Water being delivered to recharge basin. Photo: OCWD

Prado Dam

FORECAST INFORMED RESERVOIR OPERATIONS PRELIMINARY VIABILITY ASSESSMENT

August 2021

Executive Summary

This Preliminary Viability Assessment (PVA) was initiated by the Prado Dam Forecast Informed Reservoir Operations (FIRO) multi-agency Steering Committee in 2017 and follows the workplan completed in 2019. The purpose of the PVA is to provide an initial evaluation of the viability of FIRO as a strategy for improving water supply reliability for Orange County Water District (OCWD), while not impairing and possibly enhancing environmental conditions and flood risk management. Constructed and operated by the U.S. Army Corps of Engineers (USACE), Prado Dam's primary purpose is flood risk management. Stormwater capture for downstream groundwater recharge into OCWD's water supply is a secondary purpose. The PVA demonstrated that FIRO is viable, and it lays the groundwork for a Final Viability Assessment (FVA) and recommendations for updating USACE's Water Control Manual (WCM), which governs operation of Prado Dam.

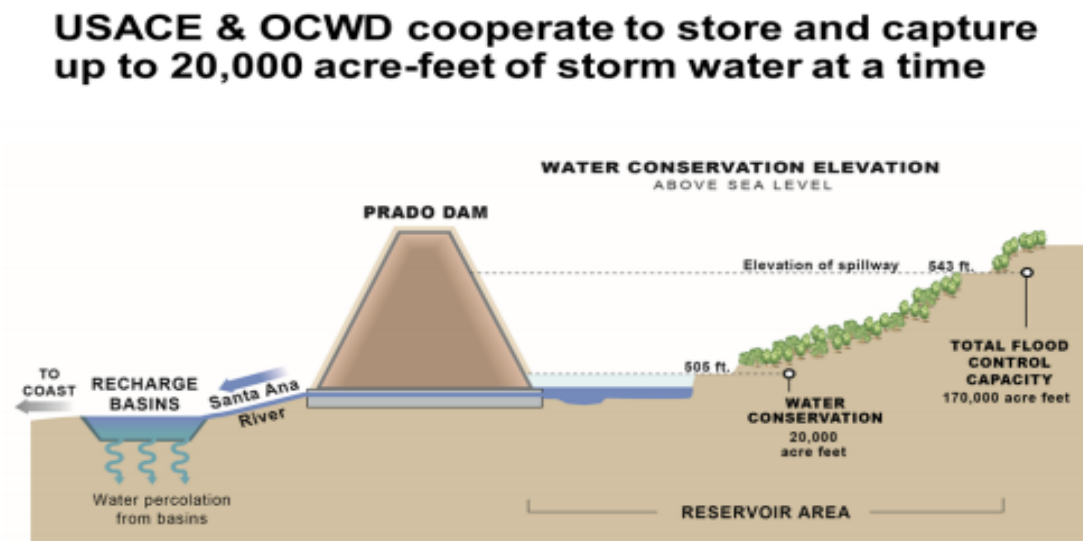
Project Overview

OCWD has been capturing and recharging stormwater in the Santa Ana River channel since 1936. Since Prado Dam was constructed by USACE in 1941, OCWD and USACE have worked together to maximize the capture of stormwater behind the dam. Figure 1 shows the elevations and volumes of the current conservation pool. USACE releases water temporarily captured at Prado Dam and OCWD recharges the water into the ground ten miles downstream. The water conservation pool has been operated at elevations up to 505 feet based on a five-year major deviation approved by USACE in March 2018. The Prado Basin Ecosystem Restoration and Water Conservation Feasibility Study

Read the full Preliminary Viability Assessment at https://escholarship.org/uc/item/3b63q04n.

Prado Dam, Photo: USACE

Figure 1. *Schematic representation of Prado Dam water conservation elevation for stormwater storage and capture.*



(Feasibility Study) was approved in 2021 to make the 505-foot conservation pool a permanent feature within the Interim WCM (IWCM). Note that all cited elevations in this report are in units of feet and the datum of NGVD 1929.

