This is accomplished by discounting the benefit stream, deferred installation costs, and operation, maintenance, and replacement costs to the beginning of the period of analysis using an established Federal discount rate. Installation costs (including construction costs) are brought forward to the end of the installation period by charging compound interest from the date costs are incurred (interest during construction). The Federal discount rate for plan formulation and evaluation is established annually by the Secretary of the Treasury, pursuant to 42 United States Code 1962d-1. A Federal discount rate of 2.75 percent (the Federal discount rate established for fiscal year 2019) is used in this feasibility study.

NED Agricultural Water Supply Benefits

The alternatives will improve water supply reliability to agricultural water users, particularly during dry and critical water year types. 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 combined application of the SWAP model to projected changes in water supply deliveries resulting from the alternatives and use of the Water Transfer Pricing model.

SWAP is an economic model of irrigated agriculture in California that is frequently applied for feasibility studies and policy analyses. It estimates the value of water supply reliability according to the change in the agricultural net income associated with changes in water supply. The SWAP model provides a regional evaluation of the benefits (or costs) of changes in water supply availability based on its projected impacts on cropping patterns and crop budgets. The SWAP model accounts for changes to crop mix, inputs, and other water supplies in response to the increased water supply provided by the project alternatives. The benefit values determined by the SWAP model were also be applied to CVP Operational Flexibility, Delta Ecosystem Enhancement and IL4 Water Supply for CVPIA Refuges.

The Water Transfer Pricing model is used to estimate the cost of the most-likely alternative water supply for the agricultural, CVP Operational Flexibility, Delta Ecosystem Enhancement and IL4 Water Supply for CVPIA Refuges. As a transaction-based valuation approach, the benefit valuations resulting from the Water Transfer Pricing model were higher than those obtained from the SWAP analysis.

Based on these two boundary values, it was determined that the mid-point values between the two approaches should be used to estimate the future water supply benefits. Evaluation the two valuation approaches found that both provided reasonable and appropriate valuation of the economic benefit of the project alternatives' water supply increase. Use of the SWAP model may be preferred as a valuation approach based on its capabilities to estimate changes to consumer surplus, land use, and farm income. As such SWAP analysis is best at characterizing the long-term response from water supply changes and its resulting impacts on the agricultural economy. In contrast, the water transfer model quantifies willingness-to-pay values for water supply across different water year types, regions, sellers and purchasers. Water Transfer Pricing model's dataset primarily consists of one-time or spot market transactions that represents the economic value of water supply mostly in times of critical need.

It was determined that a mid-point average of the two valuation approaches is the preferred benefit valuation approach since the project alternatives will provide long-term water supply during periods with major water availability shortages (i.e. dry and critical water year types). This blended valuation approaches provides a better and more moderate and characterization of the project alternatives benefits that recognizes both its provision of a reliable and long-term water supply and also its water supply contribution during times of critical need. This mid-point valuation approach is hereafter referred to as the SWAP Results with Adjustment valuations approach to distinguish it from the lower SWAP unadjusted valuation and higher Water Transfer Pricing valuation approaches.

NED M&I Water Supply Benefits

The M&I water supply benefit analysis relies on California Water Economics Spreadsheet Tool (CWEST) modeling to determine the project's future M&I water supply benefits applied to CalSim II modeling to quantify the project's expected future M&I deliveries under different water year conditions.

CWEST was developed for the US Bureau of Reclamation's Coordinated Long Term Operation of the Central Valley Project and State Water Project Environmental Impact Statement (LTO EIS) Environmental Consequences analysis. CWEST is an economic benefit valuation tool developed to provide consistent and transparent analysis of economic benefits of M&I water supplies for CVP contractors and SWP Table A contract holders. CWEST is an economic simulation and optimization tool that represents each individual CVP and SWP M&I water user's decision-making under 2030 and 2070 conditions, based on publicly available information. CWEST determines how CVP and SWP M&I water users will meet their 2030 and 2070 water demand levels at their minimum economic cost, given their supply constraints and alternatives.

The two periods of analysis, 2030 and 2070, were selected to represent conditions at the start of operation and a future condition, respectively. Population projections were obtained from the Demographic Research Unit, California Department of Finance, for 2030 as well as individual contractor agencies' Urban Water Management Plans. These datasets contain projections beyond 2030 that were used to develop the 2070 conditions. The future date of 2070 was used for the benefit analysis in part as it approximates the midpoint of the 100-year period of analysis. The CWEST model was developed by the California Water Commission to analyze and estimate 2030 and 2070 water supply benefits for its 2016 Water Storage Investigation Program. As a result, 2070 conditions was also selected for analysis to make direct use of the existing CWEST model data set. CWEST is considered the best approach to quantifying a long-term future M&I conditions due to the future population, water supply portfolios as well as and other conditions and factors incorporated in its modeling. The CWEST model includes other alternative supplies in its least-cost optimization and thereby can be expected to ensure a more realistic representation of the future demand and supply conditions for benefit analysis.

NED CVP Operational Flexibility Benefits

The CVP is operated to meet a variety of project purposes, including providing water for irrigation and domestic uses, fish and wildlife mitigation, fish and wildlife enhancement, and water quality. The

CVP has the potential to deliver about 7 MAF annually to agricultural and M&I customers in addition to environmental purposes. California's Federal and State water systems have limited flexibility in timing, location, and capacity to meet the multiple purposes of the projects due to operational and demand constraints. There are several factors that have significantly affected the availability of the CVP to store and provide water for contract delivery: Delta pumping constraints; the establishment of three major regulations – the CVPIA, State Water Resources Control Board Decision 1641, and the Reasonable and Prudent Alternatives from the 2008/2009 Biological Opinions on Long-Term Operation of the CVP and SWP; and natural variations in water supply based on annual precipitation.

The Operational Flexibility purpose, according to the WIIN Act, is defined as the benefit accruing to the Federal Government from an increased ability to allocate additional water supplies through an investment by the United States in a water supply project. The investment would enable the Federal Government to deliver benefits and better meet a project's purposes by increasing the efficiency, reuse, or multiple use of existing supplies or by reducing impacts of regulatory or capacity constraints on an existing Reclamation project.

The NODOS Project would provide additional water to relieve some of the existing operational constraints in the CVP system, and meet obligations under State and Federal law. This would include providing environmental benefits to anadromous fish, refuges, and water quality, as well as CVP yield diversification through new facilities. Operational flexibility water would be part of the CVP allocation, and the scheduling and delivery for any specific purpose would be subject to water right permit conditions and contractual requirements.

The CVP Operational Flexibility benefits for all future water use were estimated using the SWAP Results with Adjustment approach findings for water transfers for environmental water uses (as the least cost use) applied to projected changes in water supply deliveries under each alternative. As a result, the estimated total benefit value for the CVP Operational Flexibility benefits are more conservative than they would alternatively be estimated based on water transfers for agricultural supplies.

Incremental Level 4 Water Supplies for CVPIA Refuges Benefits

The alternatives provide opportunities for increased water deliveries for Incremental Level 4 refuge needs. The economic benefits of the alternatives' increases in Incremental Level 4 refuge water deliveries are estimated using the SWAP Results with Adjustment approach values applied to projected changes in water supply deliveries under each alternatives.

NED Anadromous Fish Benefits

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.

NED Delta Ecosystem Enhancement Benefits

Since 2004, monitoring programs in the Delta have documented a decline of several pelagic (open-water) fishes (Delta smelt, longfin smelt, juvenile striped bass, and threadfin shad) in the freshwater portion of the estuary. The decline may have several causes, but reduced food availability is a contributing factor. The Delta Smelt Action Plan (DWR and CDFW, 2005) identified a need for additional food resources in the lower Cache Slough and lower Sacramento River areas to sustain Delta smelt and other estuarine-dependent species (e.g., Delta smelt, longfin smelt, Sacramento splittail, starry flounder, and California bay shrimp).

DWR and CDFW performed a pilot study in collaboration with other agencies and farmers in the summer of 2016 that released water into the Delta through a wetland and tidal slough corridor. Monitoring showed that the nutrient-rich "pulse flow" resulted in a phytoplankton bloom and enhanced zooplankton growth and egg production. With the NODOS Sites Reservoir Project there is an opportunity to provide a dedicated source of water to convey water through the wetland and tidal slough corridor to provide a sustainable source of food for Delta species.

An adjusted valuation based on the SWAP Results with Adjustment values for Agricultural Water Supply benefits using North of Delta deliveries was used to estimate the Delta Ecosystem Enhancement benefits for each alternative.

The economic benefits of the alternatives' Delta Ecosystem Enhancement benefits are estimated using the SWAP Results with Adjustment approach findings applied to projected in North of Delta water supply deliveries for the purpose under each alternatives.

NED Recreation Benefits

Development of the NODOS project would provide new recreational facilities and opportunities. Recreation benefits are quantified through application of benefit transfer approach and travel cost methods using expected future recreation use levels and unit values derived from recent comparative analysis of reported use values from more than 400 economic valuation studies (Rosenberger 2016). This approach corresponds to the "market price" approach described in the P&G.

NED Flood Damage Reduction Benefits

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.

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. Additional information is provided in Appendix G. The average annual benefits reported and used for the economic analysis is a weighted average based on expected frequency and project performance under different water year conditions. This approach ensures that the variation in potential benefits for different water year types are incorporated into the economic analysis.

As identified in their respective subsections, several benefit categories lack adequate data to quantify the entire benefit. This is especially true for benefits providing ecosystem enhancement, including the Anadromous Fish, IL4 Water Supply to CVPIA Refuges, and Delta Ecosystem Enhancement benefits. No available willingness to pay studies appeared appropriate for application to these benefits, and therefore market price or alternative cost methods were applied as a proxy to estimate the benefits.

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 the M&I benefits was assumed population growth and its impact on future water demand. Each alternative is assumed to become fully operational in 2030, with a time horizon of 100 years. In estimating benefits, two future conditions were analyzed: 2030 and 2070. The 2030 and 2070 estimates of urban water demand are based on historical and projected populations and persons per household obtained from California Department of Finance (DOF) projections for 2015 to 2060. Subsequent 2060 to 2070 population growth was extrapolated based on the prior 10-year period (2050 to 2060) and then held constant after 2070.

The annualized benefit calculation interpolated annual benefits (reflecting urban population growth) between 2030 and 2070 on a yearly basis, and then assumed constant annual benefits from 2070 to the end of the alternatives' time horizon in 2129. These benefits are shown diagrammatically on Figure C-2. The total net present value (NPV) of M&I benefits over a 100-year period between 2030 and 2129 was calculated based on the aggregated discounted value the annual values estimated for each year during the 100-year period of analysis. The NPV total was then annualized (using the Federal discount rate of 2.75 percent) to determine the average annual benefit value for the 100-year study period.

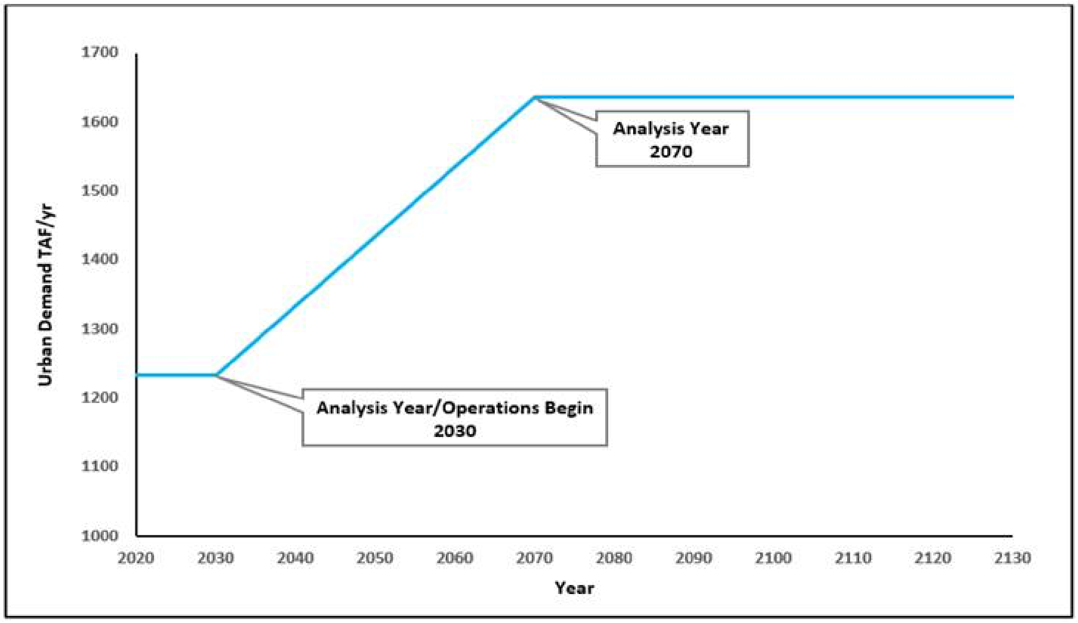

Figure C-2. Assumed Population Growth (and Associated Urban Water Demand), Interpolated between 2030 and 2070, and then Remaining Constant beyond 2070 (Example)

The same approach was used for the annualized benefit calculation of the agricultural and environmental water supply. However, given its 2030 and 2040 model years, annual benefits were only interpolated for each the interim period. After 2040, the benefits were assumed to remain constant over the remainder of the period of analysis.Water Transfer Pricing Estimation Method

Water purchases on the California spot water market are generally considered the most likely alternative to acquire similar water supplies to the expanded Los Vaqueros Project. The California water market is a developed market with set rules and transactional procedures. This section describes the development of a Water Transfer Pricing model that simulates the spot water market prices. This model is used in combination with the SWAP model analysis to estimate the least-cost supply alternative for agricultural, CVP Operational Flexibility, Delta Ecosystem Enhancement and IL4 Water Supply for CVPIA Refuges.

A database of California surface-water market sales was developed for use in estimation of the Water Transfer Pricing model. Information for each transaction was researched and recorded to allow statistical analysis of a variety of factors influencing water trading activity and prices. During the research, transactions occurring from 1990 through 2016 were documented. The transactions were filtered for this analysis according to the following criteria:

- Water sales originating outside the operating region of the SWP facilities were excluded. These regions include the North Coast, North Lahontan, and South Lahontan regions.
- The Water Transfer Pricing model, which relies upon the database of water transactions described above, is intended to estimate spot market prices and trading activity. Thus, multiyear transfers and permanent water entitlement sales were excluded.

- "Within-project" transfers were removed from the analysis, because they do not reflect "arms-length" transactions, whereby buyers and sellers are separate parties acting in their individual interests.
- Transactions associated with SWP Turnback Pool supplies were excluded because they are associated with rules that limit market participation.
- Purchases of "flood" supplies (e.g., SWP Article 21 and CVP 215) were excluded as prices are administratively set and do not have comparable reliability to the Final Alternatives.
- Reclaimed and desalination water sales were removed from the analysis because they represent cost rather than market-based supplies.
- Leases of groundwater pumping allocations within adjudicated groundwater basins were excluded because they take place within isolated markets with different regulatory conditions from the market for surface water.
- Water sales with incomplete or inadequate information were excluded.

Following application of the above criteria, 723 spot market transfers remained to support the statistical analysis. Transactions with verified terms were added since the previous analysis. These primarily consist of spot market transactions occurring in 2016 that were verified through more recent research. All prices were adjusted to July 2015 dollars using the Consumer Price Index.[6] Prices and volumes are presented from the seller's perspective and do not include conveyance charges or losses incurred by the buyer.

The regression model theorizes that the price of water traded can be estimated through consideration of the following market factors: water supply, geographic location, municipal demand, buyer type, and State and Federal water supply acquisition programs.[7] These factors are described below.

Although Federal Government and State agencies have recently been more active in recording some information related to water sales or leases, California has few sources that track water transfers between private individuals. Most of the recorded transfers involve a Federal Government or State party either because an agency had to approve the transfer, as is the case when a transfer involves CVP or SWP water, or because a government agency was directly involved in the transfer as a purchaser or a seller. Transfers involving private parties are more difficult to track, because the State does not have any reporting requirements.

In California, single-year transfers of water entitlements issued before 1914 are allowed without review by the State Water Resources Control Board (State Water Board), as long as they do not adversely impact the water rights of a third party (CALFED 2000). For entitlements issued after 1914, the buyer and seller can petition the State Water Board for a one-year temporary transfer. Nonetheless, prices for these transfers are not well documented. As a result, the data for this study were obtained from a mixture of public and private sources. Public sources include the following:

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[6] The Consumer Price Index is considered to be the most appropriate index for adjusting water prices as it is commonly applied to adjust water prices in long-term agreements.
[7] Additional demand and supply factors were tested in the model but did not result in an improvement in overall explanatory power.

