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Water Resources and Infrastructure for Flexible Load Management

This Phase 1 report examined the significant potential to increase grid integration support for carbon-free renewable energy resources by leveraging water storage facilities as â€œflexible balancing resources.â€

Additional submitted attachment is included below.

Water Sector Over-Generation Mitigation and Flexible Demand Response

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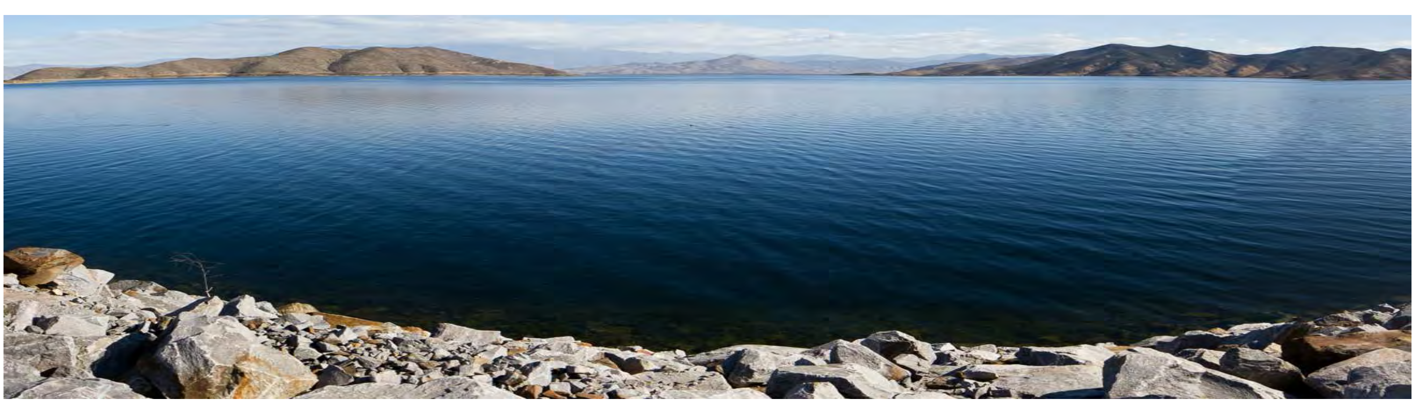
May 7, 2019



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Conducting technical review is not an endorsement of this paper's findings and recommendations.

Those, as well as any remaining errors or inconsistencies, are solely those of the authors.

Abstract

California’s next major energy challenge is “over-generation” – a situation in which real-time electric production exceeds real-time electric demand. If not properly managed, real-time imbalances between electric supplies and demand can disrupt electric service.

The challenges of balancing California’s electric grid are presently being addressed through a diverse portfolio of market mechanisms, operating strategies, energy storage, and “smart” grid management technologies. During some hours, however, real-time over-generation exceeds the ability of these remedies to solve the imbalance. When that occurs, some real-time energy production must be curtailed to keep power flowing throughout the State. Presently, most of the energy being curtailed is solar, since over-generation occurs predominantly during daylight hours when solar PV generation is highest.

California has invested billions of dollars to put California on a path to 100% carbon-free electricity. Curtailments of renewable energy are antithetical to State policy. More electric storage could substantially reduce and eventually eliminate the need for curtailments. However, the current technology of choice, large scale electric energy batteries, are costly and have long lead-times to permit. Near-term solutions are needed to bridge the gap. Fortunately, remedies exist today that are already distributed throughout the state and ready to deploy. One high potential opportunity is pumped water storage.

This report examines the significant potential to increase grid integration support for carbon-free renewable energy resources by leveraging water storage facilities as “flexible balancing resources.” Candidate opportunities include pumped storage hydropower (open and closed loop), groundwater banks, surface reservoirs, and ponds, tanks, and other types of seasonal and diurnal water, wastewater, and recycled water storage facilities. This report recommends that the State develop a Water Sector Flexible Demand Response Program that leverages the flexibility inherent in water systems to increase the State’s ability to reliably integrate large volumes of carbon-free renewable energy and reduce the frequency and amount of renewable energy curtailments.

Keywords: electric reliability, over-generation, over-supply, under-generation, under-supply, carbon-free energy, renewable energy, curtailments, electric storage, water storage, demand response, flexible demand response, Flex DR, solar, wind, pumped storage hydro, water, wastewater, recycled water, groundwater, groundwater banks, surface water reservoirs, conjunctive use, flood managed aquifers

Citation:
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Preface

California's phenomenal success in substantially increasing the State's portfolio of clean, renewable energy resources has created both challenges and opportunities.

- The primary challenge is to reduce curtailments of carbon-free renewable energy resources during periods of "over-generation" (hours during which real-time electric supplies exceed real-time electric demand).

- The primary opportunity is to expedite cost-effective electric storage solutions that reduce curtailments and support the State's rapid pace of renewable energy development, most of which is "variable" (produced when the sun shines or the wind blows).

It is within this context that Southern California Edison proposed, and the California Public Utilities Commission authorized, an over-generation pilot that identifies and evaluates opportunities for water and wastewater utilities to provide over-generation mitigation through pumped water storage.

The water sector has unique capabilities for increasing flexibility in its systems and operations. Key among these is the ability to increase operational flexibility by coordinating water sector pumping and treatment with water, wastewater, and recycled water storage. To the extent that the needs and interests of the electric sector, for electric reliability, and the water sector, for water reliability, can be synchronized, all electric and water utilities and their customers would benefit.

This report provides a conceptual framework for identifying and evaluating potential points of synergy and leverage between the electric and water sectors with the aim of facilitating development of a Water Sector Flexible Demand Response Program that will increase the water sector's abilities to support electric reliability at both the local and regional levels. The water sector also benefits – the more real-time operational flexibility a water or wastewater utility can develop, the more effective that utility will be in reducing its current and future energy costs and risks in California's increasingly dynamic electric market.

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Executive Summary

California's phenomenal success in building momentum towards a 100% carbon-free energy supply portfolio has brought a unique set of challenges. The large quantity of solar power that is being developed to meet that goal has created a situation in which real-time electric supplies exceed real-time electric demand during some hours of the day, at certain times of the year. This circumstance, referred to as "over-generation" or "over-supply", causes voltage instability that can disrupt deliveries of electricity. The California Independent System Operator (CAISO) charged with managing 80% of the State's high voltage transmission systems deploys a portfolio of wholesale power market mechanisms to remedy real-time electric system imbalances. Only when market mechanisms do not solve the imbalances does the CAISO resort to mandatory reductions ("curtailments") of excess real-time electricity production.

While the frequency, magnitude, and costs of over-generation curtailments have been modest to-date, California is poised to nearly triple the size of its already extraordinary solar portfolio. In-State utility-scale (transmission voltage level) solar generation capacity peaked at 10,736 MW in 2018. As of March 25, 2019, an additional 23,832 MW of new utility-scale generation was in queue for transmission interconnection between 2019 and 2023. Of this amount, 37.5% (9,383 MW) had already executed interconnection agreements. If all of the new solar generation awaiting transmission interconnection is implemented, much more electricity will be produced than can be used when solar energy production is high and electric demand is low (primarily during spring months).

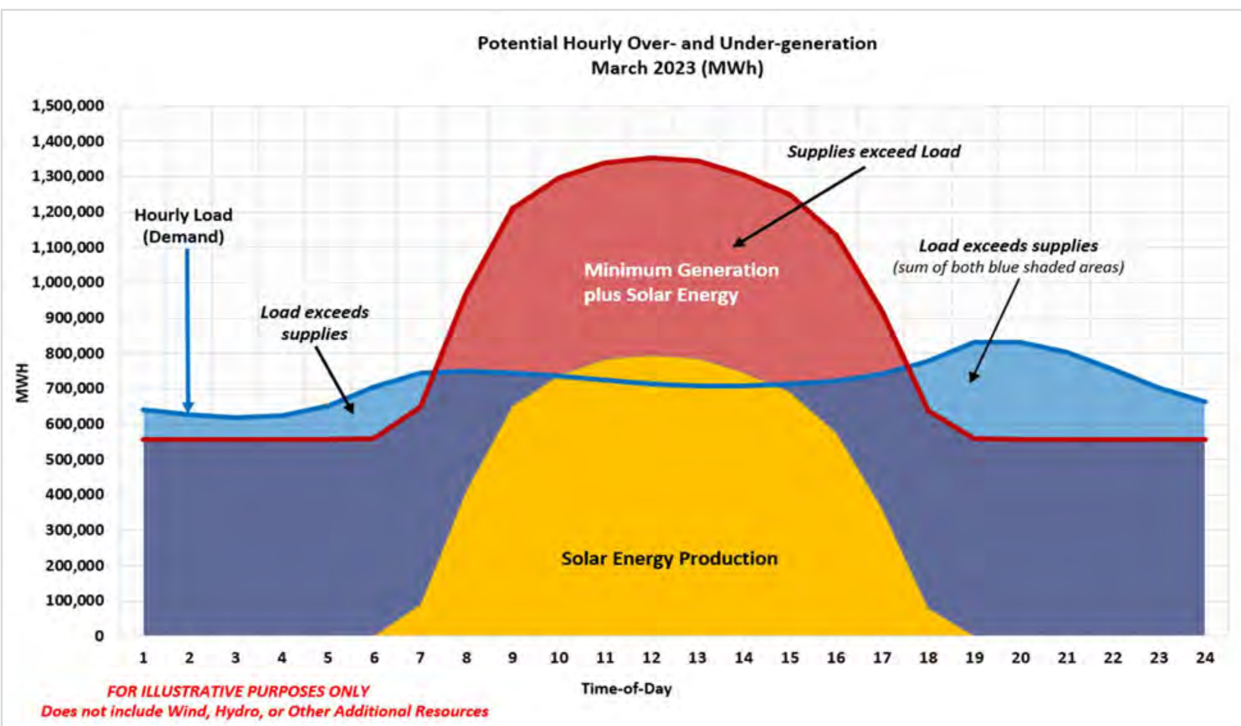

Figure ES-1. Projected Relationship of Solar Energy to Total Electric Demand during March 2023

In an optimal scenario, ample cost-effective electric storage assets would be available to effectively integrate California's unprecedented levels of variable (solar and wind, but mostly solar) energy resources. ("Variable" energy resources are those that cannot be dispatched – they are generated "when the sun shines" and "as the wind blows.") However, electric storage technologies such as chemical batteries cannot yet provide the volume and duration of integration support needed to manage the huge quantities of variable energy in California's electric resource mix. And although California has more pumped storage hydropower than any other state, energy storage needs to be electrically proximate to the variable energy generation resources it is trying to integrate; and 99% of California's pumped storage hydropower capacity resides within only four counties (Los Angeles, Fresno, Butte, and Merced).

Without enough electric storage, the California Independent System Operator (CAISO) that maintains electric reliability for 80% of the State's high voltage transmission system has one primary tool for managing surplus solar energy production: "curtailments." Curtailments may be "economic" (i.e., the market finds a home for low or negative priced energy via real-time wholesale power markets), "self-scheduled" (generators voluntarily reduce scheduled generation), or "exceptional dispatch" (the CAISO directs generators to reduce their output). To-date, most renewable energy curtailments have been voluntary and manageable - during 2018, solar curtailments accounted for only 0.19% of total electric demand ("load") within the CAISO managed grid and 1.56% of utility-scale solar PV production. However, as California's solar portfolio continues to grow, the CAISO will likely need to implement mandatory curtailments ("exceptional dispatch"). This circumstance is highly undesirable from the perspective of a State that has invested billions of dollars in renewable energy subsidies and incentives, and in upgrades to the electric transmission and distribution infrastructure needed to deliver these valuable carbon-free energy resources to customers.

California urgently needs a bridge strategy: one that will enable managing the electric reliability impacts of over-generation without curtailing the State's clean, renewable energy resources.

The Water Sector's Unique Capabilities to Increase Operational Flexibility

The water sector has a unique ability to substantially change the quantity, time, and location of its electric use through changes to water resource portfolios, and water and wastewater systems and operations. Given appropriate price signals, both water and wastewater utilities have shown that they can often increase or decrease pumping capacity at various points in their systems when beneficial to respond to electric price signals. When combined with storage, many water and wastewater systems have shown that they can increase pumping during periods of lower electric prices and reduce pumping during periods of high electric prices.

The water sector's ability to increase flexibility in its systems and operations is a valuable electric load balancing resource and renewable energy integration tool. Few industries can increase the volume of pumping at one location, and then sharply reduce the volume and rate of pumping at that site and the amount of electricity used with minimal risks or disruptions to their systems. Fewer can substantially reduce their real-time electric use simply by deferring operations (pumping and treatment), or changing the location of electric use by pumping water or wastewater to another treatment site. From an electric reliability perspective, deferred pumping and treatment has a similar physical effect on the electric system as energy storage.

Many water and wastewater utilities already reduce their use of high priced on-peak electricity as much as possible. If it can be done without incurring costs or risks to water and wastewater systems and infrastructure, these utilities would likely be amenable to shifting some of their pumping and treatment operations from periods of under-supply to periods of over-supply (over-generation).

Decreasing water sector electric use during periods of under-supply and increasing water sector electric use during periods of over-generation could provide both local and regional electric reliability support while also increasing the State's ability to cost-effectively integrate more variable zero-carbon energy resources such as solar PV and wind.

The Time is Opportune

The American Society of Civil Engineers (ASCE) reported that a significant percentage of the nation's water infrastructure is at the end of its useful life. ASCE's most recent report estimates that over the next 20 years, California will need to invest $44.5 billion in drinking water infrastructure repairs and replacements, and $26.2 billion for wastewater. The State provides billions of dollars to public water and wastewater utilities in the form of grants and low interest loans. The remainder of needed funds is being provided by water and wastewater ratepayers, presenting an excellent opportunity to encourage integration of energy smart designs into more than $70 billion of water sector capital investments.

In addition to repairs, replacements, and enhancements to aged infrastructure, multiple policy initiatives such as drought resilience are precipitating many more billions of dollars of State and local investments in new and enhanced water storage facilities. These planned investments represent opportunities for water-energy partnering and co-investment.

Table ES-1. Planned Water Sector Investments in New or Increased Water Storage

Types of New or Expanded Water Storage	Incremental Capacity		Estimated Cost	See Report Section
	Electric	Water		
Pumped Storage Hydro Facilities	3,700 MW		> $3.0 Billion	Appendix A
Groundwater Banks		1.6 MAF	> $1.4 Billion	Appendix B
Surface Water Reservoirs		3.3 MAF	> $9.7 Billion	Appendix C
Est. Incremental Capacity	**3,700 MW**	**4.9 MAF**	**> $14.1 Billion**	

MW = Megawatt
MAF = Million Acre-Feet (One MAF = 325.851 Billion Gallons of Water)

Water Sector Flexible Demand Response Capabilities

Over-generation has precipitated a need for the State to revise future models of electric utility Demand Response (DR) programs. The ideal circumstance proposed for over-generation is 2-way Demand Response ("Flex-DR"):

- Continuing to decrease electric load during periods of high electric prices, electricity shortages, and/or events that require electric use reductions in specific locations to maintain reliable power flows ***while also:***
- Increasing electric use when needed to reduce voltage instability due to conditions of over-generation.

Over the past several decades, California's water and wastewater utility operators have become sophisticated energy managers as they proactively responded to electric retail price signals, changing dynamic rates, and interruptible tariffs. However, although water sector managers are knowledgeable and experienced in strategies for decreasing electric use during periods of low electric supplies (aka "load shedding"), few are aware of the significant role that they can play in reducing curtailments of California's valuable carbon-free renewable energy resources merely by shifting as much electric use as possible to periods of over-generation.

The key to an effective water sector "Flex DR" program is managing excess water sector capacity (pumps, pipelines, treatment) in combination with water sector storage (water, wastewater, and recycled water; diurnal and seasonal). The more excess pumping capacity and storage within a water or wastewater utility's system, the greater the Flex DR potential.

A Transitional Strategy

California's dynamic wholesale electric market needs a transitional strategy that will expeditiously engage the water sector's assistance in minimizing the frequency and costs of solar curtailment while electric storage technology development (e.g., battery energy storage) advances in parallel. With some technical and financial assistance, many water and wastewater utilities may be able to provide Flex DR support "today." With additional coordination of operations and planning forecasts with SCE and the CAISO, the water sector can become effective grid "reliability partners."

As dialogues between the State's water and electric sectors advance towards finding solutions for surplus variable renewable energy resources through "Flex DR," it is important to recognize that the water sector must first meet its own mission-critical goals and objectives. Water and wastewater utilities need to assure safe and reliable water supplies and wastewater services; it is the electric sector's job to assure electric reliability.

The point at which the needs and interests of the water and energy sectors intersect – where, for example, water and wastewater utilities can earn energy revenues and reduce their net energy costs and risks while still meeting their mission critical water goals and objectives – is the "sweet spot."

Table ES-2 below describes some basic strategies that can increase water sector support for over-generation mitigation.

Table ES-2. Strategies for Flex DR in Water and Wastewater Systems

Opportunity	Strategies	Potential Constraints	Challenges
Increase or decrease the volume of water, wastewater, and/or recycled water pumped or treated during specified hours	Maximize use of existing capacity, and/or increase capacity, to enable increasing electric use during periods of over-generation: ▪ Groundwater and booster pumps ▪ Water and wastewater treatment plants ▪ Raw, potable, and recycled water distribution systems ▪ Raw, potable, and recycled water reservoirs, ponds, tanks, other storage facilities	▪ <u>Mission Critical</u>: Increasing pumping rates could impair water quality. ▪ <u>Resource</u>: Increased rates and volumes of pumping could impair the water resource. ▪ <u>Physical</u>: Insufficient pump capacity at targeted site, pipeline constraints, storage constraints. ▪ <u>Legal &/or Regulatory</u>: May not have rights to increase pumping at the planned site at the targeted volumes. ▪ <u>Economic</u>: Some water sector Flex DR opportunities may not be cost-effective on the basis of water benefits alone.	<u>Economic</u>: Energy benefits alone cannot pay for a new reservoir or other expensive water, wastewater, and/or recycled water system and infrastructure. The ideal opportunity is one that first achieves mission-critical water sector goals and objectives. Energy benefits can then be explored with the aim of offsetting a portion of the proposed water project costs while concurrently reducing water sector energy costs and risks.

A Water Sector Flex DR Program

Most of the water and wastewater utilities that provided data and information for this study already participate in Demand Response (DR) programs. These utilities stated that they could do more DR and expressed a desire to participate in designing a "Flex DR" program tailored to the water sector's special needs and capabilities to provide over-generation mitigation support. All felt that both financial and technical assistance will be needed to help the water sector identify and evaluate Flex DR opportunities. Recommended program design principles include the following:

1. **<u>Remove Disincentives</u>**. Several water and wastewater utilities cited a need to remedy disincentives in traditional DR programs. Some disincentives were financial (demand charges, penalties for not participating in specific events); some were operational (the process is too difficult, communications need to be better, operators need to be better

trained). Others related to a need for better telemetry, such as linking sub-metered electric use at the prime mover level to SCADA, and more sophisticated real-time decision-making tools. All water and wastewater utilities interviewed for this report emphasized a need to recognize that the water sector must first assure that its mission-critical priorities have been met before it can provide electric reliability support.

2. **Mitigate Incremental Costs and Risks**. Most water and wastewater utilities indicated that they could likely increase electric use during periods of over-generation, but some additional investment may be needed to make the types of changes to systems and controls that would enable effective Flex DR. Some utilities stated that automated Flex DR may be possible, provided operators are first given the opportunity to verify that the water or wastewater utility's mission-critical priorities will not be impaired. With those assurances, water sector managers may be able to provide over-generation mitigation support on both day-ahead and real-time bases.

3. **Provide Technical Assistance**. Water and wastewater systems are comprised of multiple complex interconnected systems and functions. Operational changes to one part of the system often affects operations (and electric use) both upstream and downstream of the point at which a change is being considered.

   Due to the high level of interconnectivity, system hydraulics and capacity constraints must be considered when evaluating potential changes to systems and/or operations. Although most water and wastewater utilities can increase pumping at various points in their systems, capacity limits (pumps, water and wastewater treatment facilities, conveyance and distribution pipelines, diurnal and seasonal storage facilities) can limit over-generation mitigation potential. Other types of constraints - water quality, groundwater allocations, regulatory environmental flows, and other legal and regulatory requirements – can also constrain operations.

4. **Provide Water Sector Electric Planning and Analytical Tools**. The collaborations between SCE and its water sector customers reveal a need for new ways of thinking about the energy impacts of water, wastewater, and recycled water systems and operations. New tools (checklists, economic assessments, analytical tools, predictive energy models) can facilitate efficient and cost-effective water sector identification and evaluation of Flex DR opportunities.

The goal of designing a Water Sector Flex DR Program is to expedite identification, evaluation, and implementation of near-term Flex DR opportunities that can provide meaningful electric reliability support within 1-3 years. Concurrently, larger, longer-term projects and strategies can be positioned for early conceptual development with the aim of implementing the next phase of water-related Flex DR projects within 3-5 years.

A phased approach can help to build a temporary buffer of water sector Flex DR resources that reduce renewable energy curtailments while electric storage projects and technologies advance in parallel.

Abbreviations and Acronyms

ACWA	Association of California Water Agencies
AF	Acre-foot
AFY	Acre-feet/year
aka	also known as
ASCE	American Society of Civil Engineers
AVEK	Antelope Valley-East Kern Water Agency
AVWS	Antelope Valley Water Storage
AWT	Advanced Water Treatment
BTM	Behind-the-Meter
CAISO	California Independent System Operator
CBEWP	Chino Basin Environmental Water Program
CBP	Chino Basin Program
CDFW	California Department of Fish and Wildlife
CEC	California Energy Commission
CPUC	California Public Utilities Commission
CVP	Central Valley Project
CWC	California Water Commission
CY	Calendar Year
DER	Distributed Energy Resources
DR	Demand Response
DWR	Department of Water Resources
EERE	Office of Energy Efficiency and Renewable Energy (U.S. Department of Energy)
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPIC	Electric Program Investment Charge
FERC	Federal Energy Regulatory Commission
FEMA	Federal Emergency Management Agency
Flex DR	Flexible Demand Response
FY	Fiscal Year
GSP	Groundwater Sustainability Plan
IDER	Integrated Distributed Energy Resources

IEUA	Inland Empire Utilities Agency
IOU	Investor Owned Utility
kW	Kilowatt
kWh	Kilowatt Hour
kV	Kilovolt
LACSD	Los Angeles County Sanitation District
LADWP	Los Angeles Department of Water and Power
LEAPS	Lake Elsinore Advanced Pumped Storage
LSE	Load Serving Entity
m-PSH	Modular Pumped Storage Hydropower
MAF	Million Acre-Feet
MAR	Managed Aquifer Recharge
MG	Million Gallons
MGD	Million Gallons per Day
MW	Megawatt
MWD	Metropolitan Water District of Southern California
MWh	Megawatt Hour
NEPA	National Environmental Policy Act
OCWD	Orange County Water District
ORNL	Oak Ridge National Laboratory
PV	Photovoltaics
RCWD	Rancho California Water District
SCADA	Supervisory Control and Data Acquisition
SCE	Southern California Edison
SCVWD	Santa Clara Valley Water District
SDCWA	San Diego County Water Authority
SDG&E	San Diego Gas & Electric Co.
SGMA	Sustainable Groundwater Management Act
SMWD	Santa Margarita Water District
SOMAH	Solar on Multifamily Affordable Housing
SWC	State Water Contractors
SWP	State Water Project
SWRCB	State Water Resources Control Board
TOU	Time-of-Use
USBR	U.S. Bureau of Reclamation

USDOE	U.S. Department of Energy
USEIA	U.S. Energy Information Administration
UWMP	Urban Water Management Plan
WRD	Water Replenishment District of Southern California
WSIP	Water Storage Investment Program
WSWB	Willow Springs Water Bank

I Introduction

Regulatory Background

Over-generation occurs at times and in places where real-time electric supplies exceed real-time electric demand, causing electric system instability.

On September 19, 2013, the California Public Utilities Commission (CPUC) opened Rulemaking No. 13-09-011 "To Enhance the Role of Demand Response in Meeting the State's Resource Planning Needs and Operational Requirements" (R.13-09-011). One activity conducted under this rulemaking was review and approval of the State's electric investor-owned utilities' (IOUs) proposed Demand Response Programs which include new demand response research activities to meet the future grid needs envisioned by the State.

On February 1, 2016, pursuant to the "Joint Assigned Commissioner and Administrative Law Judge's Ruling Providing Guidance for 2017 Demand Response Programs and Activities Proposal Filings",[1] Southern California Edison (SCE) filed a "Proposal for Approval of Its 2017 Demand Response Program and Bridge Funding Authorization". In its proposal, SCE recommended "*a pilot program that would study the application of an energy storage technology, specifically, pumped water storage*."[2] SCE proposed "*researching energy storage system performance; beneficial use cases for absorbing excess energy during an over-generation event; customer behavior and drivers needed; multi-use energy storage systems that use automation; ancillary services to test signal response and validate integration of the over generation pilot resources into the market; and determination of temporal and locational value of load shifting*."[3]

On June 9, 2016, the CPUC issued Decision 16-06-029 approving SCE's proposed pilot to evaluate the potential of pumped water storage as a means of addressing periods of over-supply (over-generation) on California's electric grid. The pilot was designed to provide SCE with information and insights about whether water pumping can be a feasible and reliable over-generation mitigation tool. This information is needed to support SCE's development of over-generation demand response (DR) strategies.

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[1] "Joint Assigned Commissioner and Administrative Law Judge's Ruling Providing Guidance for 2017 Demand Response Programs and Activities Proposal Filings." *California Public Utilities Commission* Rulemaking 13-09-011 [R.13-09-011]. September 15, 2015.

[2] "SCE Proposal for Approval of Its 2017 Demand Response Program and Bridge Funding Authorization." *California Public Utilities Commission* [R.13-09-011]. February 1, 2016.

[3] "Decision Adopting Bridge Funding for 2017 Demand Response Programs and Activities." *California Public Utilities Commission* Decision 16-06-029 [R.13-09-011]. June 9, 2016.

For purposes of this report, "water sector" includes water and wastewater utilities, agricultural water purveyors, groundwater bankers, wholesale water suppliers, and other types of water purveyors and water service providers, both publicly and investor-owned.

Two Types of Over-generation

Since 2014, conditions of over-generation have primarily occurred on the California electric grid when non-dispatchable electric generation resources cause the total amount of real-time electric supplies to exceed real-time electric demand (load).

California's visionary clean, renewable, and carbon-free energy policy goals have precipitated a need to expedite the engagement of customers as "reliability partners" in providing electric grid support. The most urgent current need from a policy context is to reduce electric system instability during periods of over-generation and enable more carbon-free electric generation.

Over-generation typically occurs when high quantities of solar electric generation coincide with wind energy production, causing real-time electric supplies to exceed real-time electric demand. That in turn causes voltage instability which, if not immediately solved, can disrupt electric service.

Without adequate utility-scale electric storage solutions, the primary tool for solving over-generation is presently curtailment – turning surplus real-time electricity off. For a state that has invested billions of dollars in public funds to establish solar and other renewable energy markets, curtailment of renewable energy is highly undesirable.

Over-generation affects electric reliability in Southern California Edison's (SCE's) service area at two levels: the high voltage electric transmission system that is managed by the California Independent System Operator (CAISO), and the lower voltage electric distribution system that is managed by SCE.[4] SCE and other electric utilities (as well as other types of electric service providers known as "Load Serving Entities", or "LSEs") are required to balance their loads within their respective service areas. The CAISO then provides real-time balancing services at the transmission voltage level to assure that electricity flows reliably throughout the State.

The CAISO's primary tool for addressing periods of surplus electric generation ("over-generation" or "oversupply") on the transmission system (also known as the California electric grid) is market-based curtailments. While presently essential to assuring reliable delivery of electricity, curtailments of wind and solar are

[4] "Understanding electricity." *California Independent System Operator (CAISO)* website: http://www.caiso.com/about/Pages/OurBusiness/Understanding-electricity.aspx.

antithetical to the policy perspective of a state that has invested billions of dollars to build a pathway to 100% clean, renewable, and carbon-free electricity.[5]

At the distribution system level, SCE maintains an electric sub-transmission and distribution network to provide reliable electric service for its customers. "Distributed" energy resources are those that are built and operated at the electric distribution system level - many of those are on the customer side of the meter. Supported by favorable State policies and programs, "Distributed Energy Resources" (DERs) - energy efficiency, demand response, distributed generation, and energy storage[6] – are rapidly increasing as a percentage of SCE's resource mix. Due to its versatility and relatively low cost to site and install, the primary customer-side electric generation resource is now solar photovoltaics (PV), with the result that SCE and other electric utilities face the prospect of "mini-duck curves" (over- and under-supply events) throughout their distribution systems.

Consequently, over-generation within SCE's service area needs to be addressed at two levels:

1. California's wholesale market transmission system, and
2. SCE's retail electric sub transmission and distribution system.

Managing Over-generation

Of the four DERs, demand response and energy storage are the two most critical strategies for addressing over-generation because these enable changing the time (and sometimes also the location) of electric use. Changing the time of electric use to address challenges to electric reliability is known as "load shifting" (or simply "shift").

While California's policy leaders understand the need to maintain reliable electric service, they would like to find alternatives to curtailments of wind and solar. However, the preferred technology solution, cost-effective utility-scale battery electric storage, is still in its infancy. A promising tool for mitigating over-generation at both the transmission and distribution levels that

> ***"Shift refers to a DR approach that involves moving electrical loads from one time to another to better match either, the availability of low-cost power or to "valley fill" grid-level load requirements (i.e., peak-clipping), while providing equivalent energy service to the end user. From a grid perspective, Shift resembles a storage resource."***
>
> - Dr. Brian Gerke, et.al. "Shift Demand Response: A Primer." *Lawrence Berkeley National Laboratory*, Energy Technologies Area. February 28, 2018.

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[5] "The 100 Percent Clean Energy Act of 2018" [*Senate Bill 100, De León, 2018*] established a goal of 100% renewable and carbon-free electricity by the year 2045 and increased and accelerate intermediate goals.

[6] California Public Utilities Code §769(c) ARTICLE 3. Equipment, Practices, and Facilities defines "distributed resources" as "distributed renewable generation resources, energy efficiency, energy storage, electric vehicles, and demand response technologies."

is both technically and economically feasible is Flexible Demand Response ("Flex DR") – actions taken by customers to change the time and quantity of their electric use in both directions: up and down.

The Water Sector's Unique Capabilities to Increase Operational Flexibility

It has long been known that the water sector has a unique ability to substantially change the quantity, time, and location of its electric use through changes to water resource portfolios, water and wastewater systems design, and operations.[7] Both water and wastewater utilities can often increase or decrease pumping at various points in their systems. When combined with storage,[8] water and wastewater utilities can hold pumped water or wastewater for treatment or use during other periods, deferring the electricity that would otherwise have been used to pump and/or treat that water or wastewater. Deferred pumping has a similar physical effect on the electric system as energy storage.

The water sector's ability to increase flexibility in its systems and operations is a significant electric load balancing resource. Few industries can choose to increase the volume of pumping at a specific location (e.g., to increase electric use during periods of over-generation), and then to store the pumped water or wastewater for treatment or use during periods of low electric supplies and high electric prices.

The Time is Opportune

The American Society of Civil Engineers (ASCE) reported that a significant percentage of the nation's water infrastructure is at the end of its useful life. ASCE's most recent report estimates that over the next 20 years, California will need to invest $44.5 billion for drinking water infrastructure repairs and replacements, and $26.2 billion for wastewater.[9] The State is providing many of these billions to public agencies in the form of grants and low interest loans. The balance of needed funds is being provided by water and wastewater ratepayers. This presents an excellent opportunity for encouraging integration of energy smart designs into more than $70 billion of water sector capital investments.

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[7] Park, Laurie and Kenneth Croyle. "California's Water-Energy Nexus: Pathways to Implementation." *GEI Consultants for the Water-Energy Team of the Governor's Climate Action Team (aka "WET-CAT")*. September 12, 2012.

[8] Some storage, such as tanks, enable changing the timing and pattern of diurnal flows at various facilities to defer pumping and treatment operations (and associated electric use) to non-peak periods. Larger storage systems, such as reservoirs, enable storing water or recycled water for multiple days, weeks, months, and even years.

[9] "California 2018 Report." *American Society of Civil Engineers (ASCE)* website: https://www.infrastructurereportcard.org/state-item/california/.

SCE's Over-generation Pilot Project

Goal

Continue building knowledge and understanding about water sector opportunities for developing flexible resources that enhance grid reliability and mitigate both regional and local distribution over-generation impacts. For purposes of this report, "water sector" includes water and wastewater utilities, agricultural water purveyors, groundwater bankers, wholesale water suppliers, and other types of water purveyors and water service providers, both publicly and investor-owned.

Objectives

- Identify strategies for California's water sector to increase flexibility in their systems and operations where beneficial for mitigation of electric voltage instability, physical and economic curtailments of renewable electric resources, and other undesired impacts of over-generation.
- Develop analytical models and tools to assist the water sector in identifying and evaluating opportunities to provide over-generation mitigation support.
- Evaluate the costs/benefits of water sector over-generation opportunities from the perspectives of the water sector and their ratepayers, SCE and its ratepayers, and the State.
- Develop a proposed framework, rate model, and tariff for providing incentives to water sector entities to mitigate over-generation.

Approach

- Leverage prior work and existing relationships, resources, and assets to achieve the project goals and objectives as efficiently and cost-effectively as possible.
    - Build upon relevant work already completed by SCE and its contractors, other energy utilities, water sector entities, energy and water service providers, industry associations, and other key stakeholder groups.
    - Leverage existing water-energy partnerships and projects to obtain the needed information as quickly and efficiently as possible.
    - Utilize a wide variety of technical resources, including subject matter experts in various fields that can help to complete the project deliverables quickly and at a high level of quality.
- Obtain input and insights from leading water and wastewater utilities that have already commenced identifying and evaluating strategies for minimizing energy costs and risks in the anticipated new electric markets.
- Capture stakeholders' insights in case studies that document best-in-class over-generation mitigation programs, projects, and practices.
- Convert data and information about water sector opportunities for mitigating over-generation into training materials, analytical and predictive models, and other tools that can help water and wastewater utilities increase their flexible load capabilities.

What's in this Report

Chapter II of this report describes "over-generation": what it is now, how it will change in the future, and why we care.

Chapter III describes different types of water storage and how these can be used for both over-generation mitigation support and load-shifting during periods of under-generation.

Chapter IV provides examples of how water and wastewater utilities use electricity, their historical responsiveness to price signals (e.g., deep reductions of electric use during high priced summer on-peak periods), and strategies for increasing operational flexibility into existing water and wastewater systems for Flexible Demand Response.

Chapter V summarizes this study's findings and recommends an approach to developing a Water Sector Flexible Demand Response Program.

The recommendations articulated herein support the following action items in the Joint Agencies' Energy Storage Roadmap, "Advancing and Maximizing the Value of Energy Storage Technology, A California Roadmap". (The Roadmap was jointly prepared by the CAISO, the CPUC, and the CEC.)

Item #7: Consider refinements to the valuation methodologies used by IOUs to support CPUC decisions on storage procurement and make models publicly available.
Item #10: Prepare summary of efforts underway focused on developing models for energy storage valuation and plans [for] public distribution.
Item #13: Clarify rate treatment for customer sites with a mix of resources that help meet local consumption needs and do not result in the net export of energy.
Item #36: Define and develop models and rules for multiple-use applications of storage.

II What is "Over-generation"?

> ***"To maintain reliability the ISO must continuously match the demand for electricity with supply on a second-by-second basis."***
>
> - *"Fast Facts: What the duck curve tells us about managing a green grid." California Independent System Operator. 2016.*

Assuring continuous reliable delivery of wholesale electric energy requires matching real-time supplies with real-time demand. When real-time supplies and demand are not in balance, the California electric grid experiences system instability which, if not promptly remedied, can cause disruptions to electric service.

