Truckee Basin Water Management Options Pilot Viability Assessment

Executive Summary

Truckee Basin Project, California and Nevada
California-Great Basin Region

BUREAU OF RECLAMATION

TRUCKEE MEADOWS WATER AUTHORITY

PYRAMID LAKE PAIUTE TRIBE

U.S. DISTRICT COURT DISTRICT OF NEVADA WATER MASTER

DEPARTMENT OF WATER RESOURCES STATE OF CALIFORNIA

U.S. Department of the Interior **January 2024**

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photograph – Truckee River in Reno, Nevada during a high flow event on December 16, 2016 (Mitch Barrie, Flickr).

Truckee Basin Water Management Options Pilot Viability Assessment

Truckee Basin Project, California and Nevada
California-Great Basin Region

Prepared by:

Bureau of Reclamation, Lahontan Basin Area Office

California Department of Water Resources

Pyramid Lake Paiute Tribe

Truckee Meadows Water Authority

U.S. District Court Water Master/Truckee River Operating Agreement Administrator

This page intentionally left blank.

Acronyms and Abbreviations

1985 WCM	1985 *Truckee River Basin Reservoirs, Truckee River, Nevada and California: Water Control Manual*
Accounting Model	Truckee River Operating Agreement Operations and Accounting RiverWare® Model
BAM	By-a-Model Forecast-Informed Reservoir Operations
basin	Truckee Basin/Truckee River Basin
CA-DWR	California Department of Water Resources
cfs	cubic feet per second
CNRFC	California-Nevada River Forecast Center
DOI	U.S. Department of the Interior
dSRD	dynamic Storage Reservation Diagram
ESA	Endangered Species Act
FIRO	Forecast-Informed Reservoir Operations
Flood Project	Truckee River Flood Management Project
Key Stakeholders	Technical Team members and other key stakeholders including Truckee River Flood Management Authority, California Nevada River Forecast Center, and U.S. Army Corps of Engineers
LBAO	Lahontan Basin Area Office, Bureau of Reclamation
LCT	Lahontan Cutthroat Trout
MOEA	multi-objective evolutionary algorithm
NRCS	National Resources Conservation Service
OCAP	Operating Criteria and Procedures for the Newlands Project, Nevada; a Federal rule governing the diversion of water from the Truckee River to supplement water supply in the Carson River Basin
Planning Model	Truckee River Operating Agreement Planning RiverWare® Model
PLPT	Pyramid Lake Paiute Tribe
Reclamation	Bureau of Reclamation
RMS	root mean squared
SECURE Act	Science and Engineering to Comprehensively Understand and Responsibly Enhance Water Act
SRD	Storage Reservation Diagram
TSC	Technical Service Center, Bureau of Reclamation

Technical Team	Collaborative partners who are bearing the costs of this study, also referred to as the cost-share partners, including the Bureau of Reclamation, Lahontan Basin Area Office; California Department of Water Resources; Pyramid Lake Paiute Tribe; Truckee Meadows Water Authority; Truckee River Operating Agreement Administrator/U.S. District Court Water Master
TMWA	Truckee Meadows Water Authority
TMWRF	Truckee Meadows Water Reclamation Facility
TRFMA	Truckee River Flood Management Authority
TROA	Truckee River Operating Agreement
TROA Parties	Scheduling Parties of the Truckee River Operating Agreement—City of Fernley, City of Reno, City of Sparks, Pyramid Lake Paiute Tribe, State of California, State of Nevada, Truckee Meadows Water Authority, U.S. Department of the Interior, U.S. District Court Water Master, and Washoe County
TROM	Truckee River Operations Model
USWM	U.S. District Court Water Master
U.S.	United States
USACE	U.S. Army Corps of Engineers
VA	Viability Assessment
WaterSMART	Sustain and Manage America's Resources for Tomorrow
WCM	Water Control Manual
WMOP	Truckee Basin Water Management Options Pilot
WY	water year

Symbols

>	greater than
<	less than
%	percent

Contents

Appendices (available as separate documents)

Tables

Figures

References

American Meteorological Society. 2022. *Forecast-informed reservoir operations*. Retrieved from Glossary of Meteorology (https://glossary.ametsoc.org/wiki/Forecast-informed_reservoir_operations).

Bureau of Reclamation. 2015. *Truckee Basin Study: Basin Study Report.* In partnership with Truckee Meadows Water Authority, Tahoe Regional Planning Agency, Truckee River Flood Management Authority, and Placer County Water Agency. U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado.