- Water Acquisition Program, Reclamation
- Resources Management Division, Environmental Water Account (EWA)
- State Water Bank, DWR
- OnTap database, DWR
- State Water Board, California Environmental Protection Agency
- Various irrigation districts and water agencies

These sources provided information on the Water Acquisition Program, EWA, State Water Bank, and other public water transfers. State Water Bank observations included transfers to the State Water Bank to capture the price the seller receives.

Information on water transfers was also obtained from the January 1990 through December 2010 issues of the *Water Strategist*. The publication, previously called *Water Intelligence Monthly*, assembles information on public and private water transfers. Although not all transfers are recorded in the *Water Strategist*, the publication represents a primary source for water market research. Many of the transfers reported in the *Water Strategist* were independently researched to obtain more specific information and confirm transaction terms. *The Water Strategist* ceased to report on transactions in 2010. In addition, transactions not covered by the *Water Strategist* were researched and verified through direct communication with the transfer participants.

Spot Market Transaction Data Summary

This section provides a summary of the water transaction data applied in this analysis. As described above, the data include single-year transactions from 1990 through 2016 of surface water supplies originating in California's Central Valley. The dataset includes 204 transactions for municipal uses, 367 for agricultural uses, and 152 purchases by environmental users. Figure C-3 shows the number of transactions by end use from 2000 through 2016.[8] As shown, all three end uses are active buyers in most years. However, environmental buyers did not complete any spot market transactions in 2008, 2009, and 2015. For example, in 2015, spot market prices were high due to the extended drought, and environmental buyers were unable or unwilling to purchase water during the year.

[8] Transactions from 1990 through 1999 are not included, to promote readability of the figure.

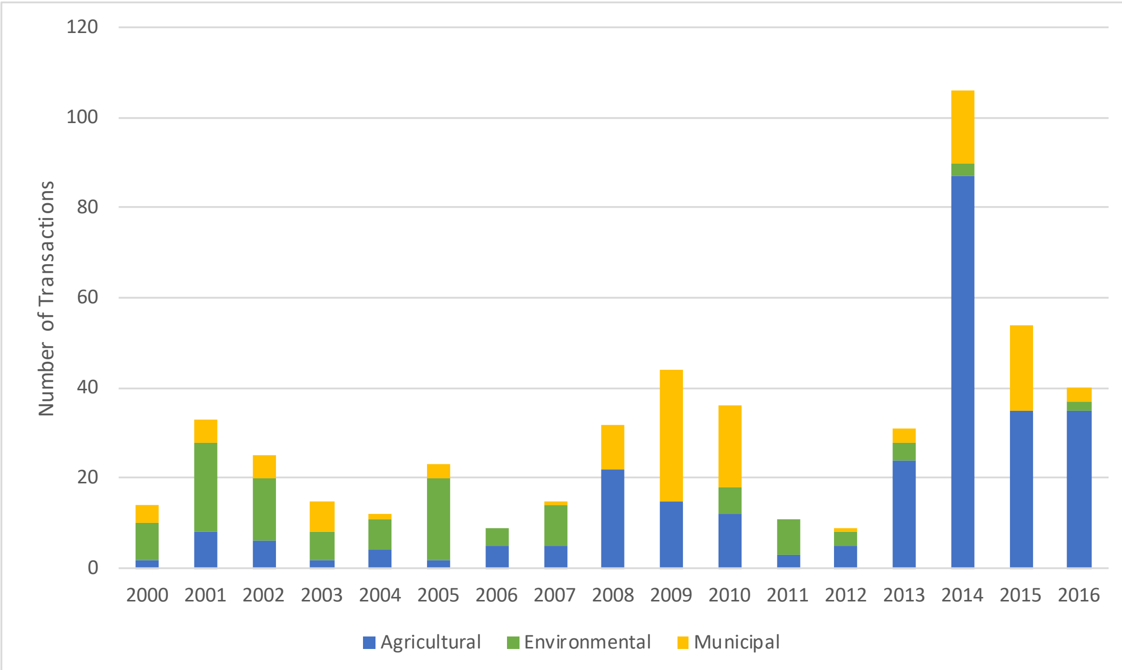

Figure C-3. Spot Market Water Transactions by End Use, 2000-2016

Annual spot market trading varies widely according to annual CVP and SWP allocations, reservoir storage, and other factors. Figure C-4 provides the volume of spot market purchases by end use. As shown, spot market purchases spiked in 2000 when nearly 800 TAF was purchased due to dry conditions. Since then, the volume of water traded in the spot market has been lower. In recent years, the total volume traded has been approximately 300 TAF. The decline may be due to several factors including conveyance constraints in the Delta, development of alternative water supplies such as long-term agreements, recycling and groundwater banking, and increased plantings of permanent crops both north and south of the Delta which have limited the potential supply to the spot market from crop fallowing.

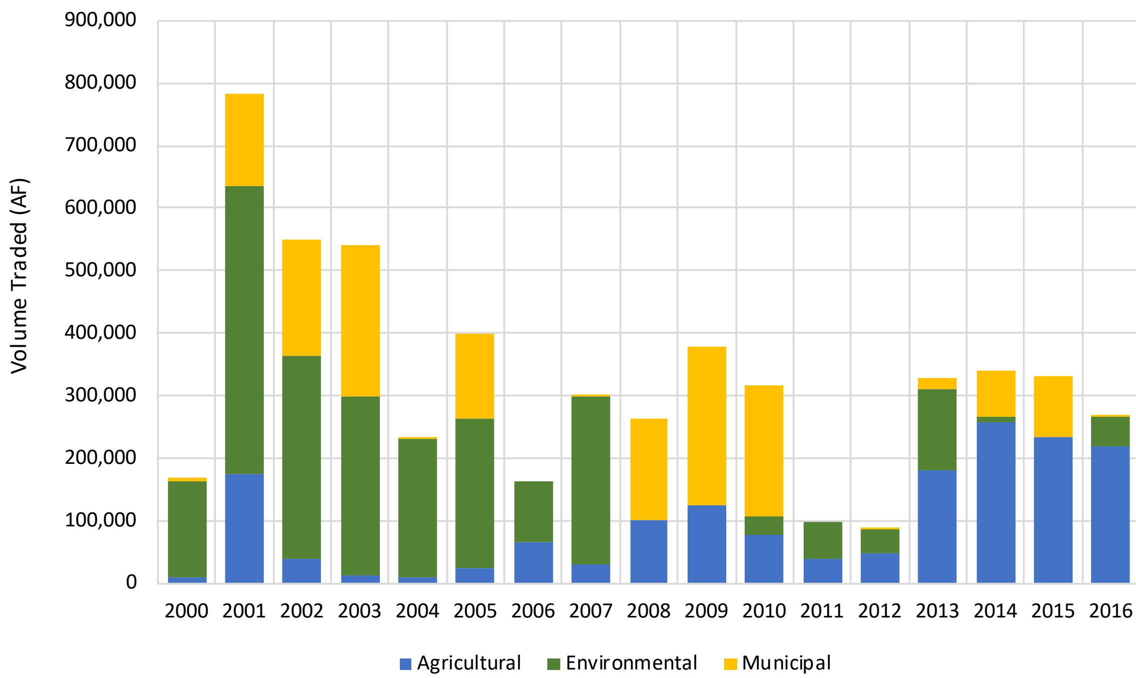

Figure C-4. Spot Market Water Volume Purchased by End Use

Figure C-5 provides average annual spot market prices by end use.[9] As shown, the average annual prices for each end-use category have tended to move together. During the recent drought, the average prices show more variation among the end uses. However, this is largely due to the limited number of transactions completed by environmental buyers during 2014 and 2015 and the limited number of transactions completed by municipal buyers during 2016.

Benefit Estimation Procedures

This study applies a Water Transfer Pricing regression model and builds on a previous analysis completed by Mann and Hatchett (2006) by applying an expanded data set and considering additional factors that influence water market trading prices. The Water Transfer Pricing model developed in this study uses an Ordinary Least Squares regression equation to estimate unit prices for spot market water transfers. The coefficients from the models may be used to forecast future water prices North of Delta (NOD) and SOD.

[9] All prices were adjusted to July 2015 dollars, using the Consumer Price Index, prior to estimating the annual averages.

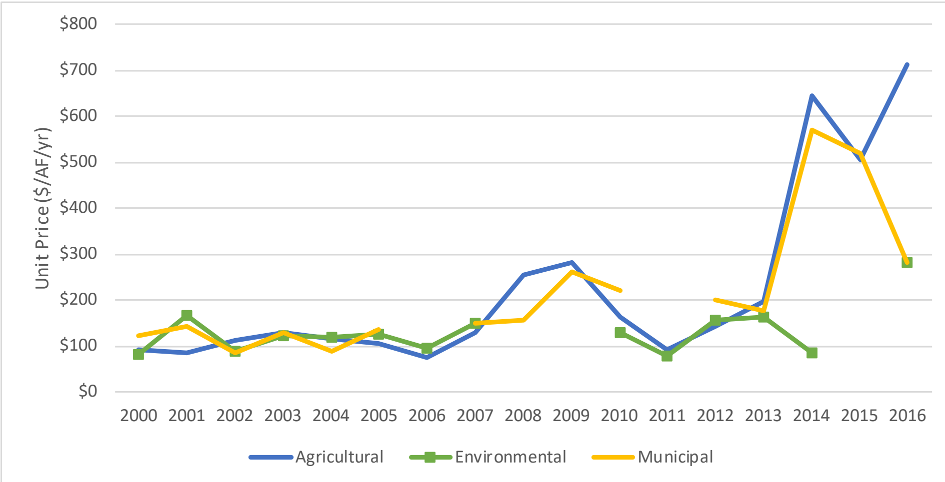

Figure C-5. Spot Market Average Unit Price for Water by End Use

The regression model theorizes that prices and volume of water traded can be estimated through consideration of the following market factors: water supply, geographic location, real water price escalation, buyer type, and State and Federal water supply acquisition programs.[10] These factors are described below.

Water Supply

Hydrologic conditions are a primary driver of water transfer market activity and prices. Therefore, it is important to include variables that appropriately capture water supply conditions to describe water trading activity and prices. In this analysis, water supply conditions are measured using the final annual SWP allocation (DWR 2017) and the final CVP allocation (Reclamation 2017).

Geographic Location

Water prices and trading activity vary by location according to water year type. Consequently, the origin of the water source for each transaction is used to determine geographic differences in water prices. Water sales applied in the regression analysis were allocated among the hydrologic regions identified by DWR. Binary variables are used to denote some of the different geographic regions of buyers and sellers including a variable that identified spot market transfers that involved through-Delta conveyance.

Urban Demand

Due to the growing urban water demand in the State, water transfer prices are anticipated to increase over time. The model includes population as an independent variable to capture the price impact of increased urban water demands (California Department of Finance, 2017). Future water market prices are estimated using forecasted population.

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[10] Additional demand and supply factors were tested in the model but did not result in an improvement in overall explanatory power.

Buyer Type

Previous economic analyses of water prices have concluded that the type of buyer (e.g., M&I, irrigation, and environmental) influences water prices. The water pricing equation tests the influence of buyer type on water price. In this analysis, binary variables are used to estimate price differences among environmental, urban, and agricultural buyers.

Seller Type

CVP and SWP agricultural contractors are the most common water sellers in the spot market. In order to test the influence of the two projects on water prices, a binary variable identifying sellers that are SWP contractors is included in the model.

Drought Water Bank and Environmental Water Account

The State has participated in the water market during drought years to facilitate trades. Under this program, DWR sets up a State Water Bank to facilitate water transfers, primarily from NOD agricultural users to SOD buyers.

The EWA acquired water supplies for environmental purposes annually between 2001 and 2007. The implementation of the EWA impacted spot market trading and prices by introducing a large, new demand for water supplies. A dummy variable separating acquisitions by the State Water Bank and the EWA from other buyers is included to test for the price impacts of the programs. A binary variable is included in the model to test the influence of the two programs on prices and trading activity.

Regression Model

The regression model terms are described below:

lnadjprice = scbuyer + nodbuyer + nodsod + lnpopulation + twppercent + ag + env + dwbewa+ swpseller + e

where:

lnadjprice=Natural logarithm of price per acre-foot, adjusted to July 2015 dollars

scbuyer=1 if South Coast Region water buyer (binary)

nodbuyer=1 if the buyer is North of the Delta (binary)

nodtosod=1 if North-of-Delta water supplier and South-of-Delta buyer (binary)

lnpopulation=Natural log of the population in the year of the transfer

twppercent=The percentage of Project Water (SWP and CVP) that was allocated in the year the transfer occurred

ag=1 if agricultural water end use (binary)

env=1 if environmental water end use (binary)

dwbewa=1 if State Water Bank/Dry Year Water Acquisitions or the Environmental Water Account Acquisitions (binary)

swpseller=1 if the seller was a State Water Project contractor (binary)

e=Error term

Table C-1. Regression Model Results

Independent Variables	Observations	Parameters	RMSE	R-Squared	F-Statistic	P-Value (P > F)
lnadjprice	723	9	0.56	0.61	126.04	0
Dependent Variable lnadjprice						
Independent Variables	**Coefficient**	**Standard Error**	**t-Statistic**	**P-Value (P > |t|)**	**95% Confidence Interval**	
scbuyer	0.23	0.08	2.97	0.00	0.08	0.38
nodbuyer	-0.30	0.06	-5.00	0.00	-0.42	-0.18
nodtosod	-0.05	0.06	-0.73	0.47	-0.17	0.08
lnpopulation	5.63	0.30	19.02	0.00	5.04	6.21
twppercent	-1.47	0.12	-12.22	0.00	-1.71	-1.24
ag	-0.05	0.06	-0.86	0.39	-0.17	0.07
env	-0.21	0.08	-2.72	0.01	-0.36	-0.06
dwbewa	0.21	0.07	2.82	0.01	0.06	0.35
swpseller	0.48	0.07	6.86	0.00	0.34	0.62
constant	-14.09	1.09	-12.96	0.00	-16.22	-11.95

Key:
RMSE = root-mean-square error

The variable twppercent is a measure of annual water availability. The amount of water available was calculated using the SWP and CVP maximum contract amounts, and the percentage of the maximum contract that was delivered each year to the different contractors. The SWP and CVP allocations decrease during drought conditions. Regulatory actions such as the Delta pumping constraints could further impact water deliveries. The statistical relationship between lnadjprice and twppercent is attributable to increased demand for additional water supplies under the hydrologic and regulatory scarcity conditions that drive reduced water allocations. As an example, the coefficient value of -1.47 on the twppercent variable indicates that water transfer prices increase by approximately 29 percent in response to a decrease in percentage of total project water allocation from 50 percent to 30 percent, all else held equal.

The coefficient value on the variable lnpopulation indicates that as population grew from 29.56 million in 1990, to 39.35 million in 2016, water transfer prices increased by a factor of four. The binary variables in the price equation describe conditions that influence prices but are qualitative in nature. The coefficients for env and ag represent the influence that end-water use has on price. When these variables are zero, the model estimates prices to urban water users. Environmental water users generally paid less for water than urban users, as indicated by the negative coefficients. Agricultural buyers were not found to be statistically different than urban buyers. The results show environmental buyers have paid 19 percent less per acre-foot (AF) than urban buyers in the market, with all else being equal.

The variable dwbewa is an indicator that the lease was either a State water lease through the Drought Water Bank of 1991, 1992, 1994, and 2009, or a lease through the EWA program. The binary variable is used to account for the price premium paid by the bank and the EWA program. The coefficient value indicates that water leased through the Drought Water Bank, and water that was purchased through the EWA program, was priced 23 percent higher than other transactions, with all else being equal.

The variable nodbuyer is a binary variable measuring the difference in spot market prices between water originating and remaining NOD and water that was purchased for use SOD. Sales from NOD suppliers to NOD buyers were 35 percent lower than sales where water was purchased for use SOD, suggesting there is a higher value for water SOD. According to the coefficient estimated for scbuyer, water transactions involving buyers in the South Coast region were priced 26 percent higher than acquisitions by buyers in other regions, with all else being equal. Premium prices paid by South Coast buyers result from strong competition for water supplies in the region, and the relatively high-value water uses in the area. The variable swpseller is a binary variable measuring the premium paid for purchasing SWP water. The coefficient on swpseller indicates SWP sellers receive a premium of approximately 61 percent over CVP and nonproject sellers, on average.

Risk and Uncertainty

With each aspect of this report, certain assumptions were made based on engineering and scientific judgment regarding best available information, guidance, methods, and tools. Careful consideration was given to the methods, evaluations, and tools for hydrology and system operations, cost estimates, and biological analyses. Analyses were developed with advanced modeling and estimating tools using historical data and trends. While this is a standard method to help evaluate potential outcomes for future operations, biological conditions, and costs, many uncertainties could affect the findings of this appendix, including the magnitude of economic benefits. Various uncertainties and risks associated with the economic benefit valuations are discussed in relation to each benefit category below, and in Chapter 10, "Uncertainty," of the Draft Feasibility Report. For example, different methods and tools are applied to some benefit categories to illustrate a range of uncertainty in the valuation estimates.

