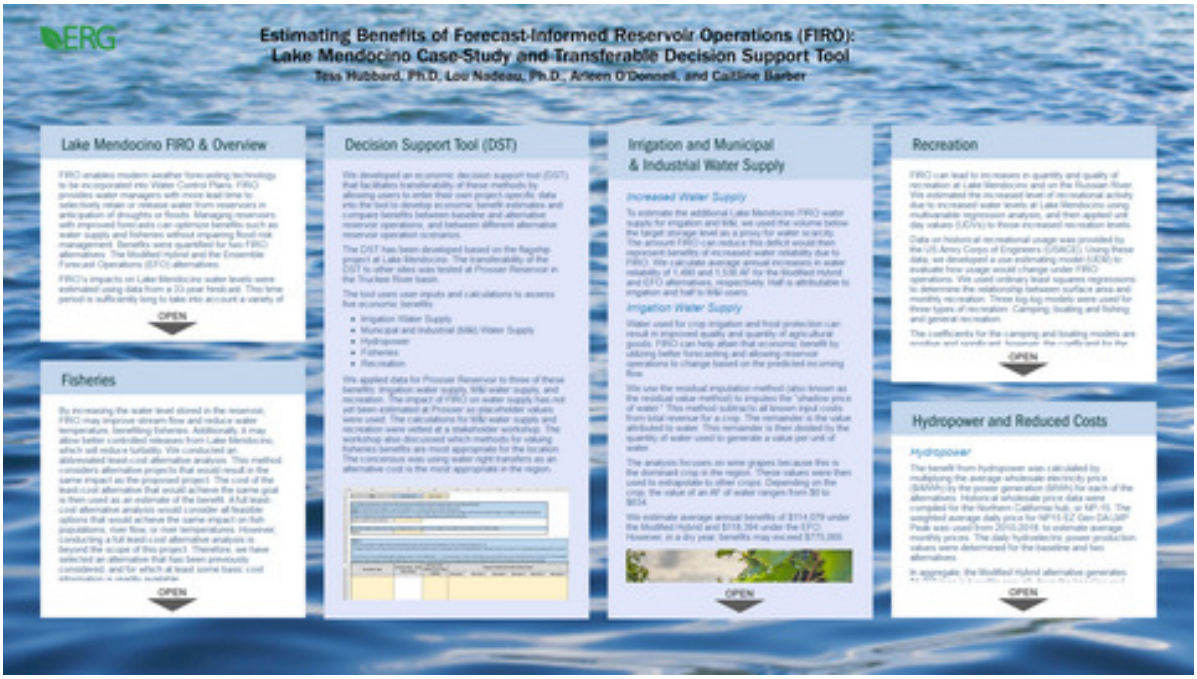
Estimating Benefits of Forecast-Informed Reservoir Operations (FIRO): Lake Mendocino Case-Study and Transferable Decision Support Tool



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LAKE MENDOCINO FIRO & OVERVIEW

FIRO enables modern weather forecasting technology to be incorporated into Water Control Plans. FIRO provides water managers with more lead time to selectively retain or release water from reservoirs in anticipation of droughts or floods. Managing reservoirs with improved forecasts can optimize benefits such as water supply and fisheries without impairing flood risk management. Benefits were quantified for two FIRO alternatives developed for Lake Mendocino.

- Ensemble Forecast Operations (EFO) - Operates without a traditional rule curve and uses the 15-day ensemble streamflow forecasts to identify required flood releases.
- Modified Hybrid EFO - Identical to Hybrid EFO but with a “corner-cutting” strategy that allows for greater storage to begin February 15 to aid with spring refill.

FIRO’s impacts on Lake Mendocino water levels were estimated using data from a 33-year hindcast. This time period is sufficiently long to take into account a variety of water year types and ensure that the benefits reflect fluctuations in water supply. For each benefit, average annual benefits, relative to the baseline, were calculated over these 33 years (and presented in 2019 dollars).

We quantified six benefits, and estimated that the **average annual marginal benefit over the baseline ranged from $9.4 million to $9.9 million** depending on the alternative.