The California Independent System Operator (CAISO) is responsible for managing the flow of bulk electric power for California's three large investor owned electric utilities (PG&E, SCE and SDG&E) and some publicly owned electric utilities. Collectively, the CAISO manages power flows across 80% of the State's high voltage transmission systems.[10] With the assistance of sophisticated monitoring and control systems, the CAISO balances electric supplies and demand at key points throughout California's electric grid every 4 seconds.[11]

A condition of "over-generation" (referred to by the CAISO as "over-supply") occurs when real-time electric supplies exceed demand. Electric storage can alleviate voltage instability by storing surplus real-time electricity production that exceeds demand. However, electric storage technologies are not yet able to store the very large quantities of excess wholesale power - especially utility scale solar photovoltaics (PV) - that are causing most of the over-generation. Consequently, the primary tool currently available to the CAISO for managing over-generation or over-supply is "curtailment" - reducing excess energy production.

Most of the power curtailed by the CAISO is wind and solar, since it is typically at the coincidence of these two variable resources and low electric demand that real-time supplies exceed real-time demand. Hydropower also contributes to over-generation during spring months.

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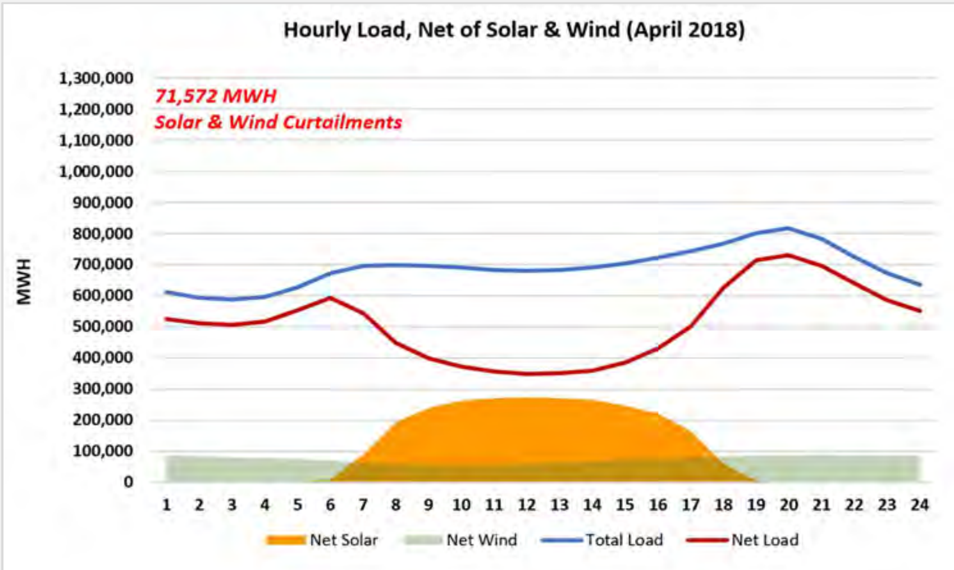
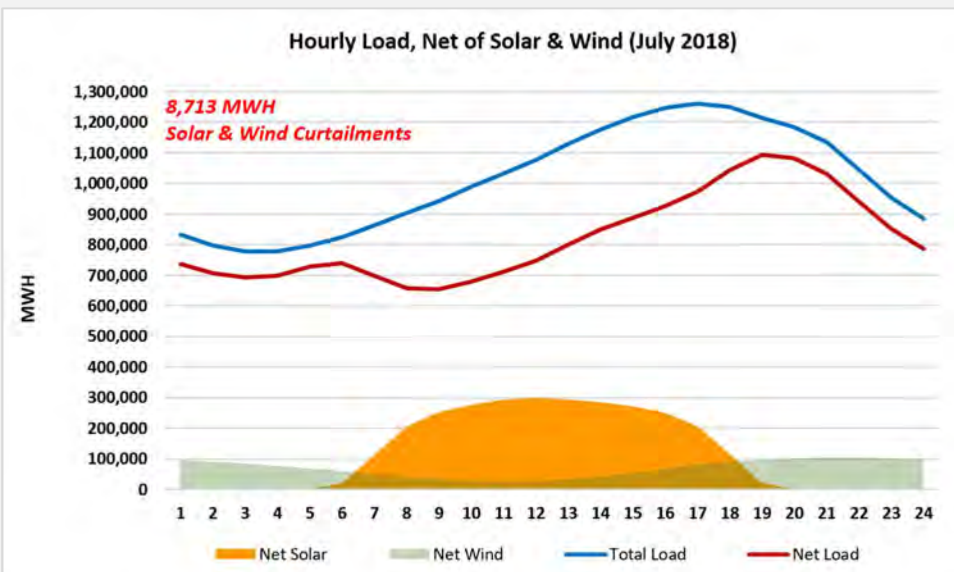
[10] "The ISO Grid." *California Independent System Operator (CAISO)* website: http://www.caiso.com/about/Pages/OurBusiness/The-ISO-grid.aspx.

[11] "Maintaining Bulk Power System Reliability While Integrating Variable Energy Resources – CAISO Approach." A joint report produced by the *North American Electric Reliability Corporation (NERC) and the California Independent System Operator Corporation (CAISO)*. November 2013.

The Relationship Between Total Load and Solar and Wind Production

The two below graphs show the relationship between Total Load (electric demand) and Net Load (electric demand net of solar and wind production). Although both months experienced similar volumes of solar and wind (variable energy) production, electric demand during April 2018 was much lower than in July 2018. Curtailments were thus higher during April than in July.





Source: Compiled from CAISO Production and Curtailment Data for CY2018.

Curtailments

The CAISO currently addresses over-generation through three types of "curtailments":[12]

1. ***Economic Curtailments***: The market finds a home for low-prices *or* negative-priced energy using the real-time market.
2. ***Self-Scheduled Cuts***: Generators reduce scheduled generation.
3. ***Exceptional Dispatch***: The CAISO orders generators to turn down output (this method of curtailment is used as a last resort).

"Economic curtailments" occur when the CAISO identifies a need to reduce over-generation during certain hours and at certain locations in the bulk power grid. Over-generation can be mitigated by reducing supply and/or increasing demand. During such events, typically noticed on the day-ahead market, generators can submit "decremental" bids to reduce energy production. The CAISO has specific protocols that determine which bid will have priority for various circumstances, but the over-arching principle is that the CAISO will accept the bids that result in the lowest costs.

Under economic curtailment, a generator can submit a bid to reduce production (offer to reduce generation for a price). Market participants can also submit bids to purchase excess power (offer to take power at a low or negative price). The CAISO makes its selection based on which bids achieve electric reliability at the lowest cost. Maintaining electric reliability is a carefully orchestrated balancing act, managed by the CAISO on behalf of all stakeholders on both pre-scheduled and real-time bases through complex and diverse wholesale power market mechanisms.

To-date, nearly all curtailments have been economic. Occasionally, a generator may choose to implement a "self-scheduled" reduction in output. Only when there are no other options does the CAISO resort to a manual "cut" (i.e., an order to the generator to reduce its generation).

[12] "Fast Facts: Impacts of renewable energy on grid operations." *California Independent System Operator (CAISO)*. 2017.

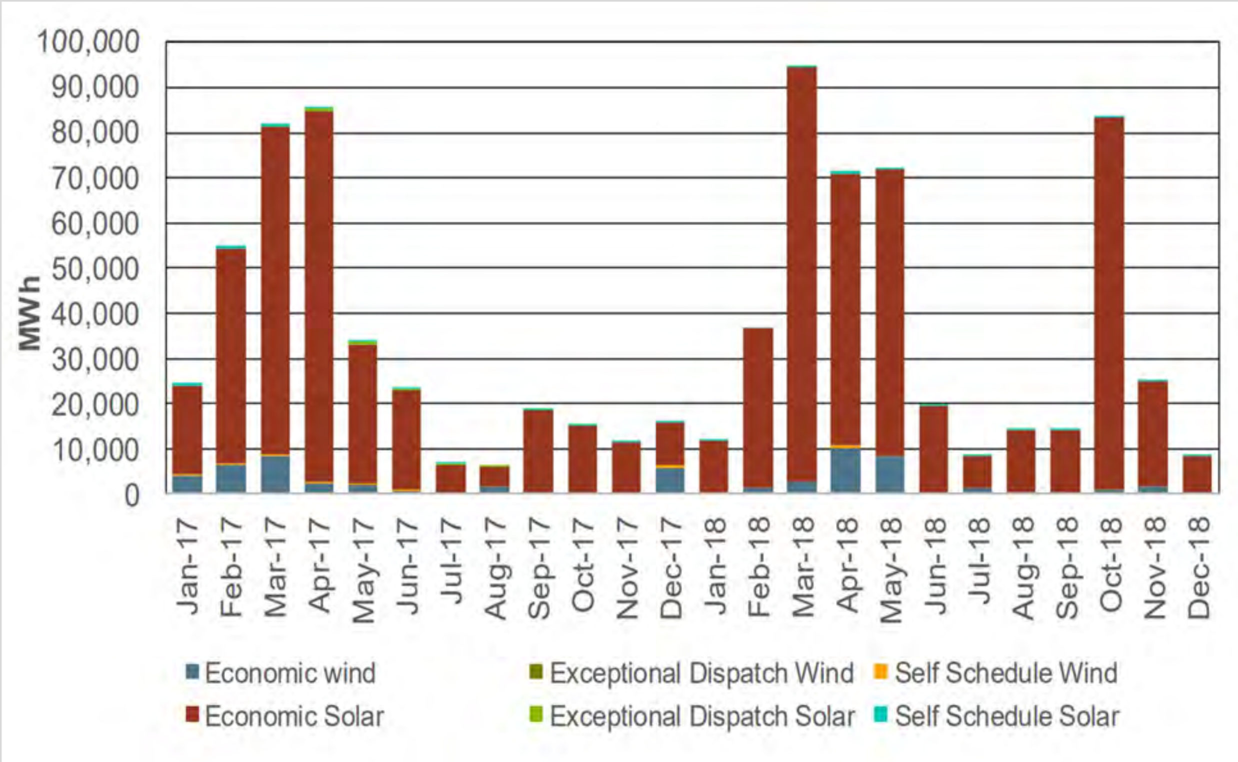


Figure 1. Types of Curtailments [January 2017 – December 2018][13]

"During times of oversupply, the bulk energy market first competitively selects the lowest cost power resources. Renewable resources can "bid" into the market in a way to reduce production when prices begin to fall. … Then, self-scheduled cuts are triggered and prioritized using operational and tariff considerations.

"Finally, if market-based solutions haven't cleared the surplus of electricity that could be generated, the last resort is for the ISO to manually intervene, which is called an "exceptional dispatch." In this scenario, ISO grid operators call on specific renewable plants to reduce output to prevent or relieve conditions that risk grid reliability. … This is not preferred, because it does not ensure the lowest cost resources are called upon to serve Californians, and in many cases, it reduces the output of renewable plants."

- *"Fast Facts: Impacts of renewable energy on grid operations." California Independent System Operator. 2017.*

[13] "Market Performance Metric Catalog", version 1.36. *California Independent System Operator (CAISO)*. December 2018.

What Causes Over-generation?

Although widely regarded as a recent phenomenon triggered primarily by unprecedented quantities of intermittent renewable energy resources – especially solar and wind – in California's portfolio of electric supplies, "over-generation" is not "new."

> ***"Intermittent" renewable resources – aka "variable" and "non-dispatchable" resources – are resources that determined by natural forces that at least thus far, California is not able to directly control ("dispatch"). In other words, "intermittent", "variable", "non-dispatchable" electricity is produced at times and in quantities that are determined by real-time weather conditions.***

Over-generation, and associated "zero-to-negative pricing" in wholesale power markets, occurs when there is surplus electric production. Until recently, the primary driver of zero or negative wholesale power prices in the western U.S. was precipitation: heavy rains in the Pacific Northwest, California, or elsewhere that literally "flooded" the market with low-cost hydropower.

These types of events tended to be seasonal and sporadic. Currently, however, California's aggressive renewable energy portfolio policies and programs have created a circumstance in which very large quantities of intermittent renewable resources—especially solar and wind—have increased the frequency and amount of over-generation that can occur during any day of the year. This, in turn, has increased the frequency of zero or negative prices.

Figure 2 on the next page shows that the frequency of 5-minute interval negative prices increased from about 2% in 2012 and 2013, to more than 6% in 2017. The CAISO explained that during 2017, "Negative prices occurred more frequently in the 15-minute and 5-minute markets compared to the previous year as a result of a growth in installed renewable capacity and increased hydro-electric generation. Negative prices during 2017 were most frequent in midday hours between February and April when loads were modest and hydro and solar generation were greatest."[14]

Figures 3 and 4 on pages 12-13 visually depict the coincidence of economic curtailments and negative prices with the hours of solar production, currently the primary driver of over-generation.

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[14] "Fast Facts: Impacts of renewable energy on grid operations." *California Independent System Operator (CAISO)*. 2017.

Figure 2. Frequency of 5-Minute Interval Negative Prices (2012-2017)[15]

Most of the negative prices from 2012-2017 were well under $50/MWH ($0.05/kWh). In fact, most were under $5/MWH ($0.005/kWh – see Figure 3 below).

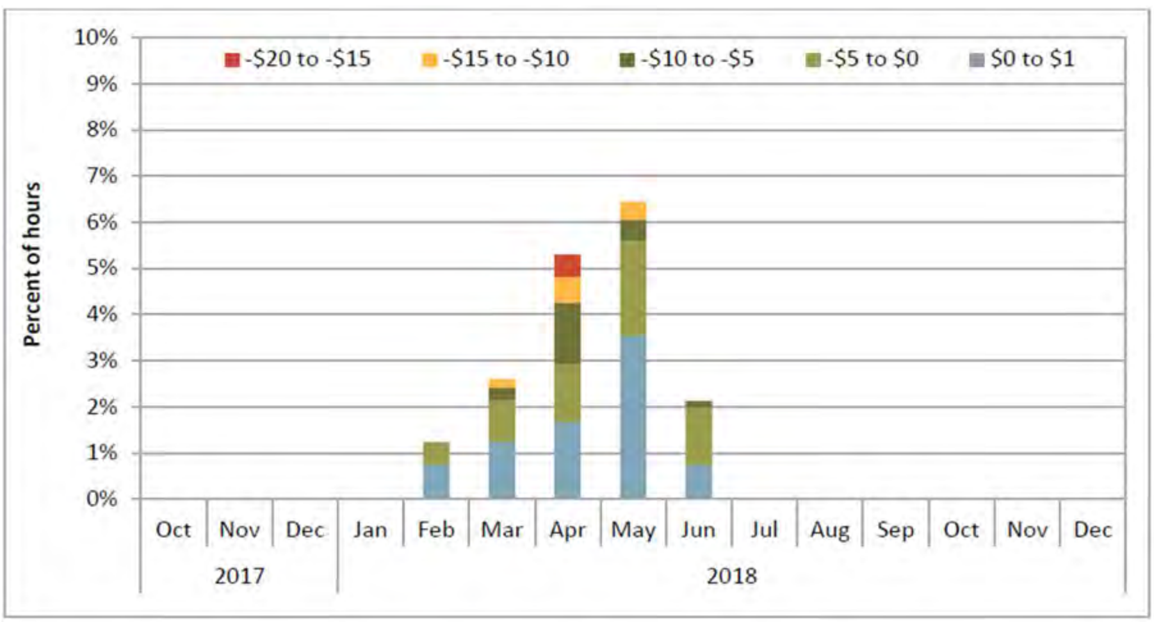

Figure 3. Frequency of 5-Minute Negative Prices by Month (Q4 2017 through CY2018)[16]

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[15] "2017 Annual Report on Market Issues & Performance." *California Independent System Operator (CAISO)*. June 2018.

[16] "Q4 2018 Report on Market Issues and Performance." *California Independent System Operator (CAISO)*. February 13, 2019.

During 2018, most of the negative prices were under $5/MWH ($0.005/kWh). The highest negative prices occurred during April 2018, but even those were lower than $20/MWH ($0.02/kWh).

Figure 4 shows the hourly distribution of negative prices for 3 years: 2013, 2015, and 2017.

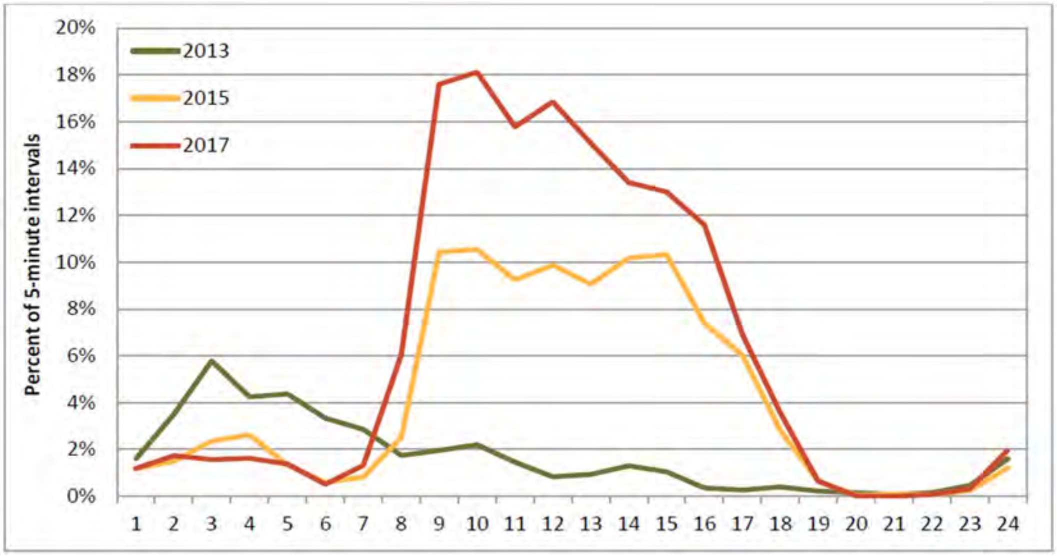

Figure 4. Hourly Frequency of Negative 5-Minute Prices (2013, 2015, 2017)[17]

Solar and Wind Energy Curtailments

Table 1 below and Figure 5 on the next page show the amount of solar and wind energy curtailed by the CAISO during 2015-2018. Clearly, curtailments are increasing, especially solar. The gap between electric supplies and demand will continue to grow as more utility scale solar and wind are brought on-line to meet California's ambitious goal of 100% carbon-free energy by 2045.

Table 1. Quantity of Solar and Wind Curtailments (MWh) [2015-2018][18]

Year	Solar	Wind	Total Curtailments
2015	137,182	50,588	187,770
2016	228,418	73,744	302,162
2017	345,545	33,873	379,418
2018	432,357	28,686	461,043

[17] "2017 Annual Report on Market Issues & Performance." *California Independent System Operator (CAISO)*. June 2018.

[18] Compiled from California Independent System Operator (CAISO) historical wind and solar production and curtailment data in the California Independent System Operator. "Managing Oversupply." *CAISO* website: http://www.caiso.com/informed/Pages/ManagingOversupply.aspx.

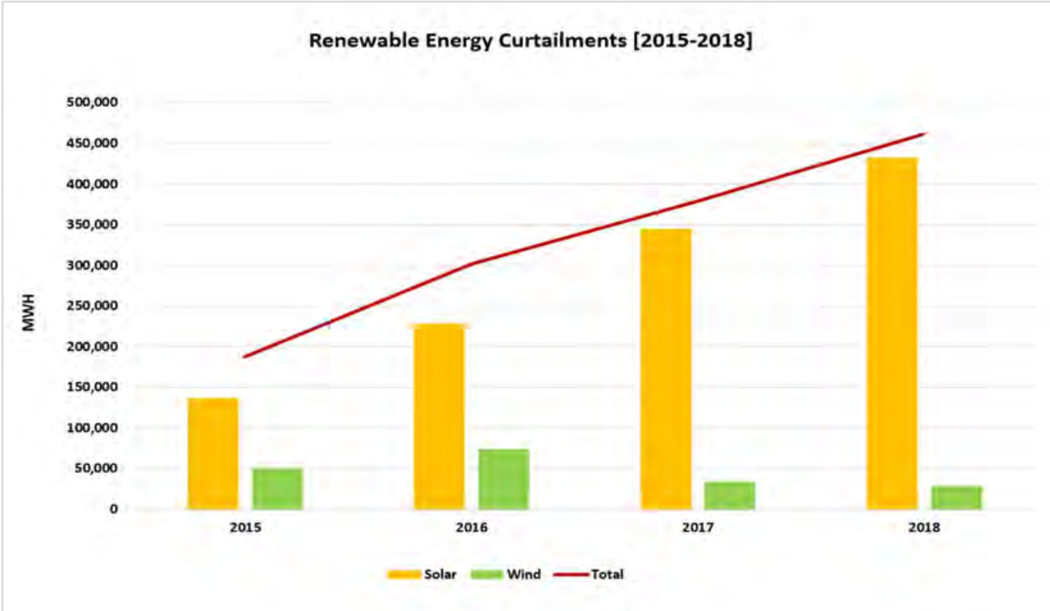

Figure 5. Annual Solar and Wind Energy Curtailments (2015-2018)[18]

Why do we care?

The California Energy Commission (CEC) estimated that as of December 31, 2018, California's renewable electric capacity totaled 30,759 MW.

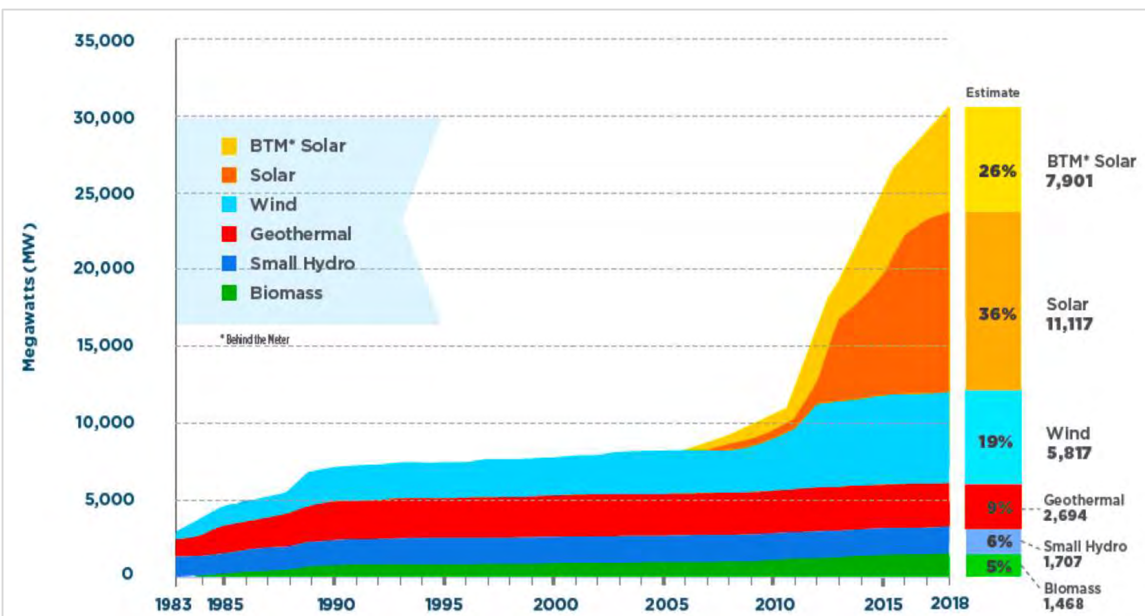

Figure 6. Annual Cumulative Installed Renewable Energy Capacity (1983-2018)[19]

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[19] "Tracking Progress: Renewable Energy." *California Energy Commission*. Updated December 2018.

According to the CEC, installed solar generation accounted for 19,018 MW (62% of total renewable energy capacity: 11,117 MW of front-of-the-meter capacity plus 7,901 MW of behind-the-meter (BTM) capacity). The CEC's number for front-of-the-meter capacity is 3.4% higher than the peak transmission-level solar PV production recorded by the CAISO in 2018 (10,736 MW).[20] Wind accounted for an additional 19% of installed capacity, bringing total in-State intermittent ("variable") solar and wind energy capacity to 81% of total renewables.

The CAISO's database shows that an additional 23,832 MW of new utility-scale solar generation has applied for interconnection between 2019 and 2023.[21] Of this amount, planned solar PV projects totaling 8,933 MW (37.5%) have already executed transmission interconnection agreements.

BTM solar capacity is also likely to ramp up quickly due to the decreased cost of solar and California's 2019 Building Energy Efficiency Standards[22] that require solar PV on all new homes. Further, the CPUC's new programs funding solar PV for low-income and disadvantaged community projects that will commence this year (2019) are also expected to increase the quantity of installed BTM solar.[23]

Adding 23,832 MW of transmission level solar PV to the existing 10,736 MW on the CAISO managed electric grid would more than triple the amount of utility-scale solar PV in California. While not all of the planned new solar generation may be implemented, the CAISO's "Duck Curve" (see page 17), the Load Duration Curves (Figures 7 and 8) and the graphs depicting Projected Hourly 2023 Over-Generation (Figures 9 and 10) on pages 18-20 illustrate why, absent sufficient electric storage resources, more new solar will mean more curtailments during periods of low electric demand (usually spring months).

- The CAISO projected that electric demand during a "typical" March day in 2020 would peak during the late evening at about 26,200 MW. During the day, however, utility-scale solar production of 10,736 MW plus the additional 9,383 MW of utility-scale solar that already have interconnection agreements will total 20,119 MW in 2020. If all of the utility-scale

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[20] Source: "Production and Curtailments Data - 2018.xlsx." *California Independent System Operator (CAISO)* website: http://www.caiso.com/informed/Pages/ManagingOversupply.aspx. This amount is 3.4% less that the CEC's estimate of 11,117 MW of solar PV capacity that may include some solar PV generation that is interconnected to transmission systems that are not managed by the CAISO, and/or that may be interconnected at the front-of-the-meter (i.e., outside a customer's facility but at distribution system voltages).

[21] ISO Generator Interconnection Queue, Excel spreadsheet, "Active" Projects only. *California Independent System Operator (CAISO)* update March 25, 2019.

[22] "2019 Building Energy Efficiency Standards." *California Energy Commission (CEC)*. March 2018.

[23] The Solar on Multifamily Affordable Housing Program and the Disadvantaged Community-Single family Affordable Solar Homes Programs will begin this year (2019). Sources: "Implementation of AB 693 - Solar on Multifamily Affordable Housing (SOMAH)." *California Public Utilities Commission (CPUC)* website: http://www.cpuc.ca.gov/general.aspx?id=6442454736 and "Solar on Multifamily Affordable Housing." SOMAH website: https://www.calsomah.org/.

solar projects currently in the CAISO's queue for transmission interconnection are brought on-line, utility-scale solar would reach 34,568 MW.[24]

> ***The 7,901 MW of "behind-the-meter" (BTM) solar PV reported by the CEC is not included in the amount of utility-scale solar on the wholesale transmission grid because the CAISO does not "see" BTM resources – the CAISO sees the impact of BTM resources as reduced electric demand on the State's high voltage transmission system.***

- When determining which actions will be needed to maintain reliable delivery of electricity, the CAISO must consider the fact that about 18,000 MW of non-solar/non-wind "minimum" (non-dispatchable) generation cannot be turned off for a variety of regulatory, reliability, and other factors.

> ***Some electric resources were developed pursuant to State or federal regulations, or may be governed by other regulations that do not allow the CAISO to control (dispatch) these resources. Other electric resources are required by the CAISO to provide real-time electric system balancing and cannot be turned off. Collectively, these types of "non-dispatchable" resources are referred to herein as "Minimum Generation."***

- Adding projected 2023 solar PV generation to 18,000 MW of minimum generation would cause in-State transmission level electric generation to reach 52,568 MW during some hours of the day. This amount that does not yet include wind or any other renewable electric resources far exceeds the forecasted peak electric demand of 26,200 MW ("typical March day") in 2020 and exceeds forecasted 2020 peak summer demands of 46,400 MW.[25]

Absent other options, the CAISO may need to curtail increasing amounts of solar power every year, for the foreseeable future.

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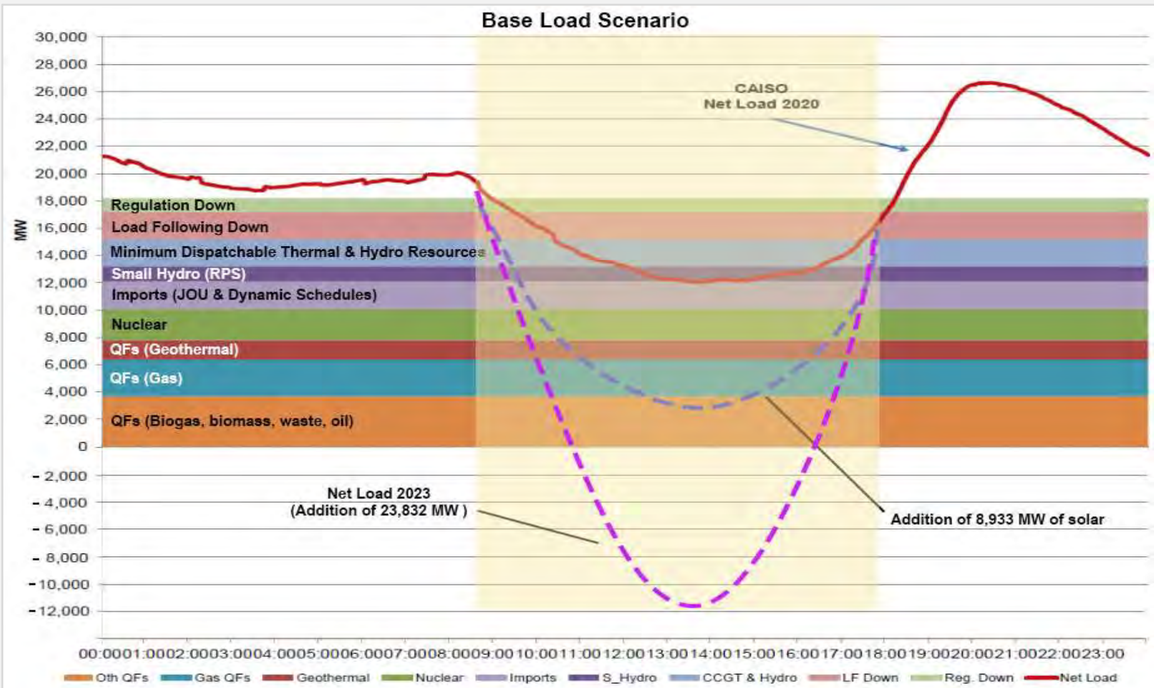
[24] ISO Generator Interconnection Queue, Excel spreadsheet, "Active" Projects only. *California Independent System Operator (CAISO)* update March 25, 2019.

[25] Estimated 2023 solar PV plus minimum generation of 52,568 MW does not yet include any wind generation. Wind is projected to increase 68% by 2023. (Peak wind generation recorded by the CAISO in 2018 was 5,167 MW. Additional wind projects totaling 3,500 MW have applied for transmission interconnection over the next 5 years.) Sources: CAISO "Production and Curtailments Data - 2018.xlsx" [CAISO website: http://www.caiso.com/informed/Pages/ManagingOversupply.aspx] and ISO Generator Interconnection Queue (see Footnote 25 above).

The CAISO's Evolving "Duck"

The CAISO's "Duck Curve" illustrates the challenges California faces as it attempts to integrate increasing quantities of intermittent renewable resources, especially solar.



Solar energy is typically produced between the hours of 9am through 6pm. The red line shows the CAISO's projected "Net Load" for a "typical March day" in 2020. The "Net Load" shows forecasted electric load (demand) ***LESS solar and wind production***. Essentially, "Net Load" is the difference between projected real-time demand and estimated real-time utility-scale wind and solar electric resources.

Each of the colored bands (from 0 to 18,000 MW) represents electric resources that are needed for a variety of regulatory, reliability, and other reasons. These types of "non-dispatchable" resources are referred to as "minimum generation" by the CAISO.

Note that addition of the 8,933 MW of solar PV facilities that already have interconnection agreements will cause Net Load to fall to 3,000 MW, well below the 18,000 MW of non-dispatchable resources. This means that during some hours, as much as 15,000 MW may need to be curtailed to maintain electric reliability. By 2023, if all 23,832 MW of new solar generation presently in queue at the CAISO is successfully completed and interconnected, Net Load could fall to negative 12,000 MW during some hours. The amount of power that may need to be curtailed (or otherwise managed) is represented by the difference between the dashed lines and the 2020 projected Net Load (red line).

Sources:

[1] "Flexible Capacity Needs and Availability Assessment Hours Technical Study for 2020." *California Independent System Operator (CAISO)* presentation. April 4, 2019.

[2] ISO Generator Interconnection Queue, Excel spreadsheet, "Active" Projects only. *California Independent System Operator (CAISO)* update March 25, 2019.

Load Duration Curves

A load duration curve depicts demand and/or supplies in declining order, from highest to lowest value, for a stipulated timeframe. In this case, the timeframe is one year. Figure 7 shows that during 2018, the sum of Minimum Generation and Variable Energy (Solar and Wind) ["***Min Generation PLUS***"] intersected Total Load about 18% of the time (yellow shaded area). During these periods, some amount of overgeneration is likely to occur.

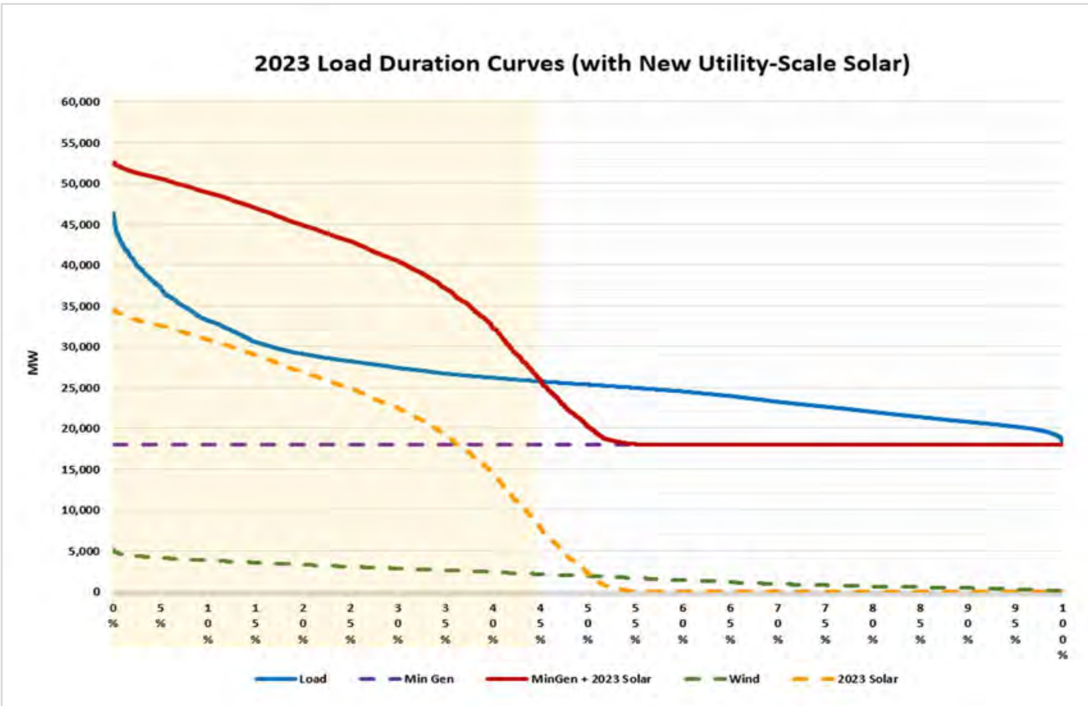


Figure 7. 2018 Load Duration Curves

Load = total electric demand within the CAISO controlled area;

Min Generation = the 18,000 non-dispatchable generation that the CAISO must consider when determining which resources to curtail;

Min Generation PLUS = the 18,000 non-dispatchable generation PLUS wind and solar generation;

Solar = the actual amount of solar energy that was available, before curtailments; and

Wind = the actual amount of wind energy that was available, before curtailments.

Note: Figure 8 is not representative of actual curtailments that are determined every 3-4 seconds on a real-time basis.