Natural Resources Conservation Service. 1991. *Technical Release No. 75 (TR-210-75), Reservoir Storage Volume Planning*. Soil Conservation Service, Washington, D.C. Retrieved from https://directives.sc.egov.usda.gov/22167.wba.

U.S. Army Corps of Engineers. 2018. *Hydrologic Engineering Requirements for Reservoirs.* Engineer Manual No. 1110-2-1420. Department of the Army, U.S. Army Corps of Engineers, Washington, D.C.

Executive Summary

This viability assessment (VA) represents the culmination of a 3½-year effort led by the Truckee Basin Water Management Options Pilot (WMOP) Technical Team, comprised of the Bureau of Reclamation (Reclamation), California Department of Water Resources (CA-DWR), Pyramid Lake Paiute Tribe (PLPT), Truckee Meadows Water Authority (TMWA), and the U.S. District Court Water Master (USWM). The purpose of the WMOP is to evaluate and recommend alternatives to the U.S. Army Corps of Engineers' (USACE) 1985 Truckee Basin Water Control Manual (WCM) (1985 WCM) that currently guides reservoir operations in the Truckee Basin. The WMOP specifically sought to evaluate the potential to better achieve water management objectives by implementing:

- Revised guide curves using dynamic Storage Reservation Diagrams (dSRDs),
- Forecast Informed Reservoir Operations (FIRO), termed By-a-Model (BAM) method,
- Changes to downstream flood flow targets, and/or
- A re-proportion of flood space requirements in the Little Truckee River.

The WMOP demonstrated that each of these actions could improve water supply reliability and environmental conditions in the basin without increasing flood risk.

Based on the work conducted in the WMOP, the Technical Team recommends a Preferred Operational Scenario for the Truckee Basin reservoirs that includes revised dSRDs; FIRO; a higher Reno, Nevada, flood flow target; and re-proportioned Little Truckee River flood space. This VA provides an overview of the WMOP process and technical analysis leading up to this recommendation, demonstrates the viability of the Preferred Operational Scenario based on a set of collaboratively determined water management objectives, and provides recommendations for operationalizing this alternative through a WCM update.

The Technical Team developed this VA to support USACE's efforts to update the WCM, with the aim of ultimately implementing the Preferred Operational Scenario in the Truckee Basin. Representatives from the USACE Sacramento District participated in most WMOP meetings and workshops and offered valuable insights on USACE policies and perspectives. This VA provides a "Proof of Concept" of the Preferred Operational Scenario, completing the first phase toward an updated WCM (Figure 1). A substantial amount of technical work went into this process and is documented in the technical studies, which are summarized within this VA and included as appendices. In phase II, the Technical Team will test and refine the Preferred Operational Scenario through planned deviations from the 1985 WCM that will be combined with adaptive management to monitor objectives and iteratively adjust policies or operations with a better understanding of uncertainties and unknowns. The proposed deviations and simulations will allow for real-world testing of operational changes, from which the Technical Team and USACE can gain insight and experience applying forecast-informed tools in the basin. The Technical Team intends that the knowledge and experience gained through the WMOP, proposed deviations, and technical studies will help inform the WCM update by USACE.