C.3 Water Supply

Water Supply – Agriculture

Increased water supply and water supply reliability for agricultural production is a primary goal of the Final Alternatives.

NED Benefit Valuation Methodology

The SWAP model and Water Transfer Pricing analyses were used to estimate the benefits of water allocated for agricultural use. The future agricultural water supply benefits for Alternatives A1 and D1 in 2030 and 2040 were estimated based on their individual CALSIM deliveries and updated SWAP and Water Transfer Pricing analysis.

SWAP is an economic model of irrigated agriculture in California that is frequently applied for feasibility studies and policy analyses. It estimates the value of water supply reliability according to the change in the agricultural net income associated with changes in water supply. The SWAP analysis for the Final Alternatives analyzed the future benefits for irrigated agricultural production in 2030 and 2040 with recognition of the expected contributing effects from Sustainable Groundwater Management Act (SGMA) related groundwater pumping limits in the Central Valley. SGMA's implementation schedule requires that water districts develop groundwater management plans for basins in critical overdraft conditions by 2020. Basins with non-critical overdraft conditions are required to have groundwater management plans completed by 2022. SGMA also requires that the management plans are implemented to meet their specific sustainability goals by 2040 (for critical basins) and 2042 (for non-critical basins) (CA DWR, 2020). As a result, market responses to SGMA implementation are currently on-going and certainly can be expected to be in effect by 2030, when groundwater restrictions are enacted to be track to meet the 2040 sustainability goals. It is expected that SGMA's full impact will be incorporated in its water supply benefit valuations by 2040.

The Water Transfer Pricing model was also used to project the agricultural supply benefits for both Alternatives A1 and D1. As a transaction-based valuation approach, the benefit valuations resulting from the Water Transfer Pricing model were higher than those obtained from the SWAP analysis. Based on these two boundary values, it was determined that the mid-point values between the two approaches should be used to estimate the future water supply benefits. This mid-point valuation approach is referred to as the SWAP Results with Adjustment valuation approach to distinguish it from the lower SWAP (unadjusted) valuation and higher Water Transfer Pricing valuation approaches.

As described in the Section C.2, Economic Principles and Methods, the estimate of annualized benefits was calculated by interpolating these annual benefits between the years 2030 and 2040, and then keeping annual benefits constant from the year 2040 to the end of the planning horizon in year 2129. The calculation of annualized benefits in effect assumes that the alternatives' benefits would increase annually from their estimated 2030 level to their 2040 level at a constant rate. After 2040, the alternatives' annual benefit would remain unchanged for the rest of the analysis period (i.e., until 2129).

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 2030 and 2040 benefit values.

Modeled Results

Table C-2 shows the estimated average annual agricultural water supply benefits for Alternatives A1 and D1, based on SWAP Results with Adjustment valuation of their individual future deliveries (Table C-3).

Table C-2. Average Annual Benefit of Increased Water Supply for Agriculture, as Estimated by SWAP Results with Adjustment Unit Values ($1,000s, 2019 Dollars)

	2030 Annual Benefits [a]		2040 Annual Benefits [a]		Annualized Benefit ($) [b]	
Alternative	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total
Average Water Conditions [c]						
Alternative A1	$385	$11,417	$542	$16,086	$518	$15,406
Alternative D1	$396	$12,025	$557	$16,925	$535	$16,211

Notes:

[a] Based on SWAP modeling and Water Transfer Pricing results for agricultural supplies for water supply delivery.

[b] Annualized benefits assume interpolated annual benefits between 2030 and 2040, and then constant annual benefits after 2040.

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

$/AF = dollars per acre-foot

SWAP = Statewide Agricultural Production model

The future agricultural supply benefits are estimated to be $15.4 million per year under Alternative A1 and $16.2 million per year under Alternative D1.

Sensitivity

A sensitivity analysis was conducted to evaluate the risk and uncertainty associated with the agricultural benefit estimates, as discussed briefly below. The sensitivity analysis is provided solely for informational purposes, and is not included in the calculation of total benefits, NED benefits, or BCRs.

Table C-3. Table Annual Deliveries Above No Action Alternative Levels

	Deliveries (TAF/yr)					
(above No Project Alternative conditions) [a]	Average	Wet	Above Normal	Below Normal	Dry	Critical
Alternative Facilities	Alternative A1 - 1.27-MAF Reservoir					
Water Supply (Authority) Deliveries in SWP Service Area	**88**	**-15**	**19**	**114**	**250**	**99**
SOD Ag	2	0	0	2	5	2
SOD M&I	86	-15	18	112	244	97
Water Supply (Authority) Deliveries in CVP Service Area	**28**	**5**	**5**	**23**	**50**	**71**
NOD Ag	28	5	5	23	50	71
CVP Operational Flexibility	**69**	**14**	**11**	**179**	**73**	**107**
NOD Ag	11	-1	2	20	29	11
NOD M&I	3	0	1	6	8	2
SOD Ag	54	15	8	154	36	94
SOD M&I	0	0	0	0	0	0
IL4 Water Supply for CVPIA Refuges	**32**	**12**	**43**	**36**	**52**	**32**
NOD	9	4	14	10	14	8
SOD	23	9	29	26	38	24
Delta Ecosystem Enhancement	**57**	**66**	**70**	**58**	**52**	**31**
Total Deliveries – Alternative A1	**274**	**82**	**147**	**411**	**477**	**341**
Alternative Facilities	Alternative D1 - 1.81-MAF Reservoir					
Water Supply (Authority) Deliveries in SWP Service Area	**103**	**-15**	**5**	**130**	**282**	**150**
SOD Ag	2	0	0	3	6	3
SOD M&I	101	-14	5	127	276	146
Water Supply (Authority) Deliveries in CVP Service Area	**28**	**5**	**5**	**21**	**44**	**84**
NOD Ag	28	5	5	21	44	84
CVP Operational Flexibility	**73**	**18**	**10**	**137**	**112**	**118**
NOD Ag	17	0	3	22	47	15
NOD M&I	5	0	1	6	15	1
SOD Ag	52	18	7	110	50	102
SOD M&I	0	0	0	0	0	0
IL4 Water Supply for CVPIA Refuges	**34**	**12**	**44**	**36**	**53**	**40**
NOD	10	4	14	11	15	10
SOD	24	9	30	24	38	31
Delta Ecosystem Enhancement	**51**	**66**	**65**	**50**	**41**	**20**
Total Deliveries – Alternative D1	**289**	**87**	**130**	**374**	**532**	**413**

Notes for Table C.3

Totals may not sum exactly due to rounding.

[a] Increases in deliveries above the No Project Alternative, including supplies for agriculture, M&I, and environmental purposes. Dry and Critical period average is the average quantity for the combination of the SWRCB's D-1641 40-30-30 Dry and Critical years for the period from October 1921 to September 2003. The "Average (TAF)" is for this period.

Ag	=	agriculture
CVP	=	Central Valley Project
CVPIA	=	Central Valley Project Improvement Act
D-1641	=	Water Rights Decision 1641 Revised (SWRCB 2000)
IL4	=	Incremental Level 4
M&I	=	municipal and industrial
MAF	=	million acre-feet
NOD	=	North-of-the-Delta
SOD	=	South-of-the-Delta
SWP	=	State Water Project
SWRCB	=	State Water Resources Control Board
TAF	=	thousand acre-feet

Table C-4 shows the estimated agricultural benefits using both the SWAP unadjusted and Water Transfer Pricing valuation approaches with the Final Alternatives' agricultural supply quantities (seeTable C-3).

Table C-4. Average Annual Benefit of Increased Water Supply for Agriculture, as Estimated by SWAP Unadjusted Unit Values and Water Transfer Prices ($1,000s, 2019 Dollars)

Alternative	2030 Annual Benefits [a]		2040 Annual Benefits [a]		Annualized Benefit [b]	
	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total
Average Water Conditions [c]						
SWAP (Unadjusted) Valuation Approach						
Alternative A1	$172	$5,086	$253	$7,504	$241	$7,152
Alternative D1	$177	$5,381	$260	$7,907	$249	$7,539
Water Transfer Pricing Valuation Approach						
Alternative A1	$598	$17,417	$832	$24,667	$795	$23,611
Alternative D1	$615	$18,669	$854	$25,944	$821	$24,884

Notes:

[a] Based on SWAP modeling and Water Transfer Pricing results for agricultural supplies for water supply delivery.

[b] Annualized benefits assume interpolated annual benefits between 2030 and 2040, and then constant annual benefits after 2040.

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

$/AF = dollars per acre-foot

SWAP = Statewide Agricultural Production model

Water Supply – M&I

Increased water supply and water supply reliability for M&I are primary goals of the Final Alternatives.

NED Benefit Valuation Methodology

The M&I water supply benefit analysis relies on California Water Economics Spreadsheet Tool (CWEST) modeling to determine the project's future M&I water supply benefits applied to CalSim II modeling to quantify the project's expected future M&I deliveries under different water year conditions.

CWEST was developed for the US Bureau of Reclamation's Coordinated Long Term Operation of the Central Valley Project and State Water Project Environmental Impact Statement (LTO EIS) Environmental Consequences analysis. CWEST is an economic benefit valuation tool developed to provide consistent and transparent analysis of economic benefits of M&I water supplies for CVP contractors and SWP Table A contract holders. CWEST is an economic simulation and optimization tool that represents each individual CVP and SWP M&I water user's decision-making under 2030 and 2070 conditions, based on publicly available information. CWEST determines how CVP and SWP M&I water users will meet their 2030 and 2070 water demand levels at their minimum economic cost, given their supply constraints and alternatives.

CWEST quantifies M&I water supply benefit by simulating the water management decisions made at the district or agency level. The model's objective is to select each Sites Project participant's set of management actions that meet their annual water demand at the lowest cost. The estimated cost difference between the with and without Sites Reservoir scenarios determines the project's M&I

water supply benefit. Similar to the other existing California M&I water economics tools, CWEST minimizes the total costs of meeting annual M&I water demands subject to applicable operational and supply constraints. These costs include:

- Conveyance and operations costs;
- Existing and new permanent supplies, transfer, or other option costs;
- Local surface and groundwater operations;
- Lost water sales revenues; and
- End-user shortage costs.

Modeled Results

CWEST incorporates level of demand, quantity and type of local water supplies, and costs for both 2030 and 2070 development conditions into its benefit value estimates. Table C-5 shows the estimated average annual M&I water supply benefits for Alternatives A1 and D1 based on CWEST valuation of their individual future deliveries (Table C-3).

Table C-5. Average Annual Benefit of Increased M&I Water Supply, as Estimated by CWEST ($1,000s, 2019 Dollars)

Alternative	2030 Annual Benefits [a]		2070 Annual Benefits [a]		Annualized Benefit [b]	
	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF	Total
Average Water Conditions [c]						
Alternative A1	$963	$82,428	$1,792	$153,469	$1,439	$123,182
Alternative D1	$963	$97,323	$1,792	$181,201	$1,439	$145,441

Notes:

[a] Based on CWEST modeling results for M&I deliveries.

[b] Annualized benefits assume interpolated annual benefits between 2030 and 2070, and then constant annual benefits after 2070.

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

CWEST = California Water Economics Spreadsheet Tool
$/AF = dollars per acre-foot
M&I = municipal and industrial
SWAP = Statewide Agricultural Production model

The future M&I benefits are estimated to be $123.1 million per year under Alternative A1 and $145.4 million per year under Alternative D1.

Sensitivity

A sensitivity analysis was conducted to evaluate the risk and uncertainty associated with the M&I supply benefit estimates, as discussed briefly below. The sensitivity analysis is provided solely for informational purposes, and is not included in the calculation of total benefits, NED benefits, or BCRs.

Future benefit values of the M&I deliveries were estimated using the Water Transfer Pricing valuation approach. Table C-6 shows the estimated total M&I supply benefits for the Final Alternatives using the water transfer valuation approach for their M&I supply quantities shown in Table C-3.

Table C-6. Average Annual Benefit of Increased M&I Water Supply based on Water Transfer Prices ($1,000s, 2019 Dollars)

Alternative	2030 Annual Benefits [a]		2070 Annual Benefits [a]		Annualized Benefit [b]	
	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total
Average Water Conditions [c]						
Alternative A1	$774	$66,299	$2,312	$197,960	$1,657	$141,829
Alternative D1	$790	$79,874	$2,359	$238,491	$1,690	$170,867

Notes:

[a] Based on water transfer modeling results for M&I deliveries.

[b] Annualized benefits assume interpolated annual benefits between 2030 and 2070, and then constant annual benefits after 2070.

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

$/AF = dollars per acre-foot

M&I = municipal and industrial

SWAP = Statewide Agricultural Production model

C.4 CVP Operational Flexibility

Integrating Reclamation's Sites Project Water with CVP operations would provide operational flexibility, which in turn would relieve some of the existing operations constraints in the CVP system, and assist Reclamation with meeting its obligations under Federal law (including regulations). Relieving these constraints would partially restore the ability of the CVP to improve existing contract allocations and ecosystem conditions. This includes the use of a new water supply to meet CVP objectives so water can be conserved in other CVP reservoirs; this new water supply would increase the operational flexibility of the system. Increased storage in existing CVP reservoirs would be operationally achieved by using water in Sites Reservoir to fulfill CVP obligations. This would increase the resilience of the CVP to drought, and provide Central Valley Operations with an increased ability to meet critical water supply and environmental needs.

NED Benefit Valuation Methodology

The SWAP Results with Adjustment model valuations of the project's environmental (e.g. water refuge) supply benefits are used to estimate the Operational Flexibility Supply benefits for each alternative. For each alternative, its estimated unit-adjusted SWAP benefit values for 2030 and 2040 are applied to its projected CVP Operational Flexibility deliveries to estimate the corresponding total annual benefits of CVP Operational Flexibility deliveries. These estimates were then annualized over the project's 100-year operating period, as described above for the project's Agricultural Water Supply benefits.

Modeled Results

Table C-7 shows the total CVP Operational Flexibility supply benefits as estimated using SWAP Results with Adjustment valuation approach with the Final Alternatives' CVP Operational Flexibility quantities (see Table C-3).

Alternative A1 would provide total CVP Operational Flexibility benefits of $47.1 million per year. Alternative D1 would provide total CVP Operational Flexibility benefits of $48.4 million per year.

Table C-7. Average Annual Benefit of Increased Water Supply for CVP Operational Flexibility, as Estimated by SWAP Results with Adjustment Unit Values ($1,000s, 2019 Dollars)

Alternative	2030 Annual Benefits [a]		2040 Annual Benefits [a]		Annualized Benefit [b]	
	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total
Average Water Conditions [c]						
Alternative A1	$454	$31,416	$720	$49,804	$681	$47,126
Alternative D1	$438	$32,059	$700	$51,194	$662	$48,407

Notes:
[a] Based on SWAP modeling results for water refuge supplies for the CVP Operational Flexibility water supply deliveries.
[b] Annualized benefits assume interpolated annual benefits between 2030 and 2040, and then constant annual benefits after 2040.
[c] Average over the entire hydrologic sequence (1921 to 2003).
$/AF = dollars per acre-foot
CVP = Central Valley Project
M&I = municipal and industrial
SWAP = Statewide Agricultural Production model

Sensitivity

A sensitivity analysis was conducted to evaluate the risk and uncertainty associated with the CVP Operational Flexibility benefit estimates, as discussed briefly below. The sensitivity analysis is provided solely for informational purposes, and is not included in the calculation of total benefits, NED benefits, or BCRs.

Future benefit values of the CVP Operational Flexibility's deliveries were estimated using the sensitivity analysis approach and values applied to the project's Agricultural Water Supply purpose above. Table C-8 shows the estimated total CVP Operational Flexibility supply benefits using both the unadjusted SWAP unit values and Water Transfer Pricing valuation approaches for the deliveries under each alternative.

