WRITTEN TESTIMONY OF

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SUBCOMMITTEE ON WATER RESOURCES AND ENVIRONMENT

WATER RESOURCES DEVELOPMENT ACTS: STATUS OF IMPLEMENTATION AND ASSESSING FUTURE NEEDS

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Introduction

Chairman Napolitano, Ranking Member Westerman, and members of the Subcommittee, thank you for the opportunity to be here today to discuss water infrastructure policies and implementation of the Water Resources Development Act. My name is Marty Ralph and I am the Director of the Center for Western Weather and Water Extremes (CW3E) at University of California San Diego's Scripps Institution of Oceanography (Scripps).

I have worked as a weather and water scientist focused on understanding the physical processes that create extremes in precipitation ranging from flood to drought, and on advancing associated observations, predictions, water management and flood control applications and decision support tools. After 21 years of experience as a scientist, manager and program manager in NOAA, performing, leading and funding research aimed at creating practical impacts on weather prediction skill and user-decision making, I moved in 2013 to the University of California San Diego/Scripps Institution of Oceanography to create what is now the "Center for Western Weather and Water Extremes." I have published over 120 peer-reviewed scientific articles, and have developed programs on new science and technology and their application to solving practical problems. I have led many aspects of research on atmospheric rivers over the last 15 years, and provide input to water managers, and policy makers related to western weather and water extremes.

A key focus of my work these last several years has been to explore the potential for use of Forecast-Informed Reservoir Operations (FIRO) based on current and future atmospheric river prediction skill. I work closely with water managers, including with the US Army Corps of Engineers and related experts. A key role is as Co-Chair of the cross-disciplinary and interagency Steering Committee for the first FIRO project, at Lake Mendocino, and now also as Co-Chair of similar committees for two other reservoirs. Recognition: elected Fellow of the American Meteorological Society, awards from the Department of Commerce such as for "For comprehensive flood mitigation efforts in response to a severely weakened Howard Hansen Dam project with the potential of catastrophic flooding," awards from NOAA and elsewhere. I have a

B. S. in Meteorology from University of Arizona, and a Ph.D. in Atmospheric Sciences from UCLA.

This testimony is organized into the following brief sections: 1) What is FIRO? What role do ARs play? What have we learned so far, primarily from the Lake Mendocino experience? 2) What is happening now and what is on the near horizon for FIRO in terms of weather, hydrology, and associated science? 3) Perspectives on the need for improved predictive skill on time scales of reservoir and downstream characteristics. Appendix) Regional water agency statements on the impacts of atmospherics, and FIRO.

1) What is Forecast-Informed Reservoir Operations (FIRO), what role do atmospheric rivers play and what have we learned thus far?

A group of scientists and engineers from local, state and federal agencies, including representatives from the U.S. Army Corps of Engineers, has been developing a proof-of-concept demonstration project for Forecast Informed Reservoir Operations (FIRO) since 2014. Last year, the group, the Lake Mendocino FIRO Steering Committee, filed a request with the Corps to allow a deviation from its established flood control operating rules. The deviation request was supported by a Preliminary Viability Assessment, which contained detailed modeling, analysis and scientific research. The assessment demonstrated that FIRO can provide water managers the information they need, with adequate lead time, to selectively retain or release water from reservoirs. The assessment identified atmospheric river (AR) type storms as the primary storm type that can cause flooding and provides up to 50% of the precipitation annually. It showed that there is enough skill in AR forecasting that it could enable FIRO, and that improved AR predictions could increase benefits. Based on the research findings and USACE review of the major deviation request, the request was approved in November 2018 by the US Army Corps of Engineers' South Pacific Division.

The major deviation allowed additional water, up to 10% of flood storage capacity and at the discretion of the operations staff, to be stored in Lake Mendocino during this winter's rainy season to improve water supply reliability and environmental conditions in the Russian River, while continuing to not only ensure but also improve flood management capacity of the reservoir. The decision would allow the Corps to use modern weather prediction technology to operate the reservoir with more flexibility to store more water when no major storms are forecasted and order releases ahead of major storms when forecasts indicate the possibility of significant reservoir inflows.

