Public Comment
Bay Delta Plan Workshop 3
Deadline: 10/26/12 by 12:00 noon

HYDROPOWER IMPACTS OF THE BAY-DELTA PLAN WATER QUALITY OBJECTIVES ON THE STATE WATER PROJECT:
An Overview of Issues and Impact Study Methodology

Prepared for State Water Resource Control Board
Phase II Comprehensive Review Workshops

October 26, 2012

Submitted by the State Water Contractors

1. ISSUE

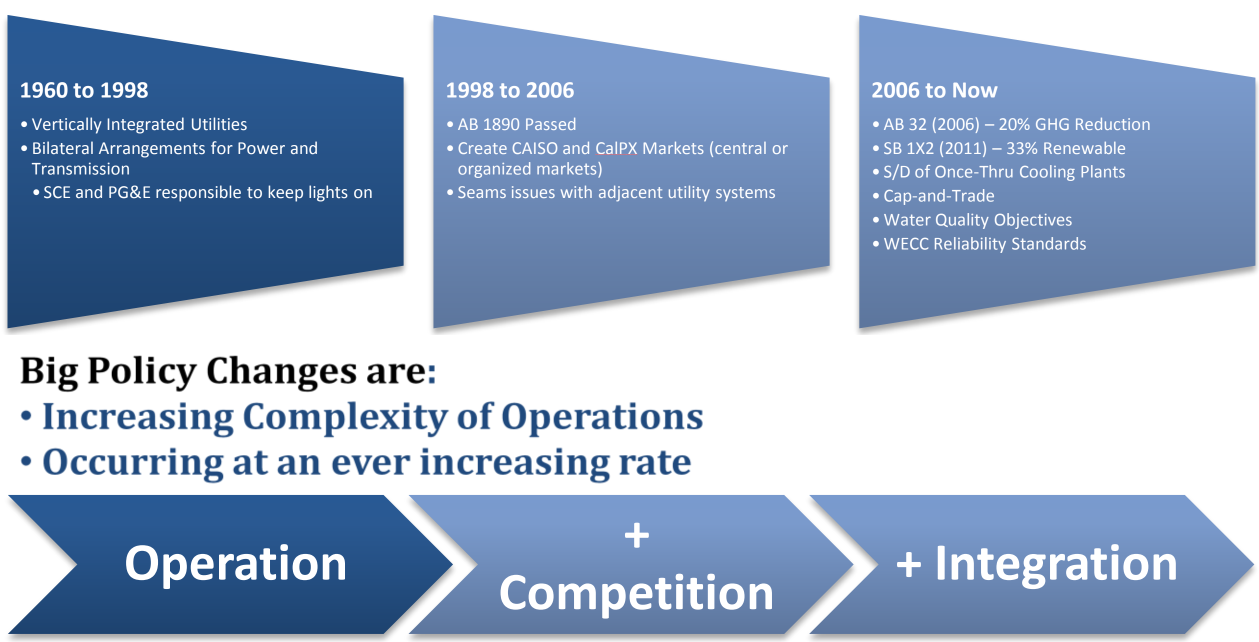
The State Water Board must ensure that its update of the Bay Delta Plan is not at cross purposes with AB32, the Global Warming Solutions Act of 2006, and SB 2(1x), 2011. These landmark legislations set California on a course to lead the rest of the country and world to avoid the most dangerous consequences of global warming. California is the world's 12th largest source of carbon dioxide, the chief heat-trapping gas that causes global warming. These laws mandate that the state must reduce its share of emissions that contribute to global warming. California's goal of supplying 33 percent of its electric energy needs from renewable energy sources by 2020 is a major building block in achieving AB 32 greenhouse gas reduction targets. Carbon free hydroelectric generation along with the role hydroelectric power must play in integrating renewable generation are vital to the State of California being able to meet the objectives of AB32. Changes in flow patterns created by Water Quality Objectives adopted by the State Water Board could have the unintended consequence of reducing the flexible hydropower production that the state is relying on to achieve its carbon reduction goals. We are prepared to assist the State Water Board to evaluate the effect any proposed Water Quality Objectives would have on the state's carbon reduction goals.

2. BACKGROUND

2.1 California Industry and Energy Policy In Transition

The California Energy Policy is to reduce greenhouse gas emissions, create jobs and contain costs. State energy and environmental agencies are joining with the California Independent System Operator Corporation (CAISO) to achieve these objectives. The new policy requires new investments in transmission, energy efficiency, smart grid applications, and increased use of renewable resources. Easing the transition are the California Air Resources Board, California Public Utilities Commission, California Energy Commission and California Environmental Protection Agency.

Though the policy is set forth in law and regulations, the industry remains in transition. One reason is the pace of change. The other is the magnitude of the change as the flowchart below shows.



For decades the California electric industry and infrastructure was based on vertically integrated utilities that owned generation, transmitted the power over their high voltage transmission lines and distributed the power to their customers. Restructuring legislation passed in 1996. It applied to investor owned utilities and allowed public owned utilities to opt in. The legislation was intended to create a competitive electric energy market in California. Fundamental to the change was a breakup of the vertically integrated utilities. The legislation created (1) the California Independent System Operator (CAISO) to operate the transmission grid and generally ensure system reliability and (2) the California Power Exchange (CALPX) as a central marketplace to conduct energy auctions that established energy prices and schedules on both a day-ahead and an hour-ahead basis. The restructured California electric industry began operation on April 1, 1998.

Under the new market structure California experienced the 2000-2001 energy crisis during which energy prices soared and blackouts cut power to millions of customers in California. By the time state and federal regulators stepped in, considerable damage had occurred. The Pacific Gas and Electric Company was forced to declare bankruptcy, the California Power Exchange was forced out of business, families and businesses in San Diego were hammered by dysfunctional market prices and the state found itself spending an estimated $40 billion on power on behalf of the IOUs.

In 2006, the Legislature passed and Governor Schwarzenegger signed AB 32, the Global Warming Solutions Act of 2006. The law requires that California reduce greenhouse gas emissions (GHG) to 1990 levels by the year 2020, and ultimately achieve an 80% reduction from 1990 levels by 2050. In passing the legislation, the Legislature found and declared:

> “Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems. “

and

> “Global warming will have detrimental effects on some of California’s largest industries, including agriculture, wine, tourism, skiing, recreational and commercial fishing, and forestry. It will also increase the strain on electricity supplies necessary to meet the demand for summer air-conditioning in the hottest parts of the state.”

A consequence of the legislation is the utility industry is required to integrate significant amounts of renewable power and participate in the California Cap-and-Trade program while continuing the recovery from the energy crisis. AB 32 requires California electric utilities to supply 20% of their customer needs with renewable power by 2020. In 2011 Governor Brown signed SB 2(1x) (Simitian) into law. This bill revises the Renewable Energy Resources Program to require an increase in the amount of electricity generated from eligible renewable energy resources per year, to at least 33% of total retail sales of electricity in California per year by December 31, 2020.

2.1.1 Reduce Greenhouse Gas Emissions

The California carbon reduction requirement is to achieve 1990 level of emissions by 2020. AB 32 designates the California Air Resources Board as responsible for monitoring and regulating GHG emissions in order to achieve reduction obligations. After extensive stakeholder input, the CARB adopted the Cap-and-Trade regulations on in October 2011. In the process of adopting the regulations the CARB conducted an extensive CEQA review including the finding that Cap-and-Trade is the least cost alternative to fulfilling its AB32 obligations. The regulations went into effect on January 1, 2012.

A cap and trade system is a means by which reductions in greenhouse gas (GHG) emissions can be implemented. It involves creating a market where GHG emission allowances can be bought and sold by entities. Setting a cap for GHG emissions is fundamental to the to the program's function. The California cap and trade system sets targets for emissions which are gradually reduced each year.