The load duration curve is useful in understanding how close Minimum Generation plus wind and solar energy (**Minimum Gen Plus)** are to total **Load** (demand). Clearly, as more wind and solar are brought on-line, the frequency during which **Minimum Gen Plus** will exceed **Load** will increase, likely requiring more curtailments. Figure 8 on the next page shows that if all new utility-scale solar that is currently in the CAISO's interconnection queue are placed in-service by 2023, **Minimum Gen Plus** will exceed **Load** about 45% of the time (yellow shaded area).

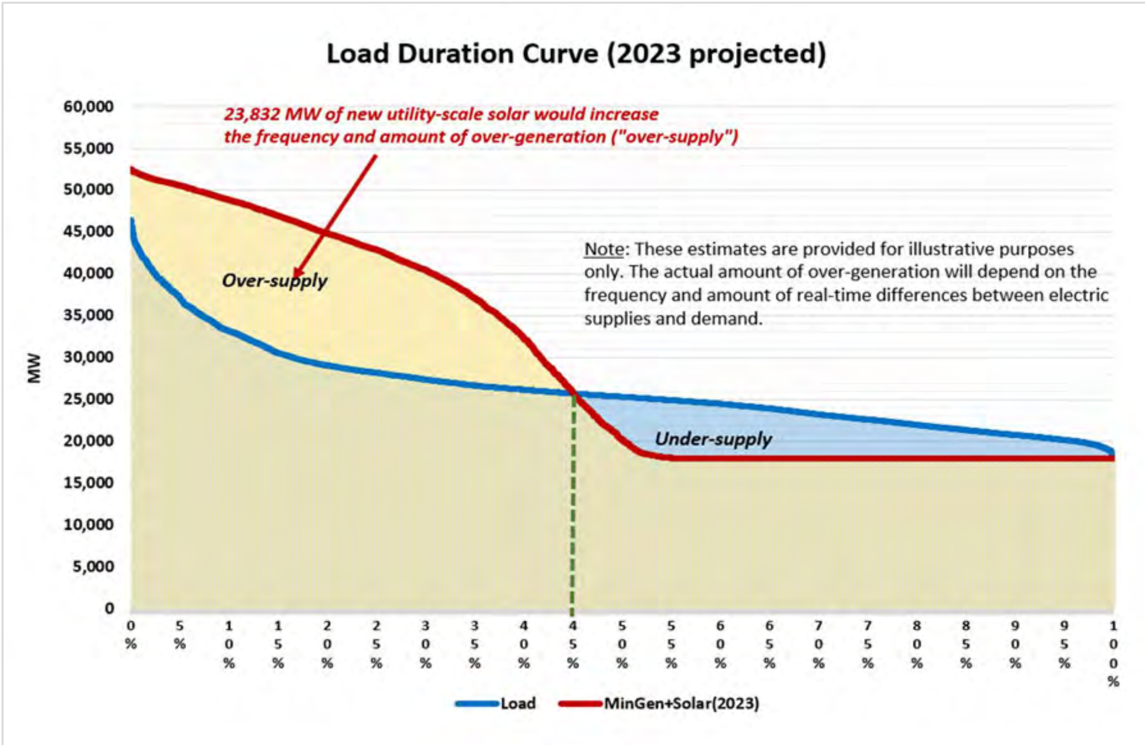


Figure 8. 2023 Load Duration Curves (Projected with New Utility-Scale Solar)

The above curve changed values for only two sets of data:

1. Solar generation was adjusted for the additional 23,832 MW of new utility-scale solar that is already in the CAISO's interconnection queue for 2019-2023.
2. The additional solar generation was also added to Minimum Generation, resulting in a much higher curve for **Min Generation PLUS** (the 18,000 non-dispatchable generation PLUS wind and solar generation).

No changes were made to:

- Minimum generation, although that may increase as new "must run" generation is brought on-line;
- Wind generation, although that is also projected to increase; and
- Load, although wholesale electric demand on the CAISO managed grid is likely to reduce over time as more customer-side Distributed Energy Resources (DERs, including energy efficiency, demand response, "behind-the-meter" (BTM) distributed generation (solar and others), and energy storage) are implemented.

This adjusted curve shows that some over-generation may occur during 45% of the hours of the year (periods during which **Min Generation PLUS** exceed **Load**).

Projected Hourly 2023 Over-Generation with 21,288 MW of New Solar

If utility-scale solar grows to 34,568 MW, solar generation will exceed electric demand from about 7:30 am through 6:00 p.m. during March 2023, and about 7:00 am through 5:00 p.m. during July 2023.

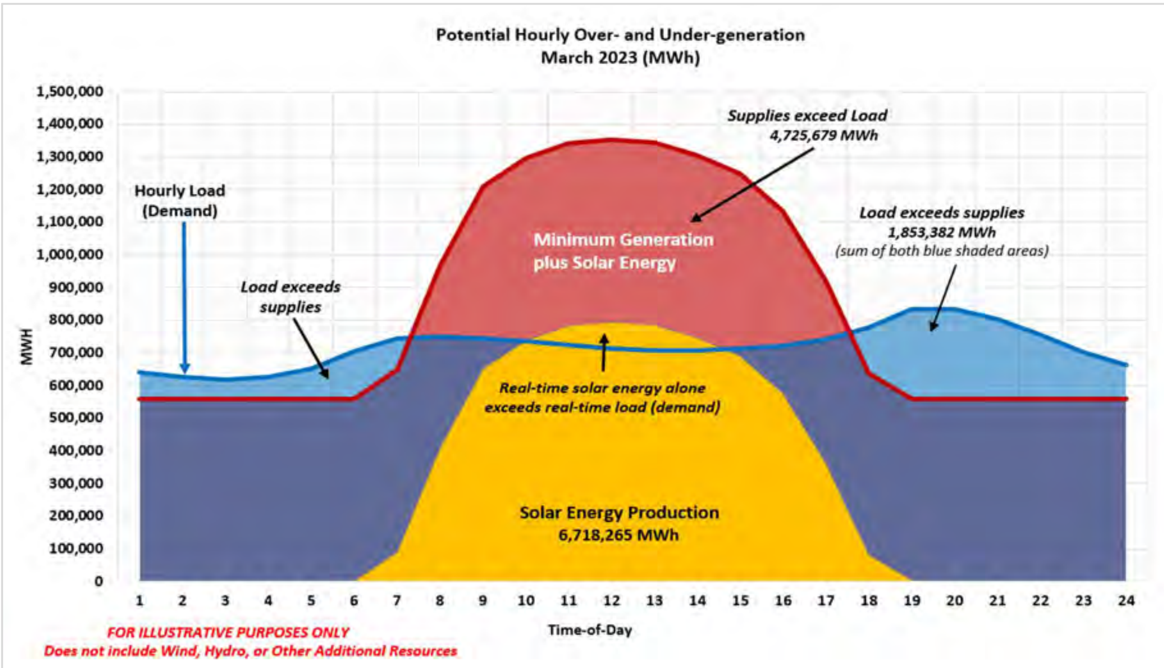


Figure 9. Potential Hourly Over-generation and Under-generation (March 2023)

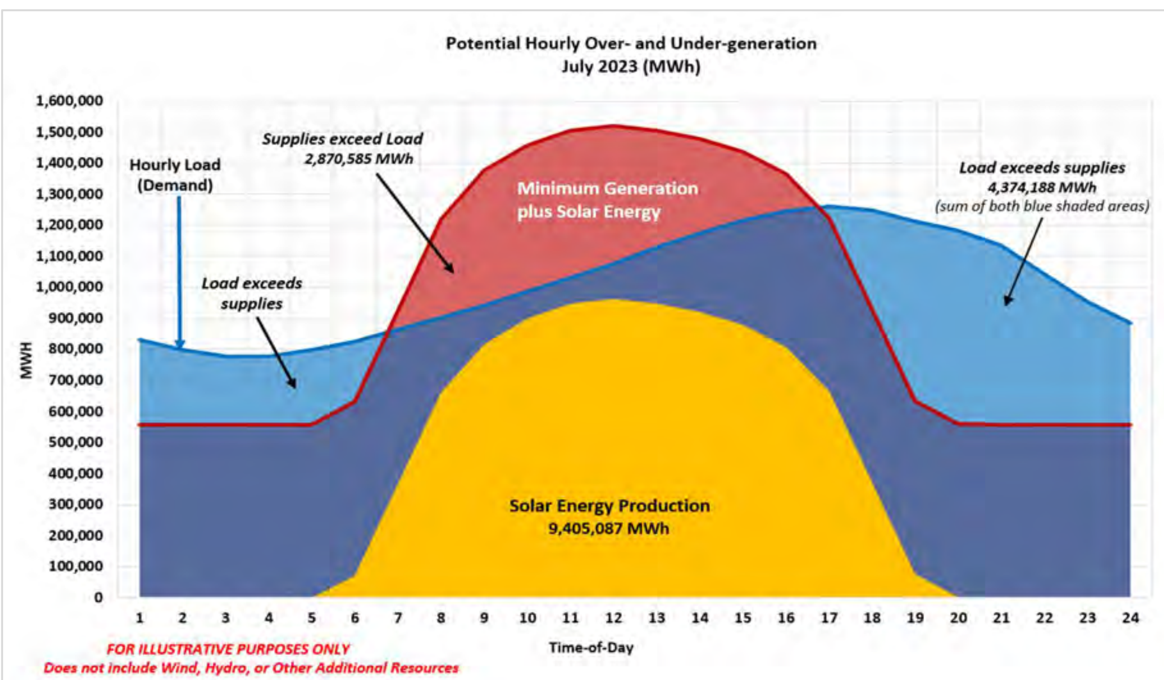


Figure 10. Potential Hourly Over-generation and Under-generation (July 2023)

Load (electric demand) on the CAISO managed grid is likely to decrease over time, primarily due to California's sustained commitment to achieving a 100% zero-carbon energy portfolio and to developing integrated distributed energy resources – customer-side energy resources such as energy efficiency, demand response, clean/renewable/carbon-free distributed generation, and energy storage. As noted previously, customer-side electric resources reduce demand on the high voltage transmission system.

The foregoing Figures 7-10 are conservative in that the estimates of "2023 Minimum Generation Plus Solar PV" do not include wind, hydropower, biogas, or any other additional renewable electric supplies that may be developed by 2023.

Perspectives

California has invested considerable public funds in the development of renewable energy resources and the transmission and distribution systems needed to deliver them to customers. Clearly, curtailments of these valuable renewable resources are not desirable. However, particularly given California's aggressive path to 100% carbon free energy, we always knew we would one day arrive at a point when electric storage technologies had not kept pace with the rate of renewable energy development, and adjustments would need to be made.

Curtailments

While curtailments may not be desirable from a policy perspective, the actual amount of curtailments has been small as a percentage of renewable energy production and total load (demand).

Table 2. Adjusted Net Load (2015-2018)

Annual Net Load	2015	2016	2017	2018
Total Load	232,486,241	231,105,805	231,111,568	226,068,212
Solar Energy Available	15,681,915	20,778,361	25,354,200	27,779,150
Wind Energy Available	12,272,834	13,879,765	13,976,687	16,544,239
Net Load	**204,531,492**	**196,447,679**	**191,780,682**	**181,744,823**
Solar Energy Curtailed	137,182	228,418	345,545	432,357
Wind Energy Curtailed	50,594	73,747	33,873	28,687
Adjusted Net Load	**204,719,268**	**196,749,844**	**192,160,100**	**182,205,867**
Solar Energy Curtailments:				
As % of Total Load	**0.06%**	**0.10%**	**0.15%**	**0.19%**
As % of Solar Energy Generation	**0.87%**	**1.10%**	**1.36%**	**1.56%**

Negative Prices

Similarly, while there has been considerable criticism about the need for decremental bids to address over-generation (i.e., paying solar energy producers to reduce output and/or power marketers to take surplus solar power to reduce risks of disruptions to electric service), actual amounts paid for over-generation mitigation to-date have been modest.

As shown in Figure 3 on p. 12, most of the negative prices during 2018 were under $5/MWH ($0.005/kWh). The highest negative prices occurred during April 2018, but even those were lower than $20/MWH ($0.02/kWh).

Looking Forward …

Over-generation impacts to-date have been responsibly managed by the CAISO and market participants in accordance with the market mechanisms for addressing these types of electric reliability challenges. Nevertheless, given the aggressive outlook for new variable electric generation resources, especially new utility-scale solar PV, there is a critical need to develop near-term interim strategies that can reduce the frequency, costs, and risks of over-generation.

Water and wastewater systems and infrastructure have unique characteristics that, with appropriate price signals, can increase the State's ability to reliably integrate a significant portion of these additional variable energy resources.

III Water Storage for Energy

One important strategy that has been proposed for mitigating over-generation costs and risks is the use of pumped water storage to manage real-time electric imbalances. There are many different types of water storage opportunities: from "conventional pumped storage" (large hydropower facilities that store energy in reservoirs), to a variety of "non-conventional pumped storage" strategies: groundwater banks, recycled water storage facilities, conjunctive use (coordinated surface and groundwater operations to maximize water yield and ecosystem benefits), and opportunities to increase flexible operations by integrating diurnal and seasonal storage into existing and new water distribution systems, water and wastewater treatment systems, and recycled water treatment and distribution facilities.

Conventional Pumped Storage

The U.S. Department of Energy (USDOE) defines "pumped storage" as "A type of hydropower that works like a battery, pumping water from a lower reservoir to an upper reservoir for storage and later generation."[26]

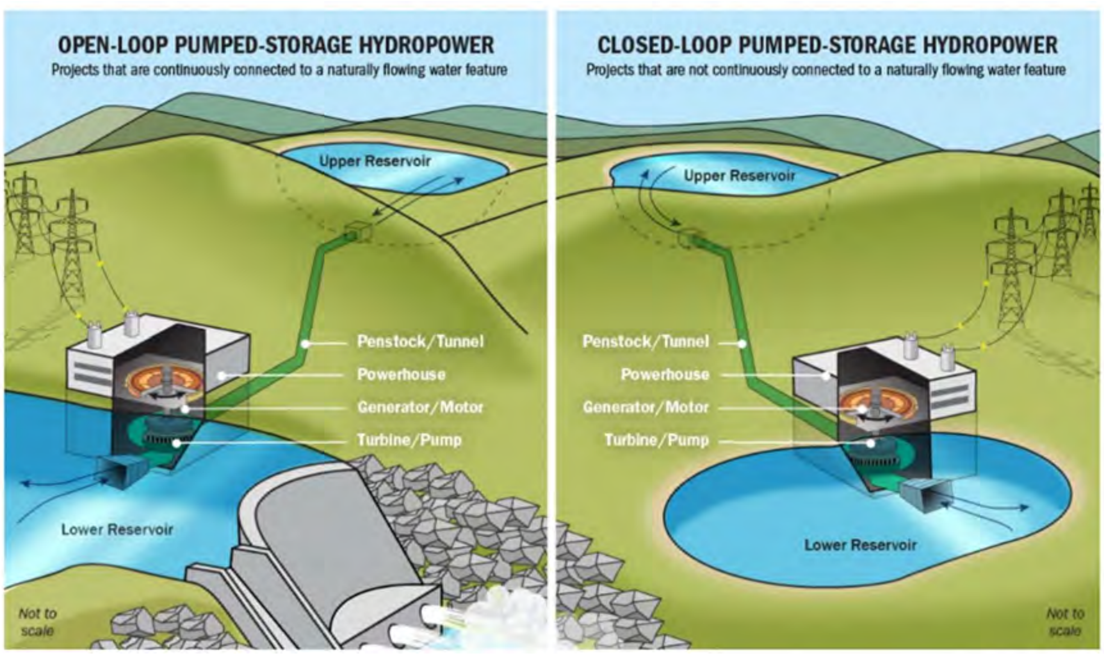


Figure 11. Conventional "Pumped Storage" Hydropower[27]

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[26] "Glossary of Hydropower Terms." *U.S. Department of Energy (USDOE)* website: https://www.energy.gov/eere/water/glossary-hydropower-terms.

[27] "Pumped-Storage Hydropower." *Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy* website: https://www.energy.gov/eere/office-energy-efficiency-renewable-energy.

Conventional "pumped storage" is the oldest type of electric energy "battery", enabling energy potential to be stored in reservoirs, and electricity to be produced by releasing water from upper reservoirs through electric turbines to lower reservoirs. There are two primary types of pumped-storage: "open loop", in which water discharged from the upper reservoir flows to a natural waterway or is conveyed to customers via a conduit of some type, and "closed loop", in which water is continually discharged from the upper reservoir, and the upper reservoir is replenished by pumping water back from the lower reservoir.

Conventional pumped storage is the most prevalent and cost-effective utility-scale electric storage technology at present; however, the reason for its cost-effectiveness is attributed in large part to the fact that most of these assets were built decades ago, so their capital costs are by now fully depreciated, leaving only marginal operating and maintenance costs. The U.S. Department of Energy reported that 97% of all installed electric storage capacity in the U.S. is provided by conventional pumped storage hydropower,[28] and most of that capacity was developed prior to the year 2000.

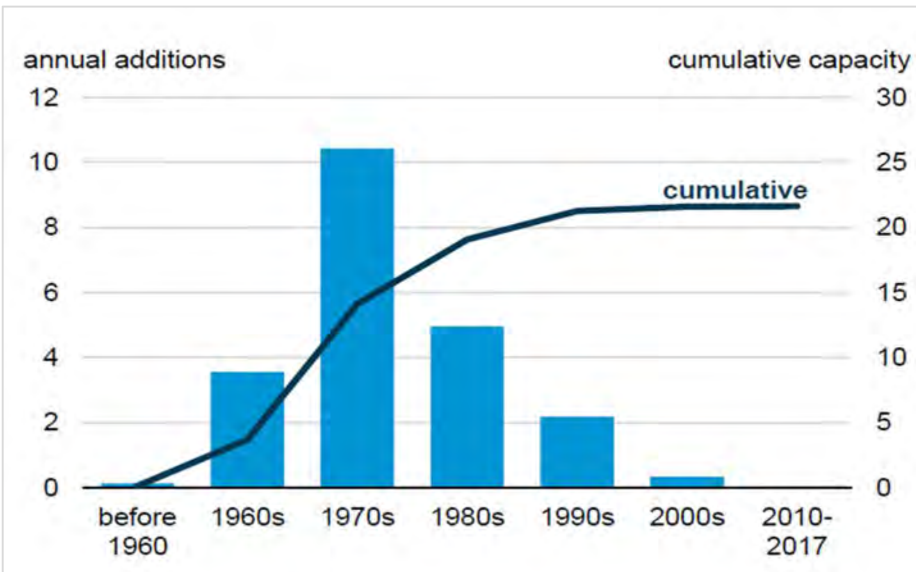

Figure 12. U.S. Hydroelectric Pumped Storage Capacity (Gigawatts) (1960–2017)[29]

California has more conventional pumped storage than any other state, with more than 4.35 GW (4,350 MW) of installed capacity as of 2017. The amount of actual energy storage provided during any year varies with hydrology.

Due to its large scale and siting within areas with sensitive ecosystems, conventional pumped storage requires extensive and long-lead time environmental studies, permits, and approvals.

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[28] "Global Energy Storage Database." *Office of Electricity Delivery and Energy Reliability, U.S. Department of Energy* website: https://www.energystorageexchange.org/.

[29] "U.S. Battery Storage Market Trends." *U.S. Energy Information Administration (USEIA)*. May 2018.

For this reason, very little pumped storage hydro capacity has been added nationwide since the 1990s.

Recently, however, since pumped storage remains by far the most effective means for integrating large quantities of utility scale variable energy resources such as solar and wind, new innovative pumped storage configurations are being explored. In California, five proposed projects could increase the amount of existing in-State pumped storage capacity by 84%. LADWP's proposed Boulder Canyon closed loop pumped storage facility at Hoover Dam is particularly interesting – if proven technically and economically feasible, this configuration could be used to increase pumped storage capacity at other existing dams.

Table 3. Pumped Storage Power Plants in California as of 2017[30]

Plant Name	County	Rated Capacity (MW)	Year Operational
Edward Hyatt Power Plant	Butte	644	1967
Thermalito Pumping-Generating Plant	Butte	120	1968
W.R. Gianelli Pumped Storage Plant	Merced	424	1968
O'Neill Pumping-Generating Plant	Merced	28	1968
Castaic Pumped Storage Plant	Los Angeles	1,682	1978
Helms Pumped Storage Plant	Fresno	1,212	1984
Balsam Meadows	Fresno	200	1987
Olivenhain-Hodges Storage Project	San Diego	40	2012
Total Operational as of 2017		**4,350 MW**	

Table 4. Pumped Storage Power Plants Under Development

Plant Name	County	Rated Capacity (MW)	Project Developer	Targeted In-Service Year
Bison Peak Pumped Storage Project	Kern	360+	Covington Mountain Hydro	2025-2026
Boulder Canyon Pumped Storage Project	Clark County, NV and Mohave County, AZ	1,000+ [est.][31]	Los Angeles Department of Water & Power (LADWP) with USBR and potentially others	2030
Eagle Mountain Pumped Storage Hydroelectric Project	Riverside	1,300	Eagle Crest Energy Company	2023
Lake Elsinore Advanced Pumped Storage Project (LEAPS)	Riverside	500	The Nevada Hydro Company	2023-2024
San Vicente Pumped Storage Project	San Diego	500	San Diego County Water Authority and City of San Diego	2025
Currently Under Development		**3,660+ MW**		

[30] "Tracking Progress: Energy Storage." *California Energy Commission (CEC)*. August 2018.

[31] LADWP has not yet provided any data about the estimated capacity of this proposed project. The 1,000 MW estimate is used here to indicate an anticipated order-of-magnitude based on LADWP's estimated project cost ($3 billion).

Conventional pumped storage hydropower is best suited for integrating bulk wholesale power. However, to be effective, energy storage needs to be electrically proximate to the variable energy generation resources it is trying to integrate, and 99% of California's pumped storage hydropower capacity resides within only four counties (Los Angeles, Fresno, Butte, and Merced).

The proposed pumped storage projects listed in Table 4 and their status are described in Appendix A. Pumped Storage Plants Under Development.

Non-Conventional Pumped Storage

Many types of water storage do not produce hydropower but could still provide valuable and cost-effective energy storage. The key characteristics of non-conventional pumped storage opportunities that could provide over-generation mitigation support and other types of Flexible Demand Response services are described below.

Characteristics of Non-Conventional Pumped Storage Opportunities

1. Typically much smaller in scale than conventional pumped storage hydropower.
2. Configured in a manner that enables water, wastewater, and/or recycled water to be pumped to storage – diurnal (days or hours) or seasonal (weeks or months) - deferring pumping during on-peak periods ("under-supply") and increasing pumping during periods of over-generation ("over-supply").
3. May or may not include production of hydropower.
4. The most valuable Flex DR resource is a "closed loop" pumped storage facility that enables cycling water back and forth between two storage facilities when needed to provide electric reliability support.

The extent to which a water storage facility can provide Flex DR depends on many factors, including the size and design of the storage facility, the purpose(s) for which that facility was constructed, and the water supply, quality, and other mission critical water sector objectives that drive the system operations.

Types of Water Storage Facilities

Water storage facilities can be classified by:

- **The Duration of Time** that water is stored (e.g., diurnal vs. seasonal), and
- **The Type of Water Storage Facility** (e.g., above or below ground, natural or man-made).

Storage facilities can also be classified by purpose:

- **Flood Management**: Divert flood flows for protection of people, property, and ecosystems, ideally in conjunction with groundwater recharge.
- **Water Supply**: Collect precipitation and runoff, maximize production and use of recycled water, collect and store stormwater.
- **Water Quality**: Cycle water supplies to avoid degradation of water quality.

Diurnal vs. Seasonal Water Storage Facilities

Diurnal Storage. Most water storage facilities are sized for one to several days' water supplies ("diurnal" storage). One or more tanks, ponds, or small reservoirs may be used to store water, wastewater, and/or recycled water for short-term water supply balancing purposes. Diurnal storage can be open (pond or reservoir) or closed (tank) because the short storage timeframe will not result in water quality degradation even in a tank.

- Local diurnal water storage is often used to balance supplies with real-time water demand, both drinking water and recycled, as well as to assure that water is always available locally for fire protection and other emergency purposes.
- Some wastewater treatment plants have storage that enables deferring treatment during some hours, if needed.

Seasonal Storage. Larger water storage facilities have capacity to store water for longer durations of time – instead of days and weeks, some reservoirs can store water supplies for weeks and months. Very large reservoirs store water supplies for multiple years, providing an excellent hedge against water supply risks from fluctuations in hydrology. Seasonal storage must be open to the atmosphere (pond or reservoir) to prevent the water quality degradation that would take place in closed storage over long durations of time.

To maximize beneficial use of all local water resources, some utilities are developing surface water reservoirs that enable production and storage of surplus recyclable water during periods of low water demand (fall through early spring). (Lacking seasonal recycled water storage, some wastewater utilities only produce recycled water during summer months when there is sufficient demand. During fall, winter, and early spring, treated wastewater effluent is not recycled, but is instead discharged to outfalls.)

- **Emergency Water**: Maintain local water supplies under pressure for firefighting and other emergency purposes.

Conjunctive Use

Many proposed water storage projects are being developed with the aim of maximizing "conjunctive use": the coordinated operations of groundwater and surface water resources to maximize water supplies and water benefits.

"*Conjunctive use means actively managing the aquifer systems as an underground reservoir. During wet years, when more surface water is available, surface water is stored underground by recharging the aquifers with surplus surface water. During dry years, the stored water is available in the aquifer system to supplement or replace diminished surface water supplies.*"[32]

Modular Pumped Storage Hydropower (m-PSH)[33]

MPS is an example of a non-conventional water storage opportunity that includes hydropower production.

"*The major differences between modular pumped storage (MPS) and conventional pumped storage is that MPS systems are much smaller, use closed water systems that are artificially created instead of natural waterways or watersheds, and sites are selected with predetermined elevation differences so that modular pre-engineered equipment can be used. With the exception of evaporative losses, reservoirs are charged only once, either with groundwater or even municipal wastewater.*"[34]

M-PSH is well suited to provide Flex DR at the distribution system level.

This section describes two primary types of "non-conventional" pumped water storage facilities:

- Underground Water Storage, and
- Aboveground Water Storage.

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[32] "Groundwater – Conjunctive Use." *Department of Water Resources (DWR)* website: http://www.cd.water.ca.gov/groundwater/conjunctiveuse.cfm.

[33] Witt, Adam with Boualem Hadjerioua, Rocio Uria-Martinez, and Norm Bishop. "Evaluation of the Feasibility and Viability of Modular Pumped Storage Hydro (m-PSH) in the United States." Oak Ridge National Laboratory (ORNL). Publication No. ORNL/TM-2015/ 559. September 2015.

[34] "Hydroelectric Power in California." California Energy Commission (CEC) website: https://www.energy.ca.gov/hydroelectric/.

Each of the types of storage described herein could be used for raw, potable, and/or recycled water supplies. Depending on the facilities' capacity, design, and operations, storage can be provided for hours, days, months; and in some cases, years.

Underground Water Storage

There are 517 groundwater basins in California.[35] California's Sustainable Groundwater Management Act ("SGMA")[36] requires that medium and high priority "critically over-drafted" groundwater basins develop Groundwater Sustainability Plans designed to put these basins on a path to "sustainability" within 20 years of plan submittal and implementation.

> *"A basin is subject to critical overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts."*[37]

While only medium and high priority groundwater basins are required to prepare and submit Groundwater Sustainability Plans (GSPs) at this time, all groundwater basins are encouraged to prepare plans.

SGMA does not specifically require energy efficiency. However, the State Department of Water Resources (DWR) charged with overseeing SGMA implementation suggested energy costs as one benchmark for determining the minimum threshold for groundwater storage.[38]

SGMA requires extensive planning and coordinated suites of actions among multiple groundwater stakeholders. Groundwater Sustainability Plans are being developed now that comply with the targeted implementation date of January 31, 2020.[39] In addition to reducing groundwater withdrawals through water efficient practices and technologies, multiple strategies are being developed that seek to leverage complementary programs and activities Key among these is "Flood-MAR" (using flood water for managed aquifer recharge).

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[35] "Basin Prioritization." Department of Water Resources (DWR) website: https://water.ca.gov/Programs/Groundwater-Management/Basin-Prioritization.

[36] "SGMA Groundwater Management." Department of Water Resources (DWR) website: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management.

[37] "Critically Overdrafted Basins." Department of Water Resources (DWR) website: https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118/Critically-Overdrafted-Basins.

[38] "DRAFT Best Management Practices for the Sustainable Management of Groundwater: Sustainable Management Criteria." *Department of Water Resources (DWR)*. November 2017.

[39] "Sustainable Groundwater Management Program: Groundwater Sustainability Plan (GSP) Emergency Regulations Guide." *Department of Water Resources (DWR)*. July 2016.

Flood-Managed Aquifer Recharge (Flood-MAR)

"'Flood-MAR' is an integrated and voluntary resource management strategy that uses flood water resulting from, or in anticipation of, rainfall or snow melt for managed aquifer recharge (MAR) on agricultural lands and working landscapes, including but not limited to refuges, floodplains, and flood bypasses. Flood-MAR can be implemented at multiple scales, from individual landowners diverting flood water with existing infrastructure, to using extensive detention/recharge areas and modernizing flood management infrastructure/operations.

"Flood-MAR projects can provide broad benefits for Californians and the ecosystems of the state, including:

- Water supply reliability
- Flood risk reduction
- Drought Preparedness
- Aquifer Replenishment
- Ecosystem Enhancement
- Subsidence Mitigation
- Water Quality Improvement
- Working Landscape
- Preservation and Stewardship
- Climate Change Adaptation
- Recreation and Aesthetics"

Source: "FLOOD-MAR: Using Flood Water for Managed Aquifer Recharge to Support Sustainable Water Resources." Department of Water Resources. June 2018.

The Potential Role of Groundwater in Flex DR

There are several different ways in which groundwater can play a role in over-generation mitigation and Flex DR.

1. **Pump During Over-generation Periods**. The most obvious opportunity is to maximize groundwater pumping during periods of over-generation. The extent to which this can occur depends on two primary factors:

   - ***Groundwater Pumping Capacity***. Is there enough pumping capacity to shift most, if not all groundwater pumping, to over-generation periods?
   - ***Surface or Other Storage***. If the amount of groundwater withdrawn cannot be immediately delivered to a customer, are there tanks or surface water reservoirs where the pumped groundwater can be stored temporarily, until it can be delivered to one or more customers?

2. **Conjunctive Use**. Is there an opportunity for water exchanges with one or more surface reservoirs? For example, could groundwater be pumped (withdrawn) during periods of over-generation, and surface water credits be provided at another location?

   Partnering with water purveyors throughout the State can help to alleviate pressure on critically over-drafted groundwater basins: building new surface water storage to maximize capture and storage of surplus water during very wet periods, and maximizing the benefits of all water supplies, both surface and groundwater, through coordinated operations and management (aka, "conjunctive use").

   > *Conjunctive use strategies include intentional groundwater recharge; the use of groundwater aquifers for water storage; in-lieu recharge; and agricultural and stormwater recharge programs to directly or indirectly increase baseflow or water levels that support groundwater dependent ecosystems*.[40]

The extent to which a groundwater project could provide Flex DR depends on many factors:

- The system design and facilities configuration;
- Regulatory, legal, and environmental requirements and constraints;
- Availability and timing of water supplies for recharge;
- Timing of water withdrawals to meet customer and contractual commitments;
- Ability of customers to store groundwater withdrawals (increasing the flexibility of the groundwater purveyor to optimize pumping schedules for water, energy, and ecosystem benefits);

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[40] Cantor, Alida, Dave Owen, Thomas Harter, Nell Green Nylen, and Michael Kiparsky. "Navigating Groundwater-Surface Water Interactions under the Sustainable Groundwater Management Act." *Center for Law, Energy & the Environment, UC Berkeley School of Law*, Berkeley, CA. 2018.

- Groundwater pumping capacity;
- Whether or not the groundwater purveyor has access to surface storage; and
- Operational requirements and constraints.

Water Transfers and Exchanges

"A water transfer is a reallocation of water among water users. Water transfers provide flexibility in the allocation and use of water in California." Water transfers can be short-term (one year or less) or long-term (greater than one year).

- The U.S. Bureau of Reclamation (USBR) has jurisdiction over requests to transfer Central Valley Project (CVP) water.
- The State Department of Water Resources (DWR) has jurisdiction over State Water Project (SWP) transfers.
- The State Water Resources Control Board (SWRCB) has jurisdiction over water transfers covered by Water Code Sections 1725 and 1735 (transfers of intra-state surface water supplies over which the State has jurisdiction).

Groundwater banking is a type of water transfer. Often, supplemental water supplies during wet periods are transferred from northern California to southern California where the supplemental water can be "banked" (used to recharge groundwater aquifers). The water can then be withdrawn by the purchaser of the supplemental water at a time when the water is needed.

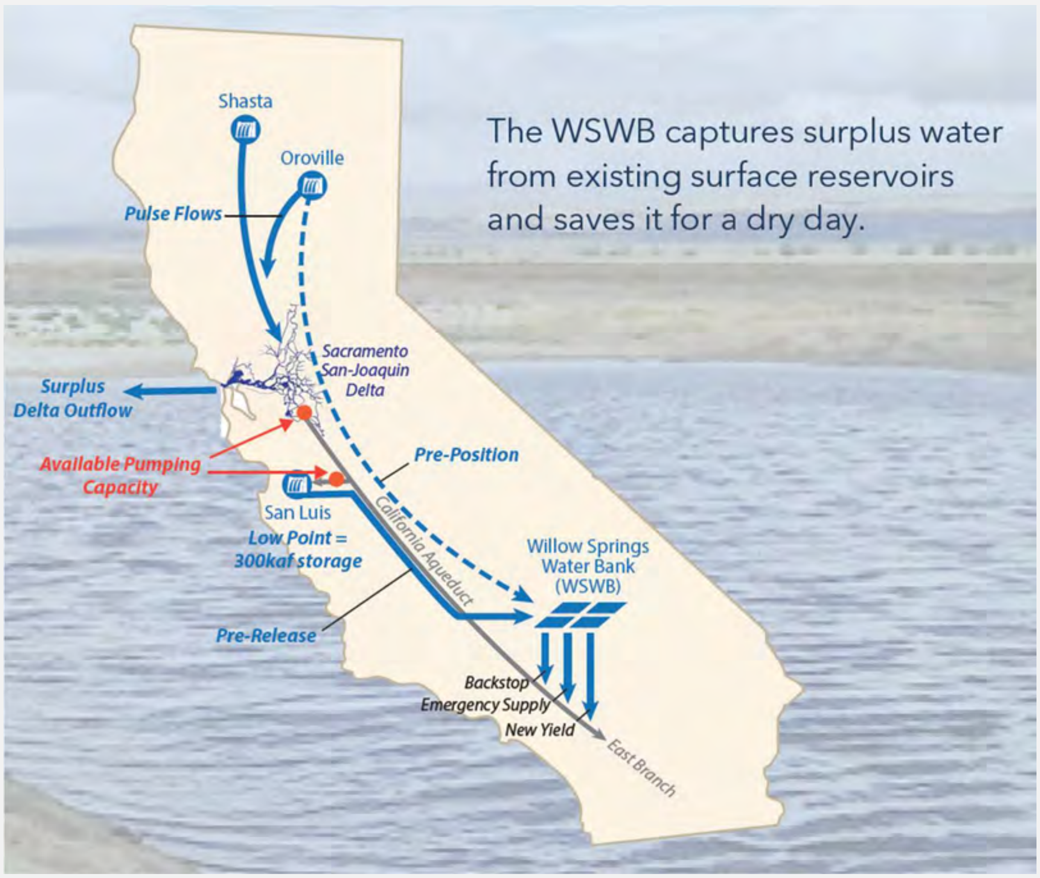
Another type of transfer involves the exchange of groundwater and surface water. In an "in lieu" project, water users agree to use surface water instead of groundwater. Other types of groundwater transfers include transfer of banked groundwater, and direct transfer of groundwater.

- "Water Transfer Program Information. *State Water Resources Control Board (SWRCB)*. September 2013.
- "Water Transfers Program." SWRCB website: https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_transfers/.

Example 1. A Proposed Groundwater Conjunctive Use Project

Willow Springs Water Bank (WSWB) Water-Energy Bank

Project Description. The Southern California Water Bank Authority proposes to leverage the Willow Springs Water Bank (WSWB) for conjunctive use to improve the operational flexibility of the State Water Project (SWP) and to provide support the Bay Delta ecosystem.