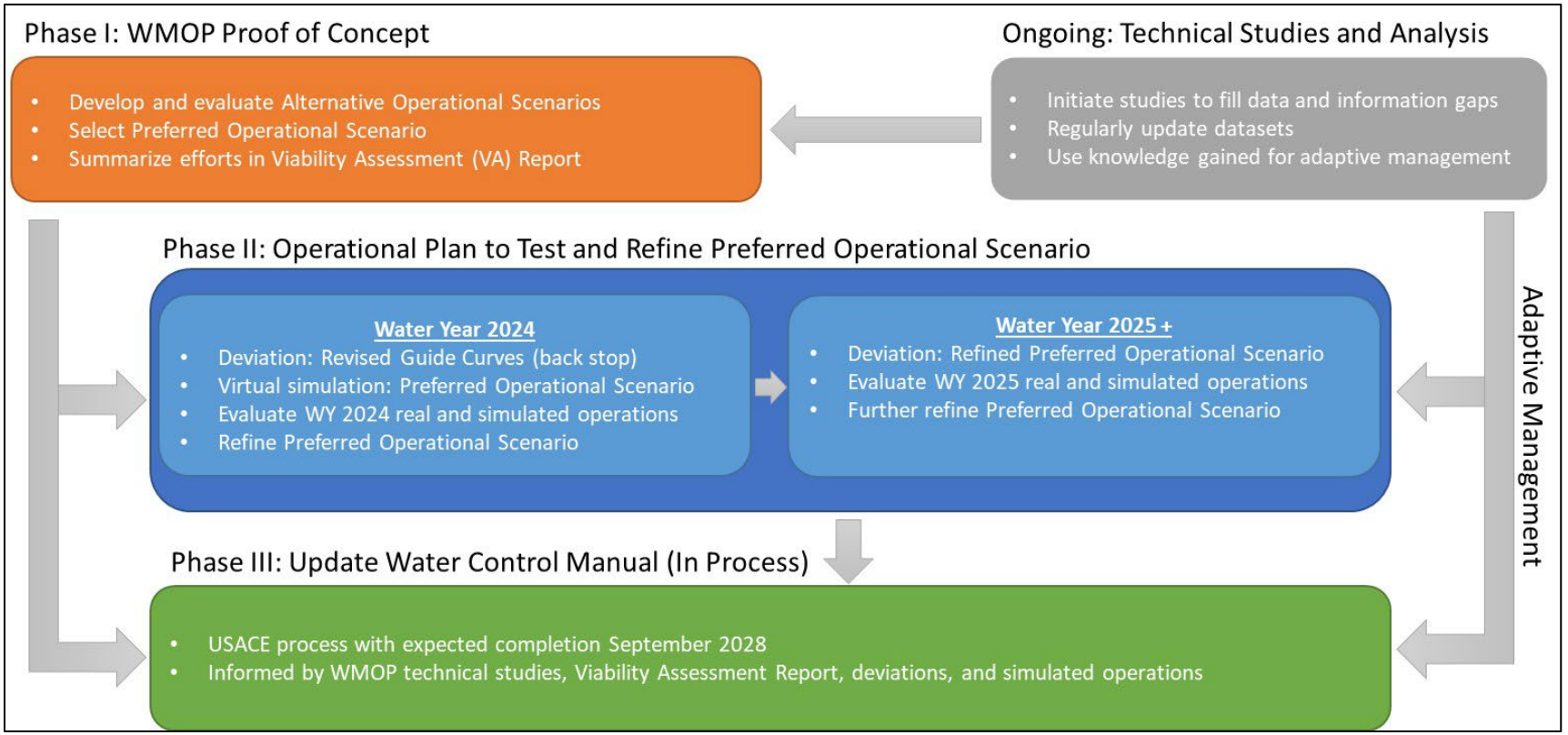

Figure 1.—Process diagram for the Truckee Basin WMOP and WCM update.

Truckee Basin and Water Management

The Truckee Basin epitomizes the challenges of many western basins (Figure 2). The snow-melt-driven system is highly variable on an intra- and inter-annual basis, with climate change expected to exacerbate extremes. Large water years, atmospheric rivers, and rain-on-snow events can bring damaging floods, while droughts exacerbate the challenge of meeting water demands for municipal, agricultural, industrial, and environmental uses in the fully allocated system. Meeting these demands requires a system of dams, canals, and other engineering works, some of which were built over a century ago. Development of the basin has yielded detrimental impacts on the Lahontan cutthroat trout (LCT) (*Oncorhynchus clarkii henshawi*) and Cui-ui (*Chasmistes cujus*) fish species, now listed as threatened and endangered under the Endangered Species Act (ESA), respectively. The history of the Truckee River is wrought with legal battles for rights to its water, which have culminated in the current set of operating agreements, decrees, and rules for managing and allocating water among a diverse set of parties. Despite, and perhaps because of, these challenges, key stakeholders in the basin have a history of working together to find mutually agreed-upon solutions to meet competing demands.

Water management studies and stakeholders in the Truckee Basin identified the 1985 WCM as a key constraint to further improving water management in the basin. The 2015 Truckee Basin Study recommended updating the WCM as one strategy to adapt to projected climatic changes (Bureau of Reclamation, 2015). To further investigate this strategy, the Technical Team initiated the WMOP with funding through Reclamation's WaterSMART Basin Study Program and invited other key stakeholders to participate in the process. The study developed five Action Alternative Operational Scenarios (Action Alternatives) and evaluated these, alongside the 1985 WCM (No Action Alternative, Baseline), for their impact on flood risk, water supply, environmental flows, and other less quantifiable objectives, such as operability and flexibility.

Development of Alternative Operational Scenarios

At the outset of the project, the Technical Team collaboratively formulated a plan for developing a set of Action Alternatives to continued operations under the 1985 WCM (No Action Alternative). During the plan formulation, the Technical Team identified four primary problems with the regulation criteria of the WCM that represent opportunities for improving water management in the Truckee Basin (Figure 3). From these, the stakeholders identified goals, objectives, and constraints to help guide and restrict the development of actions and alternatives.

