Appendix F

FLOW ANALYSIS

FREMONT WEIR ADULT FISH PASSAGE MODIFICATION PROJECT

FLOW ANALYSIS

DRAFT REPORT

NOVEMBER 29, 2016

CONTENTS

FIGURES

1 INTRODUCTION

The California Department of Water Resources (DWR) and United States Bureau of Reclamation (Reclamation) are proposing to modify an existing fish passage structure at Fremont Weir to improve fish passage in the Yolo Bypass. Modification of the existing fish passage structure would achieve partial compliance with the requirements of the Reasonable and Prudent Alternative (RPA) Action I.7 of the 2009 National Marine Fisheries Service's *Biological Opinion and Conference Opinion on the Long-term Operations of the Central Valley Project and the State Water Project* (NMFS, 2009). RPA I.7 focuses on adult fish passage improvements in the Yolo Bypass for four federally listed anadromous fish species. In addition, the California EcoRestore initiative identifies improving fish passage to known barriers along salmonid and sturgeon migration routes as a necessary near-term action to counteract declining populations of federally and State-listed fish species.

This Technical Memorandum (TM) documents the impact of increased flow from the Sacramento River to the Yolo Bypass due to the proposed Fremont Weir Adult Fish Passage Modification Project (Project). This TM is intended to support the Initial Study/Environmental Assessment (IS/EA) of the proposed Project. The proposed Project includes (i) modification of the existing Fremont Weir fish ladder, (ii) earthwork in the existing channels that extend downstream and upstream of the existing Fremont Weir fish ladder, and (iii) modification of agricultural road crossings along the Tule Canal, which is a small channel adjacent to the Yolo Bypass east levee, to improve fish passage in the Yolo Bypass.

2 PURPOSE

A major component of the proposed Project is to widen and deepen the existing fish ladder at the Fremont Weir, which would allow more flows from the Sacramento River onto the Yolo Bypass more frequently. The purpose of this study is to assess the impact of this increased flow on wetted acres within the Yolo Bypass, as well as on local Sacramento River hydraulics (stage and flow), due to implementation of the proposed Project.

3 PROJECT AREA

A description of the project area is provided in the IS/EA.

4 BACKGROUND OF THE HYDRODYNAMIC MODEL DEVELOPMENT

The 1D/2D hydrodynamic model, developed using TUFLOW Classic by DWR in collaboration with HDR and cbec for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project, was used for this study. A detailed description of (i) TUFLOW's selection as the best available tool for this project's purpose, (ii) model domain, (iii) model geometry, (iv) hydrology, (v) hydraulics, (vi) surface roughness, and (vii) model assumptions is provided in the TUFLOW hydrodynamic modeling draft report (DWR, 2014). The same report also discusses model calibration and existing condition analyses. Hence, those topics are not repeated in this TM.

5 ALTERNATIVE SCENARIOS

Three alternative operational scenarios, apart from the existing condition scenario, were modeled for this study. Each alternative operational scenario would allow different flows through the proposed fish passage structure into the Yolo Bypass. The alternative operational scenarios are described below.

Scenario 1 – In case of an overtopping event, the fish passage structure would open at a Sacramento River stage of 32.3 feet when the stage is ascending and would remain open until the stage falls below the structure's invert of 22 feet.

Scenario 2 – In case of an overtopping event, the fish passage structure would open at a Sacramento River stage of 32.3 feet when the stage is ascending and close 3 days after Fremont Weir stops overtopping.

Scenario 3 – In case of an overtopping event, the fish passage structure would open at a Sacramento River stage of 32.3 feet when the stage is ascending and close 1 day after Fremont Weir stops overtopping. The fish passage structure would reopen for the duration between river stages of 24 to 27 feet, not to exceed 5 consecutive days.

6 METHODOLOGY

6.1 Evaluate Impact on Wetted Acres

Below is a description of the step-by-step process followed to evaluate the impact on wetted acres within the Yolo Bypass.

Step 1: Generate a rating curve for the fish passage structure under varying Sacramento River stages. For this reason, stage flow relationship for the structure was derived from two HEC-RAS models – (i) FWAFP HEC-RAS model that was developed to test fish passage performance (DWR, 2016a), and (ii) modified CVFED system HEC-RAS model that was developed for hydraulic impacts assessment (HIA) for design flow condition (DWR, 2016b). The FWAFP HEC-RAS model was used to generate the rating curve for low flows, i.e. between Sacramento River stages of 22 feet to 31.7 feet, as this model contains more details of the project components than the CVFED system HEC-RAS model, and hence, is expected to generate accurate results. The CVFED system HEC-RAS model was used to generate the rating curve for the remaining high flows, i.e. between Sacramento River stages of 32.3 feet and 40 feet.

Step 2: For the existing condition scenario as well as three alternative operational scenarios, calculate daily flows through the fish passage structure for each of the 11 modeled water years in which Fremont Weir overtopping events vary.

Step 3: Set-up and run TUFLOW simulations for the existing condition scenario and the three alternative operational scenarios over 11 water years, thus totaling 44 TUFLOW simulations.

Note that the Fremont Weir was not explicitly modeled as a structure with openings in the TUFLOW model; only its crest elevations were represented using a polyline derived from the base DEM (DWR,

2014). Therefore, it was not possible to compute flows through the fish passage structure in the TUFLOW model. To account for this, for each of the three alternative operational scenarios the time series of flow coming out of the fish passage structure was subtracted from the 2D cells in the Sacramento River and added back to the Tule Canal (this was not needed for the existing condition simulations). Both of these locations are shown in **Figure 1** below.

Step 4: Generate plots comparing wetted acres between the existing condition scenario and the alternative operational scenarios.

6.2 Assess Impact on Sacramento River Local Hydraulics

Among the three alternative operational scenarios discussed in Section 5, Scenario 1 would leave the gate opened for maximum duration, thus allowing maximum flow from the Sacramento River to the Yolo Bypass. Therefore, Scenario 1 would have the greatest impact on stage and flow in the Sacramento River. Taking this into consideration, water year 1997, (which was a very wet year with an extended overtopping event) was selected to evaluate impacts on the Sacramento River local hydraulics (stage and flow) for Scenario 1 only. Four locations were selected along the Sacramento River to compare stage and flow hydrographs between existing condition and Scenario 1 – (i) at 1.7 miles upstream of Fremont Weir, (ii) at immediately upstream of Fremont Weir, (iii) at Verona Gage, and (iv) at 12.8 miles upstream of Sacramento Weir.

7 RESULTS

7.1 Impact on Wetted Acres within the Yolo Bypass

Figures 2 through 12 show simulated results of the total amount of wetted acres under existing condition scenario compared to three alternative operational scenarios for the proposed Project for eleven water years in which Fremont Weir overtopping events vary. Modeling results indicate a slight increase in inundation within the Yolo Bypass for Scenario 1. Modeling results for Scenarios 2 and 3 indicate no significant changes in Yolo Bypass drainage and inundation patterns. Due to the slight increase in inundation within the Yolo Bypass indicated for Scenario 1, Scenario 2 or Scenario 3 would be implemented for the proposed project.