WSWB plans to enter into agreements with one or more State Water Contractors (SWC) and/or SWP partners to forego SWP deliveries in exchange for receiving WSWB groundwater. Any potential energy benefits would depend on the nature of the agreements and the extent to which they allow flexibility with respect to the timing of WSWB groundwater withdrawals vs. recharge (time-of-day and seasonal).

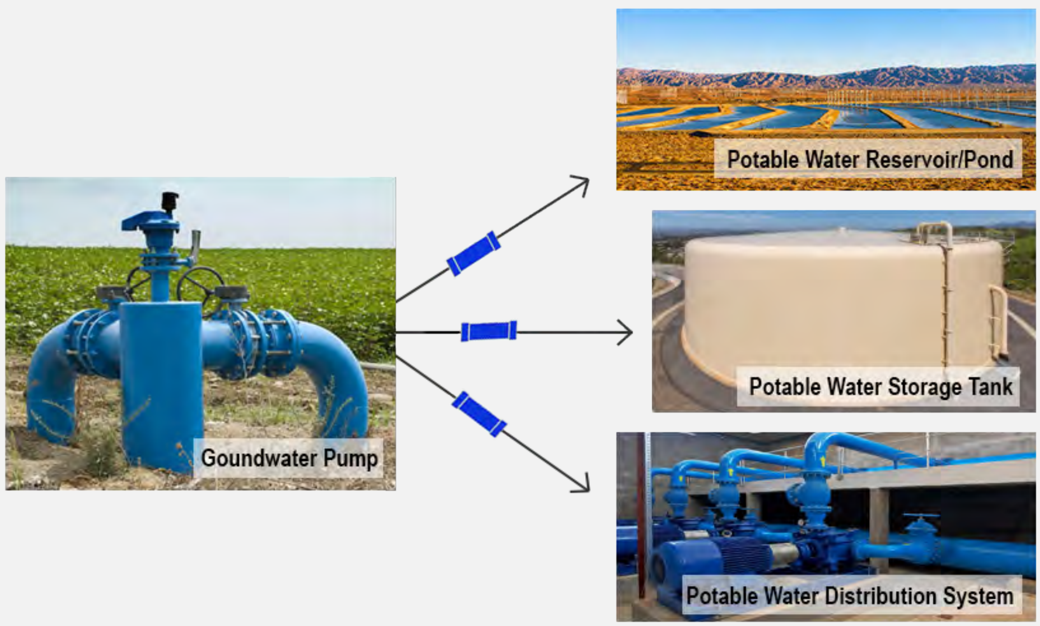
Source: California Water Commission (CWC) website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Willow-Springs-Water-Bank-Conjunctive-Use-Project.

See the description of WSWB's Water-Energy Bank concept and Appendix B. Proposed New or Expanded Groundwater Banks for more information about the WSWB planned project.

Example 2. Pumping Groundwater to Storage

Virtually any groundwater pump can become a candidate to provide over-generation mitigation support or Flexible Demand Response ("Flex DR") when combined with storage.

In the examples shown here, one or more pumps can pump groundwater for delivery to a surface storage facility (reservoir, pond, storage tank).



The extent to which one or more groundwater pumps could provide over-generation mitigation support depends on the availability of:

- Groundwater pumping capacity, and
- Water storage.

To maximize pumping during daily over-generation periods, there would need to be enough groundwater pump capacity to compress all (or most) of the groundwater pumping during 7 over-generation hours (approximately 9am to 4pm).

In addition, since many groundwater pumps are demand driven, sufficient storage capacity would be needed to hold pumped water that is not yet needed to meet water demand.

Water managers throughout the State are seeking innovative water management strategies and partnerships. Since energy is a major cost of groundwater; and further, since energy costs and risks increase as groundwater elevations fall, energy is an important consideration for sophisticated water managers that proactively seek opportunities to reduce costs and risks for their customers.

Candidate Groundwater Partners

Given the high level of water sector activity around innovative approaches to storing and managing groundwater, both for SGMA compliance and for drought resilience, there are many opportunities for groundwater-energy partnerships. In fact, there is some type of activity related to groundwater in every geographic area served by SCE, both within basins that are deemed medium-to-high priority under SGMA and those that are not yet required to prepare Groundwater Sustainability Plans (GSPs).

Current groundwater activities include:

- Groundwater sustainability planning and groundwater replenishment;
- Identification, evaluation, and pilot testing of new water and energy technologies that reduce groundwater demand and costs;
- Innovative partnerships for conjunctive use of groundwater and surface water;
- Innovative water storage and transfer agreements; and
- Exploring opportunities to earn energy revenues through provision of electric reliability services – from wholesale ancillary services to retail Integrated Distributed Energy Resources (IDER) - including over-generation mitigation, Flex DR, hydropower and other types of distributed generation, and water-energy storage.

There are too many groundwater participants to list. Potential SCE partners include:

- Every Groundwater Sustainability Agency (GSA) established to prepare GSPs pursuant to SGMA as well as those not yet required to prepare GSPs;
- Existing groundwater storage and replenishment districts;
- Groundwater bank customers, members, and partners;
- Large groundwater users (e.g., agricultural and industrial water users);
- Technology developers focused on water efficiency and groundwater remediation;
- State and local governments involved in groundwater sustainability planning and implementation; and
- A wide variety of groundwater stakeholders, including community-based and non-governmental organizations.

Table 5 contains a partial list of groundwater storage and recharge programs within SCE's service area. Table 6 on the next page lists and describes two regional water replenishment districts. All may be candidates for Flex DR.

Table 5. Partial List of Groundwater Storage & Recharge Programs

Groundwater Bank/Program	County	Maximum Storage	Service Area	Recharge Area	Notes
Arvin-Edison Water Storage District[41]	Kern	MWD alone has rights to 350,000 AF of storage[42]	132,000 acres	1,500 acres	Established in 1942 to contract for federal water service and loans to construct facilities. Perennial yield was estimated at 228,000 AFY [2003].
AVEK Westside Water Bank[43]	Los Angeles	150,000 AF		1,000 acres	1,000 acres
AVEK Eastside Water Bank[44]	Los Angeles	280,000	1,500 acre site	6 acres	70,000 AFY of SWP surface water via the California Aqueduct.
Kern Water Bank Authority[45]	Kern	1,500,000 AF		20,000 acres (7,000 acres of recharge ponds)	Conservation and Storage Project designed to divert up to 500,000 AFY of Kern River flood waters for recharge and storage.
Semitropic-Rosamond Water Bank Authority[46]	Kern	300,000 AF			Recharge 33,000 AFY, Recovery 100,000 AFY
Semitropic Water Storage District[47]	Kern	1,650,000 AF	221,000 acres	125,000 acres irrigated	Recharge 315,000 AFY, Return 90,000 AFY to SWP

[41] "Arvin-Edison Water Storage District Groundwater Management Plan." Prepared by *Provost & Pritchard, Inc. for Arvin-Edison Water Storage District*. June 5, 2003.

[42] Bodnar, James. "Update on State Water Project Groundwater Banking Programs." Staff Presentation to August 2018 meeting of *Metropolitan Water District of Southern California (MWD)* Water Planning & Stewardship Committee.

[43] "Final Antelope Valley Watermaster 2016 Report." Todd Groundwater, *Antelope Valley Watermaster* Engineer. August 1, 2017.

[44] Started recharge of its High Desert Water Bank in 2017. See "Appendix C. Proposed New or Expanded Groundwater Banks" for more information.

[45] "Kern Water Bank Authority Conservation and Storage Project Environmental Impact Report." Prepared by *ICF for Kern Water Bank Authority*. January 2018.

[46] "Semitropic-Rosamond Water Bank Authority: Storing Water Supplies for Our Future." Downloaded from Rosamond Community Services District (RCSD) website: https://www.rosamondcsd.com/home/showdocument?id=60.

[47] Semitropic Water Storage District is one of eight water storage districts in California and is the largest in Kern County. Source: "2012 Groundwater Management Plan." *Semitropic Water Storage District*.

In addition, there are two large regional groundwater recharge and replenishment districts within SCE's service area.

Table 6. Groundwater Recharge and Replenishment Districts

Groundwater Bank	Description of Activities
Orange County Water District (OCWD)[48]	OCWD's Groundwater Replenishment System (GWRS) is the largest groundwater recharge facility of its kind in the world. OCWD provides advanced treatment to secondary wastewater provided by the adjacent wastewater treatment plant owned and operated by Orange County Sanitation District (OCSD). OCWD then uses the advanced treated water to replenish the Orange County Groundwater Basin. OCWD also prevents seawater intrusion.
Water Replenishment District of Southern California (WRD)[49]	WRD is the largest groundwater agency in California with a service area of 420 square miles serving a population of 4 million residents for 43 cities. WRD's customers use about 250,000 AFY (82 billion gallons per year) of groundwater. This amount is about half of the region's water supply. WRD protects the basins it manages through artificial groundwater replenishment, injection of water into wells along the coastline to prevent seawater intrusion, and groundwater monitoring.

The combination of SGMA and the recent drought have spurred explorations into additional recharge and replenishment projects. Table 7 on the next page lists five proposed new or expanded groundwater banks that have received State and/or Federal funding assistance. Further, as described earlier, every water utility that pumps groundwater may be able to provide some degree of over-generation mitigation support and/or Flex DR services.

The proposed groundwater projects listed in Table 7 are described in "Appendix B. Proposed New or Expanded Groundwater Banks."

[48] "Created to safeguard Orange County's groundwater supply." Orange County Water District (OCWD) website: https://www.ocwd.com/about/.

[49] "Mission and History." *Water Replenishment District of Southern California (WRD)* website: https://www.wrd.org/content/mission-and-history.

Table 7. Proposed New or Expanded Groundwater Banks

Groundwater Bank	County	Groundwater Basin	New or Incremental Capacity	Developer/ Owner	Est. Cost	Targeted In-Service Year
Chino Basin Environmental Water Program (CBEWP)	San Bernardino	Chino Basin	100,000 AF	Inland Empire Utilities Agency (IEUA)	$385M	2025
High Desert Water Bank Program	Los Angeles	Antelope Valley	280,000 AF	Antelope Valley-East Kern Water Agency (AVEK)	$131M	
Kern Fan Groundwater Storage Project	Kern	Kern County Groundwater Sub-Basin of the San Joaquin Valley Groundwater Basin	100,000 AF	Kern Fan Project Authority	$172M	2025
South County Ag Program	Sacramento	South American Groundwater Sub-Basin of the Sacramento Valley Groundwater Basin	50,000 AF	Sacramento Regional County Sanitation District	$373M	2023
Willow Springs Water Bank Conjunctive Use Project	Kern, Los Angeles	Antelope Valley Groundwater Basin	1,000,000 AF	Southern California Water Bank Authority	$343M	2020
Currently Under Development			**1,530,000 AF**			

Surface Water Storage

Surface water storage projects can also support over-generation mitigation and Flex DR. Opportunities are similar to groundwater, except that the storage is on the surface – either in open reservoirs or ponds, or in closed concrete, steel, or other types of water storage tanks.

> *Pipelines can also be used like "storage": during the 2000/01 California power crisis, Inland Empire Utilities Agency (IEUA) shipped wastewater from one of its treatment plants to another to defer wastewater treatment, thereby avoiding the extremely high cost of electricity during on-peak periods.*[50]

[50] Park, Laurie and Kenneth Croyle. "California's Water-Energy Nexus: Pathways to Implementation." GEI Consultants for the Water-Energy Team of the Governor's Climate Action Team (aka "WET-CAT"). September 12, 2012. Page 26.

Precipitated largely by the need to build drought resilience, many large surface reservoirs are scheduled for development. Table 8 lists five new or expanded surface water reservoirs that are planned or under development.

Table 8. Surface Water Storage Projects Planned or Under Development

Planned New Storage	County	New or Incremental Capacity	Developer/ Owner	Est. Cost	Targeted In-Service Year
Los Vaqueros Reservoir Expansion Project	Contra Costa	115,000 AF	Contra Costa Water District (CCWD)	$795M	2027
Pacheco Reservoir Expansion Project	Santa Clara and Merced (study area includes portions of Monterey, San Benito, and Santa Cruz)	135,300 AF	Santa Clara Valley Water District (SCVWD)	$969M	2028
Sites Project	Sacramento	1,810,000 AF	Sites Project Authority	$5.2B	2030
Temperance Flat Reservoir Project	Fresno, Kern, Kings, Madera, Merced, San Benito, San Joaquin, Santa Clara, Stanislaus, Tulare	1,260,000 AF	San Joaquin Valley Water Infrastructure Authority	$2.6B	2030
Trampas Canyon Reservoir & Dam	Orange County	5,000 AF	Santa Margarita Water District (SMWD)	$123M	2020
Currently Under Development:		**3,325,300 AF**	**(1,083.6 billion gallons)**		

Note: Although Trampas is a small local reservoir, it is highlighted here as a very important type of new storage: it is being built to increase recycled water production during Fall and Winter months when recycled water demand is low and recyclable water has historically been discharged to the ocean outfall. See discussion about Recycled Water Storage on the next page.

The above projects are described in Appendix C. Surface Water Storage Projects Under Development.

Note:

- Four of the surface water projects listed in Table 8 have been awarded grants from the State's Water Storage Investment Program (WSIP) funded by *The Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1)*. WSIP is administered by the California Water Commission (CWC).
- Trampas Canyon Reservoir & Dam has not received WSIP funds but has received other types of funding assistance (including a State Water Resources Control Board low interest loan

and a Proposition 1 grant) towards construction of its new 5,000 AF surface water reservoir that will provide seasonal storage for recycled water.[51]

Recycled Water Storage

Seasonal Recycled Water Storage. Interest in expanding seasonal recycled water storage is fairly new, driven in large part by the recognition that all available water resources are needed to build drought resilience. This is especially important in densely populated urban areas that have historically been heavily dependent on imported water supplies. Currently, for example, Santa Margarita Water District (SMWD) is not able to produce recycled water during fall and winter months when recycled water demand is low. Processed wastewater that is not treated for use as recycled water is discharged to an ocean outfall, thereby losing otherwise usable water supplies. The new Trampas reservoir will enable SMWD to recycle 100% of its wastewater for use during Spring and Summer, thereby reserving precious potable water supplies for potable purposes.[52]

Diurnal Recycled Water Storage. Even small, diurnal storage facilities can provide Flex DR support. Figure 13 below illustrates types of recycled water configurations that can provide over-generation mitigation support and Flex DR.

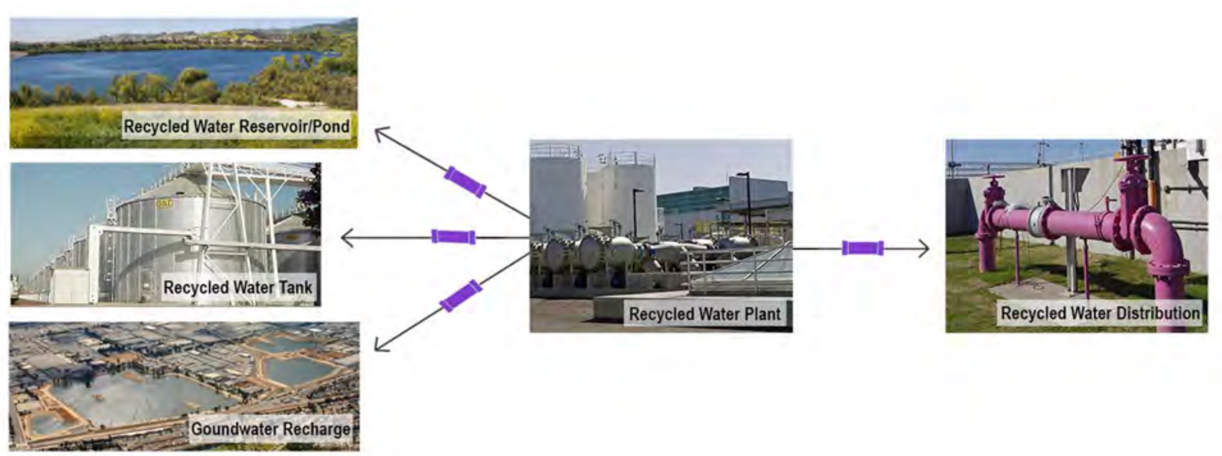


Figure 13. Recycled Water Storage Opportunities for Flex DR

[51] "Trampas Canyon Reservoir & Dam." *Santa Margarita Water District (SMWD)* website: https://www.smwd.com/313/Trampas-Reservoir.

[52] Ibid.

IV Water Sector Flexible Demand Response

Conventional Demand Response

Under conventional Demand Response (DR) programs, customers are paid for voluntarily reducing their real-time electric use when needed to reduce risks of disruption to electric service within an electric utility's service area. Southern California Edison (SCE) has been successful in gaining broad water sector participation in a wide variety of traditional and innovative DR programs: since 2005, 66 water and wastewater utilities successfully shifted and shed 1,958 GWh through their participation in SCE DR programs.

Non-Conventional Demand Response

Flexible (2-Way) DR ("Flex DR")

The need to alleviate over-generation and under-supply events for purposes of electric reliability has precipitated a need to revise and replace conventional DR programs with "2-way" ("Flexible") DR:

- Decreasing electric load during periods of energy supply shortages or events that cause a need to shed load in specific locations to maintain reliable power flows; ***and***
- Increasing electric load during periods of over-generation when needed to reduce voltage instability due to conditions of over-supply.

The key to effective participation in Flex DR is operational flexibility. And this is where the water sector can provide a unique solution.

Unique Capabilities of the Water Sector to Provide Flex DR

Most water and wastewater utilities have some ability to shift the quantity, time, and location of their electric use, both on an hourly and seasonal basis. To maximize load shifting, water and wastewater systems will need to be designed with operational flexibility in mind, but they also need appropriate price signals to make it economically beneficial.

Integration of multiple sites and types of water storage (e.g., tanks, reservoirs, ponds, pipelines) increase a water or wastewater utility's ability to defer water pumping and/or treatment during periods of high electric use and constrained electric supplies (e.g., summer on-peak periods). Increased pumping, treatment and storage capacity also increase opportunities for the inverse of peak shaving: providing over-generation mitigation support by increasing electric use during periods of excess renewable energy production.

Evidence of the water sector's ability to meet Flex DR capabilities can be found by inspecting electric time-of-use by water and wastewater systems and facilities. Clearly, price signals have been effective in encouraging water and wastewater utilities to find ways to substantially reduce their electric use during summer on-peak periods. Electric rates that encourage "Flex DR" could be similarly effective in changing the pattern of water sector operations to support electric reliability at both the transmission and distribution system levels.

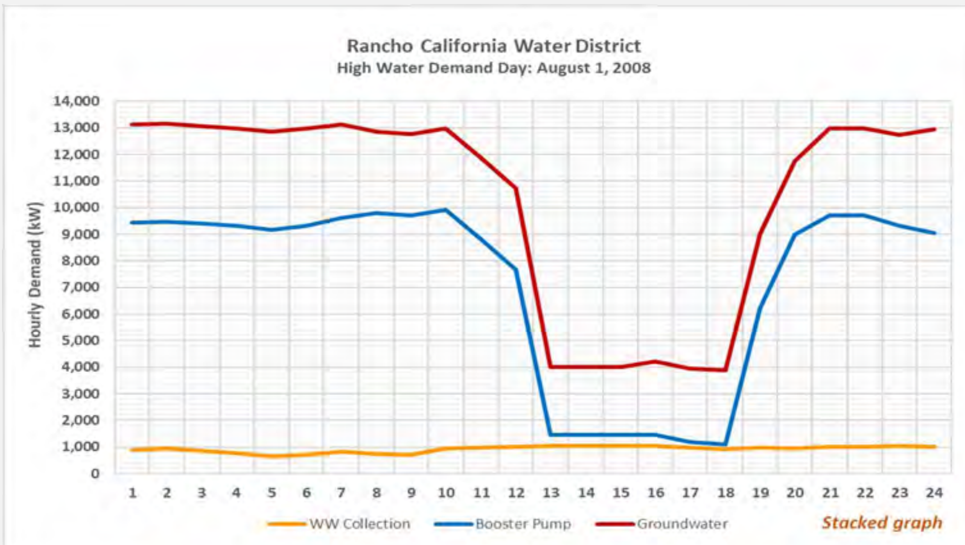
Water, wastewater, and recycled water treatment facilities have very different electric load profiles from groundwater and booster pumps. Pumps can often be scheduled – the extent to which they can be scheduled depends on the amount of pump capacity and storage available. Treatment systems, on the other hand, typically run 24/7 with little variation.

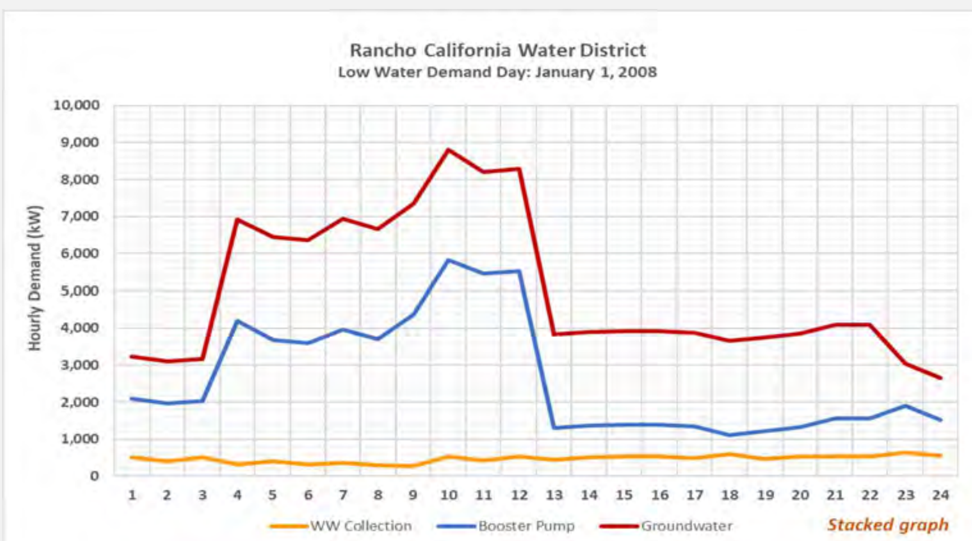
Notably, even treatment loads can provide Flex DR if storage is integrated into the systems.

> ***"What distinguishes California's water sector is its ability to substantially change its electric footprint – both with respect to the amount of energy used for various purposes (energy efficiency) and the time and place of electricity use (demand response). California's water sector is thus uniquely positioned to help the state improve electric reliability while concurrently helping to meet the state's resource efficiency, renewable energy and greenhouse gas reduction goals."***
>
> - Laurie Park and Kenneth Croyle. "California's Water-Energy Nexus: Pathways to Implementation." *GEI Consultants for the Water-Energy Team of the Governor's Climate Action Team (aka "WET-CAT")*. September 12, 2012.

Hourly Load Profiles: A High and Low Water Demand Day

The following graphs show the hourly load profiles for Rancho California Water District (RCWD) during a Summer vs. a Winter day. The deep trench during summer on-peak periods (Noon to 6pm) shows that price signals (high summer on-peak prices) work. Pumping patterns are very different during winter days when there are no energy price penalties. Distinctly different pumping patterns during summer vs. winter days is typical of most urban water utilities.

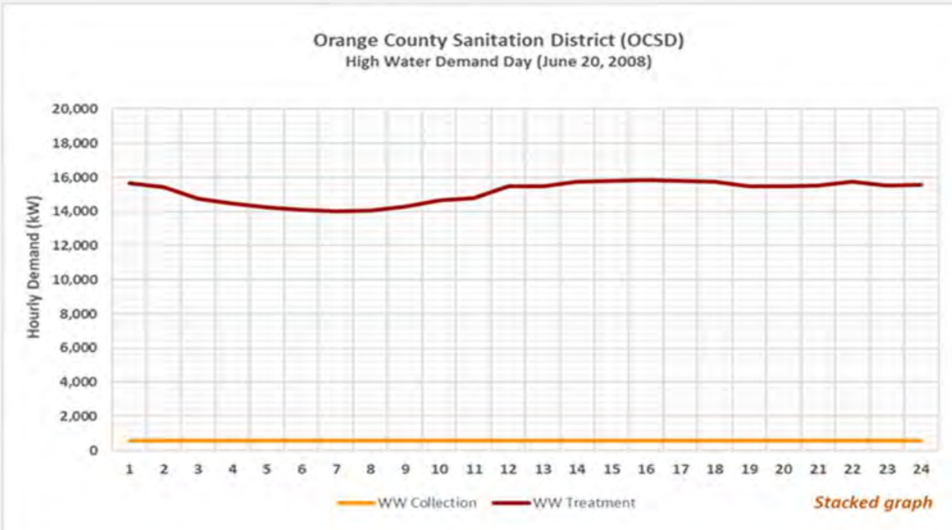


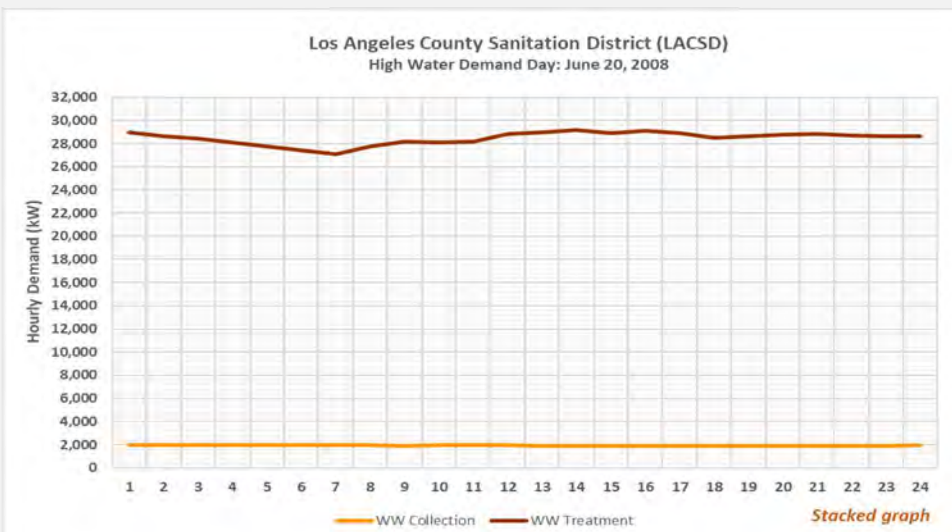


Source: Data collected for California Public Utilities Commission Water-Energy Study 2 [2010].

Hourly Load Profiles, Two Regional Wastewater Treatment Districts

Most wastewater utilities exhibit hourly electric load patterns similar to those shown below for OCSD and LACSD. Sewage collection systems pump at a fairly constant rate all day. Wastewater treatment is typically also relatively constant since treatment functions operate 24/7, although hourly treatment load varies slightly with the timing and volume of wastewater influent. Wastewater storage is typically limited to minor diurnal equalization storage because of odor concerns.





Source: Data collected for California Public Utilities Commission Water-Energy Study 2 [2010].

Water sector opportunities to provide over-generation mitigation support are not limited to pumped storage. The key to water sector Flex DR is excess capacity (pumps, pipelines, treatment) in combination with storage (water, wastewater, and recycled water; diurnal and seasonal). A diverse portfolio of facility types is optimal, because it increases the number and types of Flex DR opportunities.

Whether for potable, wastewater, or recycled water, excess capacity in combination with storage can enable shifting the amount, time, and location of water and wastewater operations. The more excess capacity and storage at any specific site, the greater the Flex DR potential.

Table 9 describes some water sector over-generation strategies (strategies for increasing electric use during some periods of time). The converse - decreasing electric use ("load shedding") - is much more commonly understood. However, water or wastewater utilities that can reduce electric use during some hours can usually also increase it. Thus, mitigation for both "over-generation" (over-supply) and "under-generation" (under-supply) – "Flex DR" – can usually be provided by the same entity.

Table 9. Strategies for Flex DR in Water and Wastewater Systems

Opportunity	Strategies	Potential Constraints	Challenges
Increase or decrease the volume of water, wastewater, and/or recycled water pumped or treated during specified hours	Maximize use of existing capacity, and/or increase capacity, to enable increasing electric use during periods of over-generation: ▪ Groundwater and booster pumps ▪ Water and wastewater treatment plants ▪ Raw, potable, and recycled water distribution systems ▪ Raw, potable, and recycled water reservoirs, ponds, tanks, other storage facilities	▪ Mission Critical: Increasing pumping rates could impair water quality. ▪ Resource: Increased rates and volumes of pumping could impair the water resource. ▪ Physical: Insufficient pump capacity at targeted site, pipeline constraints, storage constraints. ▪ Legal &/or Regulatory: May not have rights to increase pumping at the planned site at the targeted volumes. ▪ Economic: Some water sector Flex DR opportunities may not be cost-effective on the basis of water benefits alone.	Economic: Energy benefits alone cannot pay for a new reservoir or other expensive water, wastewater, and/or recycled water systems and infrastructure. The ideal opportunity is one that first achieves mission-critical water sector goals and objectives. Energy benefits can then be explored with the aim of offsetting a portion of the proposed water project costs while concurrently reducing water sector energy costs and risks.

Flex DR by Type of Pumped Water Storage

Table 10 provides a partial list of the types of Flex DR that could be provided by the various types of pumped water storage facilities.

Table 10. Flex DR by Type of Pumped Water Storage

Type of Pumped Water Storage	Types of Flex DR Opportunities	System Design & Operational Considerations
Diurnal Storage Facilities	Usually associated with municipal water, wastewater, and recycled water; best suited to distribution system balancing	▪ Flex DR capabilities exist now at thousands of water, wastewater, and recycled water facilities (surface and groundwater pumps, water and wastewater treatment facilities), most of which are proximate to electric utility distribution systems. ▪ This is the highest potential near-term water sector Flex DR opportunity: many water and wastewater utilities could begin providing support with existing diurnal storage facilities; few infrastructure changes would be needed.
Seasonal Recycled Water Reservoir	Usually associated with municipal wastewater treatment facilities, best suited to distribution system balancing	▪ Seasonal recycled water storage enables producing recycled water all year long, reducing discharges to ocean outfalls and maximizing water supplies. ▪ Seasonal and diurnal electric time-of-use patterns change markedly under this scenario: electric use increases during fall, winter, and early spring to produce and store recycled water; electric use decreases during summer due to higher availability of local recycled water (and less need to pump or treat surface or groundwater resources). ▪ Increased recycled water production coincides with over-generation season; may also be able to pump to storage during over-generation hours.
Groundwater Banks	Large capacity storage often operated for conjunctive use; could support both bulk power and distribution system balancing	▪ Electricity used to deliver water supplies for recharge and to deliver withdrawals to customers. ▪ Time of electric use depends on many factors (e.g., legal and regulatory) that may not be within the groundwater bank's sole control. ▪ Conjunctive use requires coordinating with surface water operations, complicating scheduling but creating additional Flex DR opportunities. ▪ Opportunities increase with some surface storage at or near the site.
Modular Pumped Storage Hydropower (m-PSH)	Much smaller in size, best suited to distribution system balancing	▪ "Closed loop" by definition. ▪ Comprised of man-made structures and replenished from water supplies (surface, groundwater, and/or recycled water). ▪ Design could be as simple as connecting two water tanks and cycling water between the two (beneficial for water quality). ▪ May or may not include hydropower production.
Flood Managed Aquifer Recharge (Flood-MAR)	Although highly variable in size and complexity, from single site to regional, best suited to distribution system balancing	▪ Flood management uses electricity for pumping: "*Flood control is provided by a system of levees, canals, and pump stations. All stormwater runoff is conveyed by gravity through a system of drainage lines and canals into the suction bays of various pump stations then pumped to a higher elevation into larger levees or the ocean.*"[53] ▪ Pumping facilities are typically dispersed over a large geographic area so individual pump loads may not be very high; but the coincidence of flood events with over-generation during spring months is beneficial for electric distribution system balancing.
Pumped Storage Hydropower (PSH)	Best suited for bulk power (transmission voltage level)	▪ Capable of providing substantial electric balancing services if schedules for hydropower production and pumping uphill can be synchronized with needs for electric reliability support. ▪ "Closed loop" facilities have highest value for electric reliability because they can control their own schedules for water deliveries and releases.

[53] "Flood Control." Orange County Public Works website: http://occom.ocpublicworks.com/sections/flood.

Optimizing Load Shifting for Over-generation Mitigation

System Design

Capacity Constraints

- ☐ **Existing Pumping, Pipeline, Treatment, Storage Capacity**. Is the system capacity sufficient to support the level of increased electric use?
  - What changes/additions would be needed to enable over-generation mitigation support?

Storage

- ☐ **Quantity**. How much storage is available?
- ☐ **Duration**. How much storage (hours, days, months) is available at the targeted increased levels?
- ☐ **Additions**. Will additional storage be needed?
  - How much, and where would the likely storage additions be implemented?
  - Would the location of potential storage additions require further adjustments to the potential overgeneration mitigation pumping schedule, both at this site and upstream or downstream of this site?

Operations

Potential Risks

- ☐ **Types of Operating Risks**.
  - Pump, pipeline, or well degradation or failure?
  - Impairment of water quality?
- ☐ **Risk Mitigation**. What strategies are needed to assure that mission-critical services are not impaired?

Upstream/Downstream Impacts

- ☐ **Types of Anticipated Impacts**. What types of changes may be needed to mitigate adverse impacts on upstream and downstream systems and facilities?
  - Would any of these needed changes increase operational costs and risks?
  - Might these changes increase water, ecosystem, environmental, other benefits?

Operational Changes

- ☐ **Operating Protocols and Procedures**. What types of changes are needed to implement the project?
- ☐ **Training**. Is additional operator training needed?
- ☐ **SCADA and/or Other System Management and Decision-making Tools**. Will new tools and/or changes be needed?

Economic Impacts

Δ Costs

- ☐ **Incremental Capital, Annual O&M, and Lifetime Repairs & Replacements**. What are the estimated costs to implement the proposed project?

Water Costs/Benefits

- ☐ **Water Supplies**. Will water supplies increase or decrease? How much of which types?
  - What is the estimated annual and lifetime value of the water supply changes?
- ☐ **Water Quality**. Will water quality be affected? Can the cost or benefit from changed water quality be estimated? (E.g., costs of water treatment may increase or decrease.)

Environmental Impacts

- ☐ **Costs, Benefits, and Risks**. Identify/quantify potential impacts to ecosystems, greenhouse gas emissions, etc.; include costs of additional environmental permits and approvals, if any, and monetized value of benefits, if possible.

Energy Costs/Benefits

- ☐ **Net Energy Costs (Annual and Lifetime)**. What is the value of energy costs net of benefits?
  - Will the project increase energy (kWh) and/or demand (kW) for the same volume of water pumped (e.g., due to increased friction losses that increase the amount of energy needed to pump or treat the same volume of water?
  - Are any energy efficiencies anticipated (e.g., by operating pumps, treatment plants, pipelines. etc. at "optimal" – most efficient - capacities and performance)?
  - What is the estimated value of incremental revenues (over-generation and/or other ancillary services)?

Financial Assistance

- ☐ **Grants, Subsidies, Incentives**. Are any of the investments needed to implement the project eligible for State, Federal, energy utilities, water/wastewater, other types of financial assistance that can buy down "First Costs"?

Economic Viability

- ☐ **Screening Level Assessment**. Compute the estimated number of years to recoup the investment.