Table C-8. Average Annual Benefit of Increased Water Supply for CVP Operational Flexibility, as Estimated by SWAP Unadjusted Unit Values and Water Transfer Prices ($1,000s, 2019 Dollars)

	2030 Annual Benefits [a]		**2040 Annual Benefits [a]**		**Annualized Benefit [b]**	
Alternative	**Est. Unit Value ($/AF)**	**Total**	**Est. Unit Value ($/AF)**	**Total**	**Est. Unit Value ($/AF)**	**Total**
Average Water Conditions [c]						
SWAP (Unadjusted) Valuation Approach						
Alternative A1	$260	$18,005	$554	$38,314	$511	$35,356
Alternative D1	$249	$18,230	$541	$39,573	$499	$36,464
Water Transfer Pricing Valuation Approach						
Alternative A1	$648	$44,828	$888	$61,295	$851	$58,897
Alternative D1	$627	$45,888	$859	$62,815	$826	$60,353

Notes:
[a] Based on SWAP modeling results for agricultural supplies for water supply delivery changes except for M&I supply changes, which were estimated based on water transfer values.
[b] Annualized benefits assume interpolated annual benefits between 2030 and 2040, and then constant annual benefits after 2040.
[c] Average over the entire hydrologic sequence (1921 to 2003).
$/AF = dollars per acre-foot
CVP = Central Valley Project
M&I = municipal and industrial
SWAP = Statewide Agricultural Production model

C.5 IL4 Water Supply for CVPIA Refuges

Reclamation delivers water to wildlife refuges in the Central Valley as Level 2 supply (firm supply) and Incremental Level 4 supply (acquired from willing parties). Currently, Incremental Level 4 refuge water demands are not being fully met. The project could provide dedicated storage and new conveyance facilities for the Refuge Water Supply Program to improve operational flexibility, and increase annual deliveries to the Central Valley Project Improvement Act (CVPIA) refuges (see Chapter 6, Alternative Development, for more background information).

Incremental Level 4 refuge water supplies would otherwise most likely be acquired from existing agricultural users. Therefore, obtaining incremental water from an alternative would also reduce some of the cost of water acquisition and associated costs.

NED Benefit Valuation Methodology

The SWAP-adjusted model valuations of the project's Agricultural Water Supply benefits are used to estimate the IL4 Water Supply to CVPIA Refuges benefits for each alternative. For each alternative, estimated SWAP Results with Adjustment values for 2030 and 2040 are applied to its corresponding projected CALSIM deliveries to estimate its future annual IL4 Water Supply for CVPIA Refuges. These estimates were then annualized over the project's 100-year operating period, as described above for the project's agricultural water supply benefits.

Modeled Results

Table C-9 shows the IL4 Water Supply for CVPIA Refuges benefits, as estimated using SWAP Results with Adjustment valuation approach with the Final Alternatives' CVP Operational Flexibility quantities (see Table C-3).

Table C-9. Average Annual Benefit of Increased Water Supply for IL4 Water Supply for CVPIA Refuges as Estimated by SWAP Results with Adjustment Unit Values ($1,000s, 2019 Dollars)

Alternative	2030 Annual Benefits [a]		2040 Annual Benefits [a]		Annualized Benefit[b]	
	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total
Average Water Conditions [c]						
Alternative A1	$413	$13,437	$634	$20,596	$602	$19,553
Alternative D1	$416	$14,074	$645	$21,810	$612	$20,683

Notes:

[a] Based on SWAP modeling results for agricultural supplies for water supply delivery changes except for M&I supply changes, which were estimated based on water transfer values.

[b] Annualized benefits assume interpolated annual benefits between 2030 and 2040, and then constant annual benefits after 2040.

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

$/AF = dollars per acre-foot
CVPIA = Central Valley Project Improvement Act
M&I = municipal and industrial
SWAP = Statewide Agricultural Production model

Alternative A1 would provide future IL4 Water Supply for CVPIA Refuges benefits of $19.6 million per year. Alternative D1 would provide future IL4 Water Supply for CVPIA Refuges benefits of $20.7 million per year.

Sensitivity

A sensitivity analysis was conducted to evaluate the risk and uncertainty associated with the IL4 Water Supply for CVPIA Refuges benefit estimates, as discussed briefly below. The sensitivity analysis is provided solely for informational purposes, and is not included in the calculation of total benefits, NED benefits, or BCRs.

Future benefit values for the IL4 Water Supply for CVPIA Refuges were estimated using the sensitivity analysis approach and values applied to the project's Agricultural Water Supply purpose above. Table C-10 shows the estimated total IL4 Water Supply for CVPIA Refuges benefits using both the SWAP unadjusted unit values and Water Transfer Pricing valuation approaches for the corresponding future IL4 Water Supply for CVPIA Refuges quantities projected for each alternative.

Table C-10. Average Annual Benefit of Increased Water Supply for IL4 Water Supply for CVPIA Refuges as Estimated by SWAP Unadjusted Unit Values and Water Transfer Prices ($1,000s, 2019 Dollars)

Alternative	2030 Annual Benefits		2040 Annual Benefits		Annualized Benefit [b]	
	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total
Average Water Conditions [c]						
SWAP (Unadjusted) Benefit Valuation Approach [a]						
Alternative A1	$249	$8,069	$477	$15,504	$444	$14,421
Alternative D1	$248	$8,368	$491	$16,589	$455	$15,392
Water Transfer Pricing Valuation Approach						
Alternative A1	$579	$18,806	$791	$25,687	$760	$24,685
Alternative D1	$586	$19,779	$800	$27,031	$768	$25,975

[a] Based on SWAP modeling results for water supply delivery changes.
[b] Annualized benefits assume interpolated annual benefits between 2030 and 2040, and then constant annual benefits after 2040.
[c] Average over the entire hydrologic sequence (1921 to 2003).
$/AF = dollars per acre-foot
CVPIA = Central Valley Project Improvement Act
SWAP = Statewide Agricultural Production model

C.6 Delta Ecosystem Enhancement

Water supplies would be timed and delivered to improve the Delta ecosystem by increasing desirable food sources for Delta smelt and other estuarine-dependent species (e.g., Delta smelt, longfin smelt, Sacramento splittail, starry flounder, and California bay shrimp) in the late summer and early fall. The resulting increase in desirable food sources would help improve the growth and condition of Delta smelt as they mature into adults, thereby increasing Delta smelt abundance over time. The key is to push the water high in phytoplankton and zooplankton directly into an area of good Delta smelt habitat, where additional production may occur. Two large pulses of flow over a 2- to 3-week period would be made into the Yolo Bypass (via the Colusa Basin drain past the Wallace Weir and Ridge Cut into the Tule Drain), and would flow through the toe-drain and out to the Sacramento River. The flow pulses would be adaptively managed, but are currently thought to occur in late summer and early fall, perhaps in August and September. The water pulses would not have to occur every year; but in most years, they would be desirable.

NED Benefit Valuation Methodology

The Delta Ecosystem Enhancement benefits for each alternative were estimated based on the SWAP Results with Adjustment values for North of Delta deliveries for agricultural supply use. In the absence of the project it is would be expected that the necessary quantities of water required to achieve improvement in the Delta Ecosystem conditions would most likely be sourced by diversions from North of Delta agricultural use. It was also conservatively assumed that due to the necessary timing of the deliveries and the cross Delta transfer constraints (increased by the presumed priority for other purposes), that none of Delta Ecosystem Enhancement water supplies could otherwise be used South of Delta. As a result, the SWAP Results with Adjustment valuations for North of Delta deliveries for agricultural supply will represent a conservative estimate of the Delta Ecosystem Enhancement benefit value.

For each alternative, its estimated SWAP Result with Adjustment unit benefit values for 2030 and 2040 are applied to its corresponding projected CALSIM deliveries to estimate its future annual Delta Ecosystem Enhancement benefits. These estimates were then annualized over the project's 100-year period of analysis as described above for the project's agricultural Water Supply benefits and in Section C.2.

Modeled Results

Table C-11 shows the Delta Ecosystem Enhancement benefits as estimated using SWAP-adjusted valuation approach with the Final Alternatives' Delta Ecosystem Enhancement project future quantities (see Table C-3).

Alternative A1 would provide future Delta Ecosystem Enhancement benefits of $16.7 million per year. Alternative D1 would provide future Delta Ecosystem Enhancement benefits of $14.5 million per year.

Table C-11. Average Annual Benefit of Increased Water Supply for Delta Ecosystem Enhancement as Estimated by SWAP Results with Adjustment Unit Values ($1,000s, 2019 Dollars)

Alternative	2030 Annual Benefits [a]		2040 Annual Benefits [a]		Annualized Benefit [b]	
	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total
Average Water Conditions [c]						
Alternative A1	$223	$12,746	$305	$17,396	$293	$16,719
Alternative D1	$217	$11,079	$296	$15,072	$284	$14,490

Notes:

[a] Based on SWAP modeling results for agricultural supplies for water supply delivery changes except for M&I supply changes, which were estimated based on water transfer values.

[b] Annualized benefits assume interpolated annual benefits between 2030 and 2040, and then constant annual benefits after 2040.

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

$/AF = dollars per acre-foot

SWAP = Statewide Agricultural Production model

M&I = municipal and industrial

Sensitivity

A sensitivity analysis was conducted to evaluate the risk and uncertainty associated with the Delta Ecosystem Enhancement benefit estimates. The approach and findings of the sensitivity analysis are discussed briefly below. The sensitivity analysis is provided solely for informational purposes, and is not included in the calculation of total benefits, NED benefits, or BCRs.

Future benefit values for the Delta Ecosystem Enhancement were estimated using the sensitivity analysis approach and values applied to the project's Agricultural Water Supply purpose above. Table C-12 shows the estimated Delta Ecosystem Enhancement supply benefits using both the SWAP unadjusted unit values and Water Transfer Pricing valuation approaches for the corresponding future Delta Ecosystem Enhancement delivery quantities projected for each alternative (see Table C-3).

Table C-12. Average Annual Benefit of Increased Water Supply for Delta Ecosystem Enhancement as Estimated by SWAP Unit Values and Water Transfer Prices ($1,000s, 2019 Dollars)

Alternative	2030 Annual Benefits [a]		2040 Annual Benefits [a]		Annualized Benefit [b]	
	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total	Est. Unit Value ($/AF)	Total
Average Water Conditions [c]						
SWAP (Unadjusted) Valuation Approach						
Alternative A1	$133	$7,624	$176	$10,061	$170	$9,706
Alternative D1	$131	$6,690	$171	$8,743	$166	$8,444
Water Transfer Pricing Valuation Approach						
Alternative A1	$313	$17,869	$433	$24,731	$416	$23,732
Alternative D1	$303	$15,468	$419	$21,400	$403	$20,536

Notes:

[a] Based on SWAP modeling results for agricultural supplies for water supply delivery changes except for M&I supply changes, which were estimated based on water transfer values.

[b] Annualized benefits assume interpolated annual benefits between 2030 and 2040, and then constant annual benefits after 2040.

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

$/AF = dollars per acre-foot

SWAP = Statewide Agricultural Production model

M&I = municipal and industrial

C.7 Anadromous Fish

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. 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 the 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 $1.5 billion over the next 5 years, and up to $12.3 billion over 50 years in 2019 dollars (National Marine Fisheries Service 2009). With a Federal discount rate of 2.75 percent, the annualized value of $12.0 billion over 50 years is $468 million.

Physical Benefits to Anadromous Fish

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 the Aquatic Resources Chapter of the EIR/EIS for more information).

The most feasible and effective manner to lower temperature in the Sacramento River is to conserve water in Shasta Lake so that colder (deeper) water is used for its releases. The benefits from Sites Reservoir would be appreciably enhanced through cooperative operations with Shasta Lake to increase the volume of cold water stored in Shasta Lake, and improve the ability to maintain appropriate water temperatures in the Sacramento River during summer months, especially in drought years. This would be accomplished by exchanging water dedicated to public benefits stored in Sites Reservoir to conserve water in Shasta Lake for the benefit of anadromous fish. The exchanged water from Sites Reservoir would then be released to meet CVP obligations (e.g., CVP water deliveries to CVP contractors in accordance with existing CVP contracts). This would allow the cold-water pool at Shasta Lake to be maintained at higher levels than are currently achievable.

Shasta Lake release patterns could be shifted in season and between adjacent years to improve coldwater storage and flow management for salmon that use the Sacramento River between Keswick Dam and Red Bluff as habitat.

Cooperative operation with the Sites Reservoir Project would conserve a significant volume of water in Shasta Lake, especially in dry and critical years. This results in more water (at approximately the same temperature) at the lower temperatures range. As a result, more coldwater can be released through the temperature control device. This cooperative action would result in lower water temperatures for a longer duration in the Sacramento River below the release point. It would also provide operational flexibility to meet temperature targets farther downstream in critical spawning areas.

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.[11] 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' coldwater 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 developed at Shasta Lake to ensure the availability of a greater supply of coldwater 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.

Basic assumptions for the SALMOD model, particularly those regarding the number of returning females, have changed significantly in the last few years (i.e., since the initial alternatives were evaluated – see Attachment C.1). An updated correlation was developed to support SALMOD modeling based on the updated 2019 Biological Opinion (BiOps) and amended Coordinated Operations Agreement (COA).

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

The results of the single (or dedicated) use of the Shasta Raise for temperature (assuming additional storage is held continuously and there is no change in release operations from the No Action Alternative) were reevaluated using the 2019 model version. The results are shown in Table C-13.

Table C-13. Production Estimates for Shasta Raise Using 2019 SALMOD Model

	Average Production				Change from No Action		
	No Action	6.5-foot Dedicated Raise	12.5-foot Dedicated Raise	18.5-foot Dedicated Raise	6.5-foot Dedicated Raise	12.5-foot Dedicated Raise	18.5-foot Dedicated Raise
Fall	17,747,757	18,008,170	18,219,352	18,388,463	260,412	471,594	640,706
Late Fall	2,889,046	2,900,800	2,915,621	2,932,604	11,754	26,575	43,558
Spring	423,973	432,700	441,235	447,447	8,727	17,262	23,474
Winter	1,894,094	1,934,464	1,966,662	1,983,232	40,369	72,567	89,137
Total	22,954,871	23,276,133	23,542,869	23,751,747	321,262	587,998	796,876

Using the 2019 SALMOD model results for raising Shasta Dam as an alternative project to constructing Sites Reservoir and conserving water, the recalculated cost per Habitat Unit for each level of Shasta Lake raise is provided in Table C-14.

Table C-14. Cost Per Habitat Unit for Raising Shasta Dam with 2019 SALMOD Model

Dam Raise	Habitat Units a	Annual Cost	Cost per Habitat Unit ($2018)	Increase Habitat Unit Cost compared to Prior Analysis
(feet)		($1,000s)	($)	
6.5	321	$41,568	$129,495	133%
12.5	588	$47,130	$80,153	68%
18.5	797	$52,695	$66,117	22%

The lowest cost per habitat unit using the new results is $66,117 in 2018 dollars, and $67,300 in 2019 dollar terms.

Modeled Results

Table C-15 shows the estimated Anadromous Fish benefits of each alternative based on comparable habitat improvement from the least-cost alternative.

Table C-15. Estimated Benefits of Alternatives to Anadromous Fish, Based on Habitat Improvement from the Least-Cost Alternative ($1,000s 2019 Dollars)

		Annual Benefit [b]	
Alternative	Projected Habitat Units [a]	2030	Annualized ($)
Alternative A1	214	$14,402	$14,402
Alternative D1	268	$18,037	$18,037

[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 $67,300.

Alternative A1 would provide future Anadromous Fish benefits of $14.4 million per year. Alternative D1 would provide future Delta Ecosystem Enhancement benefits of $18.0 million per year.

Sensitivity

No sensitivity analysis was conducted to evaluate the risk and uncertainty associated with the Anadromous Fish benefit estimates due to the lack of alternative benefit valuation approaches.

C.8 Recreation

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,[12] and an updated analysis of recreational opportunities and constraints has been prepared as part of this Feasibility Report (see Appendix E, Recreation).

Alternative A1 would provide developed access and facilities at three recreation areas: Stone Corral, Lurline Headwaters, and Antelope Island. Alternative D1 would provide two recreation areas: Stone Corral and Peninsula Hills. Facilities for Alternative D1 are being sized to provide a level of recreation similar to 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, Recreation. 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 an RP economic valuation method based on the time and travel expenses that users incur for their recreational activity. CVM is an SP 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.

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12 See CALFED (2000).

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 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.1-34. (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 Reservoir. Appendix E, Recreation, provides a more detailed discussion of the recreation facilities currently planned and budgeted for development under each alternative.

Table C-16. 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 ($2019) [b]	Maximum Economic Value ($2019)
Shore fishing	17,400	$93.69	$1,630,269
Boat fishing	9,000	$93.69	$843,243
Picnicking	46,000	$23.35	$1,074,056
Sightseeing	39,600	$55.73	$2,206,810
Swimming/beach use	45,200	$47.93	$2,166,452
Walking	5,800	$78.59	$455,810
Bicycling/motorcycling	2,600	$210.21	$546,533
Off-road vehicle use	200	$56.02	$11,205
Horseback riding	800	$25.70	$20,558
Boating/waterskiing	31,200	$57.02	$1,779,134
Hunting	600	$78.55	$47,127
Other	1,600	$44.30	$70,876
Total	200,000	$54.26	$10,852,073

Source: Rosenberger 2016.

[a] Based on activity patterns at Black Butte Reservoir.

[b] Visitor-day values based on Loomis 2005 and updated into 2019 dollars.

Table C-16 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 2019 dollars (Rosenberger 2016). The weighted-average value per activity expected at Sites Reservoir is $54.26

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 approximately $10.85 million.