7.2 Impact on Sacramento River Local Hydraulics

Figures 13 through 20 compare the impact of the proposed Project on flow and water surface elevation over existing conditions for water year 1997 along the Sacramento River at four locations for Scenario 1 only (see Section 6.2). The hydraulic analyses indicate no noticeable difference in simulated results between existing conditions and proposed Project conditions during periods of time when water availability may be a concern. The biggest deviation in flow results is indicated at Verona and represents an approximate 2% to 4% reduction in flow. The small reduction in flow is due to the fact that the fish passage structure would only be operated during a Fremont Weir overtopping event and for a short period after the weir stops overtopping. However, during this period the river system would be in flood conditions and approximately 50,000 cfs would still remain in the Sacramento River downstream of the proposed Project. During these flow conditions, water availability would not be an issue.

8 REFERENCES

California Department of Water Resources (DWR). 2014. Yolo Bypass Salmonid Habitat Restoration and Fish Passage Hydrodynamic Modeling Draft Report. 2014. Sacramento, CA.

California Department of Water Resources (DWR). 2016a. Fremont Weir Adult Fish Passage Modification Project Hydraulic Model Development for Fish Passage Performance Evaluation. 2016. Sacramento, CA.

California Department of Water Resources (DWR). 2016b. Hydraulic Impact Analysis (HIA) for the Fremont Weir Adult Fish Passage Modification Project Draft Report. 2016. Sacramento, CA.

National Marine Fisheries Service (NMFS). 2009. *Biological Opinion and Conference Opinion on the Long-term Operations of the Central Valley Project and the State Water Project*. Southwest Region. Long Beach (CA).

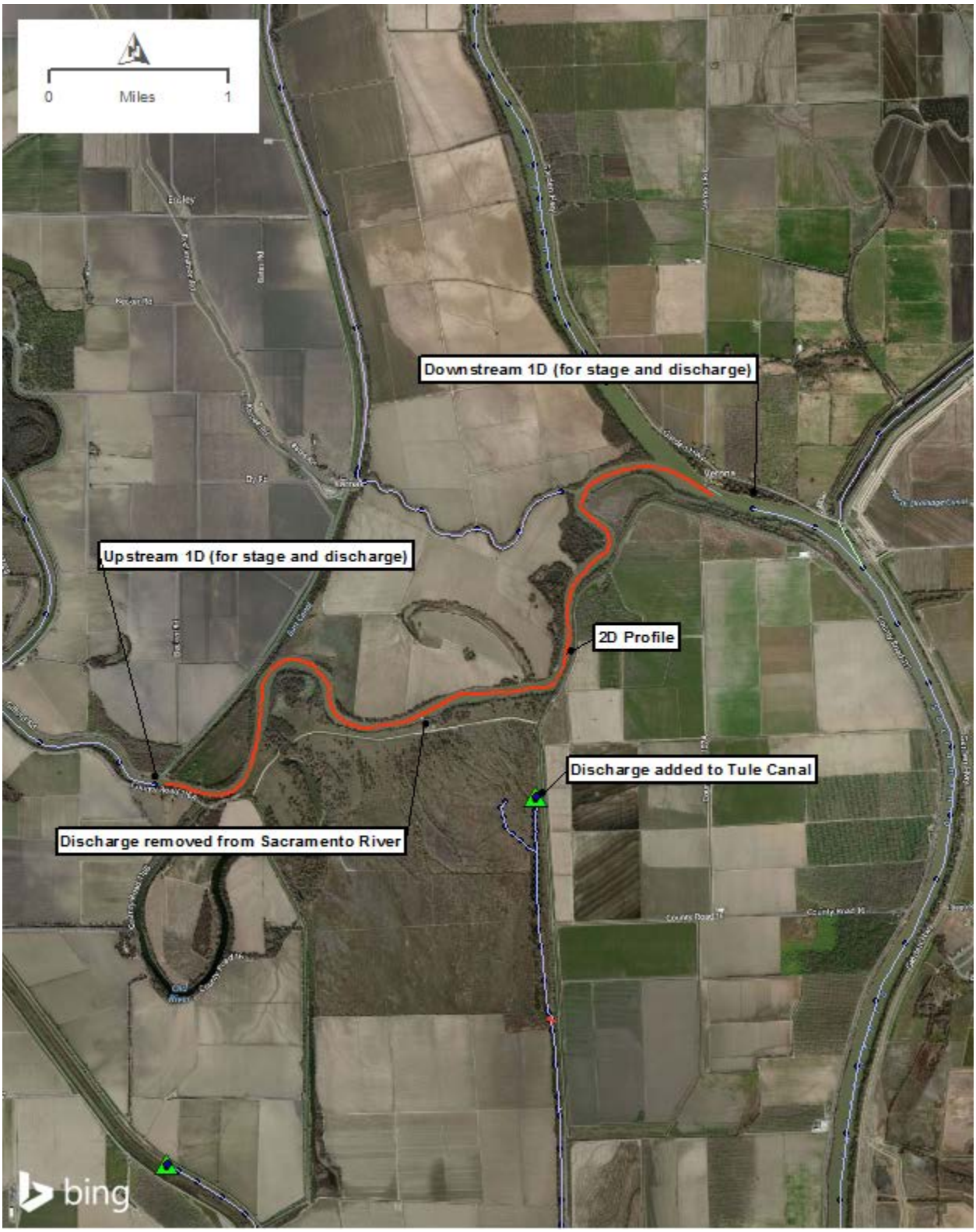

Figure 1. Modeled Flow Adjustment Locations to account for proposed fish passage structure flows for Alternative Scenarios