Per the major deviation the reservoir was operated during late 2018 to early 2019 following the FIRO method. Based on the streamflow forecasts from NWS, on new AR-forecast tools developed by FIRO, and on a new decision support tool, also developed through FIRO, the reservoir held over 10,000 acre-feet of extra water through much of the winter. A clear demonstration of the FIRO concept in the real world.

"The ability to leverage newer technology and knowledge base as it pertains to weather forecast enhances our ability to safely deliver the multiple missions at Lake Mendocino," said Nick Malasavage, chief of Operations and Readiness Division for the U.S. Army Corps of Engineers

San Francisco District. "In particular, the steps we are now taking to further develop and incrementally implement the FIRO concept adds an additional tool to maintain our primary responsibilities for flood risk management."

Under the approved request, a maximum of 3.8 billion gallons (11,650 acre-feet) of additional water could be stored in the reservoir between November 1 and February 28, which is enough water to supply approximately 97,000 people for a year.

Lake Mendocino, located near the city of Ukiah, is operated jointly by the Corps and Sonoma Water. The Corps manages the flood control operations at the reservoir, or the water in what is referred to as the "flood pool." Sonoma Water manages the water stored expressly for water supply, known as the "conservation pool" and is also responsible for maintaining minimum in-stream flows in the Russian River below Lake Mendocino.

Studies show that about 50 percent of the rainfall and 80 percent of the floods in the Russian River watershed are due to atmospheric rivers – long narrow bands of warm, moisture-laden air that carry huge amounts of water vapor propelled by high winds.

"We know that a majority of our rain each year comes from these atmospheric rivers," said Sonoma Water Chief Engineer and co-chair of the steering committee Jay Jasperse. "Because we now have the technology to better predict the timing and intensity of these storms, it allows us the opportunity to manage our water supply more efficiently and maintain flood management capacity in Lake Mendocino."

A dramatic illustration of the potential benefits of FIRO occurred in December of 2012 when a large atmospheric river storm filled the available water supply space in Lake Mendocino and filled about 25,000 acre feet of the flood pool that is normally kept empty to take the crest off of floods. Operating under the Corps procedures, which dictate that water in the flood pool be released as soon as possible to make room for the next storm, dam operators followed the operations rules and released the water from the flood pool, even though no storms or flooding was forecasted in the near future. But no additional storms occurred, and the next winter was the beginning of a severe and extended drought. If improved forecasts had been available and used in 2012 and atmospheric river storms were not predicted to occur, and operation rules were more flexible, the water that had been released could have been put to beneficial uses just as the region entered a drought.

The FIRO effort that has led to this approval by the Corps is the result of a highly collaborative effort between engineers, physical scientists, biologists and forecasters. Sonoma Water and the Corps are to be commended for their leadership and innovation on FIRO at Lake Mendocino, which is setting the stage for further exploration of this promising approach.

"This collaboration will have far-reaching benefits for the resiliency and reliability of our water supply system in the face of a changing climate," said James Gore, Chair of Sonoma Water's Board of Directors. "Improved forecasting provides us with the ability to store more water and still maintain the flood protection benefits of our reservoirs. This is another great example of the benefits of a multi-agency partnership that addresses our most challenging issues."

The success thus far of the FIRO effort is due in large part to the formation of the FIRO Steering Committee and the development of its internal culture and processes which has successfully brought together groups with often competing missions and interests, but with a common vision that better water management operations are possible through cooperation and advances in science and engineering. Additionally, with the connection and interaction of FIRO Steering Committee members and staff from the respective organizations who are engaged in the research and operations aspects of water management, the FIRO effort has eliminated the gap that can exist between research that investigates and makes scientific advances and operators who need tools that are ready for application to real world problems with requisite reliability and assurance. Research, operations and regulatory perspectives have blended in every element of the FIRO effort to produce science to inform policy and bring about improved efficiency in water management for the simultaneous benefit of flood risk management, water supply and ecologic concerns

The Lake Mendocino FIRO Steering Committee consists of representatives from Sonoma Water (Sonoma County Water Agency), the Center for Western Weather and Water Extremes at Scripps Institution of Oceanography (Scripps), U.S. Army Corps of Engineers (Corps), National Oceanic and Atmospheric Administration (NOAA), U.S. Geologic Survey (USGS), U.S. Bureau of Reclamation and the California Department of Water Resources (DWR). The deviation request was submitted on behalf of steering committee members from Sonoma Water, Scripps, the Corps, NOAA and DWR.