Lake Mendocino: FIRO Estimated Benefits ($1,000s)

Benefit Type	Modified Hybrid	EFO
Total	$9,361.4	$9,872.2
Agriculture water supply [a]	$114.1	$118.4
M&I water supply	$2,674.6	$2,778.9
Hydropower [b]	-$1.9	-$43.8
Fisheries [c]	$5,726.4	$5,726.4
Recreation	$802.7	$1,239.2
Reduced OM&R costs	$45.5	$53.0

[a] This is expected to underestimate total benefits because it only reflects the average marginal value and not the value of increased reliability.
[b] The negative annual benefit is due to a current rule in the water control manual that requires hydropower production to stop when reservoir elevations exceed 755 feet. If this rule were to change, we would expect FIRO alternatives to provide a positive benefit.
[c] Estimate using the cost to raise the height of Coyote Valley Dam as a proxy for benefits. The alternative method using water transaction prices results in larger values.

FISHERIES

By increasing the water level of the reservoir, FIRO may improve stream flow and reduce water temperature. To estimate these benefits, we conducted an abbreviated least-cost alternative analysis that considered alternative projects that would result in the same impact as FIRO. The cost of the least-cost alternative that would achieve the same goal was then used as an estimate of the benefit. In consultation with fisheries experts, and given time and scope limitations, we selected an alternative that was previously considered for which cost information was available.

Temperature and flow are the key salmonid metrics that can be correlated with FIRO operations and we selected raising the elevation of the dam as the option that could achieve similar temperature and flow benefits to salmonid populations below Lake Mendocino. Raising the dam has been studied in the past, but was never built, primarily due to cost.

Based on guidance from Sonoma Water, we assumed that raising the dam six feet would result in roughly equivalent flow and temperature benefits for fisheries as the FIRO alternatives. To estimate that cost, we use an existing estimated cost to raise the dam by 36 feet and applied certain assumptions to approximate the cost for a 6-foot increase. We estimate a cost of $154.6 million. If the dam is expected to last 50 years, the annualized value, discounted at 2.75 percent, would be $5.73 million.

DECISION SUPPORT TOOL (DST)

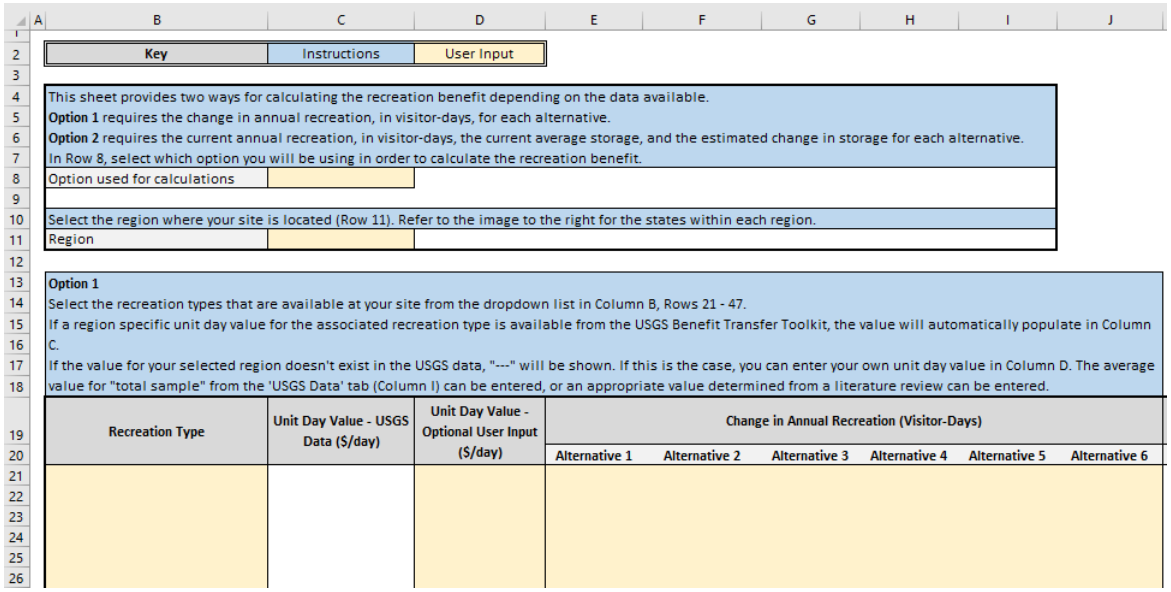
We developed an economic decision support tool (DST) that facilitates transferability of these methods by allowing users to enter their own project-specific data into the tool to develop economic benefit estimates and compare benefits between baseline and alternative reservoir operations, and between different alternative reservoir operation scenarios.

The DST has been developed based on the FIRO project at Lake Mendocino. The transferability of the DST to other sites was tested at Prosser Reservoir in the Truckee River basin.