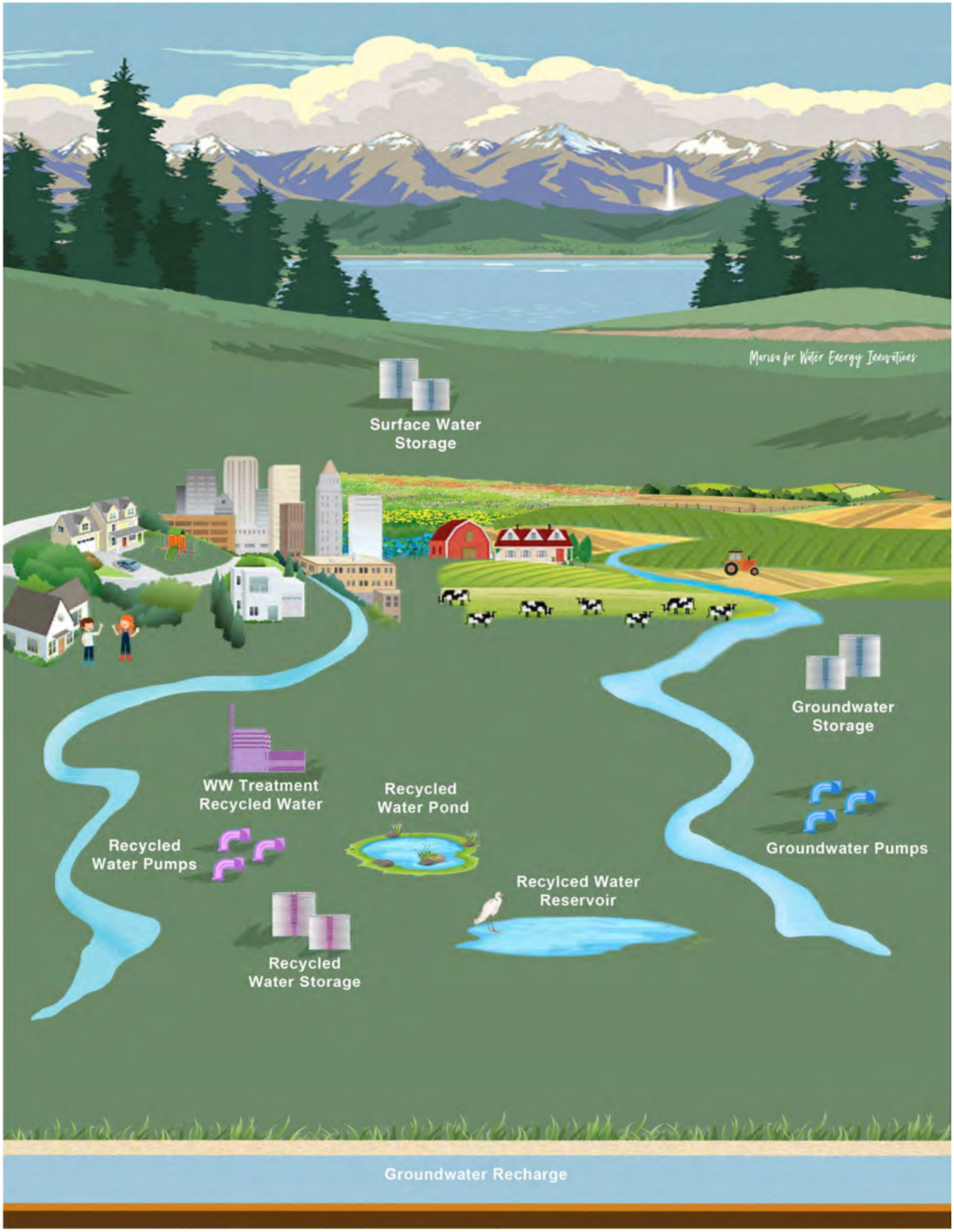


Figure 14. Water Storage Opportunities for Increasing Water Sector Flex DR

Best-in-Class Example of Water Sector Flex DR

Rancho California Water District (RCWD)

Rancho California Water District's first priority is water.

> *"The mission of the Rancho California Water District is to deliver reliable, high-quality water, and reclamation services to its customers and communities in a prudent and sustainable manner."*[54]

Managing energy and other operating costs is also important but is a supporting priority in assuring a reliable supply of water for RCWD's customers.

However, challenging is the fact that RCWD's water demand has declined over the past 10 years.

> *In its 2010 Urban Water Management Plan (UWMP), RCWD reported total water demand (net of transfers, environmental water, and losses) of 72,076 AF in 2005 and 62,477 AF in 2010 (a reduction of 13%). At that time, RCWD projected its 2015 water demand at 74,885 AF.*[55]
>
> *RCWD's 2015 UWMP reported actual 2015 water demand at 58,906 AF (21% less than projected).*[56]
>
> *Although 2018 data are not yet available, RCWD staff advised that water demand during 2019 is expected to be about 50% of 2008 water deliveries.*

RCWD attributes the substantial reduction in water demand to tiered rates, water conservation, low-flow devices, and successful water efficiency programs such as turf replacement and CropSWAP.

The combination of much lower water demand and significant redundancies in RCWD's systems and facilities that were implemented during 2006-2008 to enhance water reliability have created a circumstance in which RCWD currently has about 17 MW of Flex DR capacity. It is important to note that RCWD's infrastructure improvements were made for purposes of water reliability, not energy. However, increased operating flexibility provides benefits for both.

The screenprint from RCWD's SCADA system on the following page shows the numerous pumps and reservoirs that can be coordinated to shift RCWD's potable water pumping from high cost on-peak periods, to periods of over-generation.

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[54] "District Vision." Rancho California Water District (RCWD) website: https://www.ranchowater.com/232/District-Vision.

[55] "2010 Urban Water Management Plan." Rancho California Water District (RCWD). June 30, 2011.

[56] "2015 Urban Water Management Plan." Rancho California Water District (RCWD). June 2016.

Note the number of pumps (displayed as shaded circles) that pump to each water storage facility (reservoirs and tanks) and to groups of water storage facilities. This level of redundancy creates enormous operational flexibility, enabling RCWD to operate its pumps 12 hours per day and avoiding pumping during on-peak periods. This configuration also enables RCWD to increase pumping to storage during periods of over-generation.

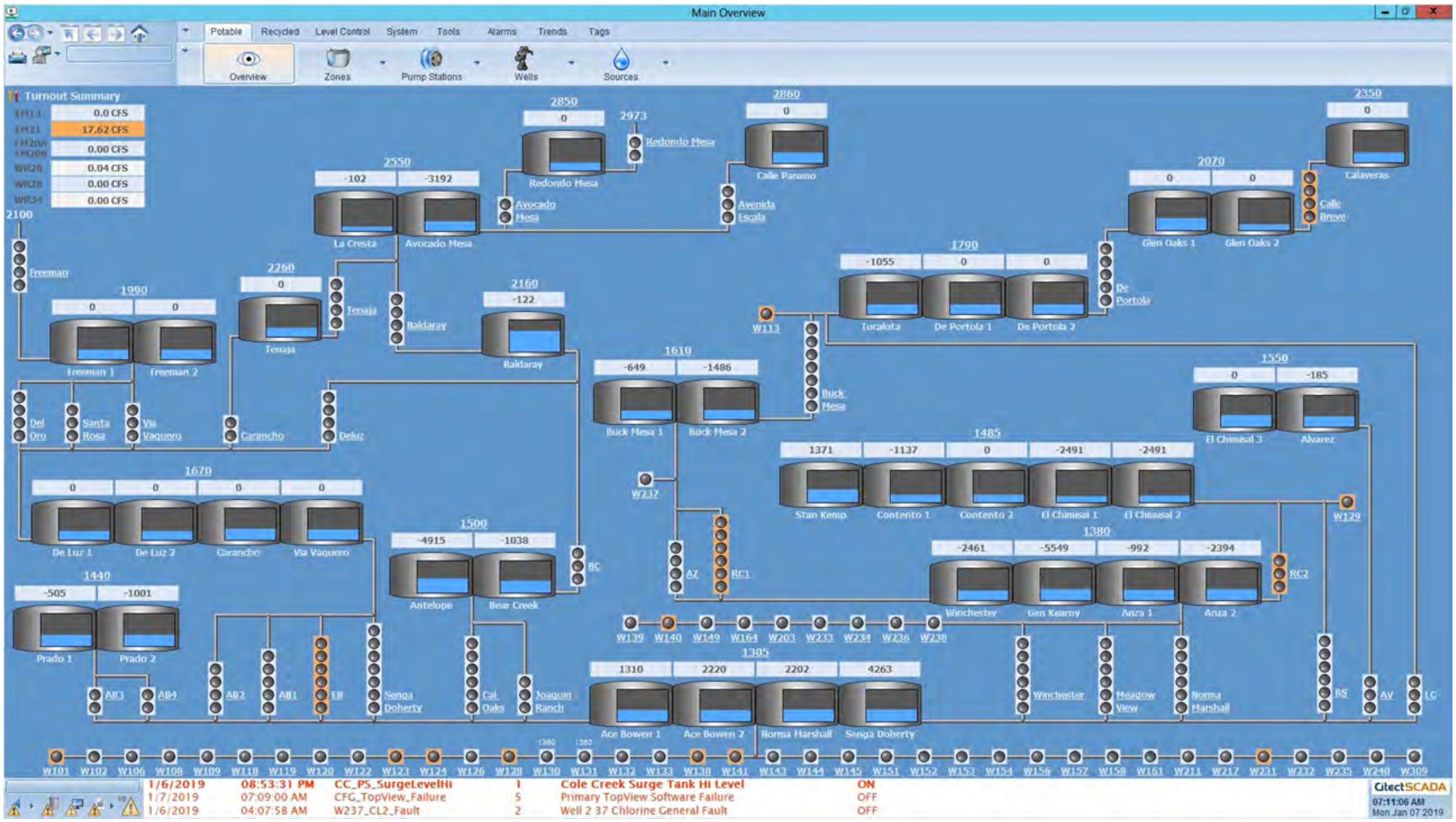

Figure 15. RCWD Potable Water System Configuration (SCADA Screenprint)

RCWD is a stellar example of how Flex DR capacity can be integrated into water and wastewater systems

Rancho California Water District (RCWD)

Supply, Distribution, Wastewater Collection, Recycled Water

Mission: *"to deliver reliable, high-quality water, and reclamation services to its customers and communities in a prudent and sustainable manner."*

Fast Facts

- 154.7 Sq. Miles
- South Coast Hydrologic Region
- DEER Climate Zone 10
- 44,827 Active Connections (2019)
- Population Served: 156,262 (2019)

Serving City of Temecula, portions of City of Murrieta, and unincorporated territory of Riverside County.

System Capacity

Potable Storage Reservoirs: 149.7 MG
Vail Lake Surface Reservoir: 45,207 AF
Recycled Storage Reservoirs: 7.5 MG
Recycled Ponds: 1,495 AF
Santa Rosa WRF: 5 MGD
Solar: 7.6 MW

Solar PV provides 12 million kWh/year, about 22% of the District's total annual electric use.

Water Supplied in 2015 (AF)

Groundwater: 37,272
Purchased/Imported: 27,771
Recycled: 4,036

Vision: *"Rancho California Water District is an innovative, responsive and prudent steward of the water and water recycling service responsibility entrusted to it."* (Strategic Plan 2017)

The District's Path to Flexible Operations

Prior to the 1990s, the District filled its reservoirs to 75% capacity. This practice limited the amount of groundwater that could be pumped.

In the late 1990s, the District decided to fill its reservoirs to 90% of capacity, enabling increased groundwater production and reduced purchases of expensive imported water. (Imports cost about $1000/AF vs. groundwater costs only the price of electric pumping, which averages about $70/AF.) This change reduced annual water purchases by about $11 million. The District also avoided the cost to build 3 new reservoirs. The additional storage capacity also enabled the District to change its pumping schedule and in 2006 the District implemented their Time of Use (TOU) strategy to reduce electric costs by 25%, a savings of $1.6 million through avoided purchases of on-peak electricity.

Subsequently, substantial decreases in water demand were achieved through water conservation, education, low-flow devices, tiered rates and water efficiency programs such as turf replacement. Currently, the District's water demand is about 50% of 2006 levels. Significantly reduced water demand further increased the District's operating flexibility.

Benefits Achieved

Annual Cost Reductions

$ 11.0 Million Purchased Water
$ 1.6 Million Electricity
$ 12.6 Million Operating Costs

Capital Cost Reductions

Avoided 3 new reservoirs

Flexible Demand Response

17 MW

Rancho California Water District (RCWD)

Best Practices for System and Operational Efficiency

The District's operational strategy is achieving roughly 23% in electric savings from on-peak avoidance. Today, that equates to savings of approximately $1.6 million a year.

- Since 2006, 28 of RCWD's 31 potable pump stations have been totally shut off during on-peak periods.
- RCWD expects to be at 100% on-peak avoidance with the advent of the new Time-Of-Use Pumping & Agricultural Rate (TOU PA 5to8) with a 5:00-8:00pm on-peak period.
- "Economic dispatch" – selecting the most economic energy option (gas v. electric) at any point in time – is managed by Operations through a manual scheduling system.

6 Million Gallons of Water Storage at RCWD. Source: RCWD

Like virtually all water utilities, the District manages for "Water First".

For the District, purchases of imported water cost much more than energy. Consequently, operating for "Water First" IS "the" economic decision.

Barriers & Challenges Faced

As with all things "new", getting buy-in from the operations staff and providing training was essential to the District's success.

Today, the value of these changes to the District and its customers is undisputed and the District is committed to remaining agile, as both water and energy policies and programs continue to evolve.

The key takeaway is that staying ahead of the curve requires being continually alert, aware, and proactive in order to reduce costs and risks and successfully transition to new water and energy policies, markets, rules, and regulations.

V Findings and Recommendations

Findings

1. **<u>Over-generation is real, and it is poised to increase substantially over the next 5 years</u>**.

   Over-generation occurs when real-time electric supplies exceed real-time electric demand. Referred to by the California Independent System Operator (CAISO) as "over-supply", over-generation creates voltage instability that can lead to electric service disruptions.

   In California, while any electric generation resource could create a situation of over-supply, most over-generation events tend to occur during the hours of solar energy production – about 9:00 am through 6:00 pm – during spring and early summer days when real-time solar energy production is high relative to real-time electric demand.

   Over-generation could be solved with electric storage. However, electric storage technologies cannot yet cost-effectively integrate thousands of megawatts of intermittent ("variable") electric resources such as solar and wind for hours at a time. As a result, the primary tool currently available for remedying over-generation is "curtailment" – turning excess generation off to maintain reliable deliveries of electricity.

   Given the substantial investment California has made in the development of renewable energy resources and the transmission and distribution systems needed to deliver renewable energy to customers, curtailments are not desirable. However, as California grapples with the policy challenges of curtailed solar, wind, and other renewable energy resources, it is important to maintain the following perspectives:

   - Over-generation is a very real physical situation that requires remedies. While curtailments are not popular, they are preferable to blackouts and brownouts that create risks to public health and safety, and to the economy.

   - Despite criticism from a wide variety of parties, the actual impacts of renewable energy curtailments have been relatively small to-date. Table 11 on the next page shows that curtailments of solar were manageable during 2015-2018, ranging from 0.06% to 0.19% as a percentage of Total Load on the CAISO managed electric grid, and from 0.87% to 1.56% as a percentage of grid-level solar energy production. It also shows, however, that curtailments have increased steadily since 2015.

   - Further, although there has been much press about California paying other states to take our solar power, the actual amounts paid, either to generators to reduce their solar energy generation or to market participants to take some surplus solar energy, has been relatively low. During 2018, most of the negative prices were under $5/MWh

($0.005/kWh). The highest negative prices occurred during April 2018, but even those were lower than $20/MWh ($0.02/kWh).[57]

Table 11. Solar Curtailments % of Total Load (Demand) and Solar Energy Generation[58]

Solar Energy Curtailments	2015	2016	2017	2018
As % of Total Load	0.06%	0.10%	0.15%	0.19%
As % of Solar Generation	0.87%	1.10%	1.36%	1.56%

The forward-looking circumstance, however, is about to change: an additional 23,832 MW of new utility-scale solar is in queue for transmission interconnection between 2019-2023.[59] While not all of this new solar PV capacity may be built, projects totaling 8,933 MW (37.5%) have already executed transmission interconnection agreements. Consequently, while over-generation has not yet posed a significant cost to electric ratepayers, it is highly likely that the frequency, amount, and costs of transmission-level over-generation will increase over the next 5 years.

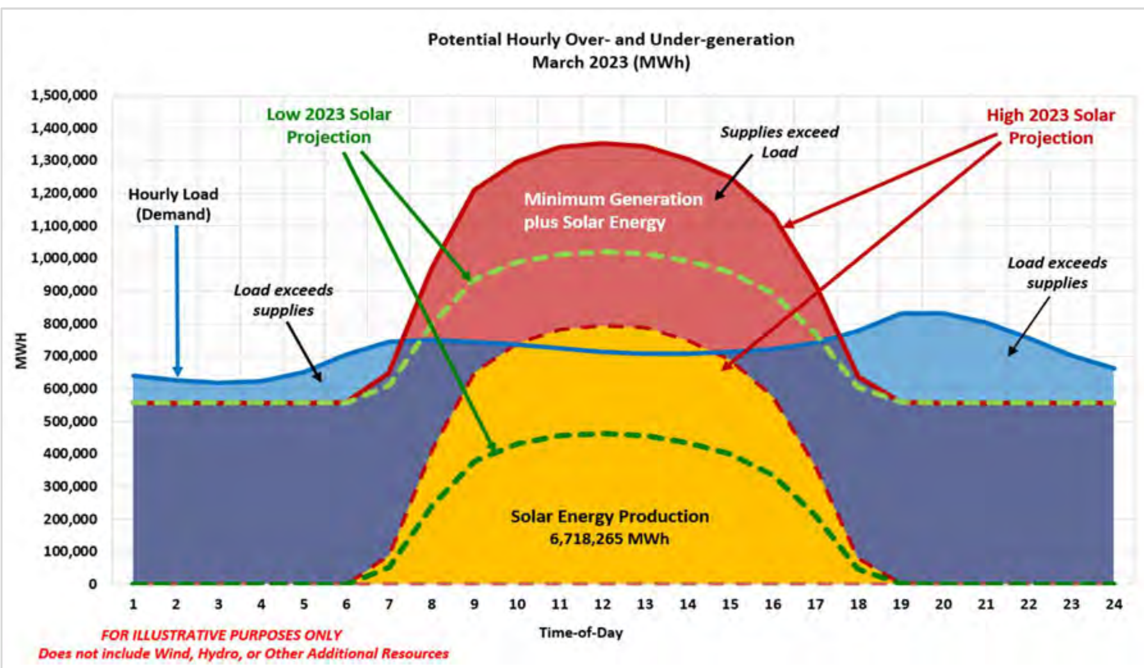

Figure 16. Potential Range of Over-generation by March 2023 [High and Low Solar PV Projections]

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[57] See Figure 3 on p.12.

[58] See Table 2 on p. 21.

[59] Source: CAISO data about the number and capacity of projects requesting generation interconnection.

Over-generation also has a distribution system counterpart: mini-duck curves created by distribution level variable energy resources (especially solar PV), most of which is "behind-the-meter" customer-side electric generation. Figure 17 below shows that BTM solar PV capacity is expected to exceed 12,000 MW by 2020.

Figure 17. Projected 2020 BTM Solar PV Capacity and Production[60]

The CAISO recently reported that its "Duck" (Net Load) is four years ahead of schedule due to under-forecasting rooftop solar PV.

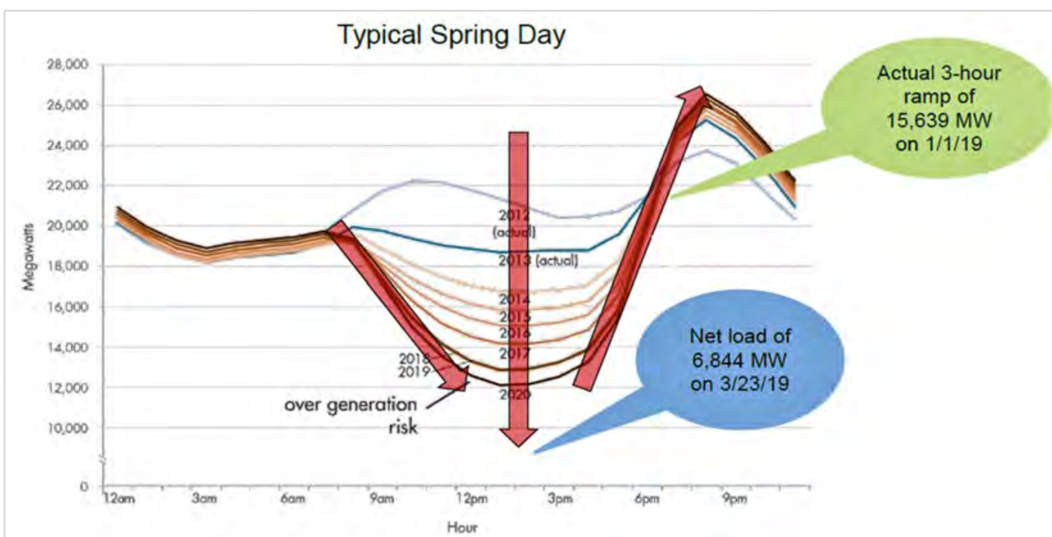

Figure 18. CAISO Duck is 4 Years Ahead of Schedule[61]

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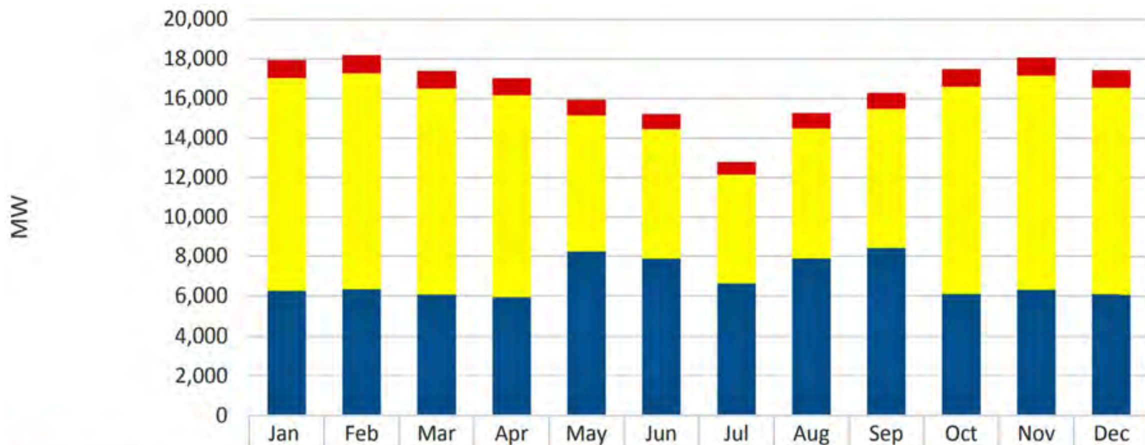
[60] Estimated BTM Solar PV Capacity was projected by Load Serving Entities (LSEs); estimated BTM Solar PV Production was projected by the California Energy Commission (CEC). Source: Loutan, Clyde, Hong Zhou, and Amber Motley. "Flexible Capacity Needs and Availability Assessment Hours Technical Study for 2020." *California Independent System Operator (CAISO)* presentation. April 4, 2019.

[61] Ibid.

Significant quantities of flexible capacity will be needed in 2020 to effectively integrate high volumes of both transmission- and distribution-level variable energy resources, most of which is solar PV. Figure 19 below shows the monthly amount of flexible resources that the CAISO estimates will be needed by 2020 by type of resource (Base, Peak, and Super-Peak).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Super-Peak Flexibility	897	910	869	851	797	761	640	763	815	874	903	871
Peak Flexibility	10,790	10,946	10,461	10,245	6,902	6,591	5,542	6,609	7,056	10,522	10,869	10,481
Base Flexiblity	6,248	6,339	6,058	5,933	8,240	7,869	6,617	7,890	8,424	6,093	6,294	6,069

Figure 19. Preliminary System-Wide Flexible Capacity Monthly Calculation by Category for 2020[62]

CAISO Flexible Capacity Categories

Base Flexibility: Operational needs determined by the magnitude of the largest three-hour secondary net load ramp

Peak Flexibility: Operational need determined by the difference between 95 percent of the maximum three-hour net load ramp and the largest three-hour secondary net load ramp

Super-Peak Flexibility: Operational need determined by five percent of the maximum three-hour net load ramp of the month

Source: "Draft Flexible Capacity Needs Assessment for 2020." *California Independent System Operator (CAISO)*. April 4, 2019.

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[62] "Draft Flexible Capacity Needs Assessment for 2020." *California Independent System Operator (CAISO)* report filed with the California Public Utilities Commission (CPUC) on April 4, 2019 pursuant to "Order Instituting Rulemaking to Oversee the Resource Adequacy Program, Consider Program Refinements, and Establish Annual Local and Flexible Procurement Obligations for the 2019 and 2020 Compliance Years" (R.17-09-020). This graph is Figure 8 in the CAISO's report. The Final CAISO Technical Study was filed with the CPUC on May 1, 2019.

2. **<u>The Water Sector has Unique Opportunities to Provide Over-generation Mitigation and Flexible Demand Response (Flex DR)</u>**. It has long been known that water and wastewater utilities have the unique ability to substantially change the quantity, time, and location of their electric use. Many water and wastewater utilities routinely minimize use of electricity during summer on-peak (high electric price) periods. The same types of changes to water and wastewater systems and operations that enable avoiding high cost summer on-peak electricity can likely be readily adapted to increase electric use during periods of over-generation.

   California's electric market needs a transitional strategy that will enable the State to minimize the frequency and costs of solar curtailment while electric storage technology development (e.g., battery energy storage) advances in parallel. With some technical and financial assistance, many water and wastewater utilities may be able to provide "Flex DR" support. Some can provide substantial amounts of Flex DR. (Rancho California Water District has confirmed 17 MW of Flex DR capacity; see how they did it on pages 49-52.)

   The water sector is expected to spend $70 billion on repairs and replacements of water and wastewater infrastructure over the next 20 years. Notably, this amount does not include the more than $14 billion of investments planned on new or expanded water storage facilities, nor the many billions more that will be invested in new systems, facilities, and infrastructure to meet load growth and support service area expansions. These estimates also do not yet include the additional billions of dollars that will be expended to comply with new water policies, rules, and regulations for flood management, sustainable groundwater, recycled water, and stormwater; nor to address environmental policy goals such as reduction of greenhouse gas emissions and protection of ecosystems.

   As dialogues progress between the State's water and electric sectors, it will be important to remember that the water sector must first meet its own mission-critical goals and objectives. Water needs to assure safe and reliable water supplies and wastewater services; it is the electric sector's job to assure electric reliability. The point at which the needs and interests of these two sectors intersect – where, for example, water and wastewater utilities can earn energy revenues and reduce their net energy costs and risks while still meeting their mission critical water goals and objectives – is the "sweet spot."

3. **<u>The Water Sector is Interested in Participating in Design of a Flex DR Program</u>**. Most of the water and wastewater utilities that provided data and information for this study already participate in SCE Demand Response programs and/or DR programs managed by aggregators. These water and wastewater utilities stated that they could do more DR and expressed a desire to participate in designing a "Flex DR" program tailored to the special needs and capabilities of the water sector. All felt that some degree of both financial and technical assistance will be needed to help the water sector identify, evaluate, develop, and implement Flex DR opportunities.

The following program needs were discussed:

a. **<u>Disincentives Need to be Addressed</u>**. Several utilities cited a need to remedy disincentives in existing DR programs. Some disincentives cited were financial (e.g., demand charges that accrue even when participating in DR); some were operational (e.g., the process is too difficult, communications need to be better, operators need to be better trained). Others related to need for better telemetry such as linking sub-metered electric use at the prime mover level to SCADA, and more sophisticated real-time decision-making tools. All water and wastewater utilities interviewed for this report emphasized a need to recognize that the water sector must first assure that its mission-critical priorities have been met <u>before</u> it can provide electric reliability support.

b. **<u>Increasing Flexibility Could Incur Incremental Costs and Risks</u>**. Most water and wastewater utilities indicated that they could likely increase electric use during periods of over-generation, <u>provided</u> operators are first given the opportunity to verify that the water or wastewater utility's mission-critical priorities will not be impaired. With those assurances, water sector managers may be able to provide over-generation mitigation support on both day-ahead and real-time bases.

   All water sector participants stated that some additional investment may be needed to make the types of changes to systems and controls needed to enable effective participation in Flex DR. Anticipated incremental investments included:

   - Increasing pumping and storage capacity (water, wastewater, recycled water; diurnal and seasonal);
   - Implementing sub-metering of electric use by all primary and secondary water, wastewater, and recycled water systems and functions, and integrating the sub-metered data with SCADA;
   - Enhancing automated controls and real-time decision-making tools so that operators have reliable real-time information before accepting or declining participation in a Flex DR event; and
   - Changing operations protocols and training operators in new systems and procedures.

c. **<u>Technical Assistance is Needed</u>**. While most water and wastewater utilities are knowledgeable about strategies for avoiding electric use during high-priced on-peak periods, much less is known about over-generation. As part of this pilot project, SCE collaborated with several water and wastewater utilities to identify and evaluate potential opportunities to provide over-generation mitigation support. Through these efforts, the following insights were gained that should be considered during design of a water sector Flex DR program:

   i. Water and wastewater systems are comprised of multiple complex interconnected systems and functions. Operational changes to one part of the system can affect operations (and electric use) both upstream and downstream of the point at which a change is planned to be implemented.

ii. Due to the high level of interconnectivity, system hydraulics and capacity constraints must be considered when evaluating potential changes to systems and/or operations. Although most water and wastewater utilities can increase pumping at various points in their systems, capacity limits (pumps; water and wastewater treatment facilities; conveyance and distribution pipelines; diurnal and seasonal storage facilities) can limit potential over-generation mitigation benefits. Other types of constraints - water quality, groundwater allocations, regulatory environmental flows, and other legal and regulatory requirements – can also constrain operations. For example:

- Even when ample unutilized pumping capacity may be available, pipeline constraints can reduce the amount of water or wastewater pumping that can be shifted to periods of over-generation.
- Increasing pumping to flows that approach a pipeline's capacity increases friction losses, requiring more energy to pump the same volume of water or wastewater.
- One of the highest benefits that water utilities could provide from the perspective of increased over-generation mitigation would be to increase electric use during spring months when over-generation is expected to be highest. Hydraulic analyses are a valuable tool for assessing the technical and financial viability of candidate projects to achieve seasonal over-generation benefits.

iii. Lacking access to sufficient seasonal storage, some wastewater utilities discharge wastewater effluent to ocean outfalls during fall and winter months when recycled water demand is low. Some water utilities are investing in new recycled water reservoirs that enable maximizing production and use of all recyclable water. Understanding the magnitude and timing of electric impacts attributable to these types of new facilities and operations can help to identify valuable renewable energy integration resources. (See "Recycled Water Storage" on p.40 and "Appendix C. Surface Water Storage Projects Under Development," "Trampas Canyon Reservoir & Dam.")

d. **<u>Water Sector Electric Planning and Analytical Tools Are Needed</u>**. The collaborations occurring between SCE and its water sector customers reveal a need for new ways of thinking about the energy impacts of water, wastewater, and recycled water systems and their operations. New tools (checklists, economic assessments and other analytical tools, predictive energy models) can facilitate efficient and cost-effective water sector identification and evaluation of potential Flex DR opportunities.

The goal of designing a Water Sector Flex DR Program is to expedite identification, evaluation, and implementation of near-term Flex DR opportunities that can provide meaningful electric reliability support within 1-3 years. Concurrently, larger, longer-term projects and strategies can be positioned for early conceptual development with the aim of implementing the next phase of water-related Flex DR projects within 3-5 years.

A phased approach can help to build a temporary buffer of water sector Flex DR opportunities to reduce renewable energy curtailments while electric storage projects and technologies advance in parallel.

Recommendations

There are many high potential opportunities to help the water sector increase its operational flexibility with the aim of providing near-term (within 1-3 years) and long-term (greater than 3 years) over-generation mitigation support and Flex DR. Maximum results will be achieved by first inventorying and prioritizing Flex DR strategies and opportunities with a diverse sample of water and wastewater utilities. Following are recommended next steps:

1. **Assess the Water Sector's Ability to Mitigate Over-generation and to Provide Flex DR**.
    a. Conduct meetings, workshops, interviews, and webinars with a broad array of water and wastewater utilities within SCE's service area to obtain their input as to:
        - The types of Flex DR opportunities that they believe their utility can provide; and
        - The types of technical support, education, and/or financial incentives that they would need to develop and implement different types of Flex DR opportunities.

    b. Working in concert with SCE technical staff, water sector participants, and other key stakeholders whose support and participation is needed for successful development and implementation of water sector Flex DR (e.g., water and wastewater technical service providers, engineering firms, and a wide variety of water and wastewater systems and hydraulic modeling subject matter experts), characterize, categorize, and prioritize different types of strategies and projects.

    c. Estimate the Flex DR potential within SCE's service area by type of strategy or project.

2. **Convene a Collaborative Process to Develop and Recommend a Water Sector Flex DR Program and Rate Design**. The program design will include technical assistance and financial incentives that assist water and wastewater utilities in identifying, evaluating, and implementing changes to their systems, facilities, and operations that increase their capabilities to provide Flex DR support. Contemplated program design elements include:
    - A portfolio of education and technical assistance that help water and wastewater utilities identify and evaluate their own opportunities to mitigate over-generation and to provide Flex DR services.

- An “opt-in” tariff that provides price signals and incentives to water and wastewater utilities that reduce local and regional electric instability during periods of over-generation, under-supply, unplanned electric system outages, and other electric reliability events. Incentives would likely vary with the electric reliability value of different types of services, with Auto Flex DR likely providing the highest value.

SCE’s new Time-of-Use (TOU) rates became effective on March 1, 2019. These new rates changed the historical time-of-use periods to hours nominated by the CAISO as the new “on-peak” (now 4:00 pm to 9:00 pm, instead of Noon to 6:00 pm). However, the new TOU rates do not yet provide the level of incentives likely needed by many water and wastewater utilities to incur the time and costs needed to make the types of modifications to systems and operations that could maximize their Flex DR potential.

Recent discussions with water and wastewater utilities indicate that they believe the price signals for over-generation should more closely align with real-time wholesale electric market prices. However, given that their first duty is to protect public health and safety, water and wastewater utilities are inherently risk averse – while reducing costs is always important and desirable, it does not rise to the level of their mission critical priorities. Since most water and wastewater utilities are not well positioned to assume both the risks and rewards of volatile wholesale power markets, a hybrid rate – one that provides some of the benefits of wholesale prices during over-generation periods without assuming wholesale power market costs and risks – would likely be prudent.

3. **Collaborate with Water and Energy Stakeholders on Development of Analytical Methods, Models and Tools for identifying and evaluating Flex DR opportunities**. Based on work completed to-date, it appears that the following types of tools would be beneficial to helping both the water and electric sectors and their respective customers and stakeholders to quickly and cost-effectively identify and evaluate water sector Flex DR opportunities.

   a. ***Load Shift Planning Tool(s) (Customer Perspective)***. Develop one or more tools that help water and wastewater utilities estimate the amount and types of storage needed to cost-effectively achieve load shifting at various points in their systems.

   b. ***IDER Planning Tools (Customer Perspective)***. Develop checklists and questionnaires that help water and wastewater utilities identify potential load shifting opportunities and evaluate the costs and benefits of those opportunities.

   c. ***IDER Screening Tools (Customer, Utility, and Statewide Perspectives)***. Develop a “Fatal Flaw” Screening Tool to help water and electric sector participants and other key stakeholders screen candidate projects for “fatal flaws.”

   d. ***IDER Planning Tools (Utility Perspective)***. Develop an Expected Value Analysis Tool (and potentially other simple Excel-based spreadsheet tools) to assist electric utilities in evaluating customer load shifting opportunities that:

      i. Quickly identify opportunities that are most important from the perspective of electric utilities’ distribution systems, and

ii. Estimate the value of potential opportunities to electric utilities and their ratepayers to guide water sector Flex DR program and rate design.

e. ***Other Potential Tools TBD in Collaboration with Water and Electric Stakeholders***.

Best-in-Class Example of Comprehensive Water-Energy Strategic Planning

The State has been grappling with what to do about its "water-energy nexus" ever since the California Energy Commission (CEC) issued its white paper, "California's Water Energy Relationship," in 2005.[63] Over the past 15 years, numerous studies have been conducted by policymakers, regulators, state and federal agencies, water and energy utilities, industry leaders, public and private research organizations, technical service companies, environmental advocates, and community based organizations to determine how best to achieve the water, energy, greenhouse gas emissions, and related multi-benefits that most stakeholders acknowledge reside at the intersection of water, energy, and climate.