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-17 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-17. 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.[13] 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

13 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.

would not be adequate to meet the region's 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.

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-18 presents the results of the recreation benefits analysis.

Table C-18. Estimated Annual Recreation Benefits ($1,000s, 2019 Dollars)

Alternative	Annual Benefit	
	2025	Annualized Benefit [b]
Average Conditions [c]		
Alternative A1	$2,448	$2,448
Alternative D1	$2,534	$2,534

Notes:

[a] Annual benefits reflect consumer surplus value for various recreational activities supported by Sites Reservoir and water operation scenarios. 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 the 2025 values due to initial short ramp-up period before full benefits are achieved.

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

As shown in Table C-19, annualized recreational benefits under average conditions are estimated to be between approximately $2.4 million and $2.5 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 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 Feasibility Report. Appendix E, Recreation, presents more details regarding the potential physical benefits to recreational resources.

C.9 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).[14]

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-6 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

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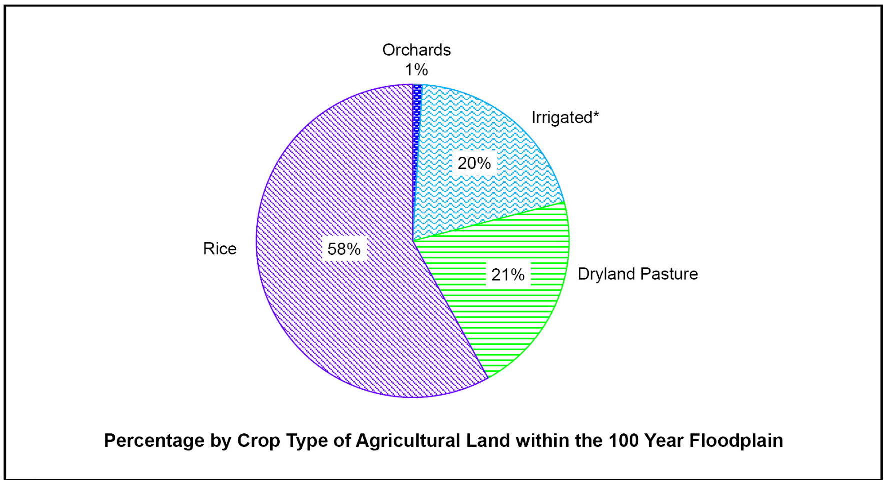
[14] F-RAM is an economic analysis tool for assessing the flood reduction benefits of floodplain management measures.

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).



Source: County parcels intersecting the 100-year floodplain (data compiled by URS).
Note:
* Irrigated production in the floodplain area predominantly consists of tomatoes, wheat, and alfalfa.

Figure C-6. 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-19 the study estimated that flood damages per acre ranged from less than zero for pasture to approximately $4,026 for wine grapes.[15]

Under the alternatives, up to 9,572 acres of farmland would experience a reduction in flood-related damages.[16] Apart from irrigated production in the floodplain, most of the land uses shown in Table C-19 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

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

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

Maxwell is in the 100-year floodplain; consequently, this area might benefit from alternative-related reductions in area flooding.

Table C-19. Per Acre Losses and Estimated Damages,100-Year Flood Event (2019 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	$263	$281	$544	6,035	$3,284
Almonds	$1,874	$281	$2,155	266	$573
Tomatoes	$1,176	$272	$1,448	731	$1,058
Wine grapes	$3,754	$272	$4,026	15	$60
Alfalfa	$289	$281	$570	731	$417
Pasture	($17)	$314	$297	1,779	$529
Other	$0	$284	$284	15	$4
Total				9,572	$5,926

Source: DWR 2008a.

Notes:

[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.

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 $544 per acre of rice and $297 for pasture,[17] their reduced farmland flood damages would be approximately $3.8 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 $1,009 per acre. The total damages to irrigated production would be $1.5 million.

The GIS analysis also indicated that approximately 266 acres of orchard production might be within 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 $0.6 million in flood damage savings.

Consequently, the total estimated agricultural flood reduction benefit would be $5.9 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.

17 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 $188,000.

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 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-20 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-20. Avoided Cost Assumptions and Estimates for 100-Year Flood Event (2019 Dollars)

Structure Type	Structure [a]	Contents [a]	Indirect [b]	Square Feet [c]	Avoided Damage
Residential one-story	53%	29%	25%	76,584	$12,558
Non-residential one-story	31%	100%	25%	52,666	$13,384
Total Avoided Costs				129,250	$25,942

Sources: DWR 2008b; USACE 2010, 2013.

Notes:

[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 F-RAM were escalated to 2019 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 over $1.6 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-21 presents the estimated avoided costs across the primary damage categories for the six flood events modeled.

Table C-21. Flood Benefits by Event and Impact Category (2019 Dollars, $1,000s)

Flood Type	Agricultural	Structures and Contents	Transportation	Total
500-year	$5,212	$10,946	$1,465	$17,623
100-year	$5,931	$25,942	$1,666	$33,538
50-year	$6,396	$25,047	$1,814	$33,256
25-year	$6,786	$12,312	$1,896	$20,995
10-year	$6,256	$8,492	$1,685	$16,433
5-year	$5,593	$26,344	$1,513	$33,450

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 $4.6 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 $4.6 million.

C.10 NED Benefit Summary

This section provides a summary of the benefit analysis developed for the Final Alternatives. Table C-22 provides an overview of the primary and sensitivity methods that were used for alternative analysis in Sections C.3 through C.8.

Table C-22. Economic Methods for Final Alternative Analysis

Benefit	NED Benefit Estimation Methodology	Sensitivity Analysis Methodology
Water Supply – Ag	SWAP Results with Adjustment	SWAP Unadjusted (low) Water Transfer Pricing (high)
Water Supply – M&I	CWEST	Water Transfer Pricing
CVP Operational Flexibility	SWAP Results with Adjustment	SWAP Unadjusted (low) Water Transfer Pricing (high)
IL4 Water Supply for CVPIA Refuges	SWAP Results with Adjustment	SWAP Unadjusted (low) Water Transfer Pricing (high)
Delta Ecosystem Enhancement	SWAP Results with Adjustment	SWAP Unadjusted (low) Water Transfer Pricing (high)
Anadromous Fish	Alternative Project Cost – Updated	NA
Flood Damage Reduction	Unchanged	NA
Recreation	Unchanged	NA

Notes:

Ag = agriculture
CVP = Central Valley Project
CVPIA = Central Valley Project Improvement Act
IL4 = Incremental Level 4
M&I = municipal and industrial
NOD = North-of-the-Delta
SOD = South-of-the-Delta
SWAP = Statewide Agricultural Production
TAF = thousand acre-feet

Modeled Results

Table C-23 presents the total NED benefits for the Final Alternatives.

Table C-23. Summary of Estimated Annual NED Benefits ($M, 2019 Dollars)

Beneficiary	Alternative A1[a]	Alternative D1[a]
Water supply [b]		
Agricultural supply	$15.4	$16.2
M&I supply	$123.2	$145.4
Total – Water Supply	$138.6	$161.7
IL4 Water Supply for CVPIA Refuges	$19.6	$20.7
Anadromous Fish	$14.4	$18.0
Delta Ecosystem Enhancement	$16.7	$14.5
CVP Operational Flexibility [c]	$47.1	$48.4
Recreation (Reservoir)	$2.4	$2.4
Flood damage reduction	$4.6	$4.6
Total Benefits	**$243.5**	**$270.4**
Benefit Cost Ratio	1.07	1.06

Note:

[a] Annualized at the Federal discount rate of 2.75 percent over 100 years.

[b] Deliveries to non-federal partners for agricultural or M&I use.

[c] Deliveries for use by CVP operations to enhance its ability to improve its existing contract allocations and ecosystem conditions. Totals may not sum exactly due to rounding.

$M = dollars in millions
CVP = Central Valley Project
CVPIA = Central Valley Project Improvement Act
NED = National Economic Development

Using the Federal discount rate of 2.75 percent over 100 years, the total annual benefits for Alternative A1 are estimated to total $243.5 million under Alternative A1 and $270.4 million under Alternative D1. Based on the estimated total annual costs for the alternatives, Alternative A1 would result in projected annual net benefits of $15.5 million with a $539 million net present value, and a BCR of 1.07. Alternative D1 would result in projected annual net benefits of $15.0 million with a $524 million net present value, and a BCR of 1.06.

Sensitivity

Table C-24 shows the range of the NED benefits based on the SWAP Results with Adjustment and Water Transfer Pricing valuation approaches for both Alternatives A1 and D1.

Table C-24. Summary of Estimated Annual NED Benefits for the Final Alternatives based on Sensitivity Analysis Results ($M, 2019 Dollars)

Beneficiary	Alternative A1[a]		Alternative D1[a]	
	SWAP Unadjusted	**Water Transfer Price**	**SWAP Unadjusted**	**Water Transfer Price**
Water supply [b]				
Agricultural supply	*$7.2*	*$23.6*	*$7.9*	*$24.9*
M&I supply	*$123.2* [c]	*$141.8*	*$145.4* [c]	*$170.9*
Total – Water Supply	$130.4	$165.4	$153.3	$195.8
IL4 Water Supply for CVPIA Refuges	$14.4	$24.7	$15.4	$26.0
Anadromous Fish [c]	$14.4	$14.4	$33.0	$33.0
Delta Ecosystem Enhancement	$9.7	$23.7	$8.4	$20.5
CVP Operational Flexibility [d]	$35.4	$58.9	$36.5	$60.4
Recreation (Reservoir) [c]	$2.4	$2.4	$2.4	$2.4
Flood damage reduction [c]	$4.6	$4.6	$4.6	$4.6
Total benefits	**$211.3**	**$294.**1	**$253.6**	**$342.7**
Benefit Cost Ratio	0.93	1.29	0.99	1.34

Notes:

[a] Annualized at the Federal discount rate of 2.75 percent over 100 years.

[b] Deliveries to non-federal partners for agricultural or M&I use.

[c] Benefits are unchanged from modeled results.

[d] Deliveries for use by CVP operations to enhance its ability to improve its existing contract allocations and ecosystem conditions.

Totals may not sum exactly due to rounding.

$M = dollars in millions
CVP = Central Valley Project
CVPIA = Central Valley Project Improvement Act
NED = National Economic Development
SWAP = Statewide Agricultural Production model

Using the Federal discount rate of 2.75 percent over 100 years, the total annual benefits for Alternative A1 are estimated to range between $211.3 million and $294.4 million. Under Alternative D1, the total annual benefits are estimated to range between $253.6 million and $342.7 million. Based on the estimated total annual costs for the alternatives, Alternative A1 would result in a BCR ranging from 0.93 to 1.29. Under Alternative D1, the BCR is estimated to range from 0.99 to 1.34.

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Acronyms and Other Abbreviations

AF	acre-feet
AS	ancillary services
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
CVPIA	Central Valley Project Improvement Act
CWC	California Water Commission
Delta	Sacramento–San Joaquin River Delta
DWR	California Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPM	Energy Portfolio Model
EPRI	Electric Power Research Institute
EQ	Environmental Quality
ESA	Federal Endangered Species Act
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
F-RAM	Flood Rapid Assessment Model
GCID	Glenn-Colusa Irrigation District
GIS	geographic information system
IDC	interest during construction
LCPSIM	Least-Cost Planning Simulation Model
LVREI	Los Vaqueros Reservoir Expansion Investigation
M&I	municipal and industrial
MAF	million acre-feet
NED	National Economic Development
NEPA	National Environmental Policy Act
NMV	non-market valuation
NODOS	North-of-the-Delta Offstream Storage
NPV	net present value
O&M	operations and maintenance

OM&R	operation, maintenance, and replacement
OMWEM	Other Municipal Water Economics Model
OSE	Other Social Effects
P&Gs	Principles and Guidelines
PARO	Power and Risk Office
PR&G	Guidelines for implementing Principles & Requirements
RA	resource adequacy
Reclamation	United States Department of the Interior, Bureau of Reclamation
RED	Regional Economic Development
RP	revealed preference
RPS	Renewable Portfolio Standard
SALMOD	Salmonid Population Model
SCRB	separable costs-remaining benefits
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
TEV	total economic value
USACE	United States Army Corps of Engineers
WSIP	Water Storage Investment Program
WTP	willingness to pay

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Attachment C1 Initial Alternative Results

The Feasibility Report for the North-of-the-Delta Offstream Feasibility Report was publicly released as a Draft in August 2017 in support of the application for State of California funding through the Water Storage Investment Program (WSIP). The report was updated and submitted to Policy for review on July 31, 2018. This attachment summarizes the economics results of the initial alternatives.

C1.1 Initial Alternatives Primary Planning Objectives

The following are the primary planning objectives of the alternatives:

- Increase water supplies, including improved water supply reliability, and greater flexibility in water management for agricultural and municipal and industrial (M&I) users.
- Provide additional water to relieve some of the existing operational constraints in the Central Valley Project (CVP) system. Relieving these constraints will partially restore the ability of the CVP to improve contract allocations and improve ecosystem conditions.
- Provide water supply for refuge needs to improve extent of Incremental Level 4 criteria attainment.
- Increase the population of anadromous fish.
- Convey food resources from the floodplain into the Delta to improve the food chain and quality of the Delta's estuarine habitat for use by Delta smelt and other species.

C1.2 Initial Alternatives 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.

C1.3 Alternatives

In accordance with the Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&Gs), the feasibility studies for the alternatives[1] analyze

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

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.Water Supply Reliability Benefits

C1.4 Water Supply

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 agricultural use. 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 CVP operational flexibility 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 Environmental Impact Report/Environmental Impact Statement (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 Appendices 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 over-adjust 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 details on 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 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.1-1). A more detailed breakdown of how deliveries are distributed is provided in Chapter 6, Alternative Development, of the main text.

Table C.1-1. 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	N/A	N/A
Alternative A	1,882	70	4.1%
Alternative B	1,848	40	2.2%
Alternative C	1,875	67	3.7%
Alternative D	1,944	136	7.5%

Notes:

[a] Based on CALSIM II modeling.

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

TAF = thousand acre-feet

N/A = not applicable

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 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 40 to 136 thousand acre-feet (TAF) annually (Table C.1-1).

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 four action alternatives.

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 2129. 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.1-2 shows the water supply benefits to agricultural users as estimated by the SWAP model for each alternative [2] for assumed levels of development/conditions and population growth in the years 2025 and 2060. For the average water conditions, the results show that Alternative D would provide the greatest total benefits to agricultural users at approximately $22.7 million per year. Alternatives A and B would provide $15.2 million and $14.2 million respectively. Alternative C would have the lowest annual benefits with approximately $8.6 million.

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.

[2] 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.1-2. Average Annual Benefit of Increased Water Supply to Agricultural Users, as Estimated by the SWAP Model ($1,000s, 2019 Dollars)

Alternative	Annual Benefits [a, b] 2025	2060	Annualized Benefit ($) [c]
Average Water Conditions [d]			
Alternative A	$12,791	$16,127	$15,189
Alternative B	$7,551	$8,979	$8,577
Alternative C	$12,201	$15,031	$14,235
Alternative D	$19,225	$24,060	$22,699

Notes:

[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

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 of other major Federal water storage projects in California 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 Los Vaqueros Reservoir Expansion Investigation (LVREI) project has developed the most recent database of California water market sales and a model for Water Transfer Pricing (Reclamation 2018). The LVREI collected data for sales of permanent water rights, long-term transfers, and the (short-term) spot market for both north- and south-of-the-Delta transactions occurring from 1990 through 2016 (Reclamation 2018).The LVREI 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 LVREI expanded on its previous studies by forecasting future agricultural, M&I and refuge water prices. The analysis focused on transactions involving water considered comparable to water supplied from Los Vaqueros. 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.

Such 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 to a high of 883,989 acre-feet (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 acre-feet per year. The alternatives would provide an average annual volume of between 441 and 451 TAF of water for agriculture, M&I, CVP operational flexibility, and environmental purposes. 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, and wheeling)—and if necessary, the costs of developing new infrastructure for implementation—could be substantial and possibly prohibitive.

The recent analysis by LVREI Draft Feasibility Report (Reclamation 2018) incorporated the data on recent water transfer transactions into the transfer pricing model previously developed for the Shasta Lake Water Resources Investigation (SLWRI) (Reclamation 2015). LVREI evaluated and updated the Water Transfer Pricing model to: (1) determine its suitability for valuing water supplies and other environmental purposes; and (2) estimate 2030 market prices for M&I, agricultural, and Incremental Level 4 supplies to its users (Reclamation 2018).

LVREI's analysis confirmed the appropriateness of the transfer pricing model's use for valuation of M&I use; estimated 2030 unit water prices to sellers by year type are shown in Table C.1-3.