The tool uses user-inputs and calculations to assess five economic benefits:

- Irrigation Water Supply
- Municipal and Industrial (M&I) Water Supply
- Hydropower
- Fisheries
- Recreation

We applied data for Prosser Reservoir to three of these benefits: Irrigation water supply, M&I water supply, and recreation. The calculations for M&I water supply and recreation were vetted at a stakeholder workshop. The workshop also discussed which methods for valuing fisheries benefits are most appropriate for the location. The consensus was using water right transfers as an alternative cost is the most appropriate in the region.



Key	Instructions	User Input

This sheet provides two ways for calculating the recreation benefit depending on the data available.
Option 1 requires the change in annual recreation, in visitor-days, for each alternative.
Option 2 requires the current annual recreation, in visitor-days, the current average storage, and the estimated change in storage for each alternative.
In Row 8, select which option you will be using in order to calculate the recreation benefit.

Option used for calculations	

Select the region where your site is located (Row 11). Refer to the image to the right for the states within each region.

Region	

Option 1
Select the recreation types that are available at your site from the dropdown list in Column B, Rows 21 - 47.
If a region specific unit day value for the associated recreation type is available from the USGS Benefit Transfer Toolkit, the value will automatically populate in Column C.
If the value for your selected region doesn't exist in the USGS data, "---" will be shown. If this is the case, you can enter your own unit day value in Column D. The average value for "total sample" from the 'USGS Data' tab (Column I) can be entered, or an appropriate value determined from a literature review can be entered.

Recreation Type	Unit Day Value - USGS Data ($/day)	Unit Day Value - Optional User Input ($/day)	Change in Annual Recreation (Visitor-Days)					
			Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6

(sample screenshot for the recreation DST tab)

IRRIGATION AND MUNICIPAL & INDUSTRIAL WATER SUPPLY

To estimate the additional Lake Mendocino FIRO water supply for irrigation and M&I, we used the volume below the target storage level as a proxy for water scarcity. The amount FIRO can reduce this deficit would then represent benefits of increased water reliability. We calculate average annual increases in water reliability of 1,480 and 1,536 AF for the Modified Hybrid and EFO alternatives, respectively. Half is attributable to irrigation and half to M&I users.

Irrigation Water Supply

Water used for crop irrigation and frost protection can result in improved quality and quantity of agricultural goods. FIRO can help attain that economic benefit with better forecasting that results in more reliable water availability.

We use the residual imputation method (also known as the residual value method) to imputes the “shadow price of water.” This method subtracts all known input costs from total revenue for a crop. The remainder is the value attributed to water. This remainder is then divided by the quantity of water used to generate a value per unit of water.

The analysis focuses on wine grapes because this is the dominant crop in the region. These values were then used to extrapolate to other crops. Depending on the crop, the value of an AF of water ranges from $0 to $634.

We estimate average annual benefits of $114,079 under the Modified Hybrid and $118,394 under the EFO. However, in a dry year, benefits may exceed $775,000.

M&I Water Supply

FIRO operations at Lake Mendocino may increase reliability of water supply to municipal, commercial, and industrial users. We use a revealed preference approach by which we estimate the demand curve for M&I water and use the price elasticity of demand to quantify changes in consumer surplus due to an increase in water reliability. The price elasticity of demand is a measure of the change in the quantity of a good or service demanded based on a change in the price of that good or service, in this case water. The elasticity is then used to generate a demand curve and calculate how price may change due to a change in water reliability. The old and new prices and quantities are then used to calculate change in consumer surplus.

The increase in consumer surplus was estimated to be $2.7 million under the Modified Hybrid and $2.8 million under the EFO. We also conducted a sensitivity analysis assuming no change in price because of the increase in water reliability. This results in an annual benefit of $1.04 million under the Modified Hybrid and $1.08 under the EFO.

RECREATION

FIRO can lead to increases in quantity and quality of recreation at Lake Mendocino. We estimated the increased level of recreational activity due to increased water levels at Lake Mendocino using multivariable regression analysis, and then applied unit day values (UDVs) to those increased recreation levels.

Data on historical recreational usage was provided by the US Amry Corps of Engineers (USACE). Using these data, we developed a use estimating model (UEM) to evaluate how usage would change under FIRO operations. We used ordinary least squares regressions to determine the relationship between surface area and monthly recreation. Three log-log models were used for three types of recreation: Camping; boating and fishing; and general recreation.

Next, a dollar value needs to be placed on the increased recreational usage. We used UDVs from Bowker et al. (2009).[1] The UDVs range from $23 to $92 depending on the activity (once adjusting to 2019 dollars). The value of increased recreation is then calculated as the product of the increased levels of recreation and UDVs. Benefits under the Modified Hybrid alternative total $802,700 per year and benefits under the EFO alternative total $1.2 million per year.