The ARB has regulated the electricity sector in the initial stage of the program. The cap for electric sector emissions is 97.7 million metric tons (MMt). Each year beginning in 2013 through 2020, the electric sector emission cap must be reduced by approximately 2%.[1]

2.1.2 Renewable Energy

Serving California businesses and families with renewable power is the other relevant component to California's carbon reduction policy. Over a period of nearly a decade, the California legislature has progressively increased the amount of renewable power that utilities must use to serve their customers. Those amounts were initially established in 2002 under Senate Bill 1078, accelerated in 2006 under Senate Bill 107/Assembly Bill 32 and expanded in 2011 under Senate Bill 2(1X). The result is California's Renewables Portfolio Standard (RPS) is one of the most ambitious renewable energy standards in the country. The RPS program requires investor-owned utilities, electric service providers, and community choice aggregators to increase procurement from eligible renewable energy resources to 33% of total procurement by 2020.[2]

SB 2 (1X) institutes three compliance periods that require the utilities use increasing amounts of renewable power to supply customers. The California Public Utilities Commission (CPUC) is responsible to establish the quantity of electricity products from eligible resources to be procured by each retail seller for each compliance period. The first compliance period requires procurement from eligible renewable resources that averages 20% of retail sales over the period between January 1, 2011 and December 31, 2013. After 2013, quantities must reflect reasonable progress in each of the intervening years sufficient to ensure eligible renewable resource procurement achieves 25% of retail sales by December 31, 2016; 33% of retail sales by December 31, 2020; and not less than 33% thereafter.

Variable energy resources, primarily wind and solar are seen as the resources most likely to fulfill the RPS requirements. There are two key characteristics of wind and solar that present challenges in integrating their output into California's existing generation fleet; specifically, high forecast errors and

[1] http://www.arb.ca.gov/newsrel/2011/cap_trade_overview.pdf
[2] http://www.cpuc.ca.gov/NR/rdonlyres/3B3FE98B-D833-428A-B606-47C9B64B7A89/0/Q4RPSReporttotheLegislatureFINAL3.pdf

the inherent variability of energy production by these resources. Figure 1 illustrates the variation in total wind output in the CAISO service area during April, 2006. The variation is continuous and occurs from second to second, minute to minute and hour to hour. The CAISO has observed that "The integration of variable energy resources will require increased operational flexibility—notably capability to provide load-following and regulation in wider operating ranges and at ramp rates that are faster and of longer sustained duration than are currently experienced.[3]" Unlike water systems where the pressure sometimes drops due to demand outpacing supply, the power system must continuously balance generation supply to load demand. If load and generation are not balanced automatic schemes kick in to shed load in order to prevent equipment damage that could lead to major system wide blackouts.

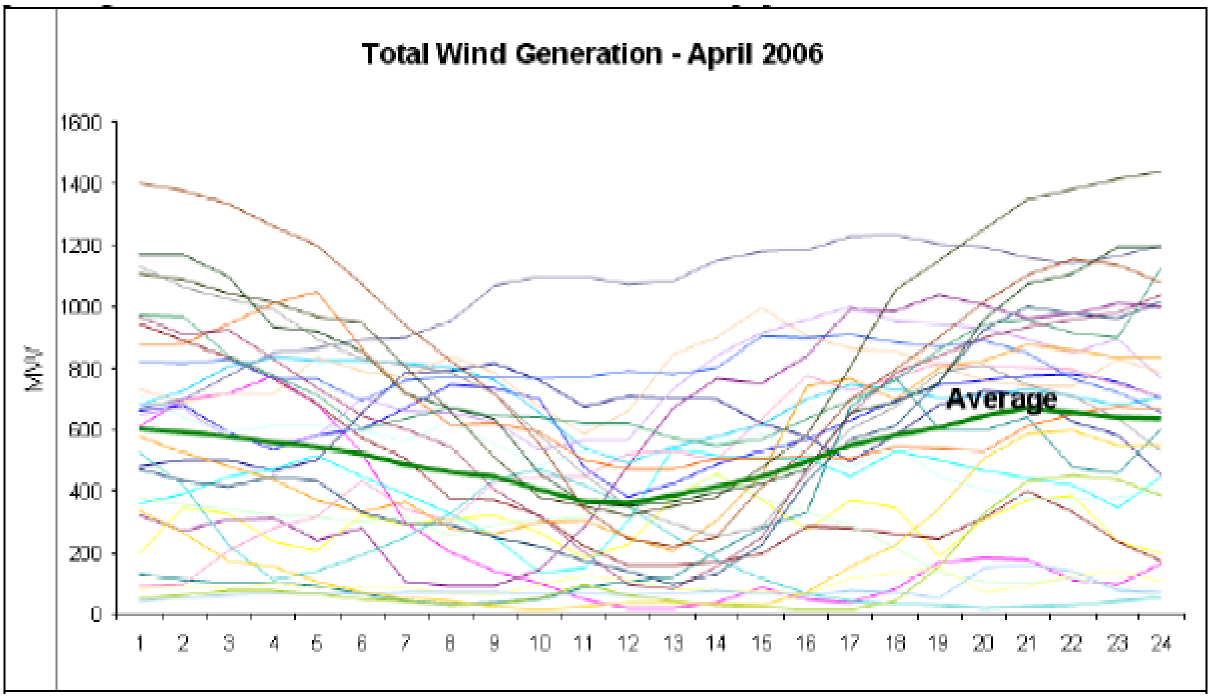


Figure 1

2.2 Water Quality Objectives

The State Water Board is considering changes to the 2006 Water Quality Control Plan for the Bay-Delta. The State Water Board has set a series of workshops to consider information that has been developed since it completed the review of the 2006 Bay-Delta Plan and since it released the 2010 Flow Criteria Report. The changes to the Water Quality Control Plan may include flow criteria that shifts releases of water from the Lake Oroville reservoir and limit the amount of water exported from the by the SWP. As described below, the SWP hydropower production is a function of water releases from Lake Oroville and water delivered south of the Tehachapi Mountains. A flow criteria that shifts power production from the summer months into the spring and fall could have a broad array of impacts on SWP power production and consumption as well as the impacts on the California power grid.

[3] CAISO, *Integration of Renewable Resources, Operational Requirements and Generation Fleet Capability at 20% RPS, August 31, 2010*, page iii

2.3 The State Water Project

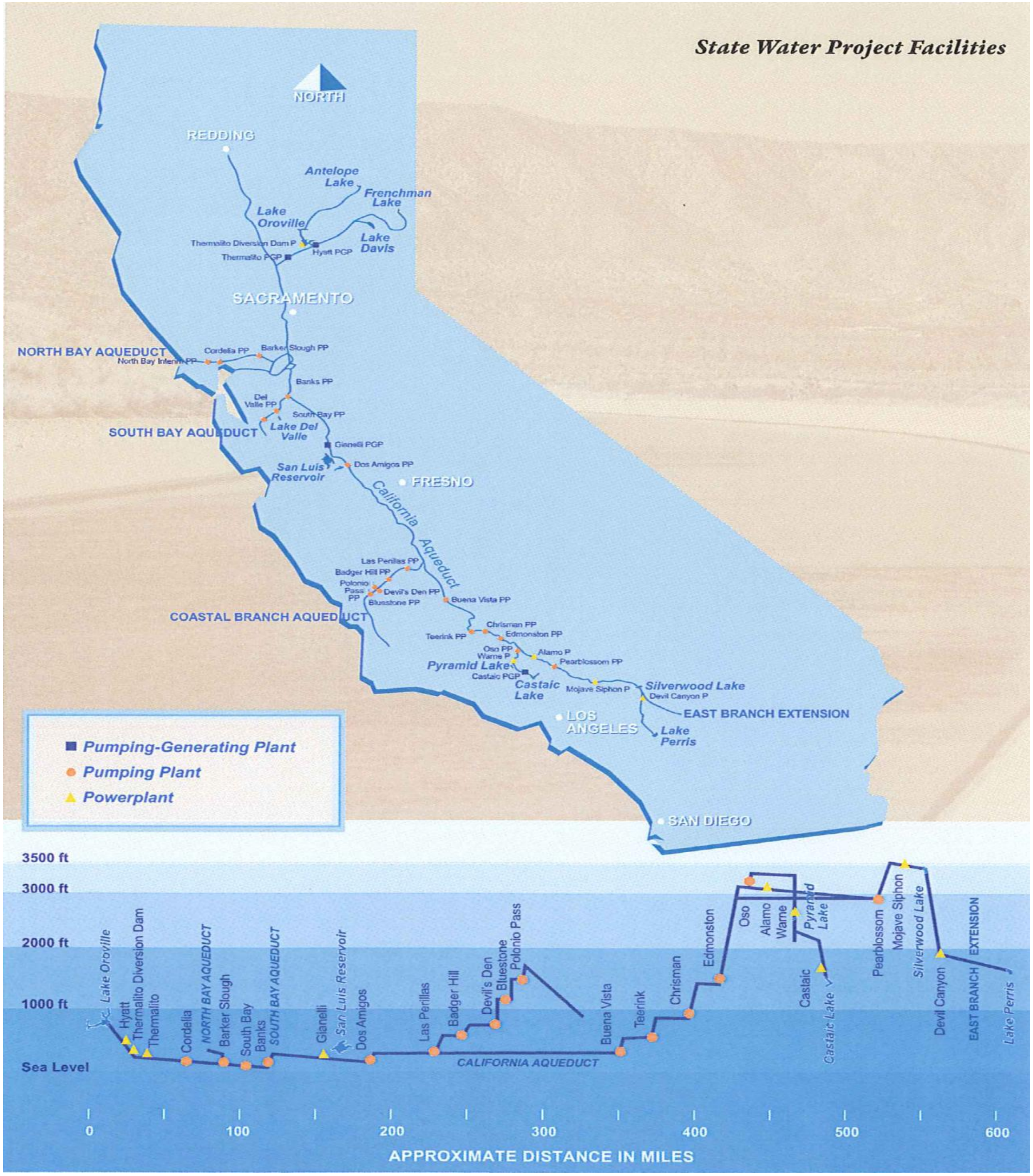
The State Water Project is the largest State-built, multipurpose water project in the United States. A primary purpose of the Project is to store and deliver water to its customers, the State Water Project Contractors. The service areas of the SWP Contractors are found throughout Northern California, the San Francisco Bay area, the San Joaquin Valley, the Central Coast and Southern California. The scope of the State Water Project is evident in Figure 2.