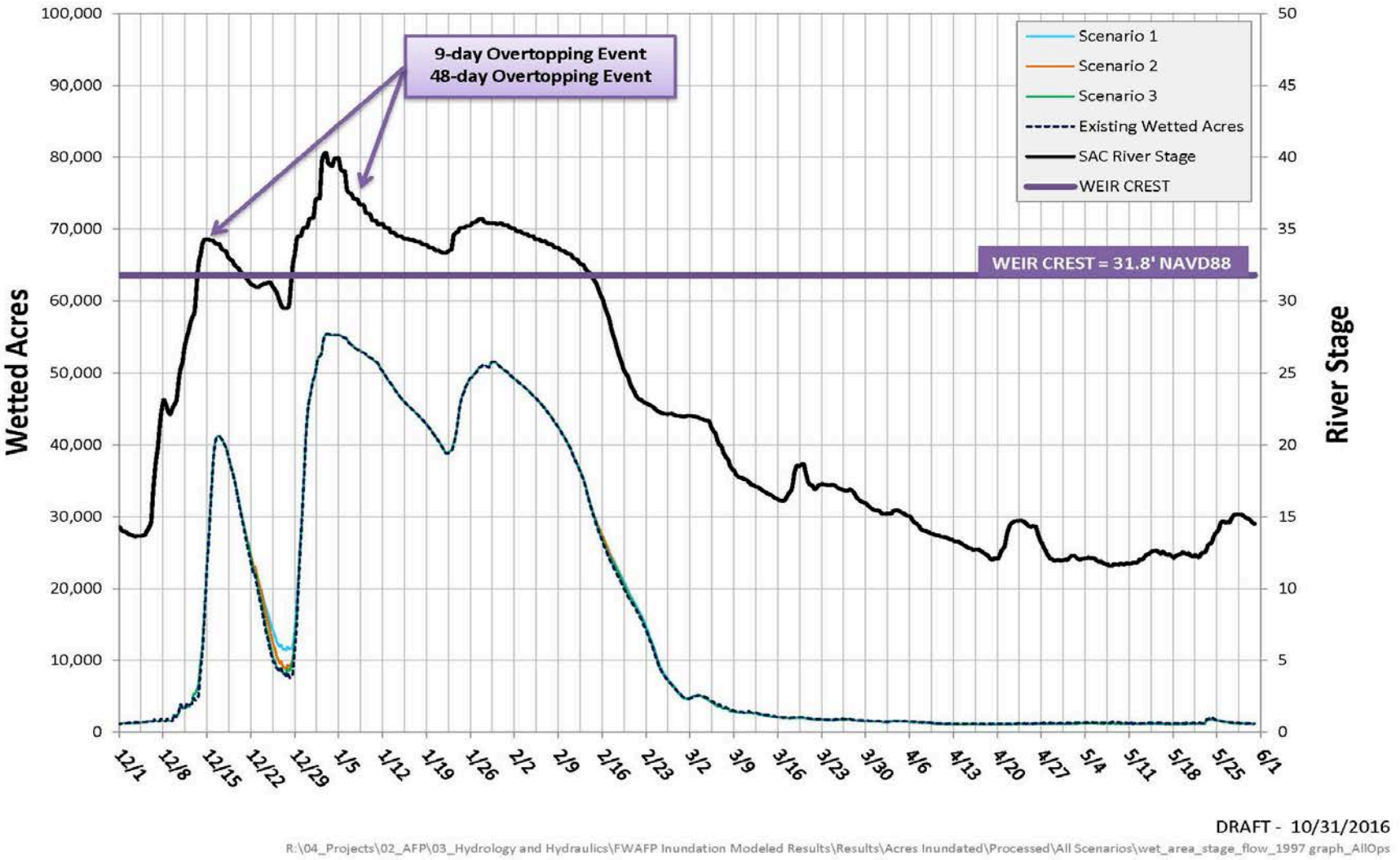

Figure 2. Comparison of Wetted Acres between the Existing Condition Scenario and Alternative Operational Scenarios for Water Year 1997

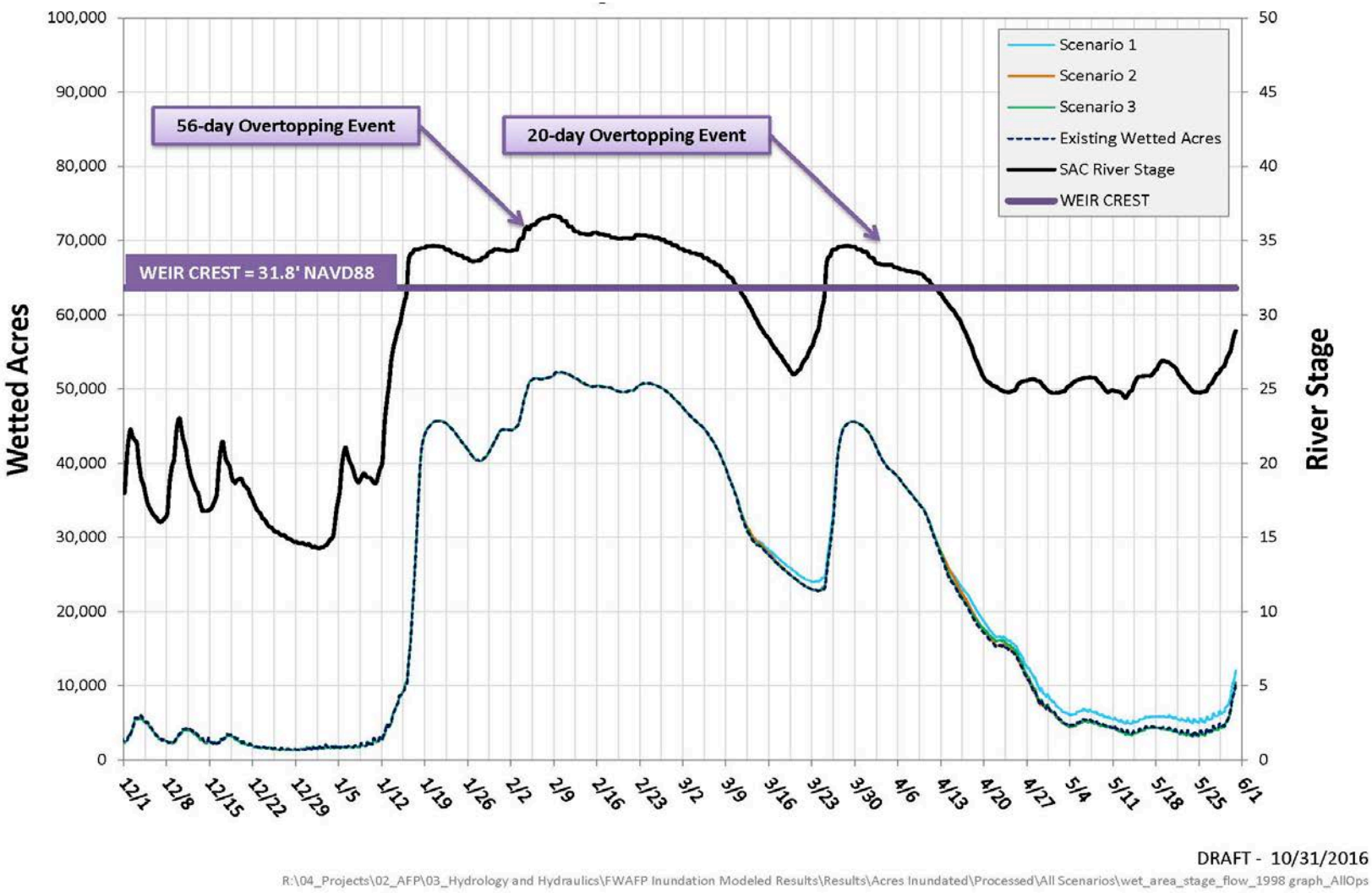

Figure 3. Comparison of Wetted Acres between the Existing Condition Scenario and Alternative Operational Scenarios for Water Year 1998