Table C.1-3. Estimated 2030 M&I Water Prices Paid to Seller by Year Type (2019 Dollars)

Water Year Type	Frequency	Water Transfer Price ($/AF)	
		NOD	SOD
Wet	32%	$490	$575
Above Normal	15%	$518	$607
Below Normal	17%	$636	$745
Dry	22%	$658	$772
Critical	15%	$840	$984
Annual Average	100%	$607	$712

Source: Reclamation 2018

Notes:

AF= acre-feet

In addition to the market price for the delivered water, buyers incur conveyance costs that vary with location and infrastructure. Conservative conveyance loss factors of 25 percent and 10 percent are applied for water transferred from sources north of the Delta and south of the Delta, respectively, consistent with other recent Federal feasibility studies (SLWRI and LVREI) and technical guidance for CWC's WSIP. It was also assumed that water is transferred from lower-priced north-of-the-Delta sources during below-normal, dry, and critical years when Delta conveyance capacity is available. During above-normal and wet years, water is transferred from south-of-the-Delta sources.

Future energy use conveyance costs for water supply deliveries (including M&I, agricultural, and Incremental Level 4 refuge) for the alternatives were modeled with LTGEN and SWP power models using CALSIM II model data for the project's future water supply deliveries. Based on the results of the modeling, the energy cost for water deliveries to the project's M&I users is estimated to average $252 per acre-foot. Combined water market prices, carriage losses, and conveyance costs for M&I supplies are provided in Table C.1-4. The values reflect the total cost of water (water price + conveyance losses + wheeling/energy charges) to water users by location and water-year type in 2030 under Alternative C. The project's M&I supply water supply benefits for the other project alternatives were similarly estimated.

Table C.1-4. Estimated 2030 M&I Supply Benefit Value by Year Type – Alternative C (2019 Dollars)

Water Year Type	Water Transfer Price [a] ($/AF)	Carriage Cost		Conveyance Avg. Cost [b] ($/AF)	Water Supply Benefit Value [c] ($/AF)
		Water Loss Factor	Price – Loss Adjusted		
Wet	$575	10%	$638	$252	$918
Above Normal	$567	10%	$674	$252	$954
Below Normal	$635	25%	$848	$252	$1,183
Dry	$658	25%	$877	$252	$1,213
Critical	$840	25%	$1,120	$252	$1,456
Annual Average	**$647**	**18.1%**	**$803**	$252	**$1,113**

Source: Reclamation 2018

Notes:

[a] M&I transfer price values based on NOD supplies except during wet and above normal water years when Delta conveyance constraints would require use of SOD sources.

[b] Includes conveyance energy and wheeling expenses.

[c] Includes expected conveyance costs for carriage water lost during delivery.

Totals may not sum exactly due to rounding.

$/AF = dollars per acre-feet

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.1-5 shows estimates for average deliveries to M&I water users under the alternatives. On average, the alternatives would provide an estimated 92 to 125 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.1-5. 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	N/A	N/A
Alternative A	2,579	92	3.7%
Alternative B	2,583	96	3.9%
Alternative C	2,586	99	4.0%
Alternative D	2,612	125	5.0%

Notes:

[a] Based on CALSIM II modeling.

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

TAF = thousand acre-feet

N/A = not applicable

Future energy use conveyance costs for water supply deliveries (including M&I, agricultural, and Incremental Level 4 refuge) for the alternatives were modeled using LTGEN and SWP power models using CALSIM II model data for the project's future water supply deliveries. Average annual total energy use costs for conveyance of future NODOS water deliveries were estimated to range from \$29.8 million (Alternative D) to \$36.8 million (Alternative C). M&I supply accounts for the majority of these costs due to the large quantities and locations of its end use. The energy use conveyance costs for M&I water supplies are estimated to range from \$21.8 million (Alternative D) to \$24.9 million (Alternative C).

SLWRI's M&I supply benefit valuation's methodology, assumptions and water transfer data were used to estimate future M&I water values for NODOS. Consistent with SLWRI and other recent Federal feasibility studies, projected 2030 water transfer market prices were adjusted to account for carriage losses by supply source location and for specific water-year type. Consequently, the analysis applies a 25 percent conveyance loss to water originating north of the Delta, and delivered south of the Delta. For water transfers originating south of the Delta, a 10 percent conveyance loss factor is used. The M&I analysis also assumed that water transfers would originate from south-of-the-Delta sales during most wet and above-normal water years, primarily due to constraints in transporting water across the Delta during those years. However, in below-normal, dry, and critical years, south-of-the-Delta water users would instead be expected to purchase cheaper north-of-the-Delta water.

The total cost of water (water price + conveyance losses + conveyance energy use cost) to M&I water users by location and year type was then estimated based on the above data and assumptions. The resulting adjusted water values are applied to each alternative's water deliveries by location and water-year type to estimate total M&I water supply reliability benefits. Table C.1-6 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.

Table C.1-6. Municipal and Industrial Water Supply Benefits—Transfer Model Values ($1,000s, 2019 Dollars)

	Annual Benefit [a]	
Alternative	**2030**	**Annualized ($) [b]**
Average Water Conditions [c]		
Alternative A	$114,891	$114,891
Alternative B	$116,705	$116,705
Alternative C	$125,050	$125,050
Alternative D	$106,517	$106,517

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

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.

The results show that Alternative C would provide the greatest projected total benefits to M&I users, at approximately $125.1 million per year. Alternative D would provide the least M&I benefits, at $106.5 million. Alternatives A and B are expected to result in annual benefits of approximately $114.9 million and $116.7 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), compared the results of SWAP modeling to transfer analysis (CWC 2016). 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 (SGMA). This suggests that the NED benefit 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 SGMA mandates that require management for a sustainable yield from groundwater pumping in affected groundwater basins by either 2040 or 2042.
- Table C.1-7 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.1-7 shows the total estimated benefit for agricultural water supply based on applying the WSIP's benefit valuation approach and unit values to the CALSIM II agricultural water supply quantities (Table C.1-8).

Table C.1-7. Average Unit Agricultural Benefit Values by Alternative—WSIP Estimated Values ($1,000s, 2019 Dollars)

Alternative	WSIP Unit Benefits Value		Annualized Benefit
	2030	2045	
Alternative A	$258	$449	$420
Alternative B	$269	$485	$442
Alternative C	$262	$473	$432
Alternative D	$259	$343	$323

Notes:
WSIP = Water Storage Investment Program

Table C.1-8. Average Annual Benefit of Total Increased Water Supply to Agricultural Users—WSIP Estimated Values ($1,000s, 2019 Dollars)

Alternative	Annual Benefits [a]		Annualized Benefit ($) [b]
	2030	2045	
Average Water Conditions [c]			
Alternative A	$19,172	$34,049	$31,029
Alternative B	$11,592	$20,850	$18,971
Alternative C	$17,666	$31,695	$28,846
Alternative D	$34,238	$46,264	$43,822

Notes:
[a] Based on WSIP modeling results.
[b] Annualized benefits assume interpolated annual benefits between 2030 and 2045 and constant annual benefits after 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 $43.8 million per year. Alternative A would have annual benefits of approximately $31.0 million, and Alternative C would provide lower annual benefits of $28.8 million. Alternative B would result in the least agricultural supply benefits ($19.0 million). These results are approximately twice the magnitude of the benefit estimates obtained using the SWAP values. 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 benefit 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-7, 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.

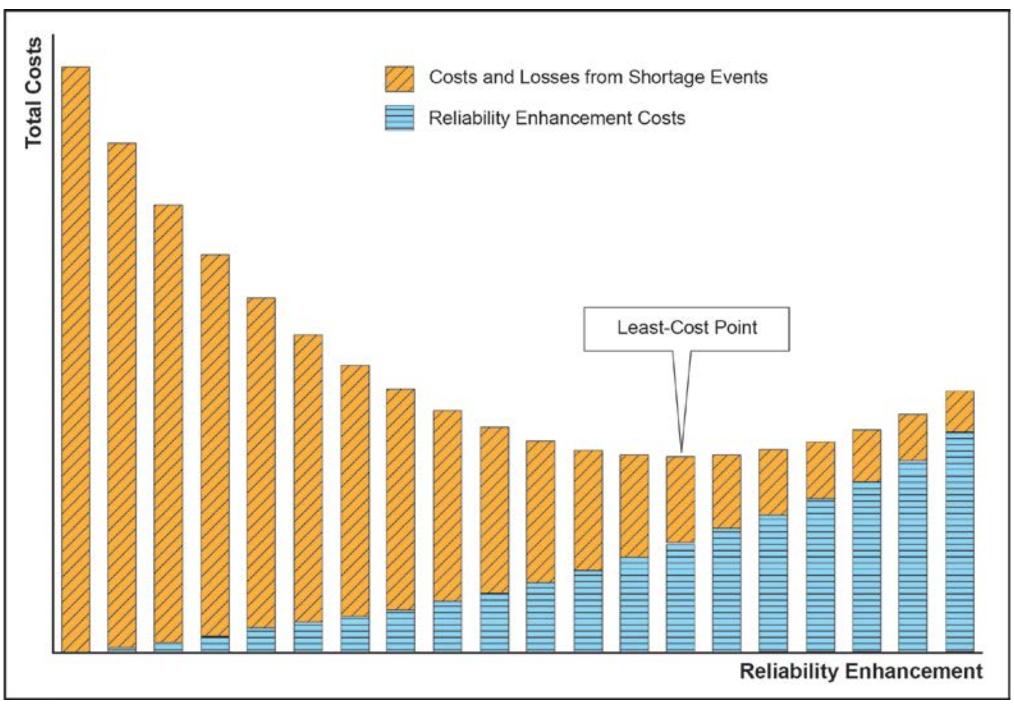

Figure C-7. The Effect of Increasing Reliability on Total Costs

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.1-9 presents the benefits of the alternatives to the urban M&I water supply as estimated by the LCPSIM and OMWEM.

Table C.1-9. M&I Water Supply Benefits—LCPSIM/OMWEM Modeled Values ($1,000s, 2019 Dollars)

Alternative	Annual Benefits [a, b, c] 2025	Annual Benefits [a, b, c] 2060	Annualized Benefit [d]
Average Water Conditions [e]			
Alternative A	$93,699	$248,750	$202,485
Alternative B	$96,123	$253,863	$206,795
Alternative C	$102,959	$260,699	$213,631
Alternative D	$57,690	$178,377	$142,366

[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 $142.4 million and $213.6 million. Alternative C would generate the greatest benefits. Alternatives A and B would all result in slightly less annual benefits. Alternative D would result in substantially lower 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.

LCPSIM benefit estimates for Alternatives A, B, and C range from 72 percent to 91 percent higher than those estimated using the water transfer valuation approach, and approximately 36 percent higher for Alternative D. A primary factor contributing to its higher valuation is that the LCPSIM modeling and values incorporate post-2030 changes in the demand and availability for M&I supplies. Water transfer analysis instead very conservatively assumes that M&I water values would remain unchanged after 2030. As a result, the LCPSIM-estimated benefits represent an upper estimate of the alternatives' potential M&I benefits.

C1.5 Incremental Level 4 Refuge Water Supply Benefits

Reclamation delivers water to wildlife refuges in the Central Valley as Level 2 supply (firm supply) and Incremental Level 4 supply (acquired from willing parties). Currently, Incremental Level 4 refuge water demands are not being fully met. The project could provide dedicated storage and new conveyance facilities for the Refuge Water Supply Program to improve operational flexibility, and increase annual deliveries to the Central Valley Project Improvement Act (CVPIA) refuges (see Chapter 6, Alternative Development, for more background information).

Incremental Level 4 refuge water supplies would otherwise most likely be acquired from existing agricultural users. Therefore, obtaining incremental water from an alternative would also 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 an alternative-cost approach. This approach involves identifying the likely least-cost alternative for achieving the same outcomes (i.e., delivering Incremental Level 4 refuge water supplies to refuges), and using that project's development or supply 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 alternative-cost approach especially relevant to securing the long-term benefit.

Two options are considered as alternatives for delivery of a similar magnitude of supplies to the refuges: (1) increased groundwater acquisitions; or (2) increased surface water purchases on the water market.

Groundwater acquisitions are available to refuges where local water districts have the ability to pump extra groundwater and deliver it to those refuges. Low-cost groundwater acquisitions and exchanges have been historically limited, and insufficient to meet Incremental Level 4 targets, particularly in dry years; they are also constrained by groundwater quality in portions of the San Joaquin Valley. Further, the volume of groundwater that can be pumped for refuge purposes is limited by existing environmental approvals. In the future, it is likely that available groundwater will be even more limited under California's SGMA, which is focused on addressing groundwater overdraft and ensuring sustainable management of groundwater basins throughout the state. Groundwater overdraft in the San Joaquin Valley has resulted in substantial land subsidence that has affected the function of water canals, flood control facilities, and other Federal, State, and local infrastructure. With SGMA implementation, limits are likely to be placed on groundwater pumping in the San Joaquin Valley, which will affect both the volume of supplies available to refuges, and the prices of some of those supplies.

Consequently, in the absence of firm water supplies from the project, short-term water market purchases are considered the most viable alternative for increasing Incremental Level 4 deliveries to the refuges.

Historically, Incremental Level 4 water supplies have been obtained through water exchange and purchase agreements. In this analysis, the benefits of refuge water supply associated with the alternatives are measured according to the estimated cost of obtaining the water supply. The Water Transfer Pricing model described in Chapter 3 is applied here to estimate the benefits of improved refuge water supply. As previously described, the economic model consists of a statistical analysis of documented spot market water transactions in California. The model seeks to explain the factors that influence California water market prices, and it is used to forecast 2030 prices under a variety of conditions, including seller and buyer location, buyer type, and hydrologic conditions.

Analysis for the Feasibility Report of Los Vaqueros Reservoir Expansion Investigation (LVREI) incorporated data on recent water transfer transactions into the transfer pricing model developed for Shasta Lake (see Chapter C-3). LVREI then evaluated the updated Water Transfer Pricing model to: (1) determine its suitability for valuing water supplies for Incremental Level 4 refuges and other environmental purposes; and (2) estimate 2030 market prices for Incremental Level 4 supplies to CVPIA refuges south of the Delta (Reclamation 2018).

LVREI's analysis confirmed the appropriateness of the transfer pricing model's use for valuation of Incremental Level 4 water supplies for CVPIA refuges, and estimated the 2030 unit water prices to sellers by year type (see Table C.1-10).

Table C.1-10. Estimated 2030 Refuge Water Prices Paid to Seller by Year Type (2019 Dollars)

Water Year Type	Frequency	Water Transfer Price ($/AF)
Wet	32%	$428
Above Normal	15%	$452
Below Normal	17%	$470
Dry	22%	$477
Critical	15%	$609
Annual Average	100%	$476

Source: Reclamation 2018
Note:
AF= acre-feet

In addition to the market price for the delivered water, buyers incur conveyance costs that vary with location and infrastructure. Conservative conveyance loss factors of 25 percent and 10 percent are applied for water transferred from sources north of the Delta and south of the Delta, consistent with other recent Federal feasibility studies (SLWRI and LVREI) and technical guidance for CWC's WSIP. It was also assumed that water is transferred from lower-priced north-of-the-Delta sources during below-normal, dry, and critical years when Delta conveyance capacity is available. During above-normal and wet years, water is transferred from south-of-the-Delta sources.

The conveyance energy cost for water deliveries to the refuges using the Mendota Canal is estimated to vary between a minimum of $13 per acre-foot (Alternative D) and up to $32 per acre-foot (Alternative A) (Reclamation 2018). Combined water market prices, carriage losses, and conveyance costs for refuge water supplies under Alternative C are provided in Table C.1-11. The values reflect the total cost of water (water price + conveyance losses + wheeling charges + power charges) to environmental water users by location and water-year type in 2030 under Alternative C. The project's Incremental Level 4 refuge water supply benefits for the other project alternatives were similarly estimated.

Table C.1-11. Estimated 2030 Refuge Water Supply Benefit Value by Year Type – Alternative C (2019 Dollars)

Water Year Type	Water Transfer Price ($/AF)	Carriage Cost: Water Loss Factor	Carriage Cost: Price – Loss Adjusted	Conveyance Energy Cost ($/AF)	Water Supply Benefit Value ($/AF)
Wet	$428	10%	$476	$25	$501
Above Normal	$452	10%	$502	$25	$527
Below Normal	$470	25%	$626	$25	$651
Dry	$477	25%	$637	$25	$662
Critical	$609	25%	$812	$25	$837
Annual Average	**$476**	**18.1%**	**$590**	**$25**	**$615**

Source: Reclamation 2018
Note:
Totals may not sum exactly due to rounding.
$/AF = dollars per acre-feet

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.1-12).