Over the past 25 years, OCWD has recharged an average of 55,000 acre-feet (ac-ft) per year of stormwater with an annual maximum of 117,000 ac-ft in 1995. For planning purposes, OCWD assumes that 40,000 ac-ft of stormwater will be captured and recharged in an average year, which is enough water for 320,000 people annually. Local stormwater capture is important because it lessens demands on imported water supplies, which are more costly and increasingly unreliable due to the fragile Sacramento Delta, oversubscribed Colorado River, and changes in weather patterns.

The Prado Dam WCM, which governs operational decision making, does not explicitly leverage weather and water forecasts. Nonetheless, USACE staff consider precipitation and streamflow forecasts in their decision process while adhering to WCM guidelines and procedures. This PVA assesses the potential application of FIRO at Prado Dam to capture larger volumes of stormwater in the future. This is an opportune time to consider FIRO. With improvements underway to raise the Prado Dam spillway crest and upgrade downstream infrastructure (Santa Ana River Mainstem Project), a very high level of flood risk management will be achieved.

Atmospheric Rivers and FIRO

Atmospheric rivers (ARs) are the major determinant of flooding and a lack of ARs leads to drought conditions in California. ARs are responsible for more than half of all beneficial precipitation and over 90 percent of flood damages. Long, narrow bands of concentrated moisture, atmospheric rivers stretch thousands of miles across the Pacific Ocean carrying up to 20 times as much water as the Mississippi River. When ARs make landfall, they can release a staggering amount of rain and snow (see example of landfalling AR in Figure 2. The absence of ARs can lead to drought. For this reason, studies of AR behavior and improved AR forecasts are essential to inform and implement FIRO.

FIRO is an innovative research and operations partnership that uses modern weather forecasting, runoff modeling, and watershed monitoring to help water managers selectively retain or release water from reservoirs in a manner that reflects current and forecasted conditions. FIRO's application of modern science and technology can optimize the use of limited water resources and represents a cost-effective option to adapt to extreme weather events and precipitation variability unique to the U.S. West Coast. The ultimate goal of FIRO is to inform the update of USACE's WCM for Prado Dam to allow FIRO flexibility, as demonstrated by rigorous analyses, and documented in the next step of this process—the FVA. Central to FIRO is an ongoing commitment to research that provides for continual improvement in operations as forecast skill allows.

What is FIRO?

FIRO is a flexible water management strategy that uses data from watershed monitoring and modern weather and hydrologic forecasting to help water managers selectively retain or release water from reservoirs in a manner that reflects current and forecasted conditions. FIRO uses emerging science and technology to optimize limited resources and adapt to changing climate conditions. Scientific research on the intensity, duration, and location of ARs is central to FIRO.

To explore FIRO as a viable approach to increase the efficiency of stormwater capture at Prado Dam, OCWD co-chairs a Steering Committee with the Center for Western Weather and Water Extremes (CW3E) at UC San Diego's Scripps Institution of Oceanography. Steering Committee members include representatives from USACE, the United States Fish and Wildlife Service, the National Weather Service's California Nevada River Forecast Center, the California Department of Water Resources, and Orange County Public Works. Using the collaborative Steering Committee process, FIRO has proven viable on Lake Mendocino in Northern California and is currently being assessed in the Yuba and Feather River watersheds, at New Bullards Bar Reservoir and Lake Oroville.