2) What is happening now and what is on the near horizon for FIRO in terms of weather, hydrology, and associated science?

As an atmospheric scientist, I will restrict my comments here to primarily the implications for weather and streamflow conditions.

The first Full, Viability Assessment (FVA) for FIRO is underway at Lake Mendocino. A second Major Deviation Request to USACE to operate the dam following FIRO this coming winter is in preparation. Scientific developments are underway to improve AR forecasts for the region and to assess the potential benefits of such improvements. Better observations offshore and onshore are aiding in understanding how major storms behave and how their precipitation runs off into the rivers and reservoir. Computer models for weather and hydrology are being improved and a decision support tools using that information are being refined.

Two new FIRO efforts have begun on systems that are very different from Lake Mendocino, and will offer lessons that extend and complement what Mendocino is teaching us. These include meteorological and hydrological conditions that differ from coastal northern California. Fewer storms each year produce more of the precipitation. Mountains are tall enough to capture some precipitation as snow, which means a delay in the runoff until it melts, some of it days or even months after the storm. The watershed is highly urbanized, meaning more of the rain runs off into rivers than soaks into the ground. Although these differences with the Russian River may serve to complicate matters, the closer proximity of Prado Dam to the ocean, relative to Lake Mendocino, allows flow to move past flood-impact areas and reach the ocean faster. Thus, forecast requirements will likely be less stringent in terms of lead times. Maybe 1-2 days shorter. Sierra Nevada reservoirs involve additional hydrometeorological challenges. These watersheds are high enough that a large fraction of their area can receive snow. Yet AR storms are often warm and can melt the snow, thereby adding to flood potential. Thus, snow prediction, and snow-melt prediction are critical to FIRO in such areas, and require different meteorological and hydrological forecast skills and tools, and supporting science.

3) Perspectives on the need for improved predictive skill for atmospheric rivers to support improvements in water supply reliability, flood risk mitigation capacity and ecological benefits through FIRO

The viability of FIRO for a given reservoir hinges on adequate predictive skill for storms and streamflow conditions that represent challenges in operations for either flood control or water supply, or for ecological concerns. In much of the US West, this means atmospheric rivers. ARs are the storm type that provide much of the annual water supply in a relatively few storms each cool season, and that can create flooding when they are too strong and impact an already saturated and vulnerable watershed.

The FIRO viability assessment at Lake Mendocino has shown that AR forecasts with 3-5 days lead time are key. Analysis has shown that current forecast skill is adequate for initial FIRO testing, and that future enhancements in skill could yield even greater benefits. Current estimates are 20,000 AF net increase in water supply reliability in about half the water years, and that additional benefits could accrue based on better forecasts.

The requirements for better predictions for FIRO boil down to better AR landfall predictions and of forecasts of how much precipitation will be created by ARs and whether it falls as rain or snow (in the case of mountainous watersheds with high terrain). Tools and methods to improve upon these include:

- Better observations of ARs and their precursors over the ocean and coast
- Better weather forecast models tailored to AR and west-coast precipitation forecasting
- Better skill in precipitation and streamflow prediction
- Decision support tools tailored to each watershed's needs
- Better scientific understanding required to make the improvements listed above.

Although FIRO has been developed for the West Coast thus far, the potential exists for it to be useful elsewhere, such as the Great Plains or eastern U.S where ARs can also cause significant flooding events such as in Nashville in May 2010 and in the Washington, DC Area in July 2018. However, the skill of extreme precipitation forecasting is best in the West Coast because ARs have some valuable predictability already. In the Great Plains, large thunderstorms, or clusters of thunderstorms are key to flooding, and yet are much harder to predict than ARs. Tropical storms and hurricanes are another cause, and they may have some of the predictability needed, but how that predictability relates to the lead times that are required by FIRO in those regions remains to be assessed.