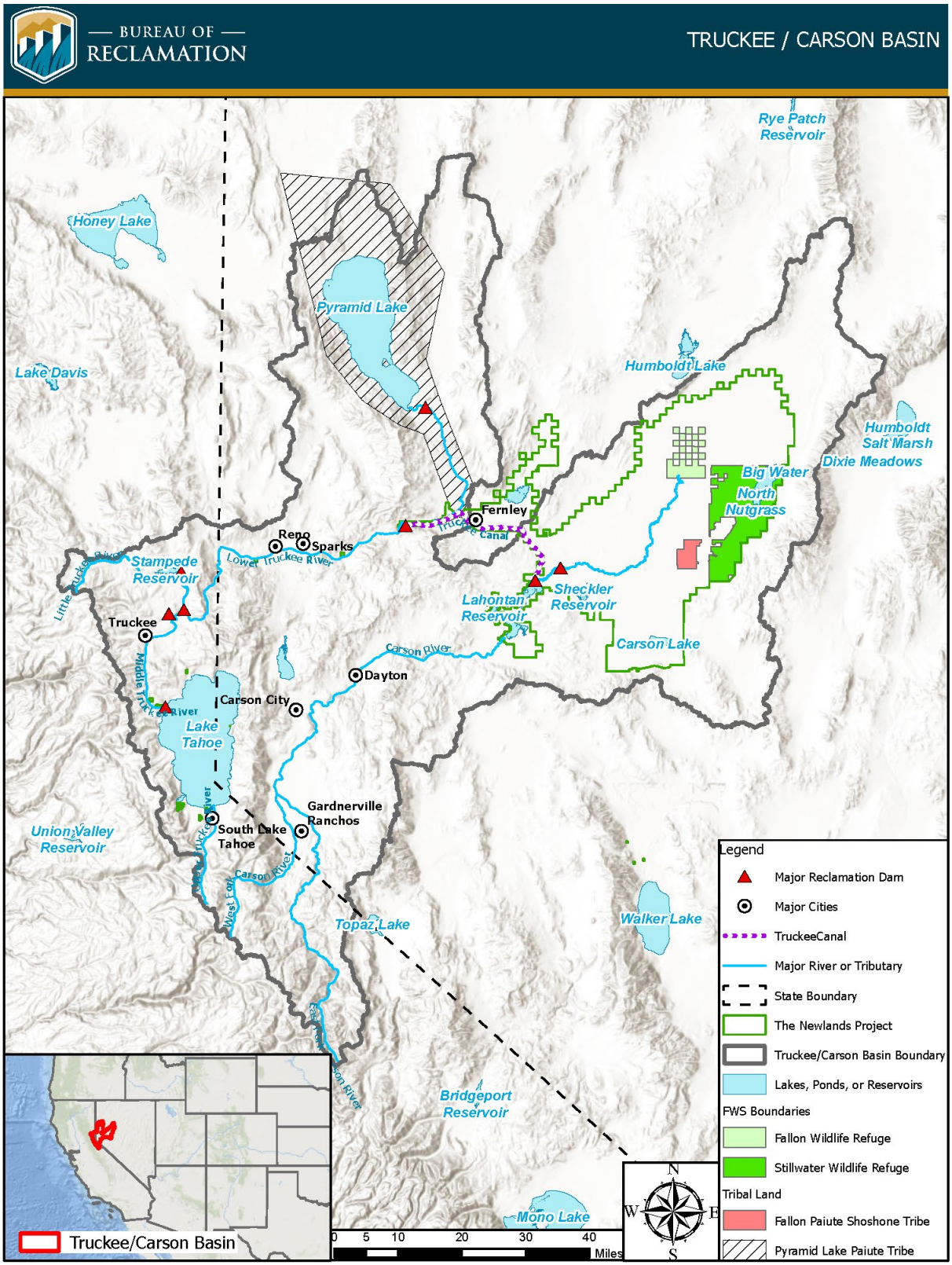

Figure 2.—Map of the Truckee and Carson Basins, including the reservoirs and other Reclamation project features.