The SWP's system contains 1,750 MW of hydropower capacity with the capability to produce and average annual generation of 4,300 GWh of energy when operating under the existing Biological Opinions (the 2008 Fish and Wildlife Service Biological Opinions for Coordinated Operations and the 2009 National Marine Fisheries Service Biological Opinion for OCAP). The SWP provides about 12.5 percent of the hydropower capacity in California. Annually the SWP pumps consume 7,750 GWh of energy on average when the SWP is operated to meet the requirements of the existing Biological Opinions. The remaining energy not supplied by the SWP hydropower is obtained from a number of sources, including contracted purchases of hydroelectric and renewable energy, the SWP's ownership portion of the Lodi Energy Center power plant, and mid-term and short-term purchases from California's power market.

2.3.1 <u>Built in Operational Flexibility</u>

Flexibility for managing pumping needs and power generation was built in as the Project was constructed. The Project designers recognized the advantages of pumping mainly during off-peak hours and generating mainly during on-peak hours. Excess pumping capability was installed in many of the pumping plants, generation plants were sized to increase peaking capacity and storage was incorporated at strategic locations, solely to increase operational flexibility. In the electric utility business, the ability to control the pattern of generation is called “shaping.” The shaping of both load and generation is a feature unique to the Project. As an additional reliability measure, an extra unit was installed in many of the pumping plants so that standard maintenance outages would not reduce a plant’s pumping capability.

Today, the SWP continues to take advantage of the Project’s built-in operational flexibility by minimizing pumping and maximizing project generation during on-peak hours when energy costs are highest. Ideally, the maximum Project pumping is scheduled during the off-peak hours. Conversely, maximum Project generation is scheduled during the peak hours. While the Project moves as much water as possible during the off-peak hours, delivery levels, storage availability and regulatory restrictions often create a need to pump water outside of the off-peak hours. This operating scheme helps support the California grid operations by supplying spare energy to the grid during on-peak hours and providing a valuable sink for off-peak generation.



State Water Project Facilities
NORTH
REDDING
Antelope Lake
Frenchman Lake
Lake Oroville
Lake Davis
Thermalito Diversion Dam P
Hyatt PGP
Thermalito PGP
SACRAMENTO
NORTH BAY AQUEDUCT
North Bay Interim PP
Cordelia PP
Barker Slough PP
Banks PP
Del Valle PP
South Bay PP
SOUTH BAY AQUEDUCT
Lake Del Valle
Gianelli PGP
San Luis Reservoir
Dos Amigos PP
FRESNO
California Aqueduct
Las Perillas PP
Badger Hill PP
Polonio Pass PP
Devil's Den PP
Bluestone PP
Buena Vista PP
COASTAL BRANCH AQUEDUCT
Chrisman PP
Teerink PP
Edmonston PP
Oso PP
Warne P
Alamo P
Pearblossom PP
Pyramid Lake
Castaic PGP
Castaic Lake
Mojave Siphon P
Silverwood Lake
Devil Canyon P
EAST BRANCH EXTENSION
LOS ANGELES
Lake Perris
SAN DIEGO
Pumping-Generating Plant
Pumping Plant
Powerplant
3500 ft
3000 ft
2000 ft
1000 ft
Sea Level
Lake Oroville
Hyatt
Thermalito Diversion Dam
Thermalito
Cordelia
NORTH BAY AQUEDUCT
Barker Slough
South Bay
Banks
SOUTH BAY AQUEDUCT
Gianelli
San Luis Reservoir
Dos Amigos
Las Perillas
Badger Hill
Devil's Den
Bluestone
Polonio Pass
CALIFORNIA AQUEDUCT
Buena Vista
Teerink
Chrisman
Edmonston
Oso
Alamo
Warne
Pyramid Lake
Castaic
Castaic Lake
Pearblossom
Mojave Siphon
Silverwood Lake
Devil Canyon
EAST BRANCH EXTENSION
Lake Perris
0
100
200
300
400
500
600
APPROXIMATE DISTANCE IN MILES

Figure 2

2.3.2 SWP Energy Sources

Figure 3 provides a simplified depiction of the energy sources that could be used to supply the SWP pumping loads in 2020. The graphic illustrates the energy sources required to serve the average annual pumping load without the complication of capturing the SWP's practice of supporting the California grid operations by generating surplus energy in the on-peak and scheduling the maximum amount of pumping in the off-peak. The SWP relies on market purchases to supply much of its off-peak pumping needs. The graphic shows only the simple energy balance required for the SWP to supply just its pumping needs. In recent years, the SWP sells into the market have ranged between 1,000 GWh and 2,000 GWh per year. The additional on-peak sale and off-peak purchases are not captured in the graph.

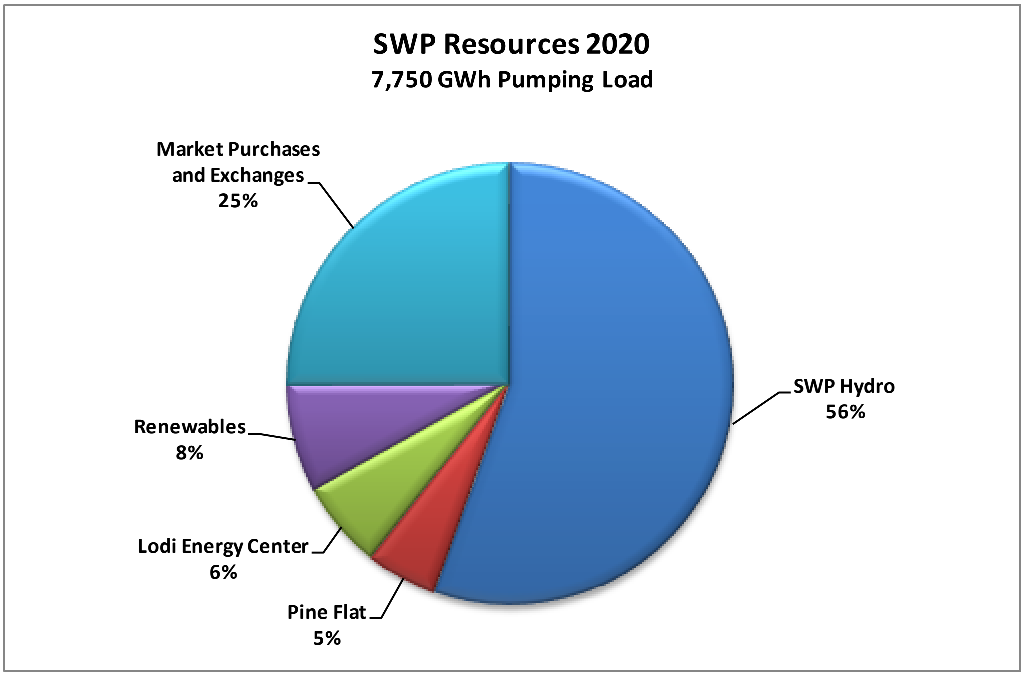


Figure 3

2.3.3 SWP Generation and Pump Load Shaping

Especially during the high-load summer months, the California market has produced two pricing segments for the traditional 16-hour on-peak period; an 8-hour super-peak and an 8-hour partial-peak. Prices are generally significantly higher in the super-peak. When not all of the pumping can be accomplished in the off-peak, it is first shaped into the partial-peak and then into the super-peak. Occasionally, some pumping is required in the super-peak. The SWP energy limited hydroelectric generation is shaped to maximize output during the super-peak, with any additional generation scheduled first into the partial-peak and finally into the off-peak.