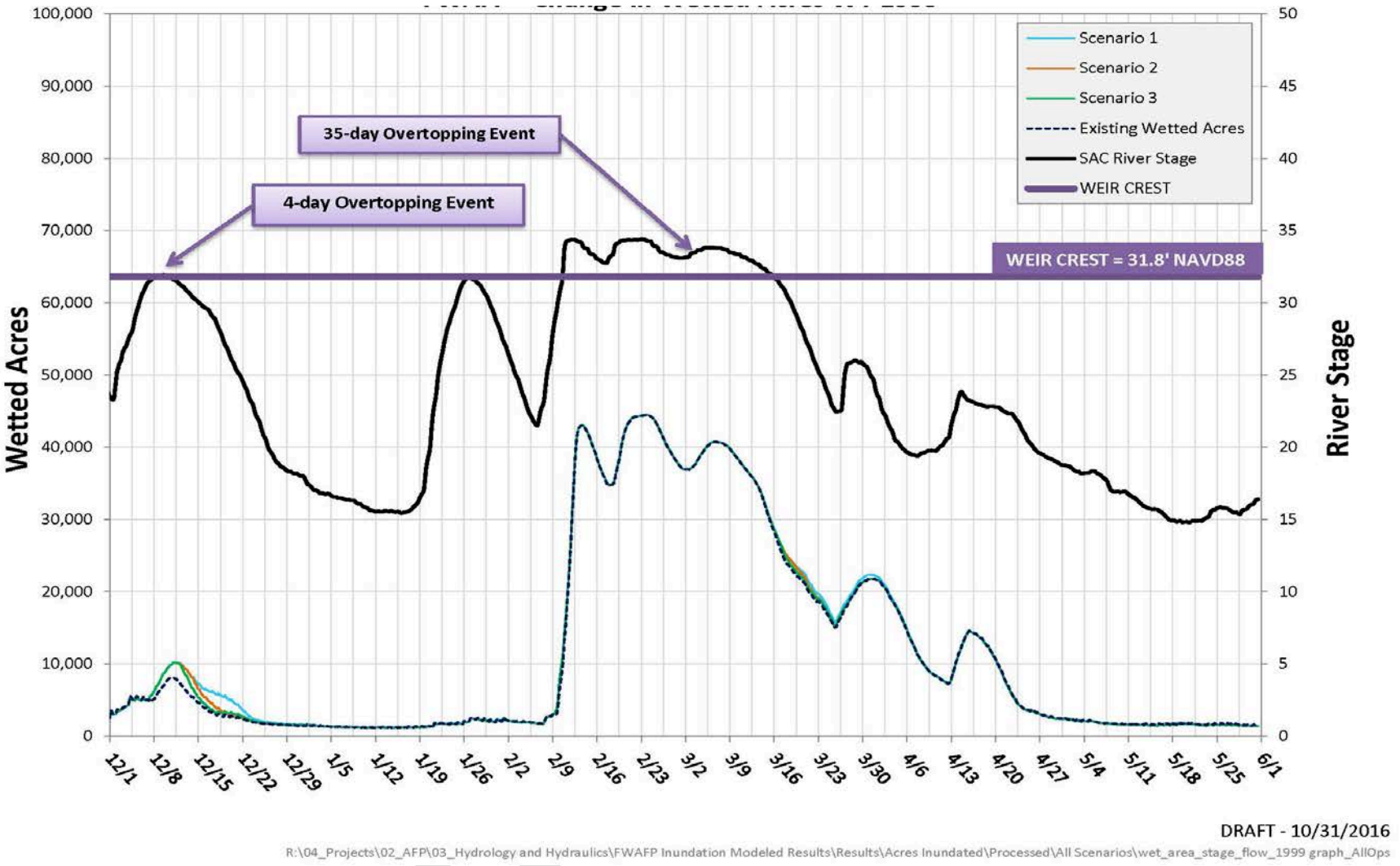

Figure 4. Comparison of Wetted Acres between the Existing Condition Scenario and Alternative Operational Scenarios for Water Year 1999

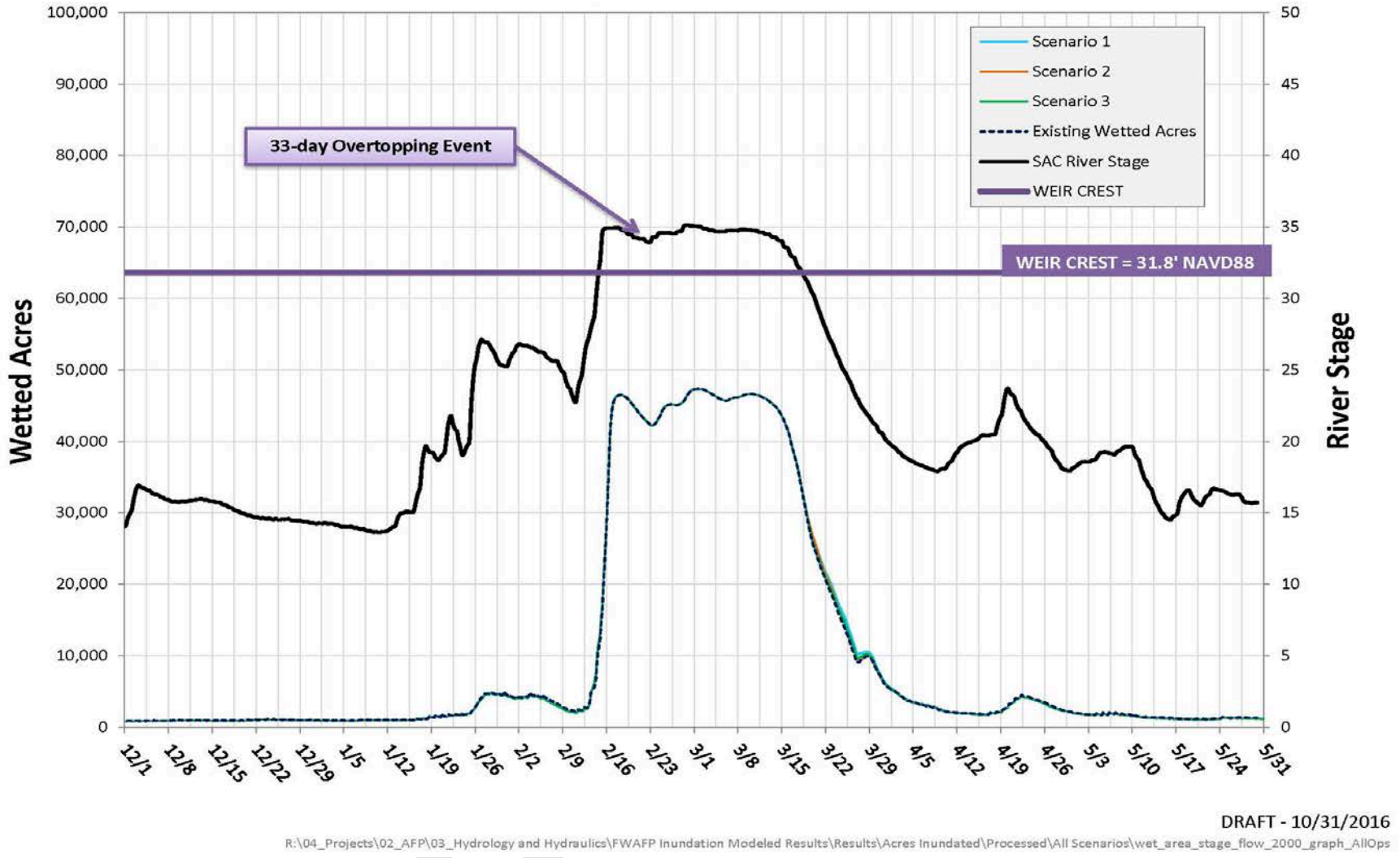

Figure 5. Comparison of Wetted Acres between the Existing Condition Scenario and Alternative Operational Scenarios for Water Year 2000