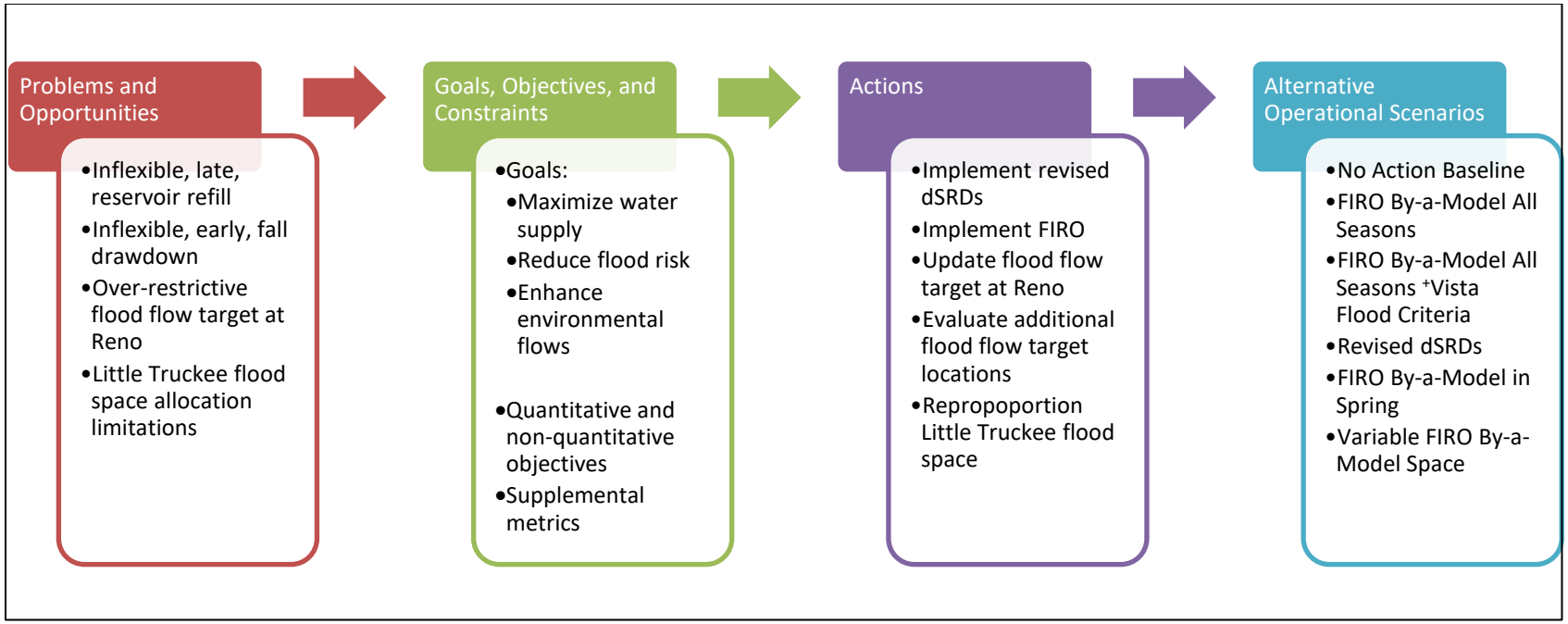

Figure 3.—A general overview of the steps taken to develop the Action Alternatives to the 1985 WCM.

The Technical Team designed the WMOP to evaluate the potential to better achieve water management objectives by implementing the following actions (Figure 3):

- **Implement Revised Guide Curves Using Dynamic Storage Reservation Diagrams (dSRDs):** This action updates the guide curves in the 1985 WCM following guidance from USACE (U.S. Army Corps of Engineers, 2018) and NRCS (Natural Resources Conservation Service, 1991). The revised dSRDs define the required flood space in each reservoir to provide flood protection for the Truckee Basin, particularly the Reno-Sparks metropolitan area. The amount of required flood space is a function of the time of year and the forecasted seasonal runoff volume, which is dependent on the snowpack state.

- **Implement Forecast Informed Reservoir Operations (FIRO) (Termed "By-a-Model" [BAM] in the WMOP):** FIRO is a reservoir-operations strategy that formally integrates improved weather and water forecasts into decisions to retain or release water, adding operational flexibility (American Meteorological Society, 2022). The BAM method developed in the WMOP uses stream forecasts from the California-Nevada River Forecast Center (CNRFC) to determine how much flood space to reserve in the Truckee Basin reservoirs.

- **Update Flood Flow Targets at Reno:** The 1985 WCM specifies that, to the extent possible, instantaneous flood flows in Reno should not exceed 6,000 cubic feet per second (cfs); however, this flow is significantly below the level believed to cause damage under modern conditions. Increasing the flow target allows for a more efficient flood space evacuation that can help minimize the risk of downstream flooding.

- **Evaluate Additional Flood Flow Target Locations:** The Technical Team also explored whether operating reservoirs during floods to both the Reno, Nevada Gage *and* the downstream Vista, Nevada Gage would provide benefits in reducing downstream flood risk. Ongoing flood management projects in the Reno-Sparks metropolitan area will retain more water within the stream channel, increasing downstream flood flows and potentially leading to advantages in operating to both an upstream and downstream target.