Some of the Project features that allow the shaping of pumping loads and generation are apparent while others are more subtle. Storage was incorporated in the Project at locations where it provided operational advantages. An example is the Oroville power facilities. Additional storage was added to the Thermalito Afterbay in order to increase the peaking operation of the Hyatt and Thermalito power plants. The Thermalito Afterbay allows water released from Lake Oroville during peak hours to be stored and released back into the Feather River at a steady rate.

San Luis Reservoir, O'Neill Forebay and Silverwood Lake provide major facilities for regulation of water en route through the main aqueduct. However, it is the nearly simultaneous operation of the hydraulically interdependent pumping plants, coupled with the extra pumping capability built into the plants, that allows heavy off-peak pumping. These unique design considerations minimized the need for off-stream storage in the original project design, while still allowing the Project to shape the water pumping as if additional storage was available.

DWR continues to construct cost-effective Project additions that reduce energy costs. The recently completed Tehachapi Afterbay provides increased flexibility for using off-peak pumping at the Edmonston Pumping Plant.

2.3.4 SWP Ancillary Services

The Project features that allow shaping of pumping loads and generation also allow the Project to effectively participate in California's ancillary services market. The ancillary services market ensures that capacity is on hand to adjust the flow of electricity when the unexpected happens, such as power plant failure or a sharp rise in the demand for power. Four types of operating reserves are included in the ancillary services market:

Regulation – Generation that is already up and running and can be increased or decreased almost instantly to keep energy supply and energy use in balance.
Spinning Reserves – Generation that is running at less than full output, with additional capacity that can be increased within minutes.
Non-Spinning Reserves – Generation that is not running, but can be brought up to speed within ten minutes. Pump-drop that can be reduced within ten minutes can also supply non-spinning reserve.
Replacement Reserves – Generation that can begin contributing to the grid within an hour.

At times there is an economic advantage for the Project to participate in the ancillary services market over simply producing energy. The Project's generation can be used to supply all four operating reserve categories. However, because of the ability of both the SWP hydroelectric generators and pumps to meet the 10-minute response requirement, the SWP does not participate in the Replacement Reserve market designed for slower responding generation. Hydroelectric generation is especially suited for providing regulation because of its ability to quickly change energy output. The Project often uses pump-drop to participate in the non-spinning reserve market.

2.3.5 Special Protection System provided by State Water Project

Owners of transmission that are connected to the CAISO controlled grid are obligated to comply with reliability standards as set forth by the Western Electricity Coordinating Council (WECC). A System Protection System is an automatic protection system designed to detect abnormal system conditions and take corrective actions. Such an action may include changes in demand or generation.

These standards have directly led to the SWP delivering a unique and valuable service to a large transmission owner and consequently the statewide power grid. The protection system was agreed to by DWR and the transmission owner in lieu of constructing reinforcements between two major substations in California.

This protection system was triggered in September 2010 and June 2012. During each event the SWP curtailed about 1,000 MW of generation and pump load in order to maintain the reliability of the power grid. [This is equivalent to being able to turn off power to 1/3 of Sacramento.] There are few, if any, comparable sources of such special protection connected to the California power grid.

3. CHALLENGES OF ACHIEVING CALIFORNIA ENERGY POLICIES - COSTS, SYSTEM RELIABILITY AND CARBON REDUCTION

Achieving the state energy policy objectives will be a tall order. Steve Berberich, president of Cal-ISO, acknowledged the need for thousands of megawatts of flexible generation in California as more renewables come on line. At the same CAISO symposium, the president of the CPUC, Michael Peevey, stated that as renewable-energy penetration grows we "especially need coordination and collaboration among various state agencies."[4] The CAISO and the CPUC have each opened proceedings to meet the challenges. Their focus is maintaining the reliability of the power grid while keeping costs down. The CAISO anticipates an increased need for load following and regulation ancillary services as additional renewable generation in integrated into the existing generation fleet. Its initial findings disclose that the existing generation fleet may not be sufficient to provide the flexible generation that the intermittent renewable generation requires.

3.1 Reliability of the Power Grid

The ISO's studies show that reliably operating the grid with a 33 percent Renewable Portfolio Standard (RPS), the potential retirement of 12,079 megawatts of once-through-cooled generation units, and the potential addition of 12,000 megawatts of distributed resources requires California to maintain a fleet of sufficient flexible and local capacity resources both now and into the future. The need for flexible capacity resources increases with the level of intermittent resources typically used to meet the state's renewable portfolio requirements.

Since 2007 the CAISO has held workshops, conducted studies and published studies that report on the challenges of integrating renewable resources into the grid. For example, CAISO completed a study in 2010 on the operational requirements for integrating renewable resources (*Integration of Renewable Resources, Operational Requirements and Generation Fleet Capability at 20% RPS, August 31, 2010*). It followed-up in October 2011 reporting that its studies "reveal that the integration of intermittent renewable resources will require resources that can flexibly and accurately respond to dispatch signals and can quickly ramp to new operating levels." The CAISO has developed a roadmap of the scope and timing of activities that will lead to the re-tooling the transmission grid and making extensive modifications to its power markets. Of interest to the State Water Board is that the CAISO finds deficiencies in flexible generation that is necessary for the integration of intermittent renewable

[4] Keith Casey, "Briefing on Renewable Integration – Market Vision and Roadmap," Briefing prepared for CAISO Board, October 20, 2011.

generation. Water Quality Objectives that impacts on flexible SWP hydropower production will require additional flexible generation be developed.

3.1.1 A Changing Net Load Shape

A reason for the concern is the dramatic change in the shape of the power demand that the CAISO must ensure is met. Historically the shape of the power demand appeared as shown in Figure 4. On a typical day the demand followed a fairly predictable shape. The figure shows how the customer demand varies throughout the day. In this case it shows a demand of about 30,000 MW at midnight. The demand continues to drop slightly until around 5:00 am when the day begins. That is followed by a steady rise until around 5:00 pm when businesses go through the daily cycle. The demand continues its steady decline as the day comes to an end.