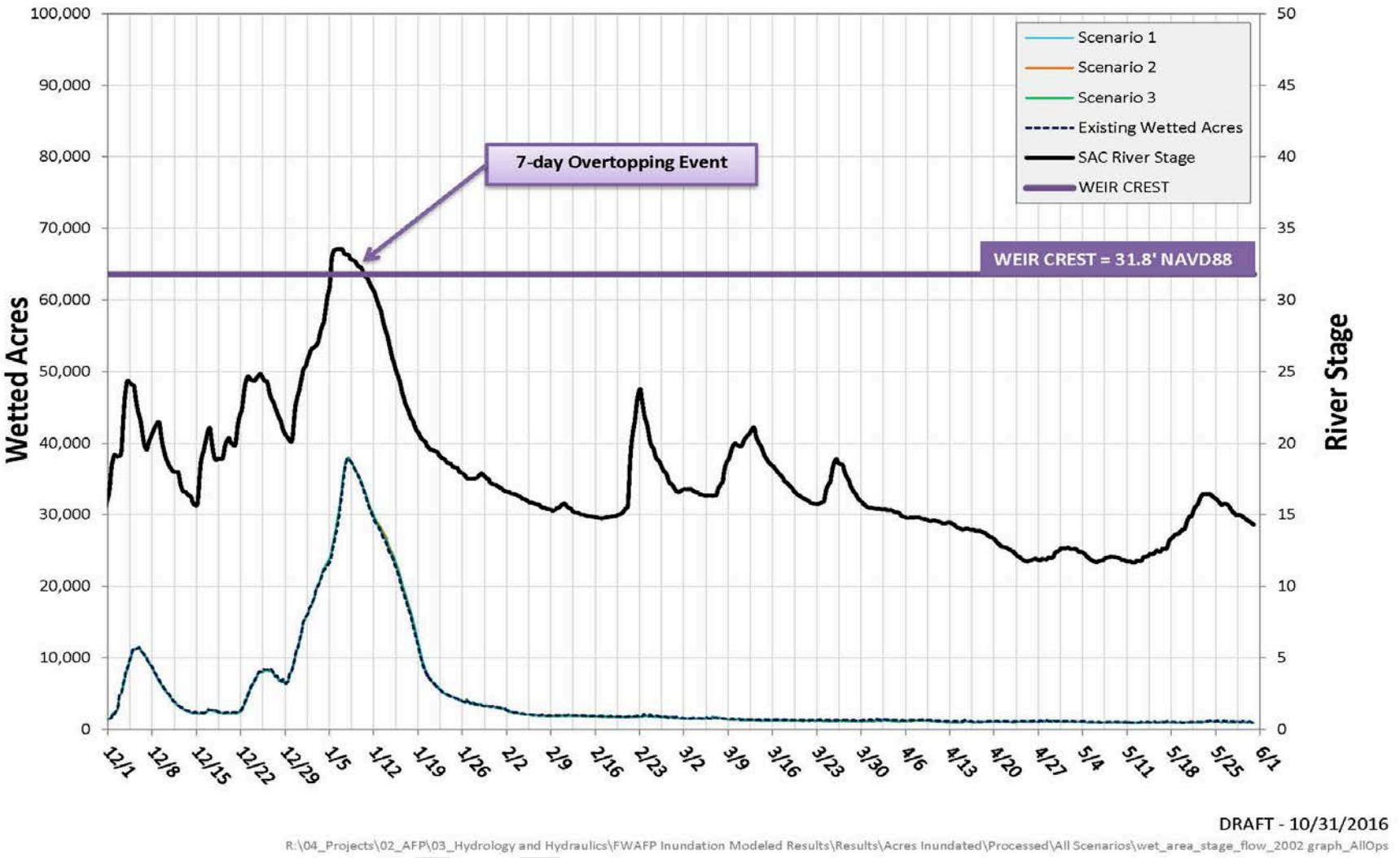

Figure 6. Comparison of Wetted Acres between the Existing Condition Scenario and Alternative Operational Scenarios for Water Year 2002