- **Re-Proportion Little Truckee River Flood Space:** Under the WCM, approximately 27 percent (%) (8,000 acre-feet) of the Little Truckee River flood space is allocated to Boca Reservoir, with the rest in Stampede Reservoir. Re-proportioning the flood space between the reservoirs to account for the 2017 improvements to Stampede Dam could benefit the water supply or help minimize the risk of downstream flooding.

The Technical Team identified five Action Alternatives through various combinations of these actions, which were evaluated against the No Action Alternative, forming a set of six Alternative Operational Scenarios (alternatives) (Figure 3). Each of the Action Alternatives increases the Reno flood target from 6,000 to 6,500 cfs and reproportions the Little Truckee flood space, as well as incorporating the actions described in Figure 4.

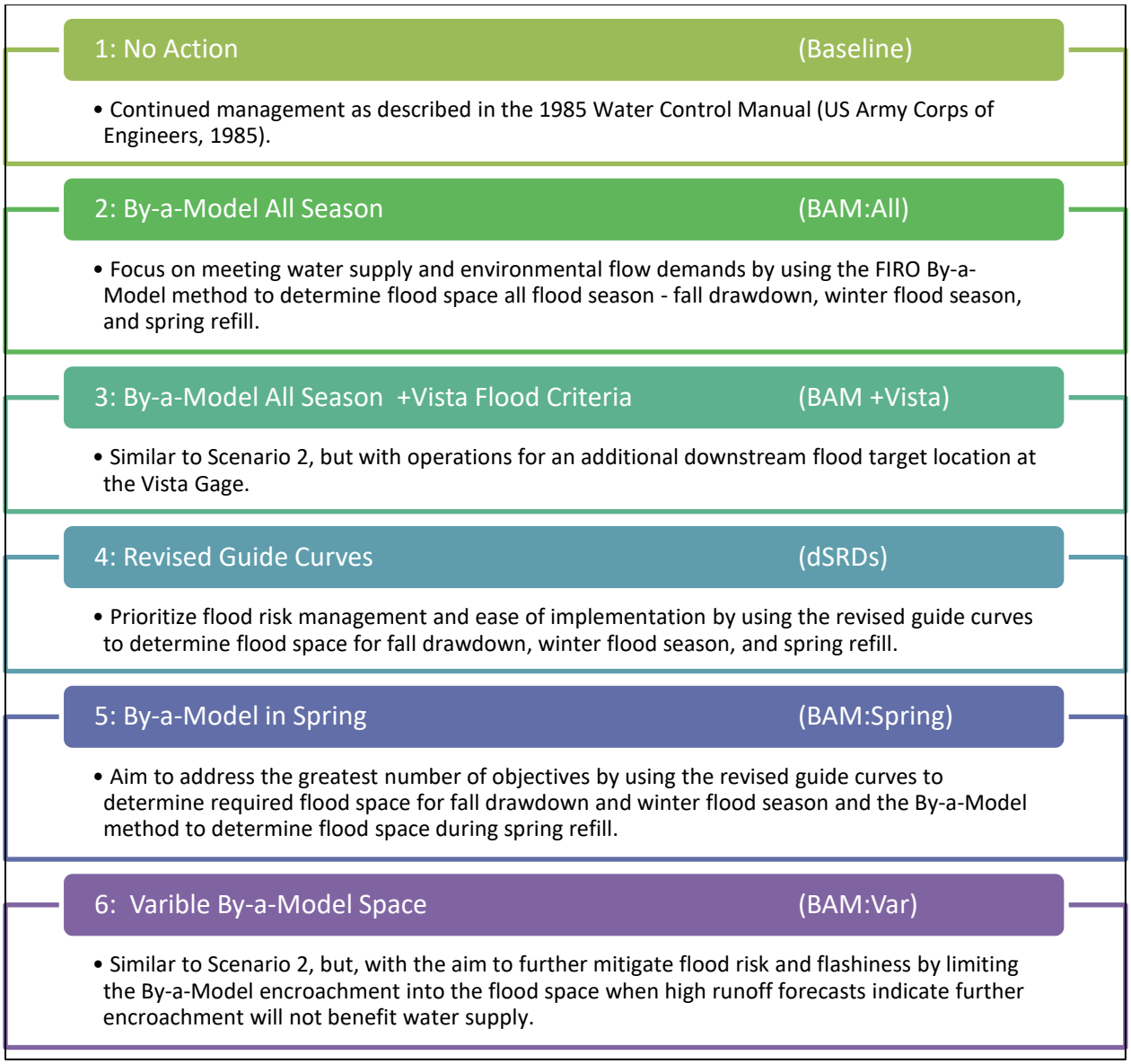

Figure 4.—Alternative Operational Scenarios developed and evaluated in the WMOP.