Despite widespread interest and support, progress has been modest to-date. While diverse groups of stakeholders have convened multiple forums to recommend changes to State programs, relatively few changes have been implemented to-date. Key among these was the CPUC's 2012 decision to recognize energy embedded in water, aka "embodied energy", as an energy efficiency resource.[64] As of today, however, there is not yet a consistent statewide policy for measuring or recognizing energy embodied in water, nor is there a way to maximize benefits for both the water and energy sectors through a single comprehensive, cross-cutting program.

One of the biggest challenges to achieving cost-effective co-benefits is a continued single-resource mindset with respect to public investment: energy investment for energy projects, water investment for water projects. Until this hurdle can be overcome, California will continue to sub-optimize water and energy public investments.

Undeterred by these hurdles, Willow Springs Water Bank (WSWB) proceeded with developing a framework for optimizing the water and energy benefits of its groundwater bank that could be adapted to other water-energy projects. WSWB's water-energy planning framework is distinguished from others in its comprehensiveness.

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[63] Klein, Gary, et. al. "California's Water-Energy Relationship, Final Staff Report." *California Energy Commission (CEC)* Staff Report, Publication No. CEC-700-2005-011-SF. November 2005.

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Best-In-Class: Comprehensive Water-Energy Strategic Planning

A Water-Energy Bank to optimize statewide water, energy and environmental benefits through coordinated design and operations of water and energy systems & facilities.

Project: Willow Springs Water Bank operates one million acre-feet of groundwater storage in the Kern County area.

Targeted Statewide Benefits

- **Increase water supplies** by capturing and storing surface water that would otherwise be "spilled" through runoff
- **Increase electric reliability support and lower electric ratepayer costs** by shifting electric demand from high demand summer periods to low demand spring periods
- **Increase carbon-free energy production and use** by reducing curtailments of solar and wind energy which results in greenhouse gas emissions reductions.
- **Increase water reliability** (emergency response) benefits during periods of water stress—droughts or in the wake of a large earthquake

State Water Project (SWP) Chrisman Pumping Plant. *Credit: DWR*

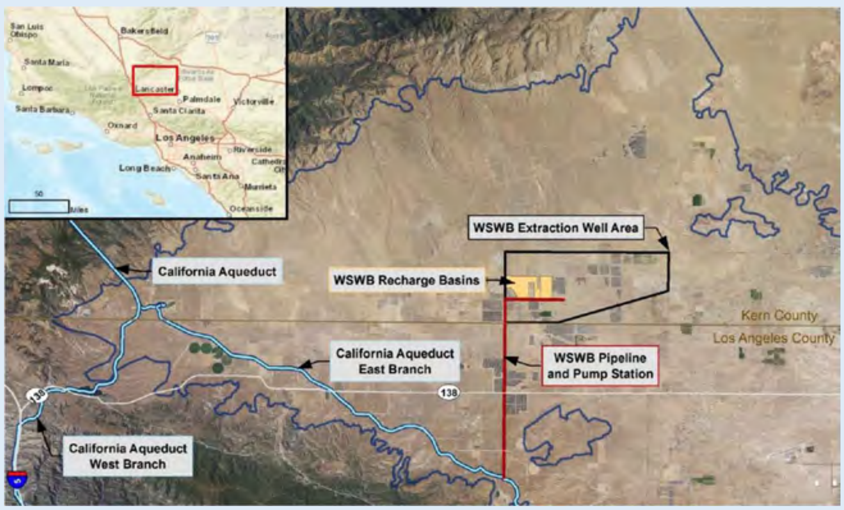
Innovative Framework

Willow Springs Water Bank (WSWB) developed an innovative framework for optimizing the water and energy benefits of its groundwater bank. This framework is distinguished from others in its comprehensiveness:

- ***Cross-Cutting*** – Seeks to optimize water, energy, and environmental benefits through coordinated planning and operations with other water and energy entities.
- ***Scenario Analyses*** - Analyzes ranges of potential impacts under multiple scenarios to identify options with high benefits and manageable risks.
- ***Leading Models and Tools*** - Conducts detailed assessments of hourly, monthly, seasonal, annual, and multi-year water supply, energy, ecosystem, and greenhouse gas emissions benefits using market-leading analytical models and tools, some of which were custom-developed for this project.
- ***Comprehensive Integrated Distributed Energy Resources (IDER)*** – Targets comprehensive portfolio of IDER opportunities and impacts – demand response, distributed carbon-free renewable energy generation, and energy storage (in this case, water) – for power market.
- ***Supply Chain*** - Analyzes its own economic impacts and electric and greenhouse gas footprint, as well as those of candidate partners, to develop strategies that maximize statewide resource and environmental benefits for the State overall.

Key Findings

- ***Coordinated operations of water systems and storage*** can increase water supply yield, reduce energy costs, and enable seasonal shifting of power use and production.
  - Both water and electric reliability are enhanced.
  - Greenhouse gas emissions are also reduced by increasing the State's ability to integrate variable energy resources (solar and wind), reducing curtailments and assuring that more carbon-free resources reach Californians.
  - Optimized operations reduce both capital and operating costs, realizing economic benefits for both the water and energy sectors.
- ***Deep understanding of the design, hydraulics, and operation of the State's water systems*** – points of connectivity, constraints that limit "optimization", creative approaches to alleviating constraints - is crucial to maximizing benefits.
- ***Understanding the needs and interests of the parties*** – finding the "win-win" (oft criticized for overuse; but still, ultimately, the key to successful negotiated outcomes) – is essential.



Conclusions: WSWB's Water-Energy Bank provides new demand response capabilities using existing infrastructure, making implementation both fast and cost-effective. Current SWP water delivery practices can be modified to provide energy benefits without changing the timing, quantity or reliability of water delivered to Southern California or affecting WSWB's primary function which is that of a water storage facility. To implement the Project, DWR must adjust its operations, and SWP Contractors must agree to a seasonal change in the source of their water. Similarly, as the beneficiaries, the IOUs must finance the necessary incentives to enable this demand response, and CAISO must coordinate the benefits. Currently, no State program incentivizes the water sector to consider its energy impacts when designing and building water infrastructure. Yet, water is the nation's oldest, largest and most cost-effective form of electric storage. Given California's urgent need for cost-effective electric storage to support the State's vision for 100% carbon-free energy resources by 2045, all water purveyors should be encouraged to expedite development of their electric storage potential. The analytical tools and techniques developed through WSWB's Water-Energy Bank Project can help to provide a quick start.

Optimizing the State's Resources

- ***True Strategic Planning*** starts with a blank sheet of paper.

  Envisioning the possibilities without concern for potential constraints creates a robust portfolio of options, some of which might otherwise not have been considered.

- ***Comprehensive Approaches*** enhance potential benefits.

  Exploring connectivity among multiple diverse water and energy resources and systems creates opportunities that would not be possible from a single resource or single system perspective.

- ***Convening multiple entities*** with complementary goals and objectives brings opportunities for leverage, collaboration, and coordination.

  Cost-effective strategies bring wins for both water and energy ratepayers.

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	Screenshot	Rancho California Water District. *Potable Water SCADA System*. Screenshot. January, 7, 2019.
Rosamond Community Services District (RCSD)	RCSD-Web01	"Semitropic-Rosamond Water Bank Authority: Storing Water Supplies for Our Future." RCSD website: https://www.rosamondcsd.com/home/showdocument?id=60.
Santa Margarita Water District (SMWD)	SMWD-Web01	"Trampas Canyon Reservoir & Dam." SMWD website: http://smwd.com/313/Trampas-Reservoir.
	Photo-10	Santa Margarita Water District. *Upper Oso Seasonal Storage Reservoir*. Photo. SMWD website: http://smwd.com/. Viewed February 13, 2019.
	Photo-11	Santa Margarita Water District. *SMWD has 4,000 million gallons of water storage.* Photo. SMWD website: http://smwd.com/. Viewed February 13, 2019.
Semitropic	Semitropic 2012	"2012 Groundwater Management Plan.
Shime	Photo-12	Shime. *Water pumping station - water treatment plant within the pumps and pipelines*. Photo. iStock.com, image 44487046.
Solar on Multifamily Affordable Housing (SOMAH)	SOMAH-Web01	"Solar on Multifamily Affordable Housing." https://www.calsomah.org/.
Southern California Edison (SCE)	SCE-2016	R.13-09-011. "SCE Proposal for Approval of Its 2017 Demand Response Program and Bridge Funding Authorization." Filed with CPUC on February 1, 2016.
State Water Resources Control Board (SWRCB)	SWRCB-2013	Water Transfer Program Information. *State Water Resources Control Board (SWRCB)*. September 2013.
	SWRCB-Web01	"Water Transfers Program." SWRCB website: https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_transfers/.
University of California, Berkeley (UCB)	UCB-2018	Cantor, Alida, Dave Owen, Thomas Harter, Nell Green Nylen, and Michael Kiparsky. "Navigating Groundwater-Surface Water Interactions under the Sustainable Groundwater Management Act." Center for Law, Energy & the Environment, UC Berkeley School of Law, Berkeley, CA. 2018.
U.S. Department of Energy (USDOE)	USDOE-2018	"U.S. Battery Storage Market Trends." U.S. Energy Information Administration, U.S. Department of Energy. May 2018.
	USDOE-Web01	"Global Energy Storage Database." Office of Electricity Delivery and Energy Reliability, USDOE website: https://www.energystorageexchange.org/.
	USDOE-Web02	"Glossary of Hydropower Terms." USDOE website: https://www.energy.gov/eere/water/glossary-hydropower-terms.

SOURCE	REFERENCE No.	DESCRIPTION
	USDOE-Web03	"Pumped-Storage Hydropower." Office of Energy Efficiency and Renewable Energy (EERE), USDOE website: https://www.energy.gov/eere/office-energy-efficiency-renewable-energy.
U.S. Energy Information Administration	USEIA-Web01	"U.S. Battery Storage Market Trends."May 2018.
Utility Dive	UtilityDive-2018	Maloney, Peter. "Los Angeles considers $3B pumped storage project at Hoover Dam." Utility Dive. July 26, 2018.
Water Education Foundation (WEF)	WEB-Web01	"San Luis Reservoir." WEF website: https://www.watereducation.org/aquapedia/san-luis-reservoir.
Water Replenishment District of Southern California (WRD)	WRD-Web01	"Mission and History." WRD website: https://www.wrd.org/content/mission-and-history.
Willow Springs Water Bank (WSWB)	WSWB-2017	Beuhler, Mark, Naheed Iqbal, Zachary Ahinga, and Lon W. House. "Groundwater Bank Energy Storage Systems: A Feasibility Study for Willow Springs Water Bank." Antelope Valley Water Storage for California Energy Commission (CEC). Publication No. CEC-500-2017-042. December 2017.

Appendix A: Pumped Storage Power Plants Under Development

Table A-1. Conventional Pumped Storage Power Plants Under Development

Plant Name	County	Rated Capacity (MW)	Project Developer	Targeted In-Service Year
Bison Peak Pumped Storage Project	Kern	360+	Covington Mountain Hydro	2025-2026
Boulder Canyon Pumped Storage Project	Clark County, NV and Mohave County, AZ	1,000+ [est.][65]	Los Angeles Department of Water & Power (LADWP) with USBR and potentially others	2030
Eagle Mountain Pumped Storage Hydroelectric Project	Riverside	1,300	Eagle Crest Energy Company	2023
Lake Elsinore Advanced Pumped Storage Project (LEAPS)	Riverside	500	The Nevada Hydro Company	2023-2024
San Vicente Pumped Storage Project	San Diego	500	San Diego County Water Authority and the City of San Diego	2025
Currently Under Development		**3,660+ MW**		

The above 5 projects are described in in this appendix.

[65] LADWP has not yet provided any data about the estimated capacity of this proposed project. The 1,000 MW estimate is used here to indicate an anticipated order-of-magnitude based on LADWP's estimated project cost ($3 billion).

Bison Peak Pumped Storage Project[66]

Project Description. A planned closed-loop pumped storage project in Kern County with an upper reservoir and three proposed alternatives for the placement of a lower reservoir. Water for the initial fill of either of the alternatives is planned to be obtained from local water agency infrastructure via a route that would be identified during studies.[67] The current project configuration anticipates a fill-water requirement of 1,300 acre-feet (423.6 million gallons); the upper reservoir surface is expected to cover an area of 20 acres.

The project site has several unique characteristics.

- Very high head (vertical drop 2,100 to 3,000 feet) that substantially increases the quantity of energy that can be produced for the same volume of water. Very high head hydro also has very quick response rates and could be used for load following.
- All facilities will be located on private property.
- The proposed site is located within the Tehachapi Renewable Energy Zone, near to high voltage transmission and thousands of current and planned wind and solar facilities.

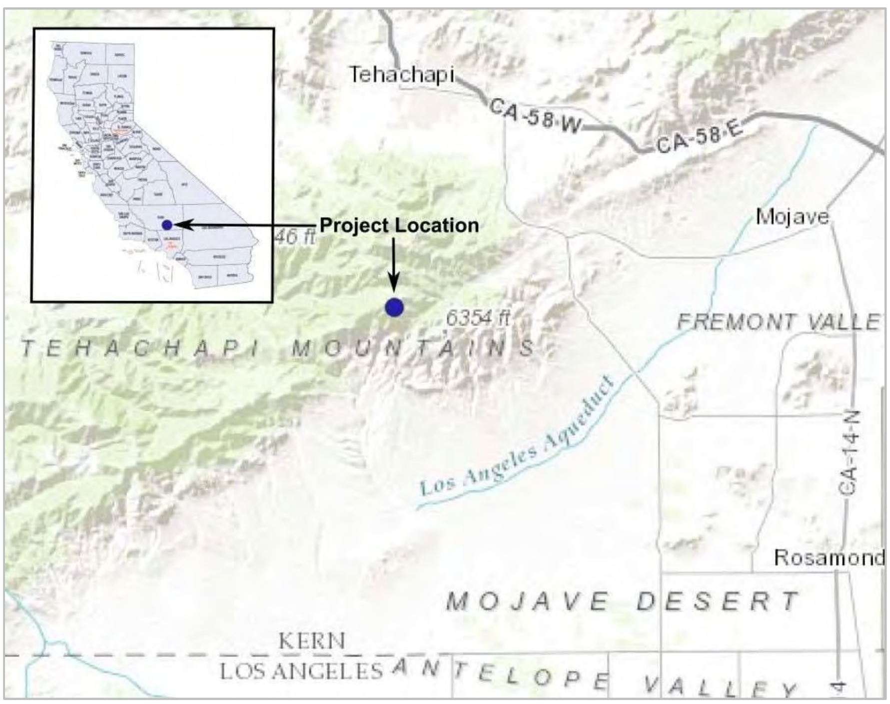

Figure A-1. Site of Proposed Bison Peak Pumped Storage Project

66 "Bison Peak Pumped Storage." *Gridflex* website: http://gridflexenergy.com/projects/bison-peak/.

67 "Covington Mountain Hydro, LLC.; Notice of Preliminary Permit Application Accepted for Filing and Soliciting Comments, Motions to Intervene, and Competing Applications." *Federal Energy Regulatory Commission (FERC)*. Federal Register Doc. 2018-00282 filed January 9, 2018.

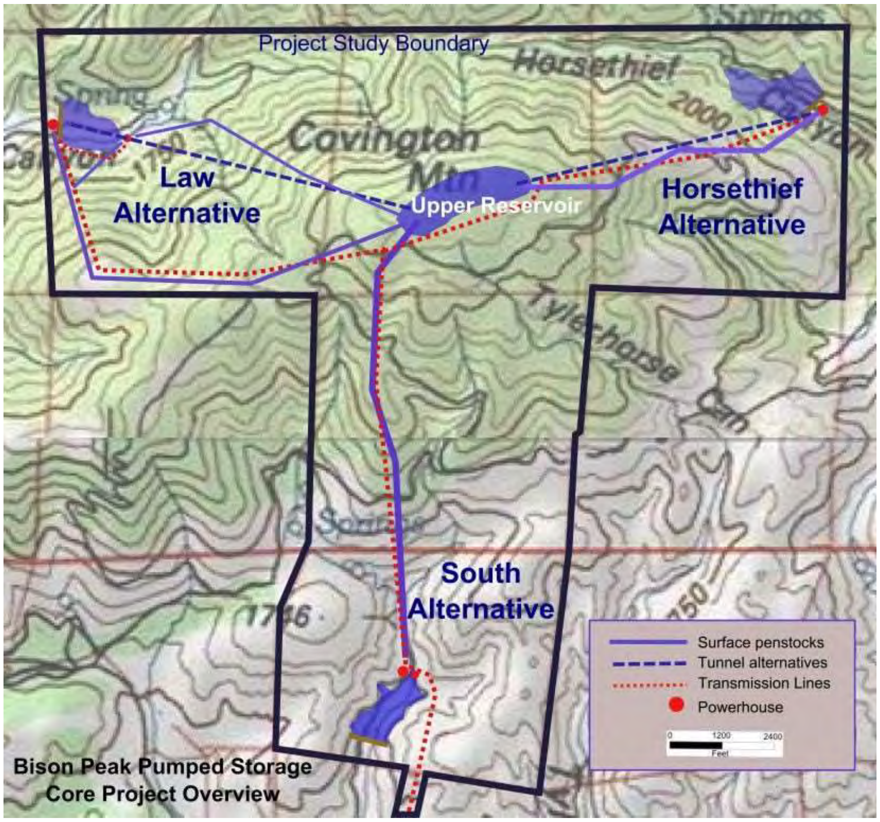

Figure A-2. Lower Reservoir Alternatives (3) for Proposed Bison Peak Pumped Storage Project

Project Status. On August 1, 2018, FERC staff issued the result of their findings: that Covington had not clearly identified the source of water for the project. FERC staff determined that FERC licensing would not be needed if the project uses groundwater. However, if the project purchases municipal water, FERC licensing would be required. Covington requested rehearing of FERC's August 1 Order. On December 20, 2018, FERC denied rehearing.[68] The primary action now needed is to determine whether the project can be supplied wholly by groundwater, which would then obviate need to obtain an expensive and long lead-time FERC license.

[68] "Order Denying Rehearing." *Federal Energy Regulatory Commission (FERC)* Docket DI18-1-001. December 20, 2018.

Boulder Canyon Pumped Storage Project[69,70]

A planned closed-loop pumped storage project proposed to be integrated into the Hoover Power Plant at Lake Mead.

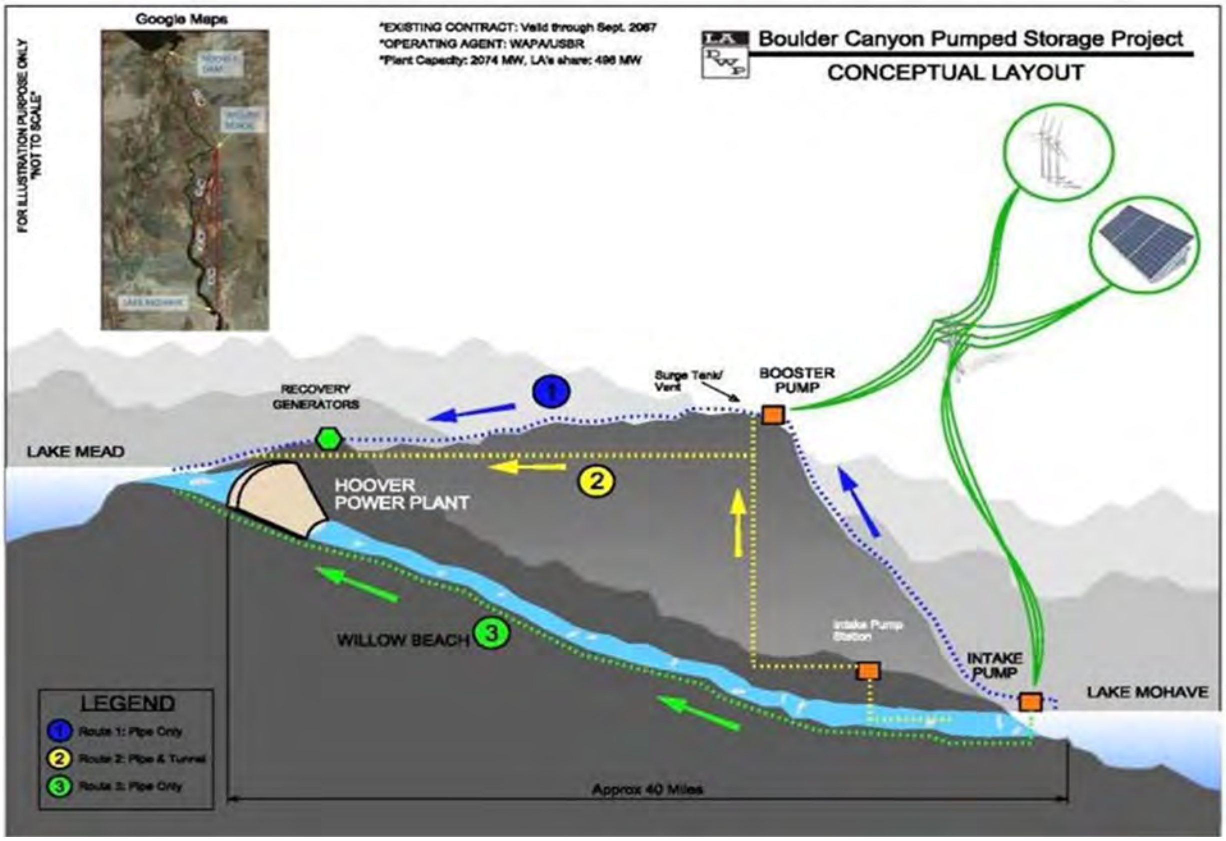

Figure A-3. Conceptual Design of LADWP's Proposed Boulder Canyon Pumped Storage Project

Project Description. Proposed installation of a pumping station about 20 miles downstream from Hoover Dam that would pump water from Lake Mohave back up into Lake Mead. The current plan anticipates producing and using solar and/or wind power to pump water back into Lake Mead.

Project Status. Initial conceptual designs have been prepared, discussions have commenced with key stakeholders (especially the U.S. Bureau of Reclamation), and engineering studies have commenced. Project description with estimated capacity and proposed operations are not yet available.

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[69] "Boulder Canyon Pumped Storage Project." Presentation by Sam Mannan, Project Manager, *Los Angeles Department of Water and Power (LADWP)*. November 19, 2018.

[70] Maloney, Peter. "Los Angeles considers $3B pumped storage project at Hoover Dam." *Utility Dive*. July 26, 2018.

Eagle Mountain Pumped Storage Hydroelectric Project[71]

Project Description. Proposed 1,300 MW closed-loop, pumped storage facility at the site of two (largely) inactive mining pits in the Eagle Mountain mine. The proposed project will occupy 2,527 acres of land of which 27.7% is federal land managed by the Bureau of Land Management (BLM). The remaining 72.3% of the land is privately owned. Both water for the initial reservoir fill and replenishment are anticipated to be supplied by groundwater wells.

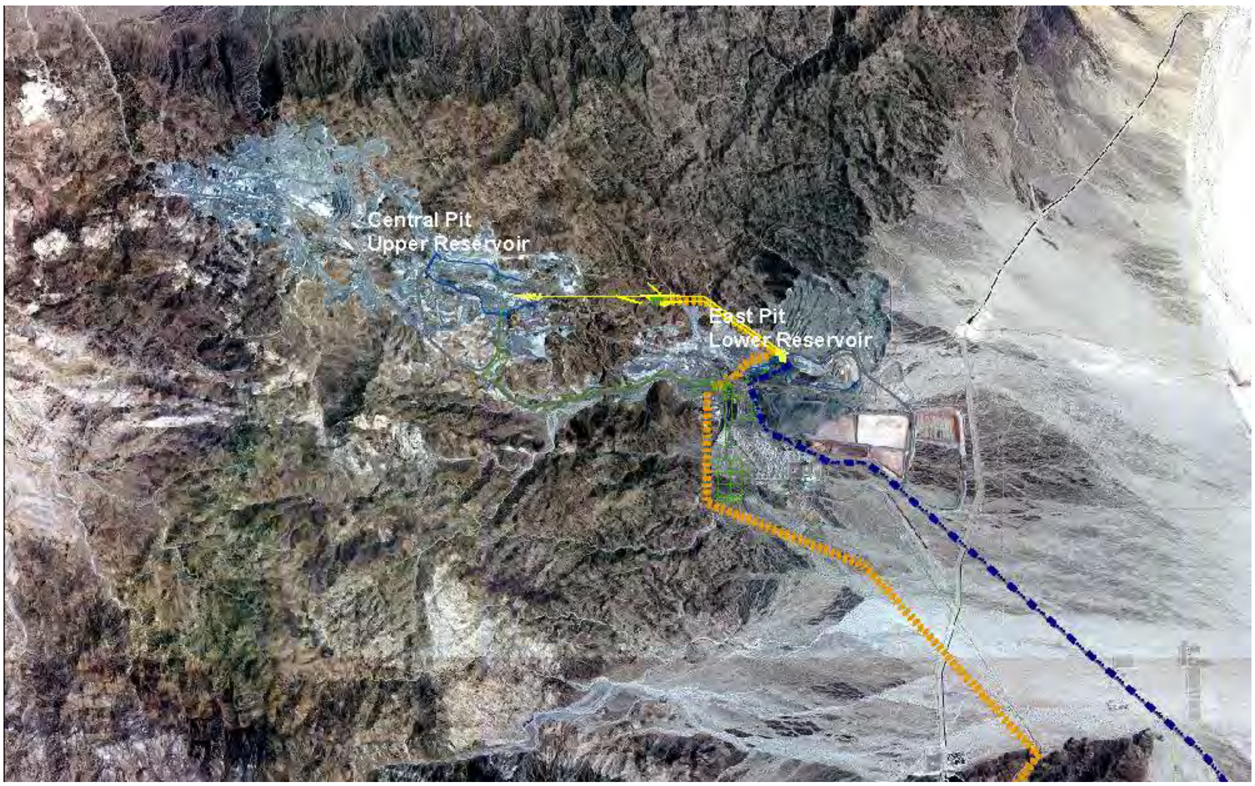

Figure A-4. Eagle Mountain Project Site

"The project's primary features will include an upper reservoir, an upper water conveyance system, a powerhouse with generating/pumping facilities, a lower water conveyance system, a lower reservoir, water supply and treatment facilities, and a transmission system."[72]

[71] "Order Issuing Original License." *Eagle Crest Energy Company filed with Federal Energy Regulatory Commission (FERC)* for Project No. 13123-002. Issued June 19, 2014.

[72] Ibid. p.4.

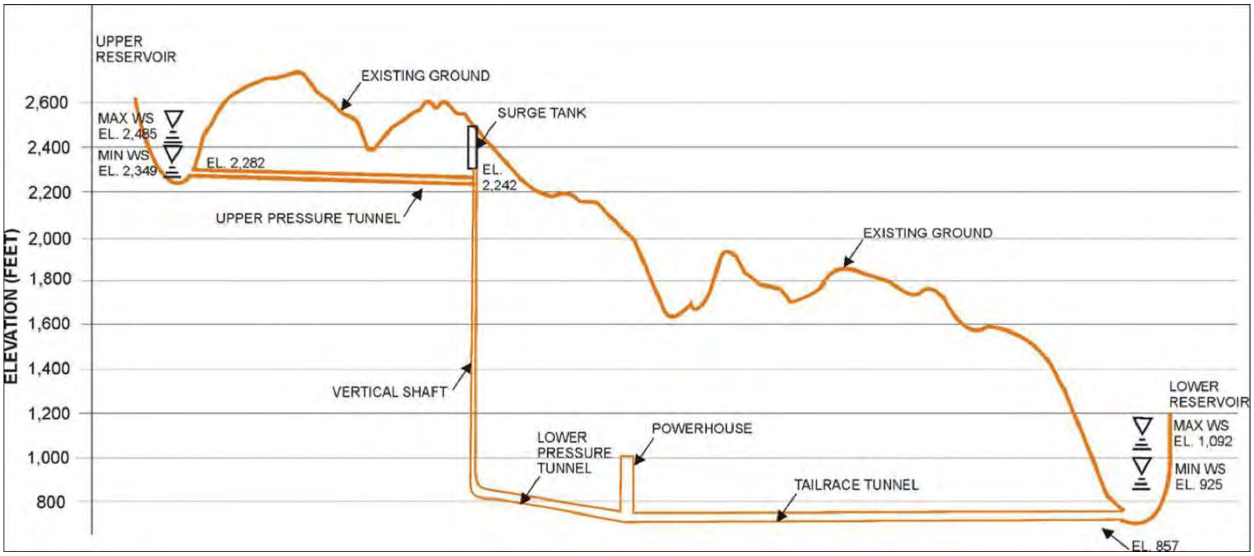

Figure A-5. Eagle Mountain Pumped Storage Hydroelectric Project Schematic

Project Status. FERC issued a license to this project on June 19, 2014. On November 6, 2018, the licensee (Eagle Crest Energy Company) requested an extension of the commencement of construction deadline.[73] On December 18, 2018, the licensee supplemented its request to include extension of the completion of construction deadline.[74] FERC has not yet acted on these requests. Project construction has not yet commenced.

[73] "Request for Extension of Commencement-of-Construction Deadline." *Eagle Crest Energy Company filing with Federal Energy Regulatory Commission (FERC)* for Project No. 13123-002. November 6, 2018.

[74] "Supplement to Request for Extension of Commencement-of-Construction Deadline." *Eagle Crest Energy Company filing with Federal Energy Regulatory Commission (FERC)* for Project No. 13123-002. December 18, 2018.

Lake Elsinore Advanced Pumped Storage Project (LEAPS)[75]

Project Description. A 500 MW pumped storage facility proposed to be located within unincorporated Riverside County at Lake Elsinore, CA. Lake Elsinore, the largest natural lake in southern California, will be the lower reservoir. A new upper reservoir is proposed to be constructed above the crest of the Elsinore Mountains at an elevation of 2,792 feet. Installed generating capacity of 500 MW and pumping capacity of 600 MW will be provided by two single-stage reversible pump-turbine units operating under an average net head of 1,484 feet. The project design allows for about 12 hours of generation at full capacity. The plant will be interconnected to the grid at separate interconnections with Southern California Edison (SCE) and San Diego Gas & Electric Co. (SDG&E).

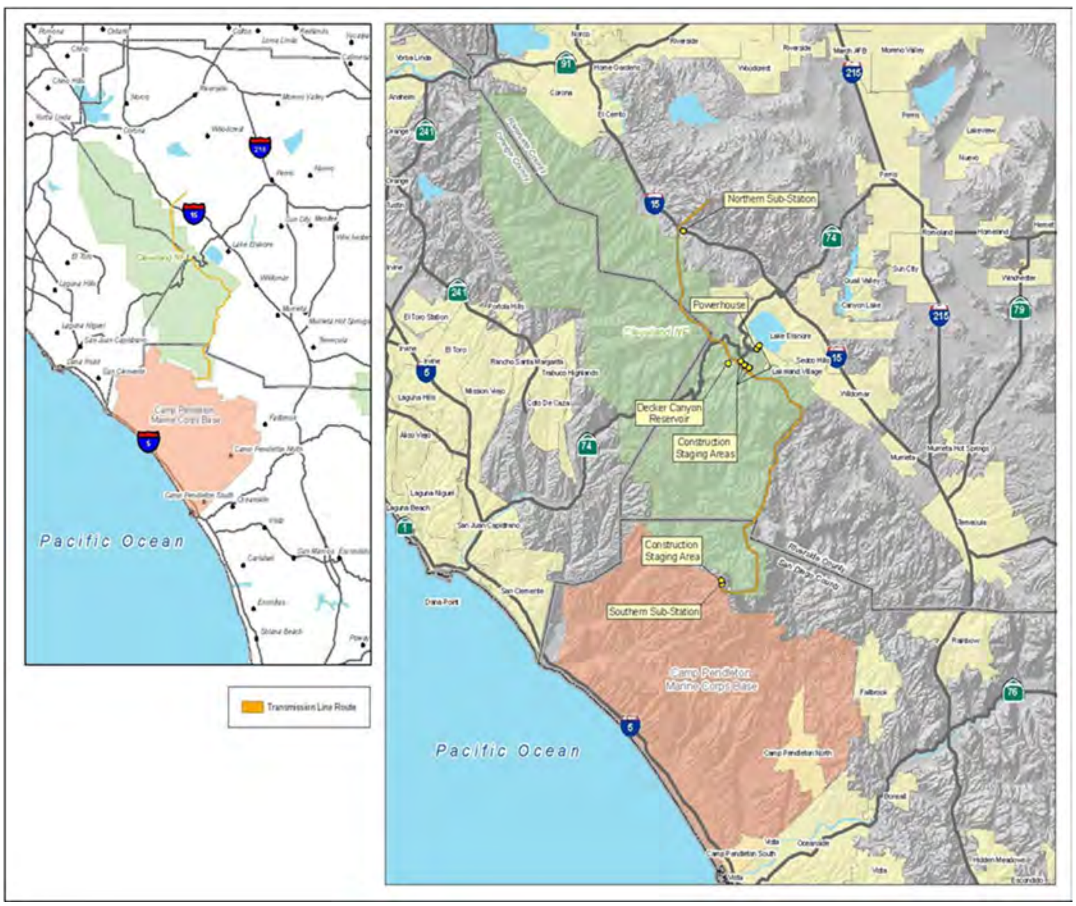

Figure A-6. Site of Lake Elsinore Advanced Pumped Storage (LEAPS) Project

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[75] "Final Application for License of Major Unconstructed Project, Exhibit A, Project Description: Lake Elsinore Advanced Pumped Storage Project." Filed by *The Nevada Hydro Company, Inc. with the Federal Energy Regulatory Commission (FERC)* in September 2017, FERC Project Number 14227.

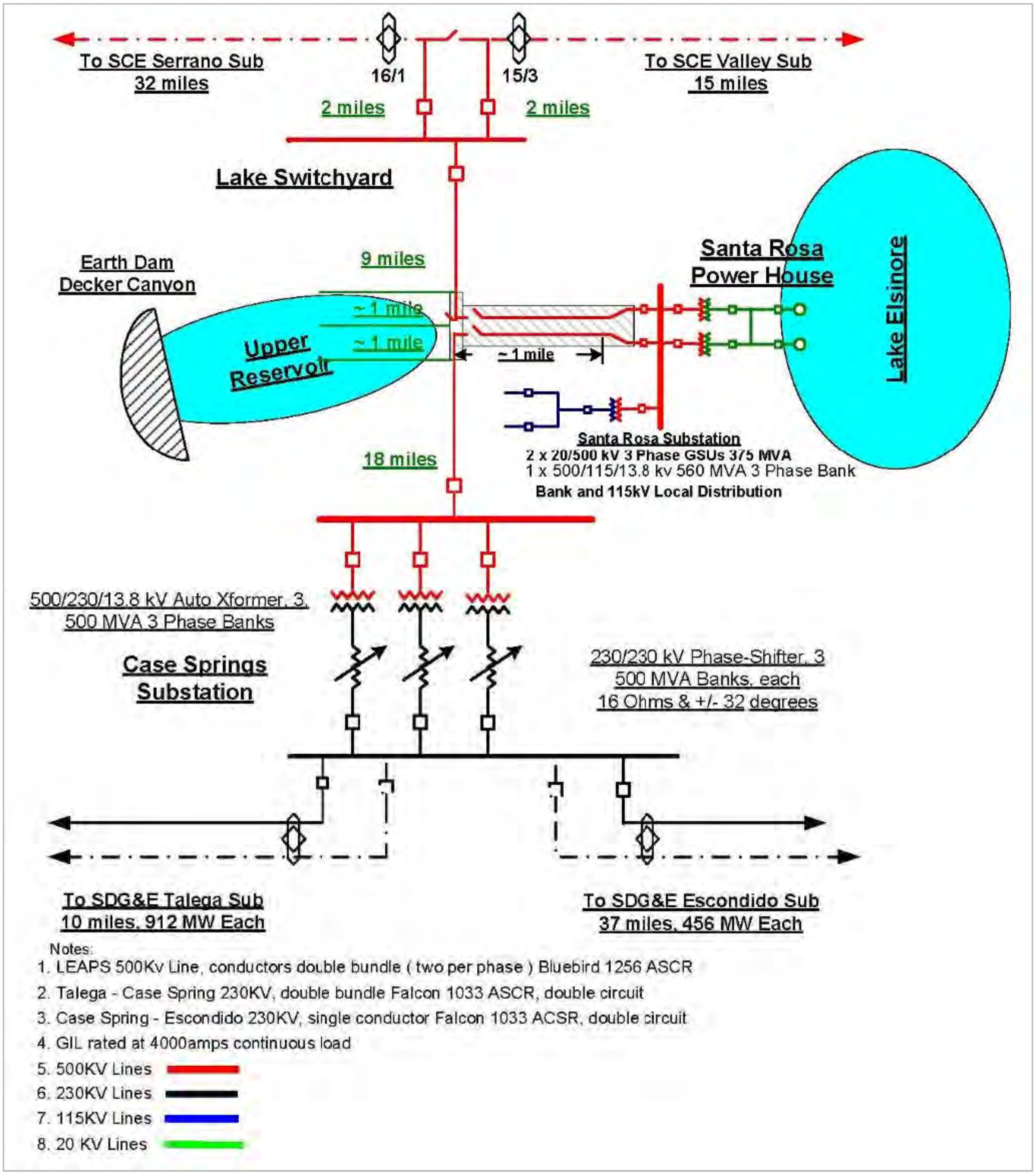

Figure A-7. Single Line Diagram of Lake Elsinore Advanced Pumped Storage Project (LEAPS)

San Vicente Pumped Storage Project[76]

Project Description. Proposed 500 MW closed-loop pumped storage project (4 x 125 MW reversible pump-turbines) within San Diego County, California. The project was designed to produce up to 500 MW of renewable energy during peak demand periods, and to generate stored energy for up to 8 hours. Power generated at the San Vicente facility would be delivered via a new connection to SDG&E's Sunrise Powerlink Project, a 117 mile long 230/500 kV transmission line designed to deliver 1,000 MW of renewable energy from the Imperial Valley to San Diego County.