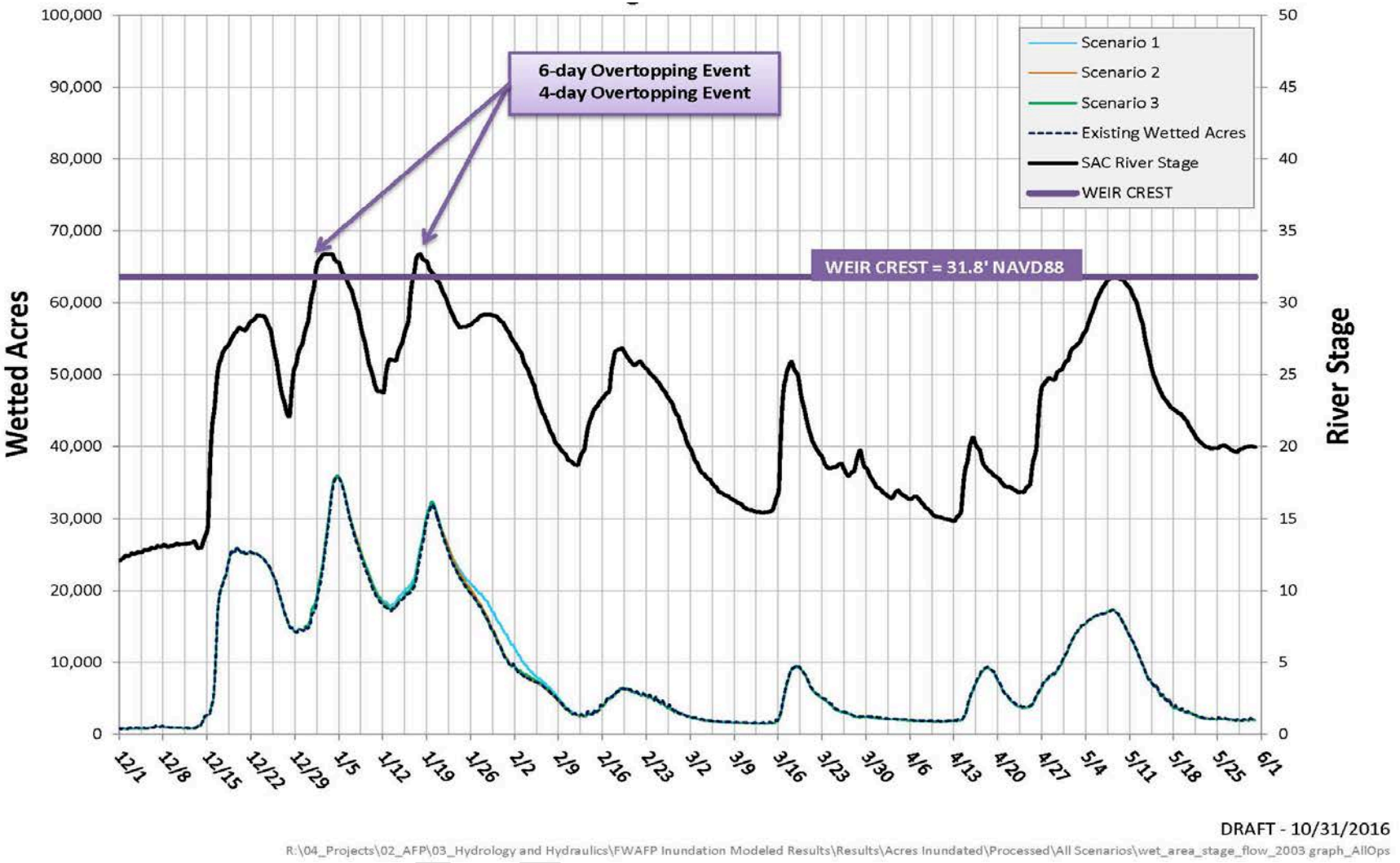

Figure 7. Comparison of Wetted Acres between the Existing Condition Scenario and Alternative Operational Scenarios for Water Year 2003

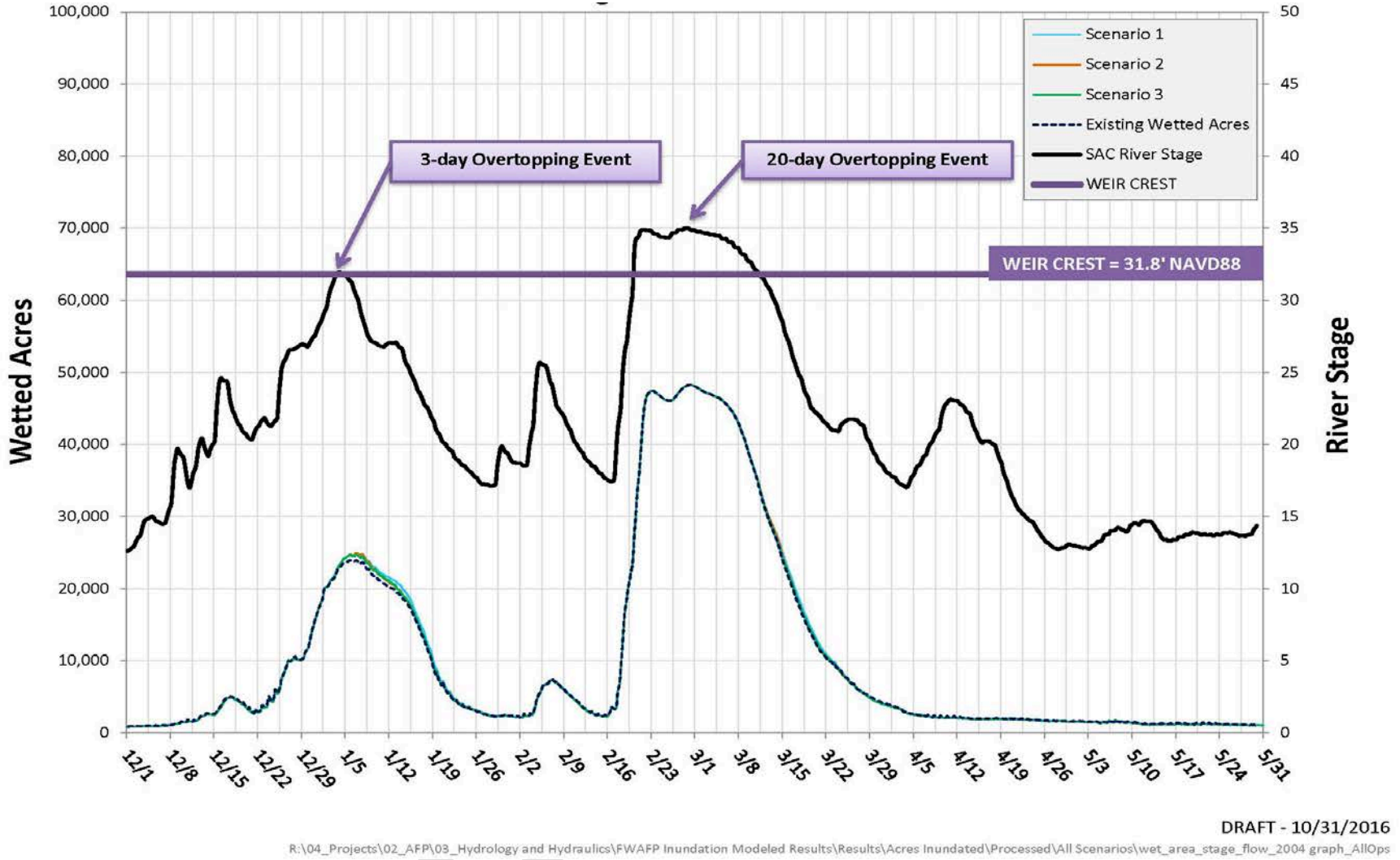

Figure 8. Comparison of Wetted Acres between the Existing Condition Scenario and Alternative Operational Scenarios for Water Year 2004