Table C.1-12. Average Annual Volume of Incremental Level 4 Refuge Water Supplies for Average Water Conditions

Alternative	Annual Volume (TAF) [a]	
	Annual Average [b]	**Dry/Critical**
Alternative A	44	22
Alternative B	71	37
Alternative C	74	37
Alternative D	48	24

Notes:

[a] Based on CALSIM II modeling.

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

TAF = thousand acre-feet

Table C.1-13 shows the alternatives' Incremental Level 4 refuge water supply benefits, as estimated based on the least-cost alternative of obtaining the supplies from water transfer purchases. The costs were adjusted into current (2019) dollar terms, and annualized using the current Federal discount rate of 2.75 percent. The average annual benefits for each alternative were then determined based on the expected frequency and water delivery quantities under each water-year type.

Table C.1-13. Estimated Annual Benefits of Alternative Water Supply to Incremental Level 4 Refuges—Water Transfer Costs ($1,000s, 2019 Dollars)

Alternative	Supply Quantity (TAF)	Annual Cost (Est.) ($)	Annualized Benefit ($) [a]
Average Water Conditions [b]			
Alternative A	44	$25,282	$25,282
Alternative B	71	$40,199	$40,199
Alternative C	74	$42,301	$42,301
Alternative D	48	$26,950	$26,950

Notes:

[a] Based on CALSIM II modeling. Annualized value reduced by first year operations.

b Average over the entire hydrologic sequence (1921 to 2003).

TAF = thousand acre-feet

The results project that the future Incremental Level 4 refuge water benefits would range between $25.2 million and $42.3 million annually. Alternative C would have the greatest benefits followed closely by Alternative B ($40.2 million). Alternatives A and D would result in far lower benefits to the Incremental Level 4 refuge water supply of $25.3 million and $27.0 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.1-14 shows the total estimated benefit to Incremental Level 4 refuge water supplies based on CALSIM II water supply quantities Table C.1-14, and using the WSIP's benefit valuation approach and unit values.

Table C.1-14. Estimated Annual Benefit of Increased Incremental Level 4 Water Supplies for CVPIA Refuges for Average Water Conditions—WSIP Values ($1,000s, 2019 Dollars)

Alternative	Annual Benefits [a]		Annualized Benefit ($) [b]
	2030	2045	
Average Water Conditions [c]			
Alternative A	$12,425	$29,189	$25,786
Alternative B	$20,050	$47,101	$41,609
Alternative C	$20,897	$49,091	$43,367
Alternative D	$13,555	$31,843	$28,130

Notes:

[a] Based on WSIP modeling results.

[b] Annualized benefits assume interpolated annual benefits between 2030 and 2045, and constant annual benefits after 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 to increased Incremental Level 4 refuge water supplies. The benefits under Alternative C are estimated to be $43.4 million per year. Alternative A would provide the least benefits ($25.8 million). Alternatives B would have annual benefits of approximately $41.6 million and Alternative D would have benefits of only $28.1 million per year. These results are slightly higher than the benefit estimates obtained using the Water Transfer Model values. The two benefit valuation approaches result in the same ranking and comparative values for the alternatives.

C1.6 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,[3] industrial, and commercial water uses. It uses mathematical functions 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 2019 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.

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[3] 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.

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.[4]

Modeled Results

Table C.1-15 presents benefits to urban M&I water quality, as estimated based on the LCRBWQM and BAWQM modeling analysis.

Table C.1-15. Estimated Annual M&I Water Quality Benefits Based on Estimated Salinity ($1,000s, 2019 Dollars)

Alternative	Annual Benefits [a, b]		Annualized Benefit [d]
	2025	2060 [c]	
Average Water Conditions [e]			
Alternative A	$17,449	$21,892	$20,642
Alternative B	$18,864	$24,170	$22,677
Alternative C	$22,642	$29,459	$27,541
Alternative D	$11,751	$16,722	$15,323

Notes:

[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 $15.3 million and $27.5 million for average years.[5] 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.

[4] 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.

[5] The annual benefit calculation method is the same approach used for the water supply benefits.

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:

- 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.[6] 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

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6 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).

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.

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.1-16). 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.1-16. Estimated Value of Irrigation Water Savings—SWAP Model Values ($/AF, 2019 Dollars)

Alternative	Annual Values [a, b] 2025	Annual Values [a, b] 2060	Annualized Value (2031 to 2130) [c]
Average Water Conditions [d]			
Alternative A	$173	$218	$205
Alternative B	$189	$224	$214
Alternative C	$182	$224	$212
Alternative D	$141	$177	$167

Notes:

[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-feet

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.[7] 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.1-17). 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.1-18). 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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7 No separate water quality modeling for the NODOS project was conducted at the 2060 level of development.

Table C.1-17. 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.1-18. 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.1-19 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.[8]

[8] 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.1-19. 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

Notes:

[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.1-20 shows the estimated benefit value for the irrigation water quantities saved under each alternative.

Table C.1-20. Benefits from Water Use Savings from Irrigation Water Quality Improvements—SWAP Model Values ($1,000s, 2019 Dollars)

Alternative	Annual Benefits [a, b] 2025	2060	Annualized Benefit [c]
Average Water Conditions [d]			
Alternative A	$474	$597	$563
Alternative B	$522	$621	$593
Alternative C	$701	$864	$818
Alternative D	$206	$257	$243

Notes:

[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.1-21 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.1-21. Irrigation Water Quality Benefits—South Coast Region ($1,000s, 2019 Dollars)

Alternative	Annual Benefits [a, b] 2025	Annual Benefits [a, b] 2060	Annualized Benefit [c]
Average Water Conditions [d]			
Alternative A	$792	$751	$762
Alternative B	$916	$905	$908
Alternative C	$964	$974	$971
Alternative D	$691	$681	$684

Notes:

[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.1-21. .

The benefits to irrigation water quality are substantially lower than the benefits to M&I water quality (Table C.1-22), and range between approximately $0.9 million (Alternative D) and $1.8 million (Alternative C).

Table C.1-22. Total Agricultural Water Quality Benefits—SWAP Model Values ($1,000s, 2019 Dollars)

Alternative	Annual Benefits [a, b] 2025	Annual Benefits [a, b] 2060	Annualized Benefit [c]
Average Water Conditions [d]			
Alternative A	$1,266	$1,348	$1,325
Alternative B	$1,438	$1,526	$1,502
Alternative C	$1,666	$1,838	$1,789
Alternative D	$897	$939	$927

Notes:

[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] 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

C1.7 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.1-23 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.1-23. 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

Notes:

[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.1-24 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.1-24 shows the estimated benefits for Delta environmental water quality improvement by alternative.

Table C.1-24. Delta Environmental Water Quality Improvement Benefits—SWAP Values ($1,000s, 2019 Dollars)

Alternative	Annual Benefits [a, b]		Annualized Benefit [c]
	2025	2060	
Average Water Conditions [d]			
Alternative A	$36,646	$46,202	$43,513
Alternative B	$40,773	$48,488	$46,318
Alternative C	$44,069	$54,292	$51,416
Alternative D	$24,596	$30,782	$29,042

Notes:

[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).

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 approximately $51.4 million per year. Alternative D would result in the least benefits, at $29.0 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 $43.5 million and $46.3 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.1-25 shows the estimated total benefit to agricultural water supply, based on CALSIM II-generated water supply quantities (Table C.1-25) 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.1-25. Total Agricultural Water Quality Benefits—WSIP Unit Values ($1,000s, 2019 Dollars)

Alternative	Annual Benefits [a, b] 2030	Annual Benefits [a, b] 2045	Annualized Benefit [c]
Average Water Conditions [d]			
Alternative A	$1,493	$1,998	$1,885
Alternative B	$1,658	$2,215	$2,091
Alternative C	$1,974	$2,719	$2,557
Alternative D	$1,067	$1,334	$1,271

Notes:

[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 $0.4 million to $0.8 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.1-26 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 approximately $222.1 million per year. Alternative D would result in the least benefits, at $159.7 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 $194.6 million and $198.3 million, respectively.

Table C.1-26. Estimated Delta Environmental Water Quality Improvement Benefits—Least-Cost Alternative Approach ($1,000s, 2019 Dollars)

Alternative	Annual Benefit [a,b]	
	2030	Annualized ($)
Average Water Conditions [c]		
Alternative A	$197,426	$197,426
Alternative B	$201,151	$201,151
Alternative C	$225,363	$225,363
Alternative D	$162,038	$162,038

Notes:
[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.1-26). 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.

C1.8 Anadromous Fish

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. 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 the 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 $1.5 billion over the next 5 years, and up to $12.3 billion over 50 years in 2019 dollars (National Marine Fisheries Service 2009). With a Federal discount rate of 2.75 percent, the annualized value of $12.0 billion over 50 years is $468 million.

Physical Benefits to Anadromous Fish

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 the Aquatic Resources Chapter of the EIR/EIS for more information).

The most feasible and effective manner to lower temperature in the Sacramento River is to conserve water in Shasta Lake so that colder (deeper) water is used for its releases. The benefits from Sites Reservoir would be appreciably enhanced through cooperative operations with Shasta Lake to increase the volume of cold water stored in Shasta Lake, and improve the ability to maintain appropriate water temperatures in the Sacramento River during summer months, especially in drought years. This would be accomplished by exchanging water dedicated to public benefits stored in Sites Reservoir to conserve water in Shasta Lake for the benefit of anadromous fish. The exchanged water from Sites Reservoir would then be released to meet CVP obligations (e.g., CVP water deliveries to CVP contractors in accordance with existing CVP contracts). This would allow the cold-water pool at Shasta Lake to be maintained at higher levels than are currently achievable. Shasta Lake release patterns could be shifted in season and between adjacent years to improve coldwater storage and flow management for salmon that use the Sacramento River between Keswick Dam and Red Bluff as habitat.

Cooperative operation with the Sites Reservoir Project would conserve a significant volume of water in Shasta Lake, especially in dry and critical years. This results in more water (at approximately the same temperature) at the lower temperatures range. As a result, more coldwater can be released through the temperature control device. This cooperative action would result in lower water temperatures for a longer duration in the Sacramento River below the release point. It would also provide operational flexibility to meet temperature targets farther downstream in critical spawning areas.

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.[9] 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' coldwater 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 developed at Shasta Lake to ensure the availability of a greater supply of coldwater 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.[10] Alternative B is projected to create 683 habitat units, and Alternative C would create 756 habitat units. The greatest increase in

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

10 Each habitat unit is equivalent to 1,000 additional salmon produced.

salmon production is projected to occur under Alternative D, which would create 986 new habitat units.

Modeled Results

Increasing the coldwater 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 coldwater pool at Shasta Lake; however, similar benefits occur to a lesser degree in the coldwater pools for Folsom Lake, Lake Oroville, and Trinity Lake. There is an opportunity cost associated with maintaining a greater coldwater pool at these facilities.

Table C.1-27 lists the projected increases in end-of-September 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.

Table C.1-27. Projected Increases in End-of-September 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	N/A	N/A
Alternative A	9,697	101	1.1%
Alternative B	9,702	106	1.1%
Alternative C	9,704	108	1.1%
Alternative D	9,728	132	1.4%

Notes:

[a] Based on CALSIM II modeling.

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

N/A = Not Available

TAF = thousand acre-feet

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.1-28 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.

Table C.1-28. Salmon Production and Annual Costs for Shasta Dam Raise Scenarios (2019 Dollars)

Dam Raise (feet)	Habitat Units [a]	Annual Cost ($1,000s) [b]	Cost per Habitat Unit ($) [c]
0.5	63	$37,198	$590,446
1.7	212	$38,057	$179,514
3.2	381	$39,483	$103,631
6.5	684	$42,682	$62,400
12.5	988	$48,393	$48,981
18.5	975	$54,107	$55,495

Source: Reclamation 2015.

Notes:

[a] Each habitat unit equals 1,000 additional salmon produced.

[b] Costs have been adjusted into 2018 dollars and are based on a 2.75 percent annual discount rate.

[c] Unit cost values have been rounded.

As shown in Table C.1.28-52, the minimum average annual equivalent cost per habitat unit was estimated to be $48,981 for a dam raise of 12.5 feet.

Table C.1-29 shows the estimated annual anadromous fish benefits of each alternative based on the cost per habitat unit from the SLWRI applied to its projected increase in habitat units.[11]

Table C.1-29. Estimated Benefits of Alternatives to Anadromous Fish, Based on Habitat Improvement from the Least-Cost Alternative ($1,000s 2019 Dollars)

Alternative	Projected Habitat Units [a]	Annual Benefit [b, c]	
		2030	Annualized ($)
Alternative A	936	$45,846	$45,189
Alternative B	683	$33,454	$32,975
Alternative C	756	$37,030	$36,449
Alternative D	986	$48,295	$47,603

Notes:

[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 $47,700.

[c] Annualized value from Shasta adjusted for a 2.75 percent discount rate and reduced by first year limited operations.

[d] Annualized benefits reduced by 15 percent to account for expected decrease in fish benefits from reallocated deliveries (CH2M HILL 2018).

Alternative D would generate the greatest annual benefits to anadromous fish of approximately $47.6 million, based on a "least-cost alternative" approach to raising Shasta Dam. Alternative A would result in slightly lower benefits, at $45.2 million. The annual benefits to anadromous fish

[11] The annualized benefit estimate based on the $47,700 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 $60,770 cost per habitat unit (Table C-27). It might therefore be expected that Alternative C's benefits would be closer to $45.9 million. Similarly, Alternative B habitat outcomes could be secured from a 6.5-foot raise, although at a greater expense.

under Alternative B and Alternative C are projected to be $33.0 million and $36.4 million, respectively.

C1.9 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 pumpback component of the alternatives' operations has been modeled separately, and pumpback 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 (TRR), 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[12]
- Net revenues resulting from an optimized pumpback operation at Sites Reservoir[13]
- 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

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 pumpback 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 pumpback 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

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[12] The O&M costs for Sites Reservoir include pumping costs to fill the reservoir and energy generation revenues from releases.

[13] This net benefit includes both pumping and generation.

- Release mode (generation) from Sites Reservoir to meet the alternatives' objectives for water releases
- A pumpback mode to better use the residual capacities of the different alternatives' components

The alternatives' pumpback 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.

Major changes in the California Independent System Operator (CAISO) operations and California energy market have occurred since the hydropower modeling and analyses were completed. As discussed in more detail in Chapter 9, Risk and Uncertainty, these changes suggest that the assumptions used by the hydropower analyses are outdated; and consequently, their modeling results no longer provide an accurate and reliable representation of the future conditions for the project.

Reclamation has funded new studies to re-evaluate the hydropower benefits under current conditions, but those results are not available to support this report. Nonetheless, until better analysis and data are available from those studies, the feasibility study continues to use the currently available analyses and findings to estimate the project's future hydropower benefits.

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 four 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 pumpback operations 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 pumpback 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.1-30 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 pumpback operations on the water diversion and release modes greatly enhance the economics of the alternatives.

Table C.1-30 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.1-30 also shows the cost and revenue effects of both the future "release only" and pumpback operations on the alternatives. Under Alternative C, future optimized pumping and generation for "release only" operations at Sites Reservoir would reduce its net power cost from \$3.4 million to \$2.0 million, which represents savings of \$1.4 million from incidental (i.e., non-optimized) pumping and generation.

The "release only" pumping and generation operations are incorporated together as a joint annual operation, maintenance, and replacement (OM&R) cost for all project purposes for the economic feasibility analysis. Under all the alternatives, their combined future optimized pumping and generation for "release only" operations are projected to result in an annual net energy cost charge ranging between approximately \$2.0 million (Alternative C) and up to \$2.4 million (Alternative B).

In addition, the future pumpback hydropower operations are estimated to generate net revenues ranging from approximately \$0.4 million (Alternative D) to \$0.5 million (Alternative C).

Table C.1-30. Estimated Net Revenue from NODOS Power Use and Generation ($1,000s, 2019 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	($311)	($311)	($374)	($374)	($293)	($293)	($333)	($333)
GCID Pumping	($497)	($497)	($565)	($565)	($488)	($488)	($534)	($534)
Delevan Pipeline Intake Facilities	($2,747)	($2,747)	N/A	N/A	($2,997)	($2,997)	($1,789)	($1,789)
TRR Pumping	($522)	($522)	($818)	($818)	($596)	($596)	($662)	($662)
Sites Pumping	($7,857)	($7,227)	($7,382)	($6,860)	($8,879)	($8,221)	($9,532)	($8,763)
Subtotal	**($11,934)**	**($11,305)**	**($9,139)**	**($8,617)**	**($13,252)**	**($12,594)**	**($12,850)**	**($12,081)**
Generation	**Annual Revenues**							
Sites Generation	$5,330	$6,231	$5,273	$5,951	$6,593	$7,264	$6,549	$7,070
TRR Generation	$900	$900	$307	$307	$952	$952	$510	$510
Sacramento River Generation	$2,040	$2,040	N/A	N/A	$2,348	$2,348	$2,217	$2,217
Subtotal	**$8,271**	**$9,171**	**$5,581**	**$6,259**	**$9,893**	**$10,565**	**$9,276**	**$9,796**
Pumpback Operations	**Annual Net Revenues**							
Pumpback during Diversion Cycle	N/A	$167	N/A	$244	N/A	$147	N/A	$139
Pumpback during Release Cycle	N/A	$70	N/A	$49	N/A	$167	N/A	$73
Pure Pumpback Operations Cycle	N/A	$188	N/A	$188	N/A	$216	N/A	$171
Subtotal		**$425**		**$482**		**$531**		**$383**
Total Net Revenues	**($3,664)**	**($1,709)**	**($3,558)**	**($1,876)**	**($3,359)**	**($1,498)**	**($3,574**	**($1,901)**
Project Optimization Potential		**$1,955**		**$1,682**		**$1,861**		**$1,673**

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

Consequently, the total revenue impact of the optimized and pumpback operations under Alternative C is estimated to be $1.9 million per year.