Building the Technical Foundation

The WMOP benefited from a strong foundation of data, models, and technical capacity to support water management initiatives in the Truckee Basin; however, achieving the objectives of this innovative WMOP required the development of additional datasets, updating and verifying models, and conducting multiple technical studies. This work not only benefited the WMOP, but it also supported water management and planning in the Truckee Basin more generally. For example, the WMOP developed a new hourly RiverWare model and hourly discharge data to assess the flooding impacts of the alternatives. This work, in combination with updating flood frequency curves and completing a channel capacity analysis, added to the overall ability to

manage and plan for floods in the basin. The WMOP also took advantage of an updated daily planning model dataset and produced a hindcasted ensemble based on historical conditions, as well as scaled hindcasts to simulate larger flood events.

Action Alternative Operational Scenarios Build-Out

The data and models developed in the WMOP provided the technical foundation to build out the revised dSRDs and the BAM method used in the Action Alternatives. The WMOP updated the guide curves in the 1985 WCM following guidance from USACE (U.S. Army Corps of Engineers, 2018) and NRCS (Natural Resources Conservation Service, 1991). The revised dSRDs were developed using the daily unregulated, natural flow at the Reno Gage and Farad, California Gage data from January 1909 through October 2021, spanning 112 years. These dSRDs define the required flood space in each reservoir based on the time of year and the seasonal runoff forecast. For the revised dSRDs, the required flood space is a function of the difference between the *observed* unregulated inflow in Reno and the flood flow target in Reno. Results show that revising the guide curves will improve operational flexibility in the Truckee Basin by allowing for later fall drawdown and earlier spring refill without changing the volume of flood space available through the winter.

The BAM method for FIRO uses CNRFC flow forecasts to determine the amount of flood space needed to store the forecasted flows without exceeding the downstream flood target(s). The BAM method uses a similar calculation as the revised dSRDs, but the required flood space is a function of the difference between the *forecasted* unregulated inflow in Reno and the flood flow target in Reno.

The CNRFC currently produces an ensemble of 41 traces of forecasted unregulated flows. The BAM method uses an exceedance-outlook curve to select what exceedance level cumulative required flood space should be used at every outlook period. For example, an operational scenario would likely use the most conservative (largest) forecasted required flood space at a 1-day outlook since there is more skill in short-term forecasts and less time to react. However, it might use the median (50% exceedance) required flood space at the 7-day outlook and higher exceedance probabilities for longer outlooks. In other words, for longer outlooks, more forecast traces need to show that additional flood space is required before that flood space is reserved. The WMOP used a multi-objective evolutionary algorithm (MOEA) to determine what exceedance level required flood space the BAM method uses at each outlook.

Evaluation of Alternative Operational Scenarios

During the plan formulation, the Technical Team defined a set of quantifiable (Table 1) and non-quantifiable project objectives through which to evaluate the alternatives' performance relative to the WMOP's goals. Developing calculations for the quantifiable objectives allowed for:

- Optimizing the decision variables in the BAM method,
- Evaluating the performance of the alternatives, and

- Making comparisons between the alternatives.

Calculations were designed to accurately quantify the alternatives' performance in the objectives using a single number for each objective. This set of quantitative objectives, along with the non-quantitative objectives and a set of supplemental metrics, played a significant role in selecting the Preferred Operational Scenario.

Table 1.—Five Quantitative Objectives Used to Evaluate and Compare the Performance of the Alternatives

Objective Name	Description	Calculation
Average Annual Volume for Floriston Rate	A measure of ability to meet demands for municipal, agricultural, industrial, ecological, and hydropower uses.	Average annual volume of water at the Farad, California Gage that meets the Floriston Rate, a legal minimum flow requirement that varies between 300–500 cfs, depending on the season and Lake Tahoe levels.
Average Annual Prosser, Boca, and Stampede Storage	A measure of ability to meet water demands and of flexibility in meeting those demands.	Average annual combined storage of Prosser, Boca, and Stampede Reservoirs.
Average Annual Volume for Flow Regime	A measure of ability to meet environmental flow demands in the lower basin.	Average annual flow at the Nixon Gage, near Pyramid Lake, Nevada, limited to the flow regime target.
Root Mean Squared (RMS) Flow Over Flood Target	A measure of ability to mitigate flood risk.	Square root of the sum of the squared hourly flows over the Reno flood flow target using the historical dataset and scaled hindcasts.
Average Daily Increase in Flood Space Requirement	A measure of operational challenges due to large daily increases in flood space requirements and potentially abrupt increases in downstream flows (flashiness).	Average daily increase in the Truckee Basin's total flood space requirement.