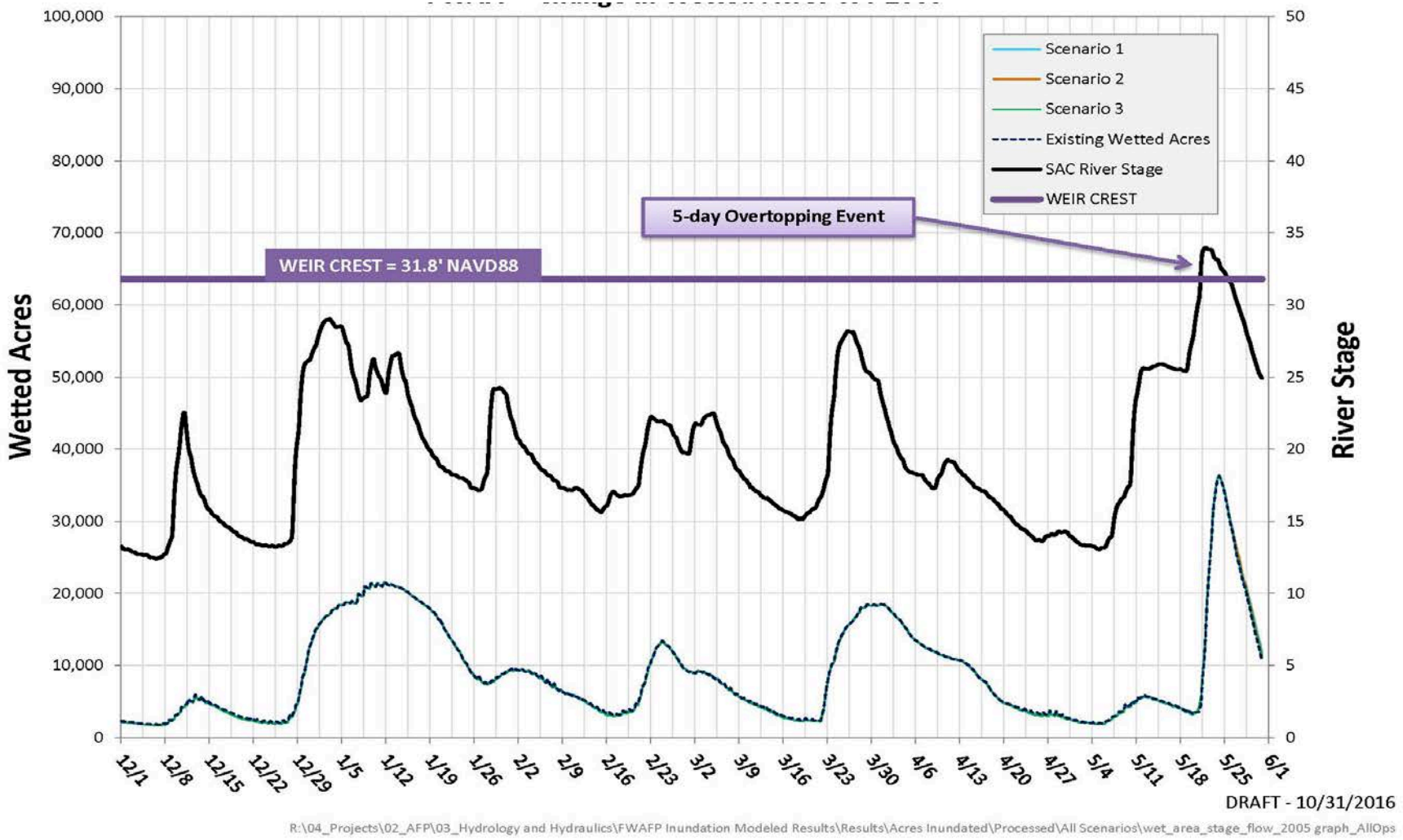

Figure 9. Comparison of Wetted Acres between the Existing Condition Scenario and Alternative Operational Scenarios for Water Year 2005

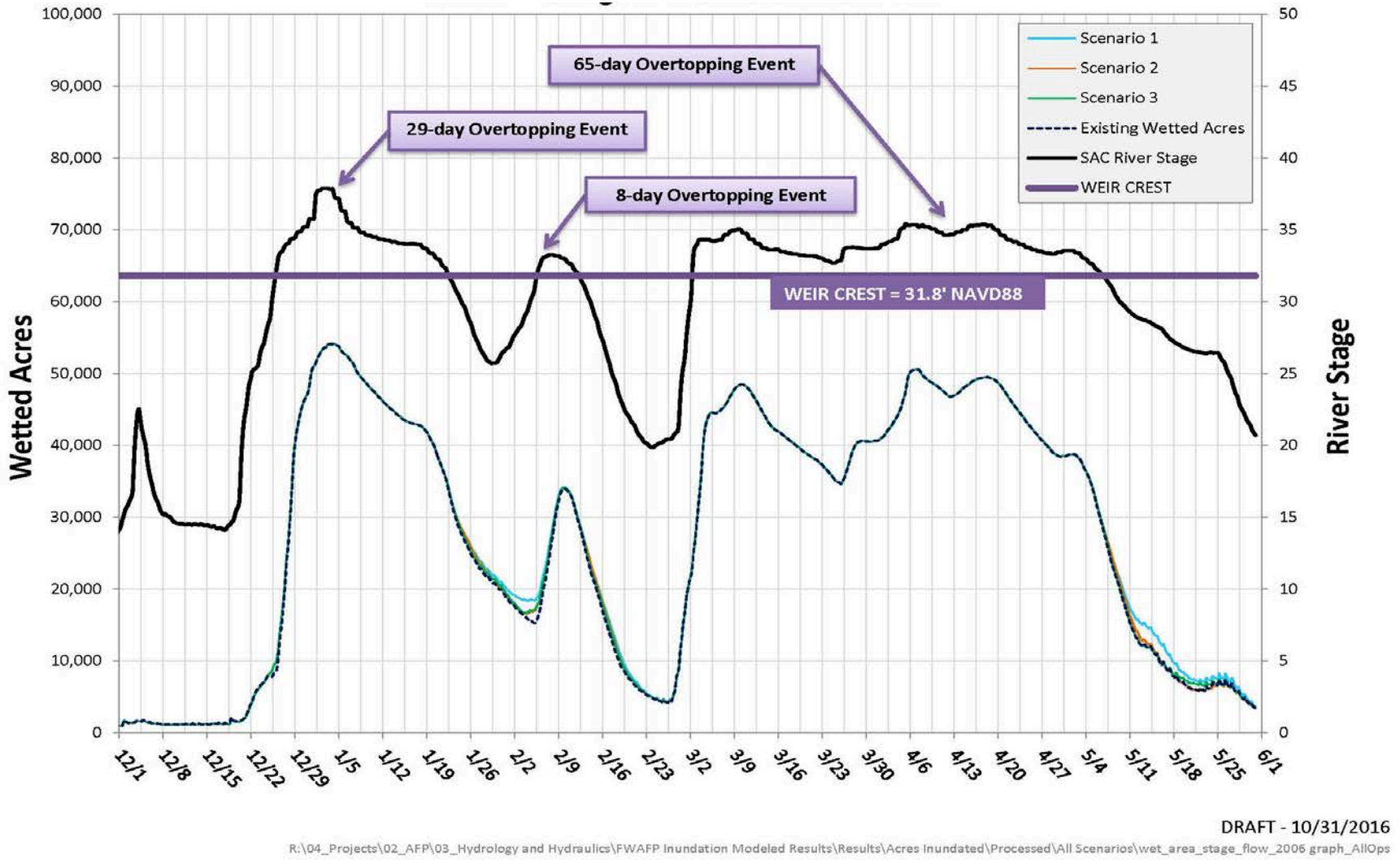

Figure 10. Comparison of Wetted Acres between the Existing Condition Scenario and Operational Alternative Scenarios for Water Year 2006