San Vicente Dam and Reservoir are owned and operated by the City of San Diego. The existing San Vicente Reservoir would be the lower reservoir; a new upper reservoir covering a surface area of about 100 acres (estimated storage capacity 7,842 acre-feet) is proposed to be built in Foster Canyon. A near constant volume of 6,342 acre-feet of water will be moved between the upper and lower reservoirs. Source water for the initial fill of the upper reservoir, as well as make up water resulting from evaporation and minor seepage losses is planned to be provided by San Vicente Reservoir.

Project Status. A four-year preliminary permit was obtained from FERC on October 29, 2018. The application for interconnection was submitted to the California Independent System Operator (CAISO) on April 6, 2018. A development agreement with the City of San Diego is planned to be completed during 2020-2021.

[76] "San Vicente Pumped Storage Project Pre-Application Document, FERC Project Number 14642-000." *Submitted by San Diego County Water Authority (SDCWA) and City of San Diego to the Federal Energy Regulatory Commission (FERC)* on July 28, 2015.

Figure A-8. Site of Proposed San Vicente Pumped Storage Project

Appendix B: Proposed New or Expanded Groundwater Banks

Table B-1. Proposed New or Expanded Groundwater Banks

Groundwater Bank	County	Groundwater Basin	New or Incremental Capacity	Developer/ Owner	Est. Cost	Targeted In-Service Year
Chino Basin Environmental Water Program (CBEWP)	San Bernardino	Chino Basin	100,000 AF	Inland Empire Utilities Agency (IEUA)	$385M	2025
High Desert Water Bank Program	Los Angeles	Antelope Valley	280,000 AF	Antelope Valley-East Kern Water Agency (AVEK)	$131M	
Kern Fan Groundwater Storage Project	Kern	Kern County Groundwater Sub-Basin of the San Joaquin Valley Groundwater Basin	100,000 AF	Kern Fan Project Authority	$172M	2025
South County Ag Program	Sacramento	South American Groundwater Sub-Basin of the Sacramento Valley Groundwater Basin	50,000 AF	Sacramento Regional County Sanitation District	$373M	2023
Willow Springs Water Bank Conjunctive Use Project	Kern, Los Angeles	Antelope Valley Groundwater Basin	1,000,000 AF	Southern California Water Bank Authority	$343M	2020
		Currently Under Development	**1,530,000 AF**			

Chino Basin Environmental Water Program (CBEWP)[77,78]

Project Description. The CBEWP is a conjunctive use program consisting of four primary components:

- ***New Advanced Water Treatment (AWT) Facilities*** that would produce 15,000 AF/year (AFY) of purified water for recharge of the Chino Groundwater Basin.
- ***New Regional Recycled Water Pipelines*** to convey treated recycled water to the planned Advanced Water Treatment (AWT) facilities.
- ***Production Wells and Wellhead Treatment Systems*** comprised of a combination of restored wells and wellhead treatment systems, and new wells and wellhead treatment facilities, will increase pumping capacity and operational flexibility for IEUA and its member agencies.
- ***New Pipeline Intertie Connections*** will enable sharing of water within the Chino Basin, and pump back of water from the Chino Groundwater Basin to "a State Water Contractor" (currently anticipated to be the Metropolitan Water District of Southern California (MWD) and/or the San Bernardino Valley Municipal Water District (SBVMWD)). This arrangement will allow an equivalent amount of water to be released from the Oroville Reservoir for ecosystem benefits in the Delta watershed and enhanced water security in times of emergency due to catastrophic events, such as extreme drought, seismic events, or fire.

The project will allocate 100,000 AF of storage capacity in the existing Chino Basin Water Bank (CBWB) towards environmental purposes.

Planned Operations.

- The project would create 15,000 AFY of new local water supply (recycled/purified).
- The existing Chino Basin Water Bank will allocate up to 100,000 AF of storage capacity towards environmental water, plus an additional 100,000 AF of "borrowing capacity" of previously stored water for early environmental benefits ahead of production of the new local water supply, with the aim of enabling up to 50,000 AFY through water exchanges for

[77] "Application for Water Storage Grant, Proposition 1 Water Storage Investment Program (WSIP): Chino Basin Conjunctive Use Environmental Water Storage/Exchange Program." *California Water Commission (CWC)* website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Chino-Basin-Conjunctive-Use-Environmental-Water-Storage-Exchange-Program.

[78] "Water Storage Investment Program Quarterly Report: Chino Basin Conjunctive Use Environmental Water Storage/Exchange Program, 4th Quarter 2018." *California Water Commission (CWC) website*, Ibid.

up to 3 consecutive dry years to support ecological flows north of the Delta during periods of low precipitation.

Project Status.

1. Project planning continues, with commencement of a rate study and a pre-design study that will further refine the project components. The studies are planned for completion by March 2020.
2. IEUA coordinated with the Chino Basin Watermaster to establish the Chino Basin Storage Framework. The Watermaster has begun updating the Optimum Basin Management Program (OBMP) with a targeted completion date of December 2019.
3. A Programmatic Environmental Impact Report (PEIR) is planned (2019-2020).
4. IEUA has commenced working with resource agencies to review regulatory roles and needs with respect to the Chino Basin Program (CBP).
5. IEUA initiated a workgroup process (the CBP Workgroup) with local partner agencies and other interested parties that will be collaborating on development and implementation of the CBP.

High Desert Water Bank

Project Description.[79] A proposed 280,000 AF groundwater bank that will be used to store State Water Project water from various State Water Contractors and other partnering agencies. The project would be implemented on a 1,500 acre site in Los Angeles County.

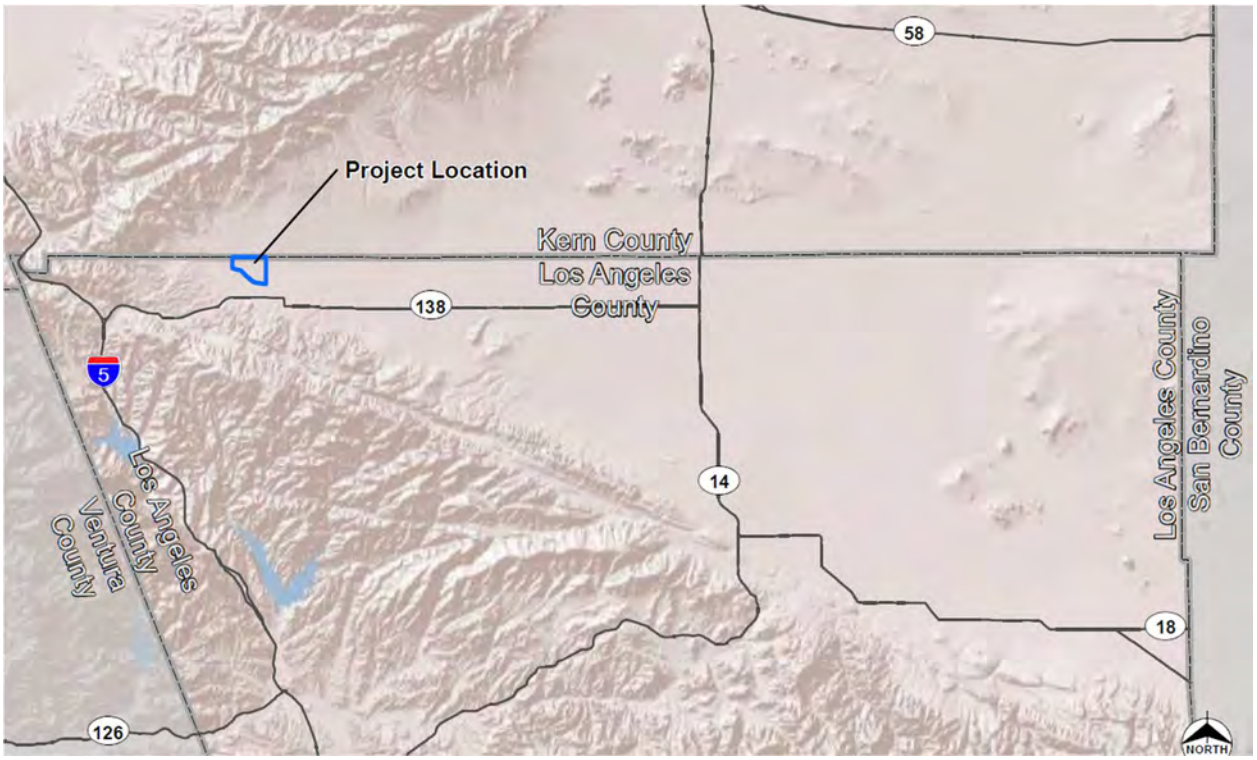

Figure B-1. Location of High Desert Water Bank

Project Operations. The project proposes to store about 70,000 AF/year of SWP surface water conveyed to the site via the California Aqueduct. Recharge would occur during wet years when SWP allocations exceed demands. A recovery rate of 90% of the stored water is anticipated, with up to 70,000 AF/year returned during dry and critically-dry water years.

[79] "High Desert Water Bank California Environment Quality Act (CEQA) Initial Study." Prepared by *AECOM for Antelope Valley – East Kern Water Agency (AVEK)*. May 2017.

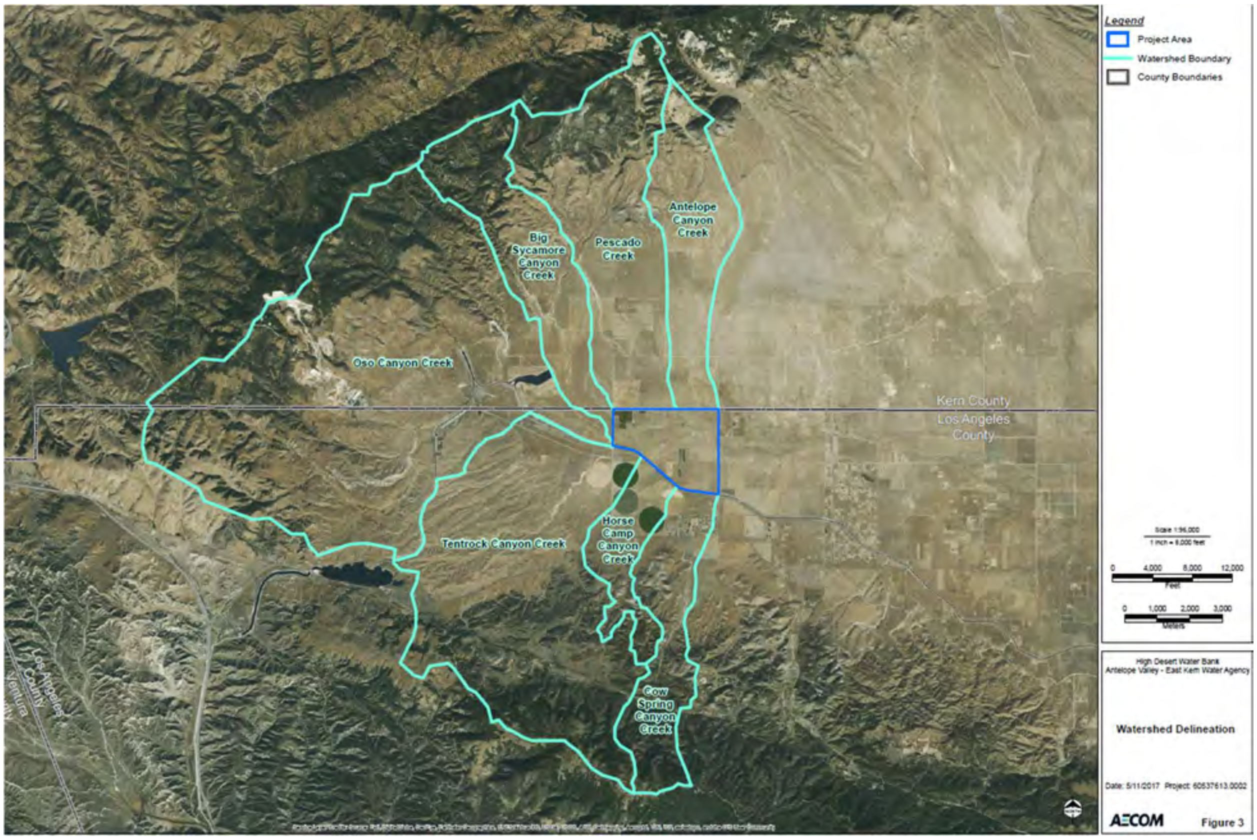

Figure B-2. Watershed Feeding the High Desert Water Bank

Project Status. AVEK has offered the 280,000 AF of groundwater storage to MWD: "Metropolitan would pay AVEK for the capital costs for construction of monitoring and production wells, turnouts from the California Aqueduct, underground and aboveground pipelines, recharge basins, water storage, and booster pump facilities. These facilities are estimated to be $131 million in 2018 dollars. Metropolitan would subsequently pay actual O&M, energy, and recovery usage fees to recover the water in storage. The Water Bank would improve water supply reliability during dry years or emergencies and provide greater operational flexibility to balance supplies and demand."

A copy of AVEK's proposed terms that were presented to MWD's Board of Directors on January 8, 2019 is provided on the following page.

The parties are currently in discussion; no commitments have yet been made. However, in general, increased groundwater bank capacity is consistent with MWD's long-term water reliability strategy.

Term Sheet for the Potential

Antelope Valley-East Kern and Metropolitan Water District High Desert Water Bank Program

Program Overview

- Storage Capacity: 280,000 AF
- Storage Losses: 10%
- Put Capacity: 70,000 AFY
- Take Capacity: 70,000 AFY (Dedicated Well Extraction Capacity)
- Term: September 20, 2037, plus twenty-year, no-cost option to extend the agreement

Program Costs

- Estimated Capital costs: $131 million to fund recharge basins, recovery wells, transmission pipelines, electrical, instrumentation and controls, and other necessary High Desert Water Bank facilities.
- The estimated capital costs include oversized power and transmission facilities. As AVEK develops additional banking capacity that uses the oversized facilities, the capital costs will be reimbursed to Metropolitan, plus interest.
- Capital payments are linked to actual construction costs and paid on a mutually agreed schedule. If capital costs exceed the estimated capital budget, Metropolitan can determine either scaling facilities to keep the costs within budget or paying the additional capital costs. Any unused funds will be returned to Metropolitan.
- Metropolitan is responsible for payment of actual O&M costs. If AVEK or other party uses facilities, AVEK or the other party are required to pay a prorated O&M cost.
- Metropolitan is responsible for paying the actual energy costs incurred to return water.
- Metropolitan shall pay AVEK a $100 per acre-foot Recovery Usage Fee that will be escalated on the Consumer Price Index (CPI) starting in 2018.
- There is no cost to Metropolitan to put water into storage.
- Metropolitan shall pay a minimum rolling average of $2,000,000 towards the Recovery Usage Fee (escalated on the CPI) per year, starting upon the earlier of (1) completion of the program facilities, or (2) first return of water to Metropolitan. Any payments made in excess of amounts owed during the year shall be credited in future years to Recovery Usage Fees. During the last five years of the agreement, Metropolitan may also use any available credits towards O&M, Recovery Treatment, or energy costs.
- Recovery Treatment Costs – If applicable, Metropolitan shall reimburse AVEK for actual capital and O&M treatment costs incurred for the return of Metropolitan-stored water.

Other Key Terms

- Metropolitan will have an exclusive first priority right to access High Desert Water Bank facilities. AVEK has an exclusive second priority right to unused capacity.
- Metropolitan and AVEK share equally on any lower priority banking by third parties.
- AVEK will enter into the necessary water storage agreements with the Antelope Valley Watermaster.

Source: "Water Storage Investment Program Progress Report: Willow Springs Water Bank Conjunctive Use Project." January 31, 2019.

Kern Fan Groundwater Storage Project[80]

Project Description. Proposed new Groundwater Storage Project in the Kern County Groundwater Sub-basin of the San Joaquin Valley Groundwater Basin for the purpose of capturing, recharging and storing State Water Project (SWP) water during wet years. Project sponsors are Irvine Ranch Water District (IRWD) and Rosedale Rio-Bravo Water Storage District (Rosedale). As the local co-sponsor, Rosedale will serve as project operator.

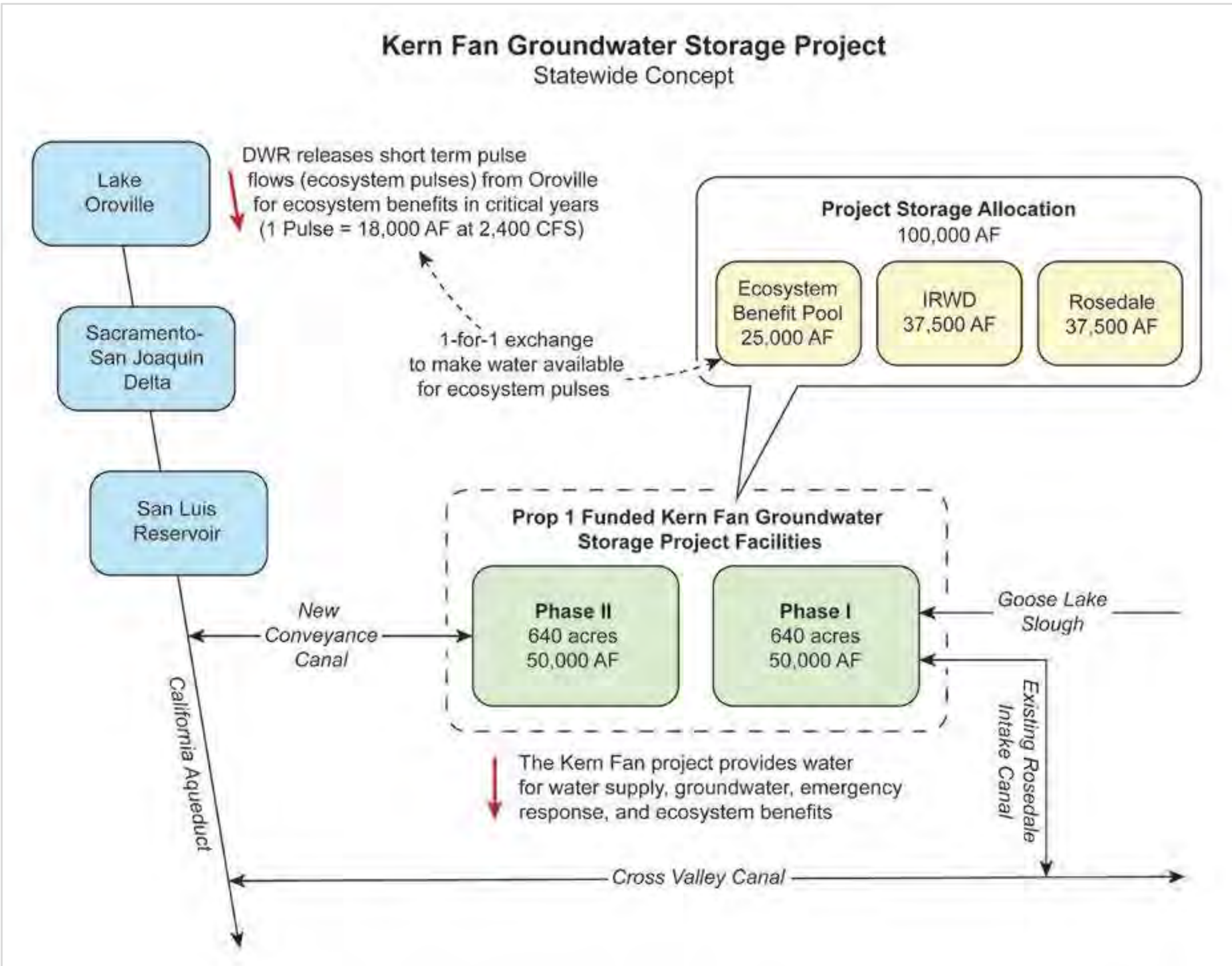

Figure B-3. Kern Fan Groundwater Project Concept

[80] "Application for Water Storage Grant, Proposition 1 Water Storage Investment Program (WSIP): Kern Fan Groundwater Storage Project." *California Water Commission (CWC)* website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Kern-Fan-Groundwater-Storage-Project.

Planned Operations.[81] The project plans to use 25% of the stored SWP water for ecosystem benefits. Extracted groundwater would be used for 1-for-1 exchanges with water held in Lake Oroville:

- Extracted groundwater would be used to meet the project owners' water demands.
- SWP water left in Oroville Reservoir would be used to provide short-term ecosystem pulse flows to improve fish habitat in the Feather and Sacramento Rivers, and the Delta.

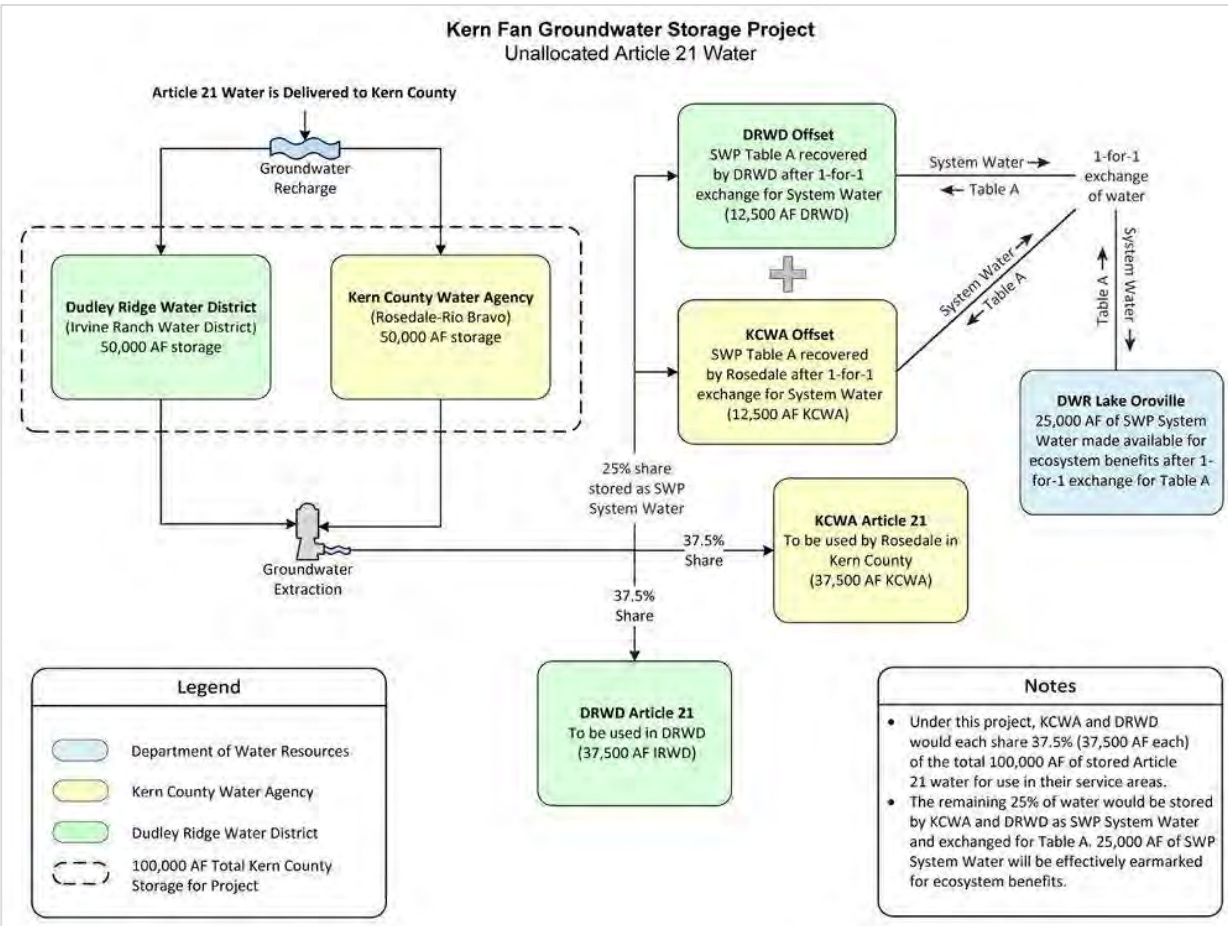

Figure B-4. Planned Project Operations

[81] "Kern Fan Groundwater Storage Project, Preliminary Operations Plan." *California Water Commission (CWC)* website, https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Kern-Fan-Groundwater-Storage-Project.

<u>Project Status</u>.[82]

1. Commenced formation of the Kern Fan Project Authority.
2. Engaged consultants to perform key studies and provide other technical support:
   a. Hydraulic Assessment of New California Aqueduct Tunnel.
   b. Pre-Project Engineering Evaluation of Canal Alignment Alternatives.
   c. Supplemental Environment Impact Report.
   d. Geophysical Investigation of Target Area.
   e. Negotiation Assistance with Department of Water Resources.
3. Issued Request for Qualifications for program management services as Applicants' Owner's Representative.

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[82] "Water Storage Investment Program Quarterly Report: Kern Fan Groundwater Storage Project, 4th Quarter 2018." *California Water Commission (CWC)* website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Kern-Fan-Groundwater-Storage-Project.

South County Ag Program[83]

Project Description. The South Sacramento County Agriculture & Habitat Lands Recycled Water, Groundwater Storage, and Conjunctive Use Program proposes to use tertiary-treated recycled water for irrigating agricultural and habitat lands. The project would provide 50,000 AFY of recycled water produced by the Sacramento Regional County Sanitation District to irrigate 16,000 acres of land. The water will be supplied by constructing 14 miles of new recycled water transmission pipelines and 25 miles of distribution mainlines in addition to a new pump station, recharge area and extraction wells.

Planned Operations.

- Average amount of recycled water delivered to irrigation customers and wildlife preserves would be 50,000 AFY: 32,500 AFY for irrigation, 17,000 AFY for wintertime recharge, and 500 AFY delivered to Stones Lakes to manage wetlands.
- Once fully implemented, the groundwater banking system would create up to 30,000 AFY available for conjunctive use during drought conditions. In addition, it will increase groundwater storage capacity by approximately 245,000 AF within 10 years and 32,000 AF within 25 years.

Project Status. [84]

1. Administration Program Management Office Consultant was selected and is under initial contract.
2. Ecological Program Management Office consultant has been selected and is under initial contract.
3. RFP for the CEQA consultant was developed for solicitation in January 2019 for the groundwater bank project and ecological program environmental reviews.
4. Communications and Outreach plan was developed to target outreach with Program stakeholders and landowners.
5. Awaiting contract from CDFW and SWRCB to move forward with contracting.

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[83] "Application for Water Storage Grant, Proposition 1 Water Storage Investment Program (WSIP): The South Sacramento County Ag Program." *California Water Commission (CWC)* website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/South-Sacramento-County-Agriculture.

[84] "Water Storage Investment Program Quarterly Report: South County Ag Program, 4th Quarter 2018." *California Water Commission (CWC)* website, Ibid.

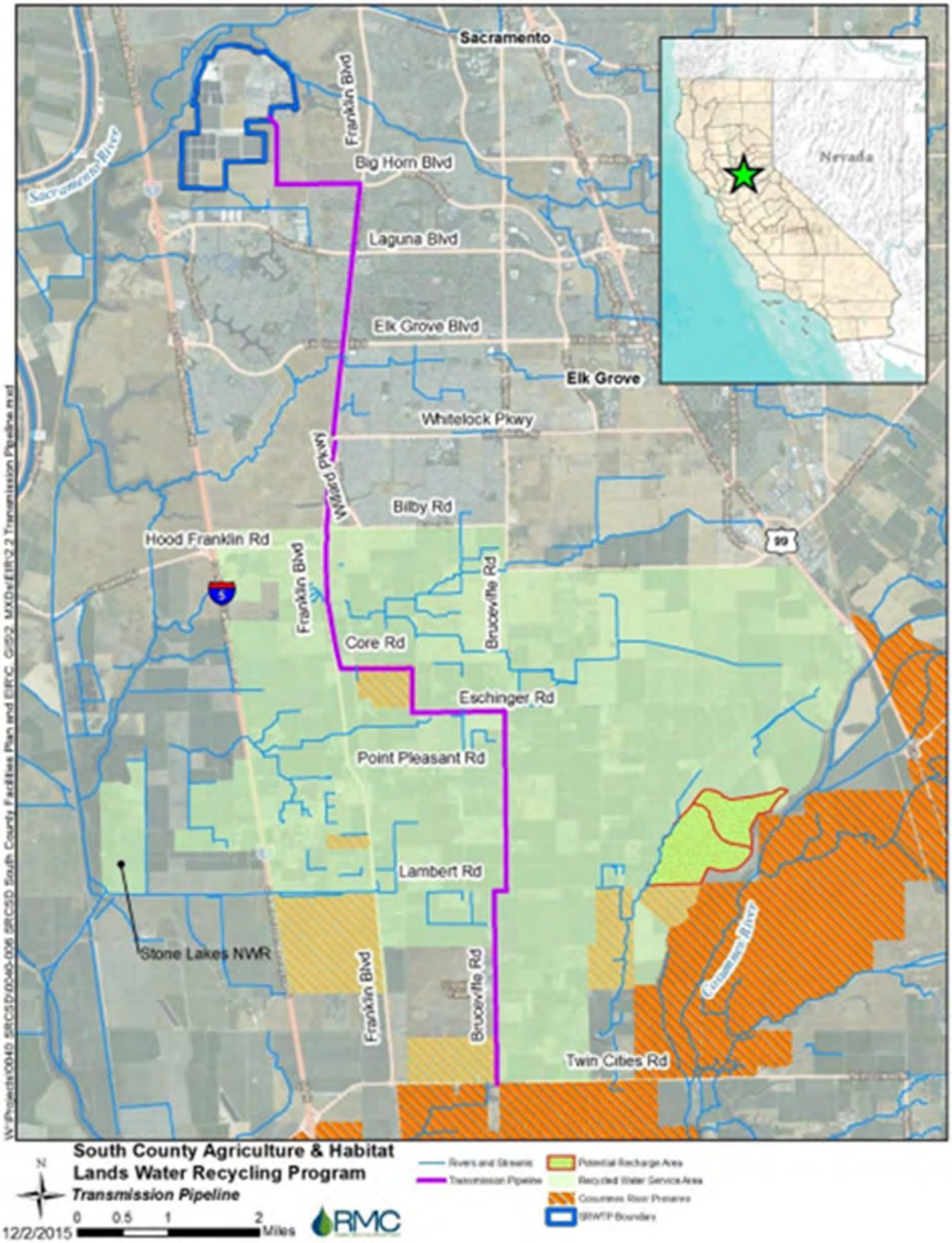

Figure B-5. Planned Program Facilities

Willow Springs Water Bank (WSWB) Conjunctive Use Project[85]

Project Description. The Southern California Water Bank Authority proposes to leverage the 1,000,000 AF Willow Springs Water Bank (WSWB) for conjunctive use to improve the operational flexibility of the State Water Project (SWP) and also to provide environmental benefits to the Bay Delta.

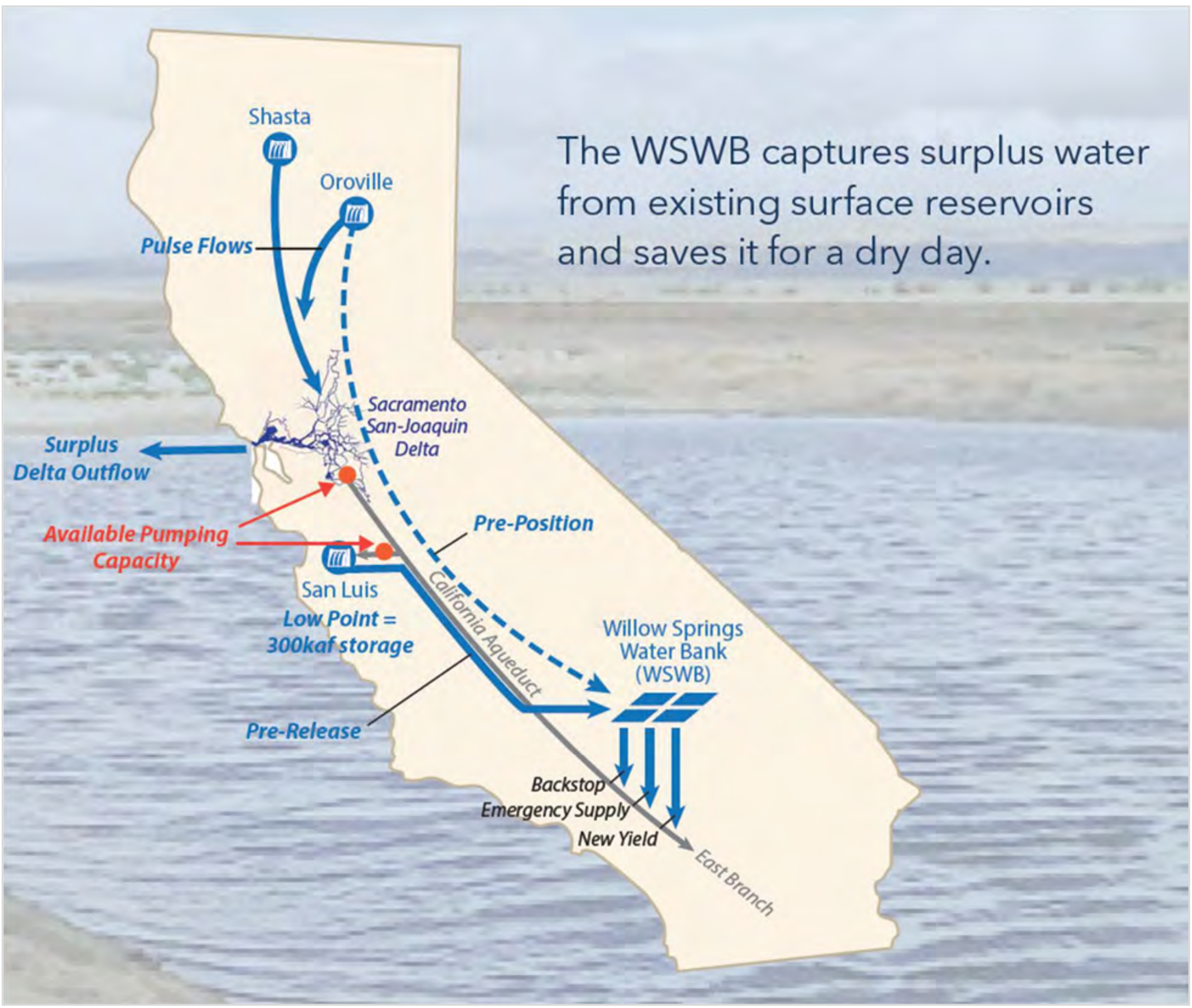

Figure B-6. Willow Springs Water Bank Conceptual Diagram of State Water Project Conjunctive Use

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[85] "Application for Water Storage Grant, Proposition 1 Water Storage Investment Program (WSIP): Willow Springs Water Bank Conjunctive Use Project." *California Water Commission (CWC)* website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Willow-Springs-Water-Bank-Conjunctive-Use-Project.