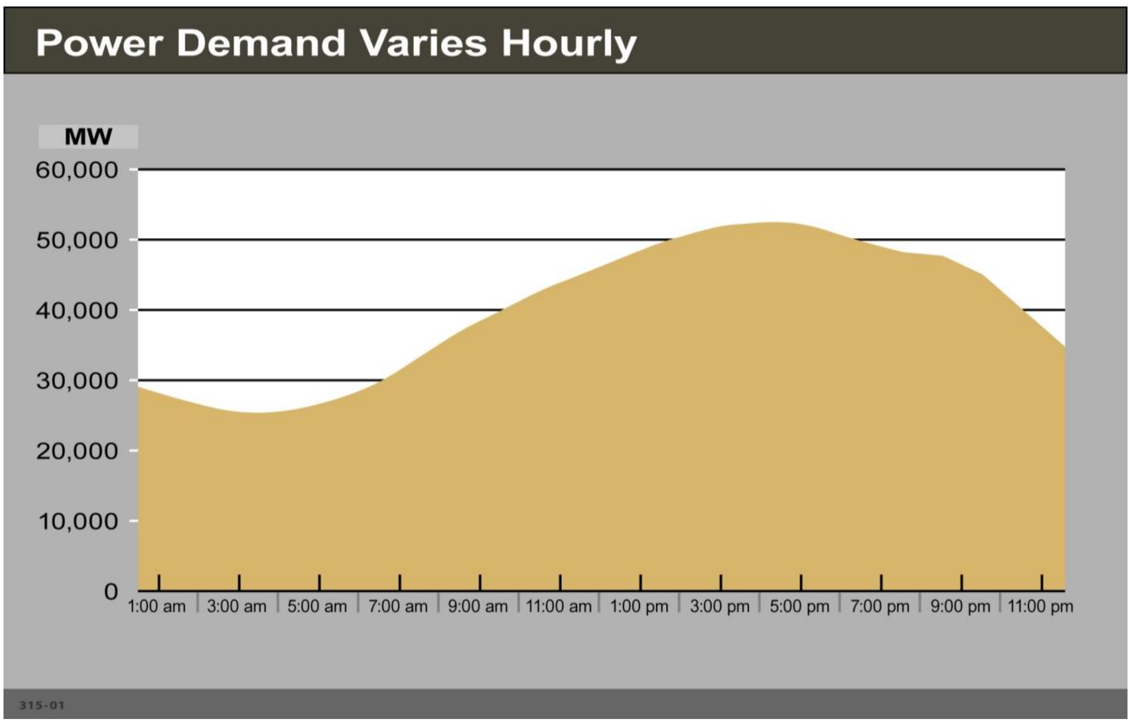


Figure 4

One of the primary CAISO responsibilities is to continuously, and almost instantaneously, balance generation to load. One of the issues the CAISO faces is the change in load following requirements as California moves to meeting the 33 percent RPS. Before the heavy penetration of variable output renewables, the intra-hour and inter-hourly variation in load was due solely to variations on the demand side. Flexible output "load following" generation was used to keep generation and load in balance. With the heavy penetration of variable output resources, the CAISO will have to supply load following to dampen both the variation in load and the variation in the output from variable output resources. This change will increase the need for flexible output resources, such as conventional hydropower generation.

Figure 5 illustrates the change in load following requirements that are expected when renewables are incorporated into the generation portfolio. Figure 5 shows the highly variable load shape that will be served by flexible output generation in the future. Flexible output resources will see a load pattern in Figure 5.that is net of energy generation from variable output resources. This net load demand curve (shown in Figure 5) illustrates a significant increase in the load following burden that will be the responsibility of the flexible output resources. The Cal-ISO has stated that by 2020, with the amount of renewables coming on line, the grid could see ramps approaching 13,500 MW in two hours. The increased load following requirement could necessitate the development of new flexible output resources.

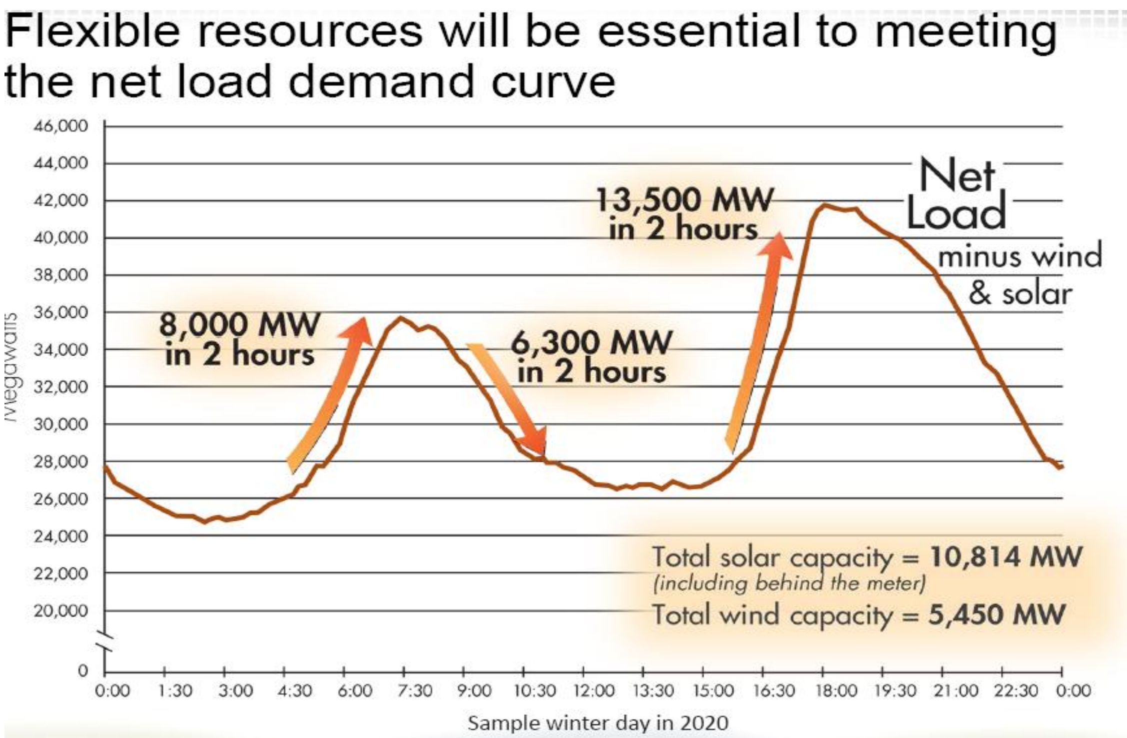


Figure 5

Integrating a 33 percent RPS, maintaining local reliability, and meeting other state energy policy goals such as the once-through-cooling mandate creates several operational challenges for the ISO. Among these challenges is ensuring that the ISO has sufficient flexible capacity to address the added variability and unpredictability created by variable energy resources. This challenge is magnified even further with the prospect of losing over 12,000 MW of flexible capacity resources to once-through-cooling mandates established by the State Water Resources Control Board.[5]

[5] same

3.1.2 Depressed Energy Market Prices

Another situation that the CAISO has identified is that production of significant amounts of renewable energy will depress energy market prices and undermine the commercial viability of needed flexible generation. This has led to the CAISO seeking unprecedented authority from FERC to contract with owners of flexible generation in order to assure grid reliability. Concerned that natural gas power plants with the ability to integrate renewables could retire in coming years for lack of sufficient revenue, Cal-ISO approved a backstop payment mechanism. Under a new risk-of-retirement provision, CISO will now offer payments to plants that are at risk of retirement and that CISO sees as necessary for system flexibility or local reliability within a two- to five-year time frame. This new market mechanism was partly spurred by controversy over the 578 MW Sutter Energy Center, a natural gas plant that was on the verge of retiring—and never returning, according to plant owner Calpine—until the CPUC directed investor-owned-utilities to negotiate a resource-adequacy contract with the plant. CISO said Sutter was needed in 2017 to integrate renewables.[6]

The CAISO studies also point out that over-generation conditions during the spring months will likely increase as solar and wind resources are added to meet the increased RPS requirements. Over-generation simply means that there is more power being produced than customers are consuming. Such a situation typically occurs during the spring when demands are low and hydropower production is high. The addition of significant amounts of renewable generation will increase the frequency of CAISO managing a potential over-generation condition. A delta flow regime that requires more reservoir releases during the spring will compound the problem.

3.2 Cost of Implementing Energy Policies

The CPUC is the principal agency responsible for implementing the RPS program. It has several proceedings underway which are in total or part intended to address challenges the RPS presents. On May 5, 2011, the Commission adopted the Order Instituting Rulemaking (R.) 11-05-005 to open a new proceeding for the implementation and administration of the 33% RPS Program. Currently, the California Public Utilities Commission (CPUC) is considering modifications to its Resource Adequacy (RA) program to incorporate flexible capacity procurement requirements and the ISO is conducting local reliability studies as part of the CPUC's 2012 LTPP proceeding.[7]

The CPUC developed this report in order to provide new, in-depth analysis on the cost, risk, and timing of meeting a 33% RPS. As identified in the report, the cost to achieve the RPS will be significant. It estimates the major new transmission lines that are needed alone will cost more than $15 billion. It also confirms that the cost of the energy supply will be higher under the RPS.

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[6] Chris Raphael, "Need for Flexible Power, Cooperation Heard at Cal-ISO Symposium," California Energy Markets, Vol. No. 1197, (September 7, 2012): 9

[7] CAISO report "Flexible Capacity Procurement Phase 1: Risk of Retirement," http://www.caiso.com/Documents/SecondRevisedDraftFinalProposal-FlexibleCapacityProcurement.pdf, September 15, 2012

4. PRELIMINARY OBSERVATIONS ABOUT WATER QUALITY OBJECTIVES AND STUDY OBJECTIVES

4.1 Impacts of Water Quality Objectives on the SWP

Preliminary assessments of the impacts of the SWRCB's Delta Flow Policy revealed both a large reduction in the expected annual SWP generation as well as a dramatic seasonal shift in generation. Similar impacts could be expected in the CVP and in other hydropower projects impacted if SWRCB Water Quality Objectives follow the “natural hydrograph” pattern of the Delta Flow Policy. Proportionately, a larger percentage of the annual generation would occur during the spring and less in the summer months with such Water Quality Objectives.