[1] Bowker, J.M., Starbuck, C.M., English, D.B.K., Bergstrom, J.C., Rosenburger, R.S., McCollum, D.C. (2009). Estimating the Net Economic Value of National Forest Recreation: An Application of the National Visitor Use Monitoring Database. Faculty Series Working Paper, FS 09-02, September 2009; The University of Georgia, Department of Agricultural and Applied Economics, Athens, GA 30602 http://ageconsearch.umn.edu/handle/59603

HYDROPOWER AND REDUCED COSTS

Hydropower

The benefit from hydropower was calculated by multiplying the average wholesale electricity price ($/MWh) by the power generation (MWh) for each of the alternatives. Historical wholesale price data were compiled for the Northern California hub, or NP-15. The weighted average daily price for NP15 EZ Gen DA LMP Peak was used from 2010-2019, to estimate average monthly prices. The daily hydroelectric power production values were determined for the baseline and two alternatives.

In aggregate, the Modified Hybrid alternative generates $1,868 less in benefits annually from the baseline and the EFO alternative generates $43,750 less annually. It is important to note that the Modified Hybrid and EFO alternatives generate less economic benefit than baseline operations due to the current Water Control Manual rule that does not allow power generation when the pool elevation is higher than 755 ft. If this rule were changed to increase the pool elevation threshold, we would expect that the Modified Hybrid and EFO alternatives would provide greater economic benefits than Baseline.

Reduced Operation, Maintenance, and Replacement (OM&R) Costs

FIRO may result in a reduction in the cost of environmental reviews because there may be fewer Temporary Urgency Change Petitions (TUCPs). Each of these petitions costs approximately $250,000 (personal communication). Using data from 1985 to 2017 we identified instances where FIRO may have avoided these TUCPs. We estimate that the Modified Hybrid approach would reduce the prevalence of these by 18.2 percent and the EFO alternative would reduce the prevalence by 21.2 percent. Therefore, we estimate an annual average savings of $45,455 for Modified Hybrid and $53,030 for EFO.

ABSTRACT

Forecast-Informed Reservoir Operations (FIRO) enables modern weather forecasting technology to be incorporated into Water Control Plans. FIRO provides water managers with more lead time to selectively retain or release water from reservoirs in anticipation of droughts or floods. Managing reservoirs with improved forecasts can optimize benefits such as water supply and fisheries without impairing flood risk management.

FIRO viability at Lake Mendocino was assessed according to five management scenarios and evaluated using 16 metrics. Through detailed hydrologic engineering analysis, the difference in water availability was calculated comparing baseline operations and the FIRO alternatives. Based on the evaluation criteria and implementation considerations, the Modified Hybrid alternative was selected and Ensemble Forecast Operations was designated as a reach goal.

The benefits assessment considered the water availability difference between baseline and FIRO operations with respect to recreation, hydropower, municipal and industrial water supply, agricultural water supply, and fisheries. To calculate the recreation benefit, daily use values were applied to estimated recreational activity at Lake Mendocino. Hydropower benefit was calculated by applying regional retail electricity prices to the increased electricity generated under FIRO operations. Municipal and industrial water supply benefit was determined by quantifying changes in consumer surplus due to an increase in water reliability. Changes in consumer surplus were determined by estimating demand curves for water usage and using price elasticity of demand. Agricultural water supply benefits were calculated as annual avoided losses and used the residual imputation method. The least-cost method was used to monetize fisheries benefit of FIRO based on changes in downstream flow and water temperature.

Results are being integrated into the Lake Mendocino FIRO Final Viability Assessment, which will be finalized by December 2020. An economic decision support tool (DST) will allow users to input data from other FIRO projects to predict benefits and inform tradeoff decisions.

This presentation will share results of the economic assessment, preview the DST, and describe a transferability test case at Prosser Reservoir in the Truckee River Basin.

REFERENCES

[1] Bowker, J.M., Starbuck, C.M., English, D.B.K., Bergstrom, J.C., Rosenburger, R.S., McCollum, D.C. (2009). Estimating the Net Economic Value of National Forest Recreation: An Application of the National Visitor Use Monitoring Database. Faculty Series Working Paper, FS 09-02, September 2009; The University of Georgia, Department of Agricultural and Applied Economics, Athens, GA 30602 http://ageconsearch.umn.edu/handle/59603