All five Action Alternatives result in improvements in the water supply, environmental flow, and flood risk objectives relative to the No Action Alternative; however, tradeoffs exist between objectives, as summarized in Table 1. Through a series of meetings, workshops, and collaborative discussions, the Technical Team selected the Variable By-a-Model Space (BAM:Var) as the Preferred Operational Scenario. This alternative reserves a variable percentage of the required flood space in the revised dSRDs exclusively for flood control and operates the remaining flood space using the FIRO BAM method. The percentage of revised dSRD flood space reserved varies between 30 and 100% depending on the runoff forecast, such that, during wet years, 100% of the dSRD flood space is reserved exclusively for flood control. In drier years with lower flood risk, a larger percentage of flood space is operated using the BAM method. This scenario ranks favorably across all objectives by leveraging the water supply benefits associated with the BAM method and mitigating flood risk by limiting and/or foregoing BAM encroachment into flood space during wet years. BAM:Var explicitly uses the uncertainty in

streamflow forecasts, offers a pathway for growth with improved forecast skill and model refinements, and can be implemented feasibly with USACE standard decision tools.

After selecting BAM:Var as the Preferred Operational Scenario, the Technical Team layered on refinements to this alternative. First, all the Action Alternatives incorporated a 6,500-cfs Reno flood flow target, but after further analysis and discussion, the Technical Team agreed that the target could be increased to 7,000 cfs without additional out-of-bank flood risk while allowing for more efficient evacuation of flood space in reservoirs, subsequently reducing flood risk from potential secondary event(s). Secondly, the Technical Team agreed to recommend the use of the revised dSRDs as the backstop operational plan in the event of the inaccessibility of CNRFC forecasts or any other seen or unforeseen operational roadblock.

Table 2.—Comparative Summary of the Action Alternatives' Performance in the Quantitative Objectives

Action Alternatives' Performance Summary in Quantitative Objectives
All the Action Alternatives outperform the No Action Alternative in four out of five of the quantitative objectives: • Average Annual Volume for Floriston Rate • Average Annual Volume for Flow Regime • Average Annual Prosser, Boca, and Stampede Storage • Root Mean Squared (RMS) Flow Over Flood Target
The Action Alternatives that apply the BAM method throughout the flood season (BAM:All and BAM $^{+}$Vista) also outperform the Baseline in regard to the objective: • Average Daily Increase in Flood Space Requirement
The Action Alternatives that include the BAM method for fall drawdown (BAM:All, BAM $^{+}$Vista, and BAM:Var) outperform the Action Alternatives that use the revised dSRDs for fall drawdown (dSRDs and BAM:Spring) in regard to the objectives: • Average Annual Volume for Floriston Rate • Average Annual Volume for Flow Regime • Average Annual Prosser, Boca, and Stampede Storage • Average Daily Increase in Flood Space Requirement
The Action Alternatives that use the revised dSRDs for fall drawdown (dSRDs and BAM:Spring) outperform the Action Alternatives that include the BAM method for fall drawdown (BAM:All, BAM $^{+}$Vista, and BAM:Var) in regard to the objective: • RMS Flow Over Flood Target

Recommendations

Key Recommendation: The Technical Team and other key stakeholders in the WMOP recommend consideration of the Variable By-a-Model Space Alternative with a 7,000-cfs Reno flood flow target as the new WCM criteria and the revised guide curves used as the backstop operational plan in the case of the inaccessibility of CNRFC forecasts or any other seen or unforeseen operational roadblock.

This VA also recommends three components to continue the evolution of FIRO and the BAM method in the Truckee Basin:

- An **Implementation Plan** for sequentially and strategically updating dam operations during the WCM update processes, including working with the USACE to implement planned deviations to test and refine the Preferred Operational Scenario;

- **Flexibility and Adaptive Management** to refine the Preferred Operational Scenario as new information accrues; and

- **Additional Studies and Future Work** to fill data and information gaps identified in the WMOP, such as conducting a sensitivity analysis of the decision variables and a more probabilistic flood risk and dam safety assessment, as well as those uncovered while enacting the Implementation Plan (Figure 1).

The Technical Team intends that this multiyear, technically sound, collaborative effort will inform the WCM update initiated by USACE, with a tentatively planned completion date of September 2028 for implementation in water year 2029.