SWP pumping loads would also be reduced due to less water being available for delivery to the SWP Contractors. The water supplied by the SWP is important to California's economy. Replacing the water would have additional energy impacts. A limited amount of increased groundwater pumping may be feasible, but this will require additional energy use and energy supplies. Water desalinization would likely be required to make up water supplies for urban water users. Water desalinization is energy intensive.

4.2 Water Quality Objectives

Any major changes to the power production at California's hydroelectric generation facilities can materially alter the operations of the entire generation system and transmission network serving California's electric load. The impact extends to the entire WECC power system, since California's power operation is tightly integrated with its neighboring utilities. The impacts may extend beyond the level of hydroelectric energy generation forgone as the result of Water Quality Objectives. Electric system dispatch, and the associated CO2 emission rates, may also respond if Water Quality Objectives produce a shift in energy generation from the summer into the spring and winter months, a reduction in maximum hydropower operating capacity, and a reduction in the capability of the hydropower system to produce ancillary services. As an example of the complex interaction, an inability of California's generation fleet to supply sufficient regulation to dampen the deviation in energy production from variable output renewable resources will require electric system dispatch changes. Possible solutions include the addition of flexible output resources such as gas-fired combustion turbines to supply additional ancillary services or the curtailment of variable output renewable generation in order to reduce the ancillary service requirements. Both of these changes would increase CO2 emissions.

Fortunately, there are a large number of available models with the capability of simulating hourly integrated power system dispatch that can be used to assess the impact of changes in hydropower capability on CO2 emission within the WECC power system.

5. ASSESSING HYDROELECTRIC IMPACTS OF POTENTIAL CHANGES TO THE WATER QUALITY OBJECTIVES

Changes to flow patterns under new Water Quality Objectives could have direct impacts on the power production at California's system of hydroelectric generation facilities. In addition, when these impacts are significant, the changes can materially alter the operation of the entire generation system and transmission network serving California's electric load. It is imperative that the State Water Resources Control Board perform a comprehensive evaluation that addresses both the direct impacts on hydroelectric generation, along with the associated generation system and transmission network impacts.

The State and Federal Contactors Water Agency has facilitated a broad-based effort to evaluate the potential-power related impacts that could result from changes to Water Quality Objectives. To date the SFCWA's effort has focused on (1) identifying the modeling structure required to perform a comprehensive evaluation of the direct hydroelectric generation impacts along with the related power system and transmission network impacts, (2) identifying available modeling tools and modeling techniques for addressing power related impacts, (3) applying and refining existing modeling tools directly available to the SFCWA, (4) developing data so that other entities can apply existing modeling tools and (5) formulating and applying meaningful alternatives for assessing impacts where additional modeling studies are not readily accessible to the SFCWA.

The SFCWA has limited its initial effort to developing the tools to assess the hydropower impacts of Water Quality Objectives to the water system within the boundaries of the State Water Project and the Central Valley Project. The structure of the evaluation process outlined by the SFCWA is expandable to cover hydropower impacts that encompass a larger geographic area.

5.1 Modeling Structure

Comprehensive evaluation of complex hydrologic and hydropower systems is a challenging process that is best approached using a set of interrelated tools. The usual approach in studying complex systems is to consider the total system as being organized in terms of hierarchies or levels. This hierarchical approach permits separate application of modeling tools for addressing various parts of the total system. In this process, model resolution can be varied from one component sublevel to another, depending on the overall study requirements, knowledge of the system at each particular sublevel and the availability of tools to support studies at each sublevel.

Hierarchical study approaches are equally robust for spatial and temporal decomposition of complex systems. An overview of the hierarchical structure employed for model studies based on changes in SWP and CVP hydroelectric generation levels and patterns is provided in Figure 6. All elements in the hierarchy reflect common modeling and analytical processes in a standard electric utility resource planning evaluation. The major components of the modeling hierarchy and their roles in the impact assessments include:

- First Level - High Level Coordination
  Function: High level coordination is required in a hierarchical modeling structure to set modeling goals and objectives and coordinate the flow of data between the models and assessment techniques used at, and within, each level of the hierarchy.

- Second Level - Direct Operational Impacts to the SWP and CVP Hydroelectric and Pumping Systems and Replacement Water Impacts on Power Use
  - SWP and CVP System Operations Modeling
    Function: Evaluate the monthly generation characteristics of the SWP and CVP over the available 81-year synthetic hydrologic record. All of the remaining modeling and numerical assessments in the hierarchy feed off the generation and pumping load data developed at this level.
  - Replacement Water Power Requirements Assessment
    Function: Account for the power requirements for makeup water due to the reduction in SWP and CVP water deliveries under alternative WQO.

- Third Level - California and Western Electricity Coordinating Council (WECC)-Wide Operational Dispatch Modeling
  - Electric System Operational Dispatch Modeling for CO2 and Energy Cost Impacts
    Function: Evaluate the annual CO2 emission levels and hourly marginal energy costs within California and over the entire WECC.
  - Electric System Operational Dispatch Modeling for Ancillary Services Impacts
    Function: Evaluate the ability of California's generation fleet to supply the ancillary services required for integrating renewables at the 33 percent level.

- Fourth Level - Reliability Assessment
  - Resource Adequacy Assessment and Modeling
    Function: Evaluate the ability of California's generation fleet to meet standard utility capacity reserve requirements, such as a 1-day-in-10 year Loss-of-Load Probability (LOLP).
  - Transmission Grid Adequacy and Security Assessments
    Functions: Assess the ability of the transmission grid to deliver generation to load under normal and peak demand conditions and the ability of the system to withstand sudden disturbances.

5.2 Studying the Power Impacts of the Water Quality Objectives

The SFCWA's effort has addressed modeling and evaluation at all levels of the hierarchy. The approach and findings provide a workable template for the SWRCB to perform similar assessments, or expand the assessments to a broader geographic area. The following summarizes the SFCWA's effort to date and offers recommendation for moving forward.

5.2.1 SWP and CVP System Operations Modeling

Approach and Background The SFCWA has limited its initial effort to develop the tools to assess the hydropower impacts of Water Quality Objectives on the water system within the boundaries of the State Water Project and the Central Valley Project. The availability of the CALSIM II water system simulation model facilitated the assessment of power impacts on the SWP and CVP hydroelectric generation. CALSIM II is a long-term water system planning model for simulating the monthly operation of the State Water Project and the Central Valley Project. The simulated monthly water movement through each of the SWP and CVP hydropower generation facilities and pumping plants is easily converted to monthly generation capacity and energy values and pumping loads using spreadsheet based postprocessing routines. CALSIM II currently models the monthly SWP and CVP operations over an 81-year hydrologic period. The results of CALSIM II simulations provide all of the SWP and CVP capacity and energy information for studies at lower levels in the hierarchy.

The SFCWA is approaching the impact assessment by comparing hydroelectric operations for Water Quality Objectives cases to operations under a basecase scenario. The basecase scenario uses flow requirements based on reasonable and prudent alternatives contained in the 2008 Fish and Wildlife Service Biological Opinions for Coordinated Operations and the 2009 National Marine Fisheries Service Biological Opinion for OCAP (the BO Basecase). WQO cases are built around SWRCB Water Quality Objectives scenarios (WQO cases).

A key element in studying hydroelectric system operations is capturing the variables that control the decisions on when to release water stored in the system. The SWP and CVP are operated to meet water quality and flood control objectives, in addition to delivering water to their urban and agricultural water contractors. Hydroelectric power is produced in the process of meeting the water quality, flood control and water delivery objectives. From a practical point of view, it is safe to assume that power production is never a factor in determining the monthly movement of water through the SWP and CVP. However, there is flexibility to shape water releases and water deliveries to meet power production and power use objectives for weekly and shorter time-periods.

Changes in the level of water deliveries impact both the hydroelectric generation and project pumping loads in the SWP and CVP. The CALSIM II results also allow the monthly energy use at each pumping plant to be calculated for both the SWP and CVP.