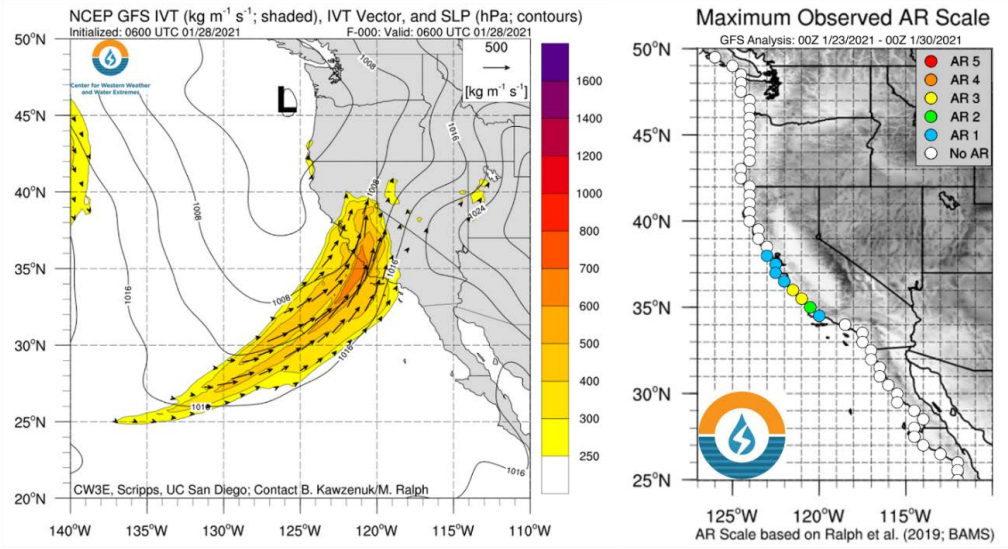


Figure 2. *A landfalling atmospheric river (AR) generated 15–20% of Los Angeles Basin precipitation on January 29, 2021.*

Prado Dam FIRO Steering Committee

- Greg Woodside, *Orange County Water District* (Co-chair)
- F. Martin Ralph, *CW3E* (Co-chair)
- Jay Jasperse, *Sonoma Water*
- Michael Anderson, *California Department of Water Resources*
- Cary Talbot, *USACE Engineer Research and Development Center*
- Alan Haynes, *California Nevada River Forecast Center*
- Rene Vermeeren, *USACE Los Angeles District*
- Jon Sweeten, *USACE Los Angeles District*
- James Tyler, *Orange County Public Works*
- Karin Cleary-Rose, *U.S. Fish and Wildlife Service*

Results of the PVA

This Prado Dam PVA evaluated current forecasting technology and incorporated research to understand and therefore better predict precipitation processes in the Santa Ana River Watershed. The Ensemble Forecast Operations (EFO) model, which was used to assess FIRO at Lake Mendocino, was successfully generalized and applied to Prado Dam for the simulation of operations needed to assess strategies for implementation in the updated WCM. The EFO model operates without a traditional guide curve and uses the 15-day ensemble streamflow forecasts to identify required flood releases. The Steering Committee's preliminary assessment of FIRO was based on five operational strategies, described in Table 1 below.

The EFO model was successful in simulating the reservoir operations strategies listed in Table 1 over the hindcast period of record (1985-2011) and for 3 large events scaled to 100- and 200-year return frequency levels. Hindcast period of record simulations for all alternatives remained well below the spillway crest and higher buffer pools led to greater groundwater recharge, averaging nearly 7,000 ac-ft per year. The scaled events (100- and 200-year return frequency), which generated spillway flow for all FIRO alternatives (ones that use forecasts), exhibited slightly lower spill rates than the baseline. The upper limit of the buffer pool is largely a function of community and environmental tolerance for more frequent flood pool inundation than operational constraints of the dam. Land and easement purchases coordinated by USACE and Orange County Public Works are required for the spillway raise and will be critical to easing impacts of more frequent inundation. At the highest pool elevation that was assessed (512 feet), the use of forecasts is needed to avoid increased flood risk.

Prado Dam, Photo: USACE

The PVA also concluded that, while precipitation gages are adequate to support FIRO, improvements are needed at two stream gage locations to support operations and model calibration and development. In addition, the hydrologic engineering management plan (HEMP) initial assessment was found to provide a consistent framework within which Water Control Plan (WCP) alternatives can be simulated and compared. Identified refinements will improve the quality of the FVA.