The project proposes to operate conjunctively with the SWP by entering into agreements with one or more State Water Contractors (SWC) and/or SWP partners to forego SWP deliveries in exchange for receiving water from the WSWB. The Authority would also need to enter into agreements with the Department of Water Resources (DWR) and the California Department of Fish and Wildlife (CDFW) to enable re-operating the Oroville Dam and San Luis Reservoir in a manner that provides ecosystem benefits to the Delta.

Project Operations.[86] The proposed project anticipates that "modest" re-operation of the SWP's Lake Oroville and San Luis Reservoirs could provide significant ecosystem benefits while enabling significant volumes of new water supplies to be captured and stored during periods of high flows when Delta outflows exceed regulatory requirements.

The preliminary operating plan anticipates that WSWB recharge would occur when it is "operationally convenient" for San Luis and Oroville Reservoirs. This would typically occur during normal water years when there is capacity for the water to get through the Delta. Water will be shifted from the Reservoirs to WSWB creating additional capacity in the Reservoirs to capture wet year flows. The captured water will create new water supply and provide environmental water "pulse flows" to assure regulatory compliance with in-stream releases. The CDFW would retain authority to call for blocks of dedicated water from the WSWB when needed to assure protection of the Bay-Delta ecosystem.

Project Status. [87]

1. Securing an agreement with a SWP partner is essential to this project's success. An agreement has been proposed and discussions are in progress.
2. WSWB became aware of a discussion between Antelope Valley-East Kern Water Agency (AVEK) and the Metropolitan Water District of Southern California (MWD) regarding the potential purchase by MWD of rights to 280,000 AF of groundwater storage in AVEK's High Desert Water Bank. The outcome of these discussions could have an impact on the feasibility of WSWB's proposed project. Consequently, WSWB stated its intent to coordinate with development of the High Desert Water Bank.
3. WSWB obtained a $15 million Federal Emergency Management Agency (FEMA) grant that will enable WSWB to integrate flood and drought emergency response into its operations plan. Kern County has partnered with WSWB and serves as sponsor for the FEMA grant. WSWB subsequently learned that it is eligible to apply for a second FEMA grant in the

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[86] "Willow Springs Water Bank Conjunctive Use Project, Preliminary Operations Plan." *California Water Commission (CWC)* website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Willow-Springs-Water-Bank-Conjunctive-Use-Project#.

[87] "Water Storage Investment Program Progress Report: Willow Springs Water Bank Conjunctive Use Project, 4th Quarter 2018." January 31, 2019. *California Water Commission (CWC)* website, Ibid.

amount of $10 million, and a third grant for an additional $10 million (a potential total of $35 million in FEMA grants).

4. The original Environmental Impact Report (EIR) was submitted online to the State CEQA clearinghouse in 2006. An EIR Addendum was finalized in August 2018 to increase the amount of storage to one million acre-feet (1 MAF). It has now also been filed with the State clearinghouse.
5. Feasibility studies were completed in 2005, 2011, 2014, and 2016. Additional planning is needed to start the design/build process.
6. Securing rights-of-way for the 7.75 miles of 84" diameter recharge pipeline is a critical path item.
7. Targeted date for operational recharge capabilities is 2020.

Energy Operations Plan. WSWB needs electricity to pump wells and operate its pump station. WSWB plans to use small reservoirs to maintain flows over 24 hours and to limit or altogether avoid electricity use during the On-Peak and Mid-Peak hours when electricity rates are higher than in Off-Peak hours. Additionally, optimization of energy use will be achieved by installation of an on-site hydroelectric turbine and on-site solar PV facilities. The turbine could be used for pumped storage as well as to generate electricity during recharge operations.

A California Energy Commission (CEC) funded study, "Groundwater Bank Energy Storage Systems"[88] examined the potential of using "Peak Hour Pumped Storage" (pumped storage having all the components aboveground) in conjunction with demand response at WSWB and found it to be feasible. (The Study explored an additional pumped storage concept, "Aquifer Pumped Hydro" which uses the aquifer as the lower reservoir. This concept was not found to be feasible.) Figure B-7 on the next page illustrates both pumped storage concepts.

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[88] Beuhler, Mark, Naheed Iqbal, Zachary Ahinga, and Lon W. House. Antelope Valley Water Storage, LLC. 2017. "Groundwater Bank Energy Storage Systems: A Feasibility Study for Willow Springs Water Bank." *California Energy Commission*. Publication Number: CEC-500-2017-042.

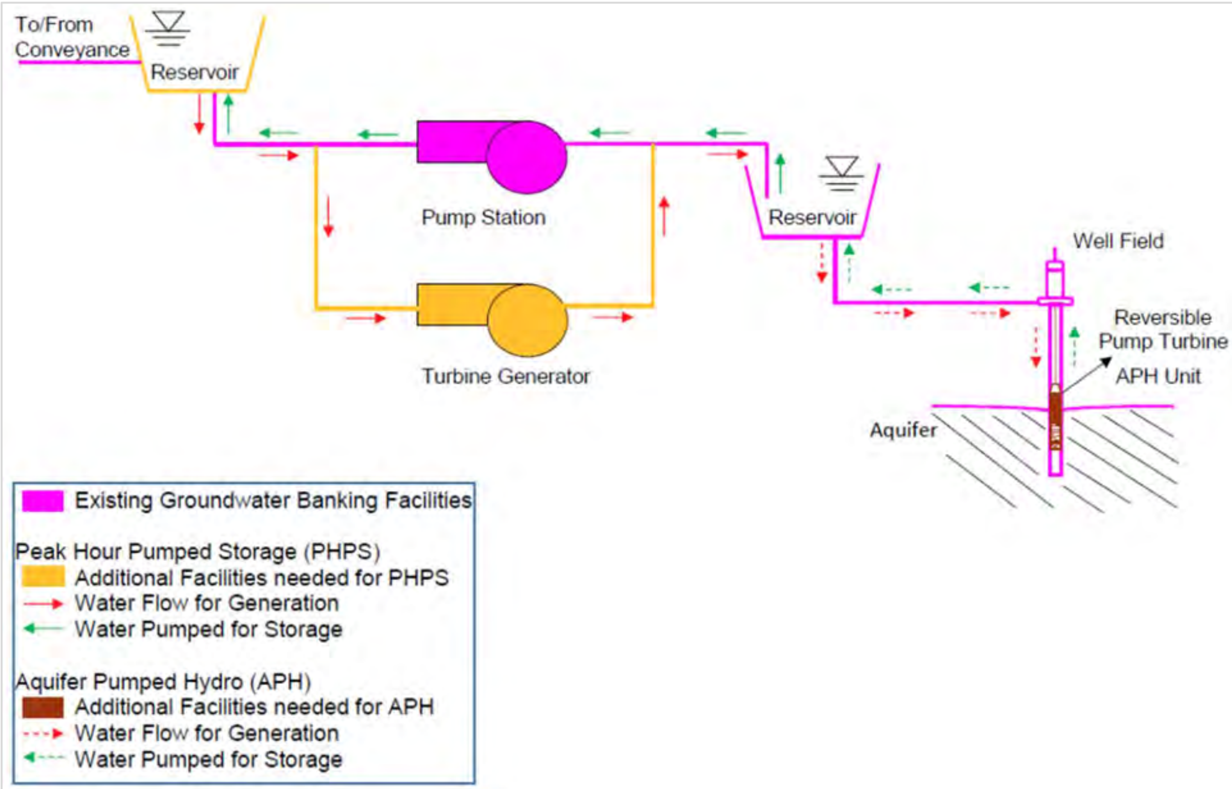

Figure B-7. Conceptual Peak Hour Pumped Storage and Aquifer Pumped Hydro Configuration[89]

"During off-peak periods, both the systems pump water from a lower reservoir to a higher reservoir for storage (green arrows). During the on-peak periods, the stored water is released from the higher reservoir to the lower reservoir (red arrows). The released water passes through the turbines which convert the kinetic energy of moving water into electrical power. In this way, the water can be cycled repeatedly between the higher and lower reservoirs to generate energy."[90]

Another CEC funded study, "Water-Energy Bank Project" is currently ongoing and will be completed by July 2019. This study is evaluating using WSWB to facilitate reduction of the California SWP pumping peak energy use, costs, and greenhouse gas emissions.

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[89] Beuhler, Mark, Naheed Iqbal, Zachary Ahinga, and Lon W. House. "Groundwater Bank Energy Storage Systems: A Feasibility Study for Willow Springs Water Bank." *Antelope Valley Water Storage for California Energy Commission*. Publication Number: CEC-500-2017-042. December 2017.

[90] Ibid.

Appendix C: Surface Water Storage Projects Under Development

Table C-1. Surface Water Storage Projects Planned or Under Development

Planned New Storage	County	New or Incremental Capacity	Developer/ Owner	Est. Cost	Targeted In-Service Year
Los Vaqueros Reservoir Expansion Project	Contra Costa	115,000 AF	Contra Costa Water District (CCWD)	$795M	2027
Pacheco Reservoir Expansion Project	Santa Clara and Merced (study area includes portions of Monterey, San Benito, and Santa Cruz)	135,300 AF	Santa Clara Valley Water District (SCVWD)	$969M	2028
Sites Project	Sacramento	1,810,000 AF	Sites Project Authority	$5.2B	2030
Temperance Flat Reservoir Project	Fresno, Kern, Kings, Madera, Merced, San Benito, San Joaquin, Santa Clara, Stanislaus, Tulare	1,260,000 AF	San Joaquin Valley Water Infrastructure Authority	$2.6B	2030
Trampas Canyon Reservoir & Dam	Orange County	5,000 AF	Santa Margarita Water District (SMWD)	$123M	2020
Currently Under Development:		**3,325,300 AF**	**(1,083.6 billion gallons)**		

Los Vaqueros Reservoir Expansion Project[91]

Project Description. Enlarge the existing off-stream reservoir from 160,000 AF to 275,000 AF (an increase of 115,000 AF). The primary objectives are:

- To develop water supplies for environmental water management, and
- To increase water supply reliability for Bay Area water providers.

In addition to the reservoir expansion, the project will upgrade existing water conveyance facilities, construct new conveyance facilities, and reoperate existing facilities.

Project Status[92]

1. Executing updated cost sharing agreements with potential Local Agency Partners (targeted completion: September 2021).
2. Draft Federal Feasibility Report released January 2018. Final Report in development; planned for release during March 2019.
3. Draft Supplement to Final EIS/EIR was released June 2017. Final environmental documentation in development; planned for release during March 2019.
4. Coordination with federal, state, and local agencies is ongoing; targeting completion by September 2021.

[91] "Application for Water Storage Grant, Proposition 1 Water Storage Investment Program (WSIP): Los Vaqueros Reservoir Expansion Project." California Water Commission (CWC) website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Los-Vaqueros-Reservoir-Expansion-Project.

[92] "Water Storage Investment Program Quarterly Report: Los Vaqueros Reservoir Expansion Project, 4th Quarter 2018." California Water Commission (CWC) website: Ibid.

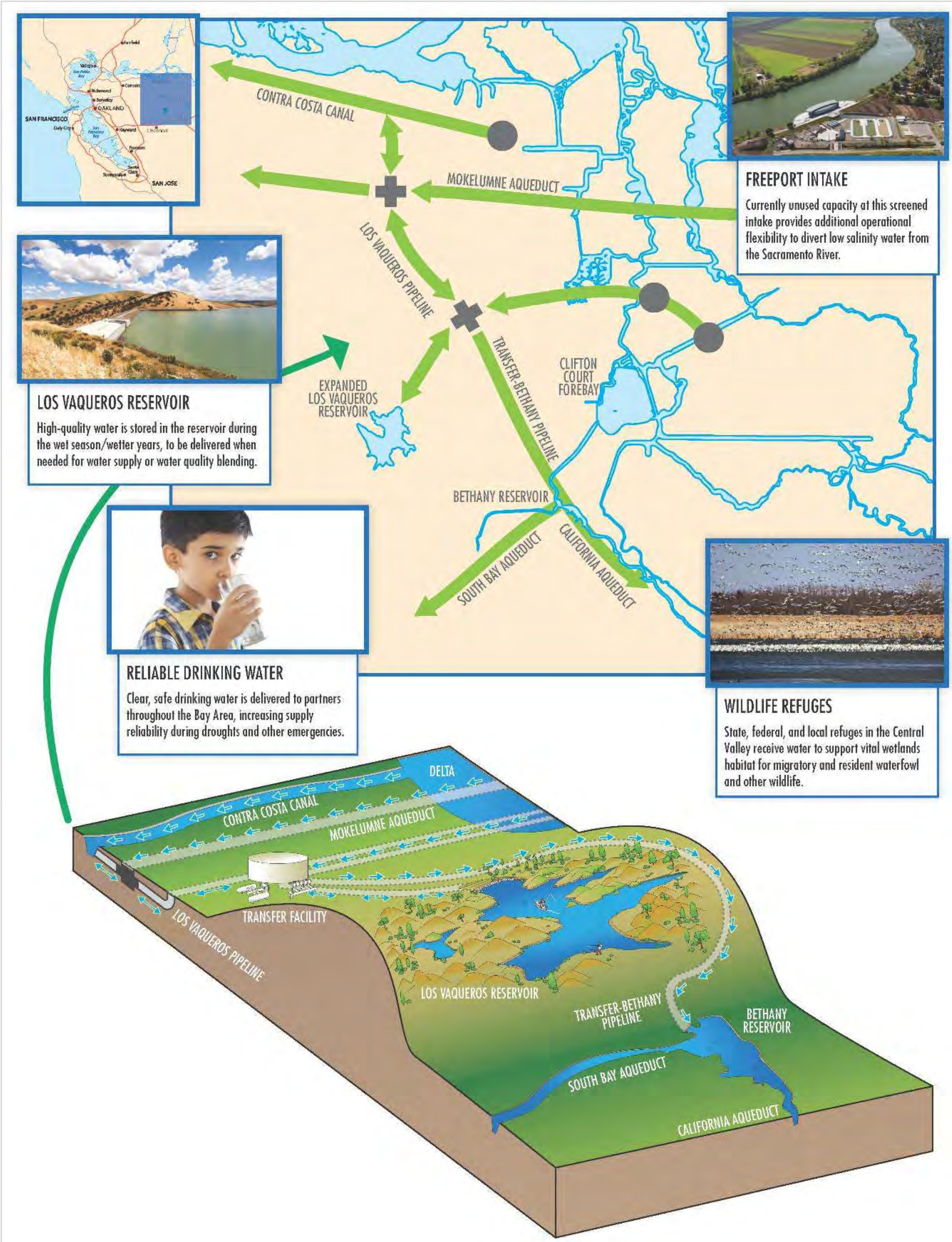

Figure C-1. Description of Los Vaqueros Reservoir Expansion Project

Pacheco Reservoir Expansion Project

Project Description. Increase the capacity of the existing Pacheco Reservoir from 6,000 AF to 141,600 AF (increases active storage capacity from 5,500 AF to 140,800 AF, an increase of 135,300 AF). Planned project facilities include a new dam and reservoir, pump station, conveyance facilities, and related infrastructure (e.g., roads). The reservoir will collect winter runoff from the local watershed, as well as potential diversion of Central Valley Project (CVP) supplies from the Pacheco Pipeline when needed.

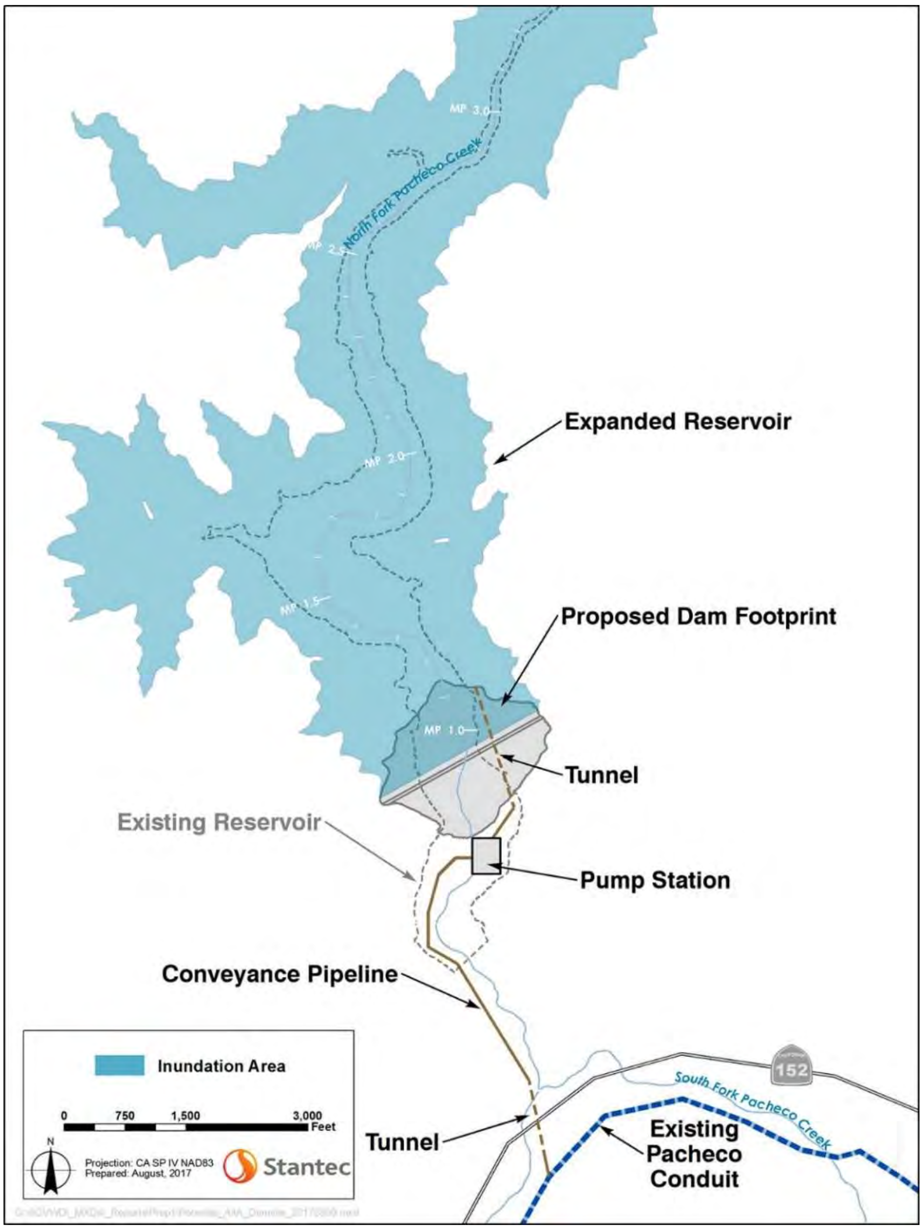

Figure C-2. Conceptual Diagram of Planned Pacheco Reservoir Expansion

Planned Operations.[93] Operational objectives are:

1. To capture and store water during wet periods from natural inflows for release during dry periods, both annually (i.e., capture winter flows for summer release and use), and across multiple years (i.e., capturing and storing water during wetter years for release and use during drier years and/or emergencies).
2. Optimize use of all available SCVWD supplies:
   - Central Valley Project (CVP) and State Water Project (SWP);
   - Other water supplies (imported, local, and recycled); and
   - Conjunctive use/groundwater recharge.

The project will be filled primarily from natural inflows from the North and East Forks of Pacheco Creek (typically December through March).

SCVWD water supplies stored in San Luis Reservoir[94] will be conveyed, when needed, to the Pacheco Reservoir. Supplemental flows will be provided from SCVWD's share of contracted CVP water from San Luis Reservoir.

Project Status.[95]

1. Operating Agreement among SCVWD, San Benito County Water District, and Pacheco Pass Water District being negotiated (target completion by June 2020).
2. SCVWD participating with USBR in a federal feasibility study of the proposed Pacheco Reservoir expansion.
3. Draft Feasibility Study and Administrative Draft EIR targeted for completion by July 2021, with a plan to distribute for public comments by October 2021 and submission of the Final EIR by 2022.
4. Administrative Draft EIS targeted for review by agencies and partners by July 2021, with a plan to distribute for public comments by October 2021. Final EIS and NEPA documents targeted for completion by end 2023.

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[93] "Preliminary Operations Plan: Pacheco Reservoir Expansion Project*." California Water Commission (CWC)* website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Pacheco-Reservoir-Expansion-Project.

[94] San Luis Reservor is the largest offstream reservoir in the United States. It is jointly owned by the U.S. Bureau of Reclamation (45%) and the State Department of Water Resources (55%). The reservoir has a capacity of 2 million acre-feet. [Source: "San Luis Reservoir." Water Education Foundation website: https://www.watereducation.org/aquapedia/san-luis-reservoir].

[95] "Water Storage Investment Program Quarterly Report: Pacheco Reservoir Expansion Project, 4th Quarter 2018." *California Water Commission (CWC)* website (Ibid).

Sites Reservoir[96]

Project Description[97]

A proposed new reservoir in the Sacramento Valley with an estimated capacity of 1.81 million acre-feet (MAF). The project proposes to inundate 14,200 acres within Antelope Valley. Eleven dams would need to be constructed. The maximum "normal" water surface elevation would be 520 feet above mean sea level; the minimum operating water surface would be at elevation 340 feet.

Existing conveyance facilities will be used including the Tehama-Colusa Canal and Glenn-Colusa Irrigation District (GCID) Canal. Excess water from the Sacramento River will be used to fill the proposed reservoir.

Multiple facilities are proposed to be constructed in groups of facilities (called "complexes"):

- Sites Reservoir Complex
- Holthouse Reservoir Complex
- Terminal Regulating Reservoir Complex
- Delevan Pipeline Complex
- Overhead Power Lines and Substations
- Project Buffer

Estimated hydropower generation capacity is 118 MW.

Project Operations:[98]

The Sites Reservoir is proposed to be filled by diversion of "excess" Sacramento River flows. Diversions could occur during any month or water year type but would most likely be during wet winter months.

Operations will be coordinated with the State Water Project (SWP), Central Valley Project (CVP), existing CVP and SWP system facilities. Water would be pumped from the Sacramento River into Sites Reservoir during times when water can be diverted. During wet years, the

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[96] "Application for Water Storage Grant, Proposition 1 Water Storage Investment Program (WSIP): Sites Reservoir." *California Water Commission (CWC)* website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Sites-Project.

[97] "Water Storage Investment Program Project Description: Sites Reservoir." *California Water Commission (CWC)* website (Ibid).

[98] "Water Storage Investment Program Operations Plan: Sites Reservoir." *California Water Commission (CWC)* website (op.cit.).

Reservoir could reach maximum storage levels of 1.8 MAF. Water would be released throughout the year to help meet demands.

A SCADA system would control all operational modes and would be located onsite where operators could coordinate flows in and out of Holthouse and Sites Reservoirs. The Sites Reservoir would deliver approximately 441,000 AF of water per year for drinking, irrigation, recreational activities, flood management, ecosystem and improvements.

Role of the Sites Project Authority

"Pursuant to California Water Code 79759(c), the Authority will own, govern, manage, and operate the Sites Project; which will be accomplished by working in partnership with the agencies participating in the project for both water supply and Proposition 1-eligible public benefits. As such, the Authority will, in addition to other responsibilities, be the holder of the water right, enter into water delivery contracts for both water supply and Proposition 1-eligible public benefits, coordination with the Central Valley Project (CVP) and State Water Project (SWP) operators, and be responsible for environmental compliance obligations, operations and maintenance, and dam safety.

"Organizationally, the Authority plans to establish a governing body, which is conceptually referred to as the Water Operations Committee. The Water Operations Committee's responsibility is to develop, in partnership, both long-term and annual operational plans that would be implemented by the Authority in cooperation with the operators of the State and Federal projects. As such, the Water Operations Committee will be comprised of investors and stakeholders in the project's development:

• the water agencies participating in the project's development; which is currently referred to as the Reservoir Committee;

• the state and federal resource agencies delegated the responsibility to have management control over the investment by the state and/or Federal government, respectively;

• the operators of the Central Valley Project and State Water Project, respectively; and

• operators of other facilities needed to move water to where it has been contracted for (i.e., both Proposition 1-eligible and non-Proposition 1-eligible benefits).

• Other stakeholders as deemed appropriate.

- Source: Water Storage Investment Program Operations Plan: Sites Reservoir. California Water Commission Water Storage Investment Program (WSIP) website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Sites-Project.

Project Status: [99]

1. Sites Authority approved the budget for 2019 and has approved new contracts for project integration, project control, communications, real estate, and geotechnical engineering. The Authority has also commenced negotiating contracts for environmental analyses and operations simulation modeling. Contracts with task orders for 2018 are anticipated to be effective by spring 2019.
2. Meetings have commenced among the Authority, U.S. Bureau of Reclamation (USBR), and the State Department of Water Resources to define the processes needed to cooperatively operate the planned project.
3. A final feasibility report being prepared by USBR is scheduled for completion during June 2019.
4. The Authority is working with USBR to prepare the required CEQA/NEPA and permit applications for all field investigations and surveys needed to complete the feasibility studies, preliminary engineering, and permit applications.

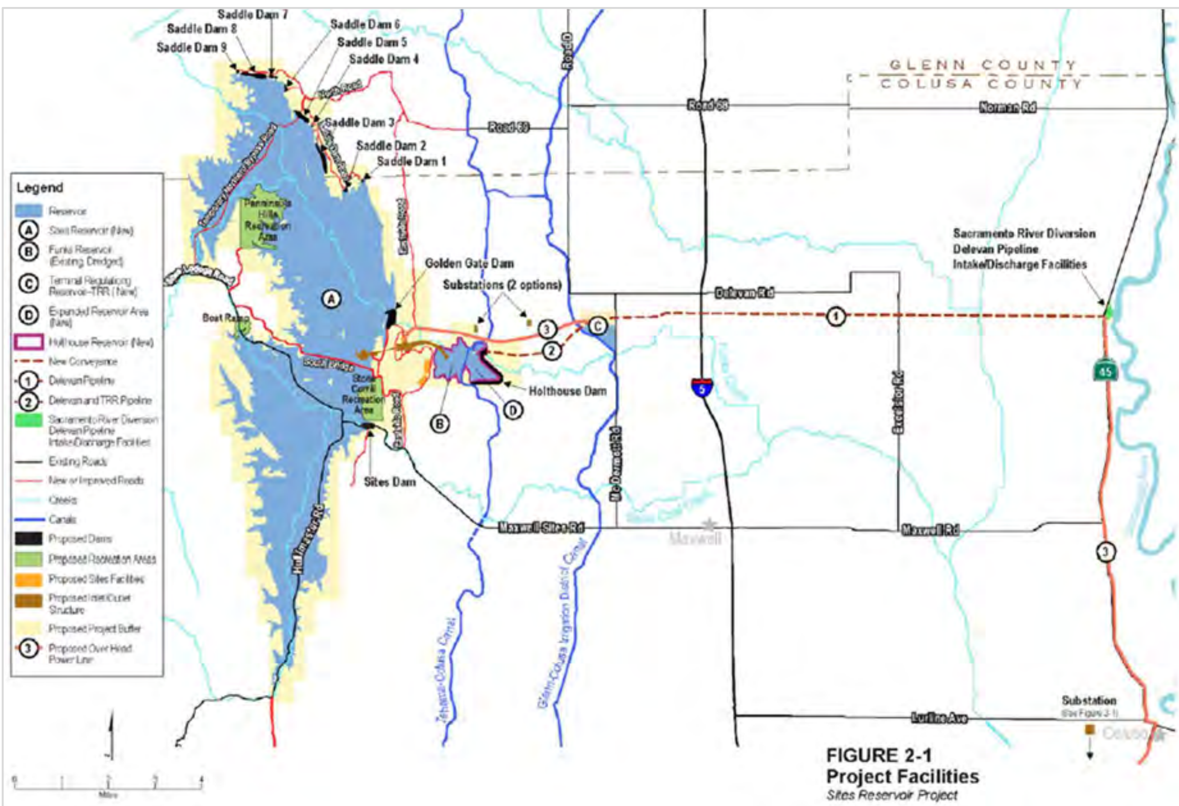

Figure C-3: Primary Project Facilities

[99] "Water Storage Investment Program Sites Reservoir, 4th Quarter 2018." *California Water Commission (CWC)* website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Sites-Project.

Temperance Flat Reservoir Project (TFR)[100,101]

Project Description

The proposed TFR project would construct a new surface reservoir by constructing a new dam at Millerton Lake. This would provide an additional 1.26M AF of water storage on the San Joaquin River. The TRF water supplies will do the following:

- Provide additional water supplies to users located south of the Delta, including wildlife refuges;
- Increase conjunctive management to support groundwater sustainability;
- Improve ecosystem and water quality conditions for fish;
- Provide water that could support emergency response needs;
- Increase recreation opportunities; and
- Increase operational flexibility and drought resilience of statewide water systems.

Project Operations

The TFR Project will be operated in coordination with other statewide water system facilities. The dam itself will be approximately 665 feet high. The proposed reservoir will have a maximum surface area of 5,700 acres. The reservoir would provide about 1,330,000 AF of total storage (overlapping with Millerton Lake reduces net storage to 1.25 M AF).

Project Status[102]

1. The Temperance Flat Joint Powers Authority (JPA) was formed to promote, develop, design, permit, finance, acquire, construct, manage, maintain and operate the reservoir.
2. The Final Feasibility Report is currently being prepared by Reclamation for the Upper San Joaquin River Basin Storage Investigation.

[100] "Application for Water Storage Grant, Proposition 1 Water Storage Investment Program (WSIP): Temperance Flat Reservoir." *California Water Commission (CWC)* website: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Temperance-Flat-Reservoir-Project.

[101] "Water Storage Investment Program Project Description: Temperance Flat Reservoir Project." *California Water Commission (CWC)* website (Ibid).

[102] "Water Storage Investment Program Quarterly Report: Temperance Flat Reservoir, 4th Quarter 2018." *California Water Commission (CWC)* website (op.cit.).

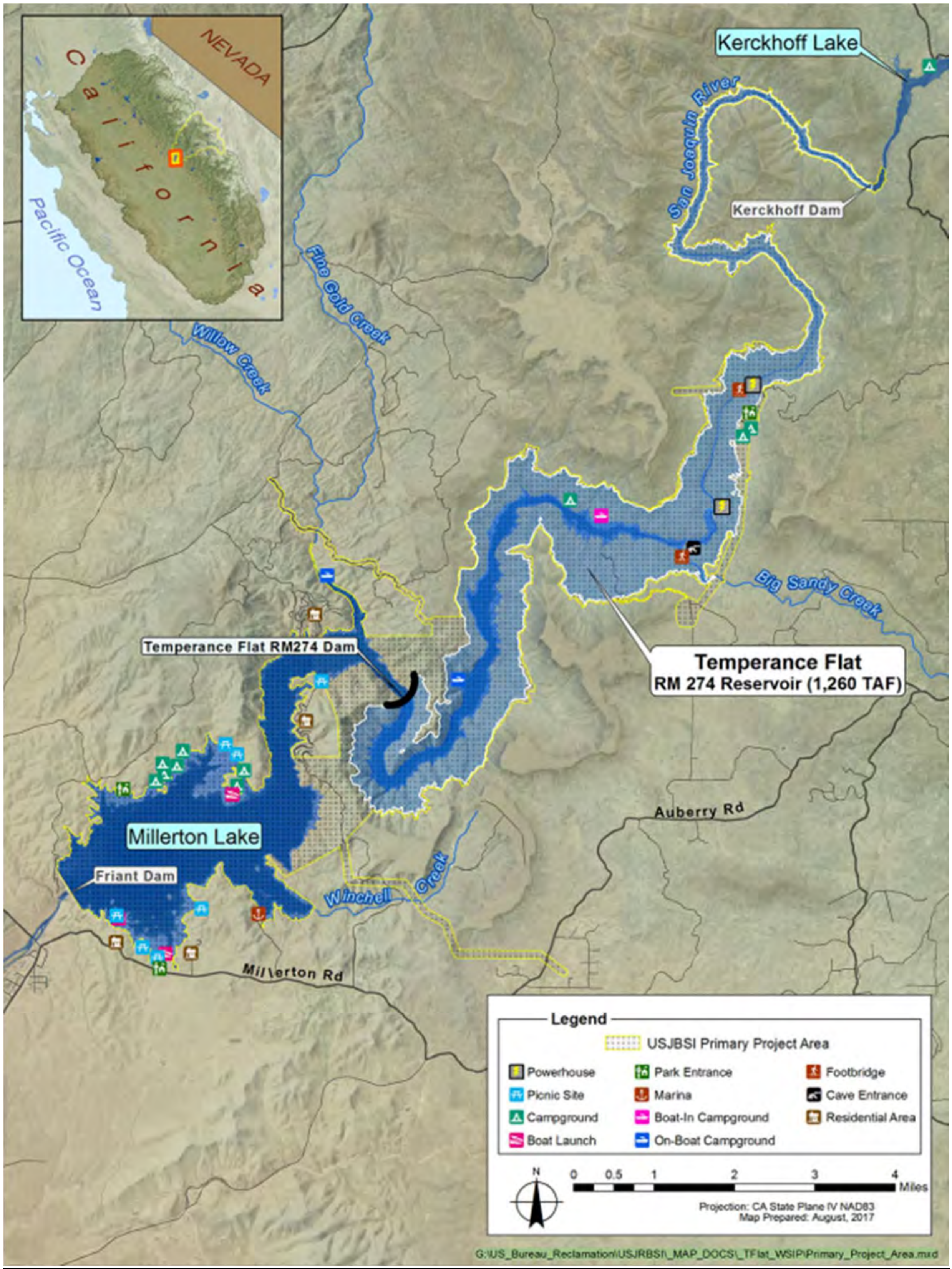

Figure C-4: Primary Project Area

Trampas Canyon Reservoir & Dam[103]

Project Description. A new 5,000 AF (1.6 billion gallons) surface storage reservoir that will provide seasonal storage for Santa Margarita Water District's (SMWD) existing and proposed recycled water system. The project was authorized by SMWD's Board of Directors in November 2017. A groundbreaking ceremony was conducted on February 22, 2018.

The new reservoirs will enable SMWD to store much of its treated recycled water during cooler months of the year for use during spring and summer months when recycled water demand is high. Increasing availability of recycled water will reduce the District's reliance on expensive and politically volatile imported water supplies.[104] Upon completion, Trampas will be the largest surface water reservoir in south Orange County.

Figure C-5. Birdseye artist's rendition of new Trampas Canyon Reservoir and Dam

[103] "Trampas Canyon Reservoir & Dam." Santa Margarita Water District (SMWD) website: http://smwd.com/313/Trampas-Reservoir.

[104] Leach, Jim. "Santa Margarita Water District Breaks Ground on New Recycled Water Reservoir." *Association of California Water Agencies (ACWA)* newsroom. February 22, 2018.

Project Operations. Recycled water will be provided by SMWD's Chiquita Water Reclamation Plant (WRP). The Chiquita WRP is capable of producing recycled water during winter months but there currently is no place to store it. The new Trampas Reservoir will enable SMWD to produce and use 100% of the wastewater sent to the Chiquita WRP for use during periods of high recycled water demand.

Project Status. This project is currently under construction with a targeted in-service date of Spring 2020.

Note: SMWD completed construction of the Upper Chiquita Reservoir, a 750 AF (244 MG) surface water reservoir, in October 2011. This facility is a large-scale emergency potable water reservoir that was developed by SMWD in partnership with Moulton Niguel Water District (MNWD), the City of San Juan Capistrano, the City of San Clemente, and South Coast Water District. The reservoir can provide emergency water supplies of 200 gallons of fresh water to as many as 168,000 families for one week.