Initial Findings/Status CALSIM II is being used to capture the impacts of potential WQO on monthly SWP and CVP hydropower generation and pumping loads over the 81-year study period. The initial findings indicate that the WQO may reduce the total annual energy generation, shift the annual generation pattern, impact the maximum hydropower operating capacity, and reduce the annual water deliveries and pumping loads.

- Water Impacts - The WQO may result in a shift in water releases from the summer into the spring and some winter months. Such a shift may lead to long-term reservoir storage being depleted more frequently. The WQO may also result in less water deliveries to both the SWP and CVP contractors. These changes will have an impact on hydropower generation and power consumption as discussed below.

- Energy Generation Impacts - A shift in the water release pattern from long-term storage reservoirs under the WQO may result in a shift in energy production from the summer months into the spring and some winter months. Annual energy generation may also be reduced due to (1) lower average elevations in long-term storage reservoirs and (2) a reduction in recovery generation, mainly within the SWP, resulting from reduced water deliveries to the SWP and CVP contractors.
- Qualifying Renewable Energy Impacts - A portion of any energy generation lost due to the WQO will be qualifying renewable energy that counts towards the State's goal of supplying 33% of its energy needs from renewables by 2020.
- Pumping Load Energy Impacts – If the WQO reduces water deliveries, the annual pumping load energy use will also be reduced due to the reduction in water delivered to the SWP and CVP urban and agricultural water contractors. However, replacing the water is likely to have additional energy impacts.
- Net Energy Impacts - Calculating the net energy impact on a monthly basis will be complex and can be misleading for the SWP. The SWP was constructed with additional generation and pumping capacity to allow generation to be concentrated in the on-peak period and pumping to be concentrated in the off-peak period. The majority of the lost energy generation will likely be in the on-peak while the majority of the reduced SWP pumping requirement will likely be during the off-peak.
- Capacity Impacts - The CALSIM II results provide the information required to determine the maximum operating capacity at each hydropower plant in each month of the 81-year study period. Power plants were divided into two categories; fixed head plants and variable head plants. Fixed head plants consist of power plants associated with pondage reservoirs with comparably small water storage. Fixed head plants are assumed to have a constant maximum operating level. The SWP and CVP variable head plants consist of Shasta, Folsom, Gianelli (San Luis Reservoir) and Hyatt (Oroville Reservoir). The maximum operating capacity for variable head plants is tied to the monthly storage levels in the reservoirs above these plants. The maximum monthly operating capacity at variable head plants may be reduced under the WQO due to the reduction in the average reservoir storage.

  There is a second step in determining capacity impacts. The capacity must be able to operate for a given number of hours each month in order to be counted as firm or dependable capacity. This aspect of capacity impacts is discussed further in the Resource Adequacy Assessment Modeling section. Thus, the WQO may reduce the dependable capacity at both the fixed head and variable head hydropower plants.

  Any lost dependable capacity will need to be replaced by new generation plants. While the SFCWA has not evaluated the likely options for supplying the lost capacity, the SWRCB needs to establish the environmental impacts due to replacement of the Resource Adequacy capacity lost under alternative WQOs.

5.2.2 Replacement Water Power Requirements Assessment

Approach and Background New power uses will be associated with supplying the makeup water needed to replace the reduced water deliveries to the SWP and CVP contractors. Alternative supply options, such as groundwater pumping and desalinization, will likely shift the power loads from the current SWP and CVP pumping locations closer to the water users. The shift in water supply sources will have a number of potential impacts on power system and power grid operations; including, changes in California and WECC generation resource dispatch, altered flows on the California and WECC transmission grid and shifts in the sources and availability of ancillary services. Assumptions regarding the location and characteristics of the water replacement options are required to ensure a complete analysis of the power system and transmission grid impacts.

A detailed assessment, and the selection of options, for makeup water is beyond the scope of the SFCWA's power assessment. However, the SFCWA has developed tools to analyze the power impacts once assumptions have been made regarding makeup water.

The power requirements of any new makeup water sources could increase the need for new capacity and capacity reserves. While the SFCWA has not evaluated the likely options for supplying any new capacity requirements, the SWRCB should evaluate the environmental impacts due to adding additional capacity requirements within the California power system.

5.2.3 Electric System Operational Dispatch Modeling for CO2 and Energy Cost Impacts

Approach and Background Any major changes to the power production at California's hydroelectric generation facilities can materially alter the operations of the entire generation system and transmission network serving California's electric load. Fortunately, there are a large number of available models capable of simulating hourly integrated power system dispatch. Typically, the models simulate the operation of the entire WECC power system, since California's power operation is tightly integrated with its neighboring utilities. The models simulate hourly integrated generation dispatch while accounting for unit commitment and transmission loading constraints, energy pricing, variable renewable generation output, emission limitations and many other operational factors.

The SFCWA recommends that the energy system operational dispatch modeling be divided into two tasks; CO2 and energy cost impact studies, and ancillary services impacts studies. This will allow the CAISO to evaluate the relationship between the integration of renewable generation and the need for ancillary services and determining the ability of California's generation fleet to meet future ancillary services needs.

A related assessment would be the impact on CO_2 emissions and electric energy costs. System operational dispatch models are typically applied for simulating a single year's operation. The first step is to establish a future reference year, such as 2020, in order to establish a load and generation system configuration. A second step is a representative year from the CALSIM II results to describe the SWP and CVP operational characteristics. Power requirements would be added to the WQO case, based on assumptions regarding the amount and means for replacing reduced SWP and CVP water supplies.

For the SWP and CVP, hourly dispatch simulation models usually require a further breakdown of the monthly generation and pumping loads into weekly baseload and dispatchable or on-peak and off-peak quantities. This information can be developed by further parsing the CALSIM II output for a representative year. Power requirements for replacement water can then be developed. For example, with desalinization plants replacing the water supply, the desalinization plants would be assumed to operate in a baseloaded mode, but at different levels each month. Such an approach can provide estimates of the effects on CO_2 emissions and customer costs.

5.2.4 Electric System Operational Dispatch Modeling for Ancillary Services Impacts

Approach and Background The CAISO has determined that the integration of renewable generation at a 33 percent level will challenge the operational flexibility of California's generation fleet. The SWP and CVP systems currently help support the ancillary services needs by supplying both generation and load side products.

From a day-to-day operational perspective, the principal ancillary services are regulation up, regulation down, spinning reserves and non-spinning reserves. The ability to schedule and dispatch both its generation and pumping load allows the SWP additional flexibility for providing all of these ancillary services. In fact, the SWP provides about one-sixth of the CAISO's non-spinning reserve needs based primarily on its ability to curtail pumping loads.

The CAISO has performed detailed assessments regarding the ability of the California's generation fleet to provide the ancillary services necessary to integrate renewable generation resources at the 33 percent level by 2020. The flexibility in scheduling and dispatching the SWP generation and pumping loads is a valuable asset for assisting the CAISO in providing the regulation necessary to dampen the variable output of new renewable resource additions. The CAISO recognizes that integrating additional variable output resources into the existing generation fleet will be a challenge. The CAISO has two initiatives currently underway to help ensure it has sufficient flexible capacity to reliably operate the grid as additional variable output resources come on line to meet the state's 33 percent renewable target; specifically, Flexible Capacity Procurement and Flexible Ramping Product.

The CAISO possesses the expertise and tools to assess how any changes to the availability of California's hydroelectric generation and dispatchable pumping loads will interplay with the ability of California's generation fleet to successfully integrate renewable generation. The SFCWA will supply information on SWP and CVP generation and pumping loads to the CAISO in order to allow the CAISO to formulate a study approach. Specifically, the data will consist of monthly on-peak and off-peak generation and pumping loads at each of the SWP and CVP facilities for a selected year with representative hydrologic conditions. Monthly energy requirements based on assumptions for the sources of makeup water will also be provided.

The loss or reduction of hydropower generation and dispatchable pumping loads will place a heavier burden on other resources to supply the ancillary services required for integrating new renewable generation sources. New and additional gas fired plants may be required to fill the gap. The reliance on gas fired generation to replace the sources lost due to the WQO could result in additional CO2 emissions and work against the emission reduction goals of AB 32. The SWRCB should work with the CAISO in order to address the environmental impacts of replacing the lost generation and pump load flexibility with alternative power sources.