Table 1. *Alternative WCP strategies assessed for the Prado Dam FIRO PVA.*

ID	Alternative Strategy	Description
1	Unrestricted: 505 feet (Baseline)	Buffer pool allowed to extend up to 505 feet without a seasonal restriction. Releases when pool is less than or equal to 505 feet at maximum recharge rate. Releases above 505 feet are at the maximum scheduled rate. No forecasts were used.
2	Ensemble Forecast Operations (EFO) to 508-foot pool	Buffer pool allowed to extend up to 508 feet. Uses ensemble inflow forecast to determine release required to mitigate risk of exceeding spillway crest.*
3	EFO: 512 feet	Buffer pool allowed to extend up to 512 feet. Uses ensemble inflow forecast to determine release required to mitigate risk of exceeding spillway crest.*
4	No Forecast: 512 feet	Buffer pool allowed to extend up to 512 feet. Releases when pool is less than or equal to 512 feet at maximum recharge rate. Releases above 512 feet are at the maximum scheduled rate. No forecasts were used.
5	Perfect Forecast: 512 feet	Buffer pool allowed to extend up to 512 feet. Uses observed inflows as forecasts (perfect forecasts) to determine releases that avoid exceeding spillway crest.*

** Spillway crest of 543' was evaluated for POR simulations, and spillway crests 543' and 563' were evaluated for 100-year and 200-year scaled hydrologic events.*

Note: The buffer pool is a USACE Los Angeles District term used to describe an acceptable temporary encroachment into the flood pool for water conservation purposes.

High-level PVA findings that support FIRO viability include the following:

- Evaluation of FIRO WCP alternatives suggests that higher buffer pools can enhance groundwater recharge, averaging nearly 7,000 ac-ft per year, while not impacting and perhaps enhancing flood risk management outcomes.
- Much progress has been made to improve AR forecasts and AR tools. Evaluation of the AR landfall tool for Prado Dam location showed full internal agreement at three-day lead times and a high degree of reliability at greater than five days lead time, which is sufficient for dam operators to make timely releases.
- Studies of least Bell's vireo (a federally listed endangered species of bird that nests in the water conservation space behind the dam) indicate tolerance to inundation, but further studies are needed to assess prolonged inundation at higher elevations. An adaptive management approach with planned mitigation measures will be pursued.

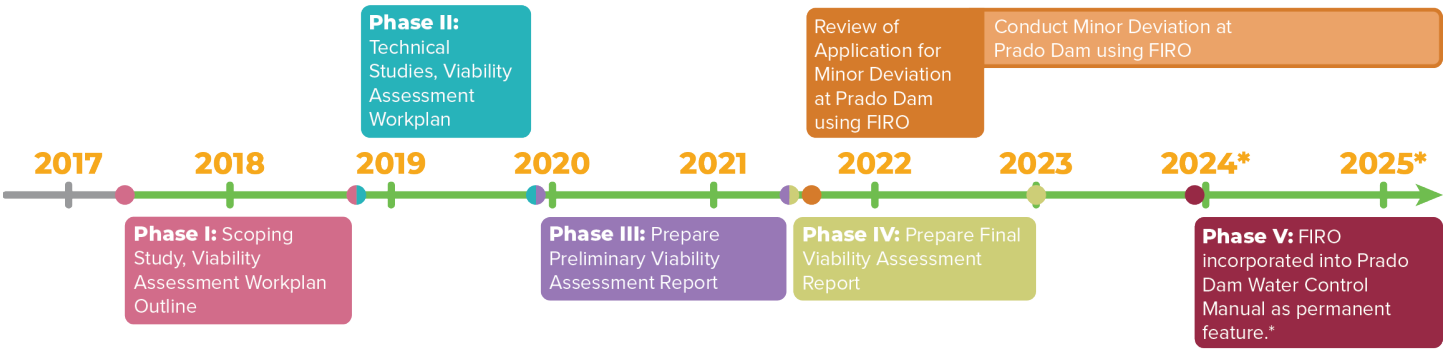


Figure 3. *Prado Dam FIRO project and WCM update timeline.*

Prado Dam making flood releases, December 2010: Photo: USACE

Recommendations and Roadmap for the FVA

Based on these findings, the FIRO Steering Committee recommends continued research and monitoring to further improve potential FIRO outcomes; coordination with and support of the USACE WCM update process; development of operational decision support tools designed specifically for FIRO implementation; refinement of the HEMP for evaluating the WCP alternatives; and interim operational testing through USACE's deviation process. In particular, the Steering Committee recommends submitting a multi-year deviation beginning in Water Year 2023 (October 2022) to gain operational experience with a FIRO maximum buffer pool greater than 505 feet.

Figure 3 provides the timeline for the FVA and WCM update.

Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

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