However, the pumpback revenues and pumping expenses are incurred, and only required by its operations. Consequently, the $0.4 million to $0.5 million in net revenues projected from the alternatives' pumpback operations are recognized as separable revenue benefits for the hydropower operations. These revenues are combined with each alternative's projected ancillary and capacity benefits (discussed below) to determine the hydropower NED benefits for the feasibility analysis.

The pumpback hydropower analysis estimated the *net* revenues from the pumpback operations, but did not specify its associated pumping costs or the quantities of pumping and generation solely incurred by the pumpback operations (i.e., distinct from the project's "release only" pumping and power generation). However, comparison of the reported pumping costs and

generation revenues indicated that pumpback generation was approximately equivalent to between 7 percent (Alternative C) and 5 percent (Alternative D) of total generation. The corresponding separable annual pumping costs for the pumpback operations are estimated to be approximately $0.6 million (Alternative C) and $0.4 million (Alternative D).

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 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. 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 $73 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.[14] 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.

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, Hydropower, provides additional information on the hydropower analysis and findings.

[14] 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.

The additional hydropower analysis confirmed DWR's direct net energy benefits, and estimates annual AS benefits of approximately $2.7 million, and systemwide capacity benefits of $20.3 million per year. The resulting ancillary services and systemwide capacity NED benefits potentially attributable to the hydropower facilities would be $23.0 million per year. Combined with the estimated $0.5 million net revenues from its pumpback operations, Alternative C would be expected to result in total net hydropower benefits of $23.5 million per year.[15]

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 $14.0 million in ancillary services and systemwide capacity NED benefits annually. Combined with the estimated $0.5 million net revenues from its pumpback operations, Alternative B would be expected to result in total net hydropower benefits of approximately $14.5 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 $19.9 million annually in ancillary services and systemwide capacity NED benefits. Combined with the estimated $0.4 million net revenues from its pumpback operations, Alternative A would be expected to result in total net hydropower benefits of $20.3 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 result in approximately $21.1 million annually in ancillary services and systemwide capacity NED benefits. Combined with the estimated $0.4 million net revenues from its pumpback operations, Alternative D would be expected to result in total net hydropower benefits of $21.5 million per year.

C1.10 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.

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[15] As previously discussed, the project's OM&R cost includes the "release only" pumping costs and generation revenues.

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).[16]

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-8 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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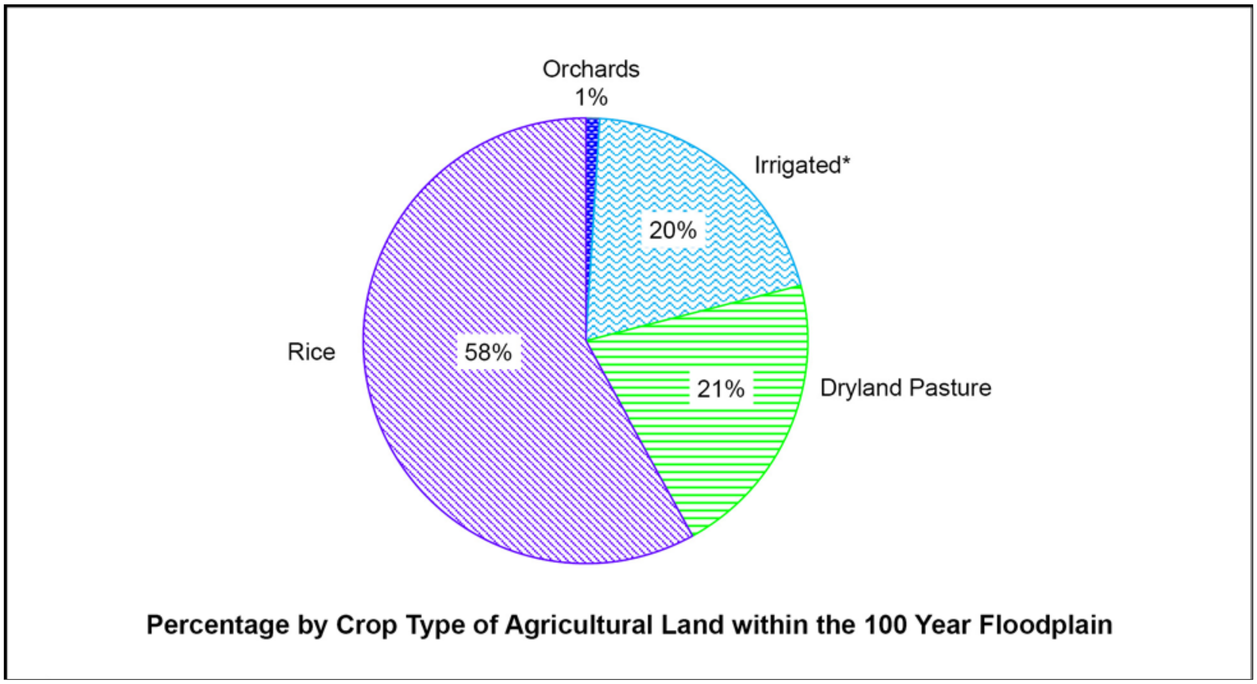
16 F-RAM is an economic analysis tool for assessing the flood reduction benefits of floodplain management measures.



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

Note:

* Irrigated production in the floodplain area predominantly consists of tomatoes, wheat, and alfalfa.

Figure C-8. 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.1-31. the study estimated that flood damages per acre ranged from less than zero for pasture to approximately $4,026 for wine grapes.[17]

Under the alternatives, up to 9,572 acres of farmland would experience a reduction in flood-related damages.[18] Apart from irrigated production in the floodplain, most of the land uses shown in

[17] The negative damages (i.e., benefit) to pasture from flooding reflect the expected yield gains from the additional water content in the soils.
[18] The specific locations and related agricultural production in the floodplain that would be less affected by flood events are not known.

Table C.1-31 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.

Table C.1-31. Per Acre Losses and Estimated Damages,100-Year Flood Event (2019 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	$263	$281	$544	6,035	$3,284
Almonds	$1,874	$281	$2,155	266	$573
Tomatoes	$1,176	$272	$1,448	731	$1,058
Wine grapes	$3,754	$272	$4,026	15	$60
Alfalfa	$289	$281	$570	731	$417
Pasture	($17)	$314	$297	1,779	$529
Other	$0	$284	$284	15	$4
Total				9,572	$5,926

Source: DWR 2008a.
Notes:
[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.

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 $544 per acre of rice and $297 for pasture,[19] their reduced farmland flood damages would be approximately $3.8 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 $1,009 per acre. The total damages to irrigated production would be $1.5 million.

The GIS analysis also indicated that approximately 266 acres of orchard production might be within 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 $0.6 million in flood damage savings.

Consequently, the total estimated agricultural flood reduction benefit would be $5.9 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.

[19] 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 $188,000.

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 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.1-32. 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.1-32. Avoided Cost Assumptions and Estimates for 100-Year Flood Event (2019 Dollars)

Structure Type	Structure [a]	Contents [a]	Indirect [b]	Square Feet [c]	Avoided Damage
Residential one-story	53%	29%	25%	76,584	$12,558
Non-residential one-story	31%	100%	25%	52,666	$13,384
Total Avoided Costs				129,250	$25,942

Sources: DWR 2008b; USACE 2010, 2013.

Notes:

[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 F-RAM were escalated to 2019 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 over $1.6 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.1-33 presents the estimated avoided costs across the primary damage categories for the six flood events modeled.

Table C.1-33. Flood Benefits by Event and Impact Category (2019 Dollars, $1,000s)

Flood Type	Agricultural	Structures and Contents	Transportation	Total
500-year	$5,212	$10,946	$1,465	$17,623
100-year	$5,931	$25,942	$1,666	$33,538
50-year	$6,396	$25,047	$1,814	$33,256
25-year	$6,786	$12,312	$1,896	$20,995
10-year	$6,256	$8,492	$1,685	$16,433
5-year	$5,593	$26,344	$1,513	$33,450

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 $4.6 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 $4.6 million.

C1.11 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,[20] and an updated analysis of recreational opportunities and constraints has been prepared as part of this 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 level of recreation similar to 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, Recreation. 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 an RP economic valuation method based on the time and travel expenses that users incur for their recreational activity. CVM is an SP 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 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

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[20] See CALFED (2000).

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.1-34. (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 Reservoir. Appendix E, Recreation, provides a more detailed discussion of the recreation facilities currently planned and budgeted for development under each alternative.

Table C.1-34. 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 ($2019) [b]	Maximum Economic Value ($2019)
Shore fishing	17,400	$93.69	$1,630,269
Boat fishing	9,000	$93.69	$843,243
Picnicking	46,000	$23.35	$1,074,056
Sightseeing	39,600	$55.73	$2,206,810
Swimming/beach use	45,200	$47.93	$2,166,452
Walking	5,800	$78.59	$455,810
Bicycling/motorcycling	2,600	$210.21	$546,533
Off-road vehicle use	200	$56.02	$11,205
Horseback riding	800	$25.70	$20,558
Boating/waterskiing	31,200	$57.02	$1,779,134
Hunting	600	$78.55	$47,127
Other	1,600	$44.30	$70,876
Total	200,000	$54.26	$10,852,073

Source: Rosenberger 2016.

[a] Based on activity patterns at Black Butte Reservoir.

[b] Visitor-day values based on Loomis 2005 and updated into 2019 dollars.

Table C.1-35. 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 2019 dollars (Rosenberger 2016). The weighted-average value per activity expected at Sites Reservoir is $54.26 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 approximately $10.85 million.

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 C1.35. 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.1-35. 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.[21] 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 the region's 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.

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.

[21] 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.

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.1-36. presents the results of the recreation benefits analysis.

Table C.1-36. Estimated Annual Recreation Benefits ($1,000s, 2019 Dollars)

Alternative	Annual Benefit	
	2025	Annualized Benefit [b]
Average Conditions [c]		
Alternative A	$2,448	$2,448
Alternative B	$2,448	$2,448
Alternative C	$2,534	$2,534
Alternative D	$2,534	$2,534

Notes:

[a] Annual benefits reflect consumer surplus value for various recreational activities supported by Sites Reservoir and water operation scenarios. 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 the 2025 values due to initial short ramp-up period before full benefits are achieved.

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

As shown in Table C.1-36, annualized recreational benefits under average conditions are estimated to be between approximately $2.4 million and $2.5 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 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 Feasibility Report. Appendix E, Recreation, presents more details regarding the potential physical benefits to recreational resources.

C1.12 Initial Alternatives - Summary of Benefits

Table C.1-37 presents the total NED benefits for the alternatives.

Table C.1-37. Summary of Estimated Annual NED Benefits for the Alternatives ($M, 2019 Dollars)

Beneficiary	Alternative A [a]	Alternative B [a]	Alternative C [a]	Alternative D [a]
Water supply [b]				
Agricultural supply	$15.2	$8.6	$14.2	$22.7
M&I supply	$114.9	$116.7	$125.0	$106.5
Total – Water Supply	$130.1	$125.3	$139.3	$129.2
Incremental Level 4 refuge	$25.3	$40.2	$42.3	$26.9
Anadromous fish	$45.8	$33.5	$37.0	$48.3
Water Quality				
Agricultural	$1.3	$1.5	$1.8	$0.9
Urban	$20.6	$22.7	$27.5	$15.3
Delta Environmental	$43.5	$46.3	$51.4	$29.0
Total – Water Quality	**$65.5**	**$70.5**	**$80.7**	**$45.3**
Hydropower (system) [c]	$20.3	$14.5	$23.5	$21.5
Recreation (Reservoir)	$2.4	$2.4	$2.5	$2.5
Flood damage reduction	$4.6	$4.6	$4.6	$4.6
Total benefits	**$294.1**	**$290.9**	**$330.0**	**$278.4**
Benefit Cost Ratio	1.11	1.07	1.13	0.97

Notes:

[a] Annualized at the Federal discount rate of 2.75 percent over 100 years.

[b] Energy use conveyance costs included in benefit valuations and also recognized as separable annual operation, maintenance, and replacement (OM&R) costs by the benefit-cost ratio (BCR) and cost allocation/assignment analyses.

[c] Ancillary and capacity benefits are approximated for Alternatives A, B and D.

Totals may not sum exactly due to rounding.

CVP = Central Valley Project
M&I = municipal and industrial
NED = National Economic Development
$M = dollars in millions

Using the Federal discount rate of 2.75 percent over 100 years, the total annual benefits for the alternatives would range from $278.4 million for Alternative D to $330.0 million for Alternative C. Based on the estimated total annual benefits and costs for the alternatives, Alternative C was identified as the NED plan, with projected net benefits of $39.0 million and a BCR of 1.13.

Table C.1-38 shows the sensitivity results by purpose and alternative.

Table C.1-38. Sensitivity Analysis Summary of Estimated Federal Annual NED Benefits for the Alternatives ($M, 2018 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 [b]								
Agricultural	**$15.2**	**$8.6**	**$14.2**	**$22.7**	*$31.0*	*$19.0*	*$28.8*	*$43.8*
M&I	**$114.9**	**$116.7**	**$125.0**	**$106.5**	*$202.5*	*$206.8*	*$213.6*	*$143.4*
Total – Water Supply	**$130.1**	**$125.3**	**$139.3**	**$129.2**	$233.5	$225.8	$242.5	$186.2
Incremental Level 4 refuge	**$25.3**	**$40.2**	**$42.3**	**$26.9**	$25.8	$41.6	$43.4	$28.1
Anadromous fish	**$45.8**	**$33.5**	**$37.0**	**$48.3**	**$45.8**	**$33.5**	**$37.0**	**$48.3**
Water Quality								
Agricultural	**$1.3**	**$1.5**	**$1.8**	**$0.9**	$1.9	$2.1	$2.6	$1.3
Urban	**$20.6**	**$22.7**	**$27.5**	**$15.3**	**$20.6**	**$22.7**	**$27.5**	**$15.3**
Delta Environmental	**$43.0**	**$45.7**	**$50.8**	**$28.7**	$197.4	$201.2	$225.4	$162.0
Total – Water Quality	**$65.5**	**$69.6**	**$79.7**	**$44.7**	$220.0	$225.9	$255.5	$178.6
Hydropower (system) [c, d]	**$20.3**	**$14.5**	**$23.5**	**$21.5**	**$20.3**	**$14.5**	**$23.5**	**$21.5**
Recreation [c]	**$2.4**	**$2.4**	**$2.5**	**$2.5**	**$2.4**	**$2.4**	**$2.5**	**$2.5**
Flood damage reduction [c]	**$4.6**	**$4.6**	**$4.6**	**$4.6**	**$4.6**	**$4.6**	**$4.6**	**$4.6**
Total	**$294.1**	**$290.9**	**$330.0**	**$278.4**	$552.5	$548.3	$609.0	$469.9
Benefit Cost Ratio	**1.11**	**1.07**	**1.13**	**0.97**	2.08	2.01	2.09	1.64

Notes:

[a] Annualized at the Federal discount rate of 2.75 percent over 100 years.

[b] Energy use conveyance costs included in benefit valuations and also recognized as separable annual operation, maintenance, and replacement (OM&R) costs by the benefit-cost ratio (BCR) and cost allocation/assignment analyses.

[c] No sensitivity analysis alternative values determined.

[d] 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 supply and CVP operational flexibility. The NED approaches generally result in more conservative benefit valuations than the alternate valuation methodologies used for the sensitivity analyses.

For the NED plan (Alternative C), combining its lower valuation approaches is the same as that show in Table C-37 and results in a the annual NED benefit totaling $330.0 million, which would correspond to an annual net benefit of $39.0 million and a BCR of 1.13. However, using the higher-valuation approaches and sensitivity analyses results, the maximum annual NED benefit would total $609.0 million, which would correspond to an annual net benefit of $318.0 million and a BCR of 2.09.

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