5.2.5 Resource Adequacy Assessment and Modeling

Approach and Background The CPUC sets criteria intended to ensure utilities maintain sufficient capacity reserve margins. The CPUC's year-ahead requirement obligates utilities to secure capacity reserves equal to 15% to 17% of the utilities' peak demand. The CPUC year-ahead capacity rating procedure is incorporated into the CAISO's tariff. The SWRCB should determine the impact the WQO has on the firm or dependable capacity available from the SWP and CVP.

The CPUC's RAR also establishes criteria for counting hydropower capacity. The CPUC's counting rules for hydropower facilities other than run-of-the-river plants are:

- Hydrologic conditions for the 1-in-5 dry year.
- The requirement to operate at full output for at least 30 hours in May, 40 hours in June and July, 60 hours in August and 40 hours in September. The requirement is 1 hour per month in the remaining months.
- Ability to operate for a minimum of 4 hours per day on 3 consecutive days.

As explained earlier, the maximum monthly operating capacity was determined for each hydroelectric generation facility over the 81-year study period. Fixed head plants can be assumed to have a constant maximum operating level, while the maximum monthly operating capacity at variable head plants is tied to the monthly storage level in the reservoir above the plant. The SWP and CVP variable head plants are Shasta, Folsom, Gianelli (San Luis Reservoir) and Hyatt (Oroville Reservoir).

In order to develop a complete picture of WQO capacity impacts, the monthly firm/dependable capacity should be determined at each hydropower plant over the 81-year study period by applying the hours per month counting rules. With sufficient energy available to support the operating hours the firm/dependable capacity at a plant is set at the maximum monthly operating capacity. In a situation where the monthly energy cannot support operation for the required hours, the firm/dependable capacity for the plant is set by reducing the maximum monthly operating capacity based on a ratio of the available operating hours divided by the required operating hours for the month. This step in the rating process is based on operating the plant for the required number of hours, but at a reduced capacity level. The firm/dependable capacity rating at the 1-in-5 dry year is easily extracted from the rating over the 81 study years.

The WQO could reduce both the maximum monthly operating capacity and firm/dependable capacity of hydroelectric generation in the SWP and CVP systems. That is because capacity is tied to two main factors. First, the level of storage within the long-term storage reservoirs at Shasta, Folsom, Gianelli and Oroville. Second, the amount of water delivered to the SWP and CVP contractors. Water delivered to SWP contractors beyond the south end of the Central Valley is pumped over hilly terrain. As the water descends the mountains, it is used to generate power at a number of "recovery" power plants. Coordination of this pumping results in an operation similar to the operation of a traditional pumped-storage hydro plant; water is pumped mainly in the off-peak with recovery generation occurring mainly during the on-peak hours. With water deliveries curtailed under the WQO, there could be extended periods when insufficient water is moved through the plants to support the operating hours required by the firm/dependable capacity counting rules.

The CPUC established the RAR and hydropower counting rules based on the results of a Loss-of-Load-Probability analysis. The loss of significant hydroelectric generation within California would trigger the need to revisit the LOLP analysis. Performing an LOLP of California's generation fleet is not within the capabilities of the SFCWA.

Any lost dependable capacity will need to be replaced by new generation plants. While the SFCWA has not evaluated the likely options for supplying the lost capacity, the SWRCB needs to establish the environmental impacts due to replacement of the Resource Adequacy capacity lost under alternative WQOs.

5.2.6 Transmission Grid Adequacy and Security Assessments

Approach and Background In earlier documents in this proceeding, the SWRCB established that "adequacy refers to the amount of capacity resource required to meet peak demand while security refers to the ability of the system to withstand contingencies or other system disturbances, such as the loss of a generating unit or transmission line."

Resource adequacy requires a distribution of generation and loads that complements the transmission grid operations. Too much demand and too little generation within specific geographic area will result in overloading of the transmission system. Additional transmission lines or strategically located generation is then required to remedy the potential for transmission line overloading. The WQO has the potential to impact all aspects of the grids adequacy and security needs.

First, the SWP and CVP generation and loads provide essential ancillary services that support grid operations. The WQO may impact the availability of these resources and could result in replacement generation and new loads associated with makeup water supplies being located in new areas of the power grid. Alternative supply options, such as groundwater pumping and desalinization, will likely shift the power loads from the SWP and CVP pumping locations closer to the water users. In addition, within the SWP, reduced water delivery to southern California results in less generation at power plants installed to recover energy as water is delivered over the mountains at the end of the Central Valley. These shifts in the location of power use and power generation require assessments of the impacts on the adequacy and security of the transmission grid.

Second, the SWP generation and pumps participate in a number of Remedial Action Schemes (RAS). RAS are important elements in maintaining system security. RAS are used to make interconnected transmission grid operation more reliable. The use of RAS helps protect the transmission grid from experiencing conditions that may result in cascading system wide outages that lead to the curtailment of power supplies to electricity utility end-use customers. The SWP hydropower generation and pumping facilities support a number of RAS. Without this support, new transmission lines may be needed to support grid operations. These potential impacts need to be investigated and understood by the SWRCB.

The SFCWA has not attempted to develop tools for investigating the impacts the WQO will have on the adequacy and security of the transmission grid. However, the SWP's flexibility in scheduling generation and pumping loads, ability to instantaneously curtail generation and pumping loads, along with the unique location of many of the facilities within the transmission grid, allow the SWP to support a number of RAS. A reduction in hydropower generation and use of the SWP pumps could impact the SWP's participation in RAS. Without this support, additional new transmission lines may be required to securely deliver power within the transmission grid.

While the SFCWA recognizes that ensuring adequacy and security are important aspects of maintaining reliable transmission grid operations, adequacy and security assessments are beyond the capabilities of the SFCWA. Therefore, the SFCWA has been working with the CAISO to obtain their input on these important issues. The SWRCB should also interface with the CAISO to complete the necessary studies.

6. CONCLUSION AND RECOMMENDATION

The 1,750 MW of State Water Project hydropower resources are increasingly vital to the reliability of the California power grid and achieving the California objective of reducing greenhouse gases. The SWP hydropower resources are called on when grid emergencies threaten blackouts. The SWP hydropower does not emit greenhouse gases when producing power. More SWP-like flexible generation will be needed as greater amounts of wind and solar power come on line. The State Water Board is contemplating Sacramento-San Joaquin flow objectives as part of its update of the 2006 Delta Plan. The flow criteria could hamper the ability of the State of California to achieve its goal of reducing greenhouse gases if it alters the operation of the SWP hydropower resources.

The State Water Contractors are prepared to work with State Water Recourses Control Board, the California Independent System Operator, the California Public Utilities Commission, the California Energy Commission, the California Air Resources Board and other interested parties to align the update of the 2006 Delta Plan with California laws that require greenhouse gases be reduced.

FIGURE 6: HIERARCHICAL MODELING DECOMPOSITION - TEMPORAL-GEOGRAPHIC DECOMPOSITION

Third & Fourth Level Fed from Second Level Data

FIRST LEVEL - HIGH LEVEL COORDINATION

Modeling Goals and Objectives

SECOND LEVEL

SWP AND CVP SYSTEM OPERATIONS MODELING

- Geographic Range: SWP-CVP System Boundaries
- Time Step: Monthly
- Simulation Period: 81-year synthetic hydrologic record
- Output: Energy & capacity values by power & pumping plant
- Modeling Tool: CALSIM II with spreadsheet postprocessing

REPLACEMENT WATER ASSESSMENT

- Geographic Range: SWP-CVP System Boundaries
- Time Step: Monthly
- Output: Power load for supplying replacement water

THIRD LEVEL

ELECTRIC SYSTEM OPERATIONAL DISPATCH MODELING - CO2 EMISSIONS AND ENERGY COSTS

- Geographic Range: WECC
- Time Step: Hourly
- Simulation Period: 1 year
- Output: Hourly CO2 emissions and marginal energy costs
- Modeling Tool: PLEXOS

ELECTRIC SYSTEM OPERATIONAL DISPATCH MODELING - ANCILLARY SERVICES (CAISO)

- Output: Ability of California's generation fleet to meet system regulation requirements

POWER SYSTEM OPERATIONS

FOURTH LEVEL

RESOURCE ADEQUACY ASSESSMENT AND MODELING (CPUC)

- Geographic Range: CAISO Balancing Authority
- Output: Reserve margin at target LOLP

TRANSMISSION GRID ADEQUACY/SECURITY ASSESSMENT

- Geographic Range: CAISO Balancing Authority
- Output: Capability of grid to supply load requirements and withstand major transmission/generation outages

RELIABILITY