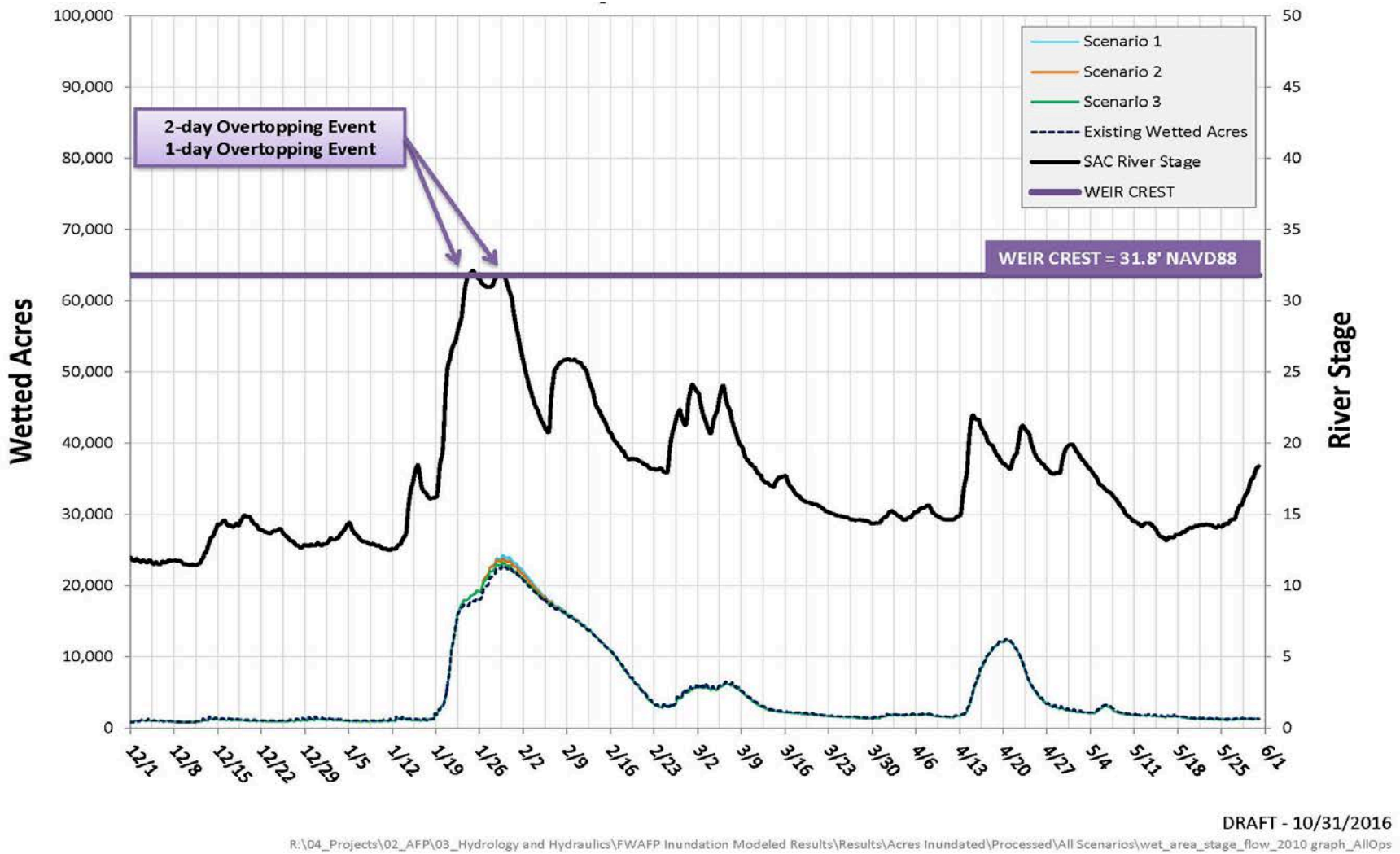

Figure 11. Comparison of Wetted Acres between the Existing Condition Scenario and Alternative Operational Scenarios for Water Year 2010

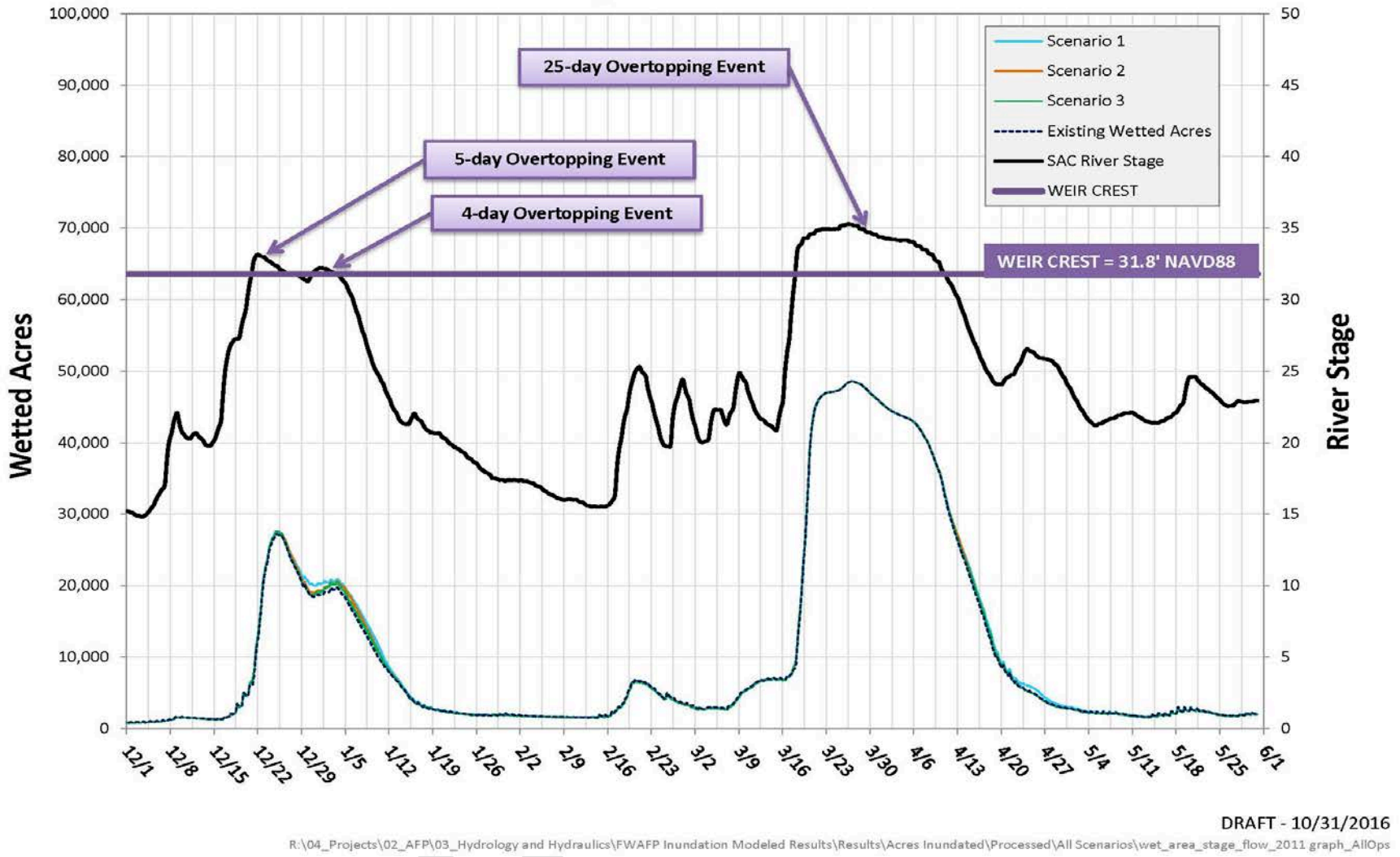

Figure 12. Comparison of Wetted Acres between the Existing Condition Scenario and Alternative Operational Scenarios for Water Year 2011

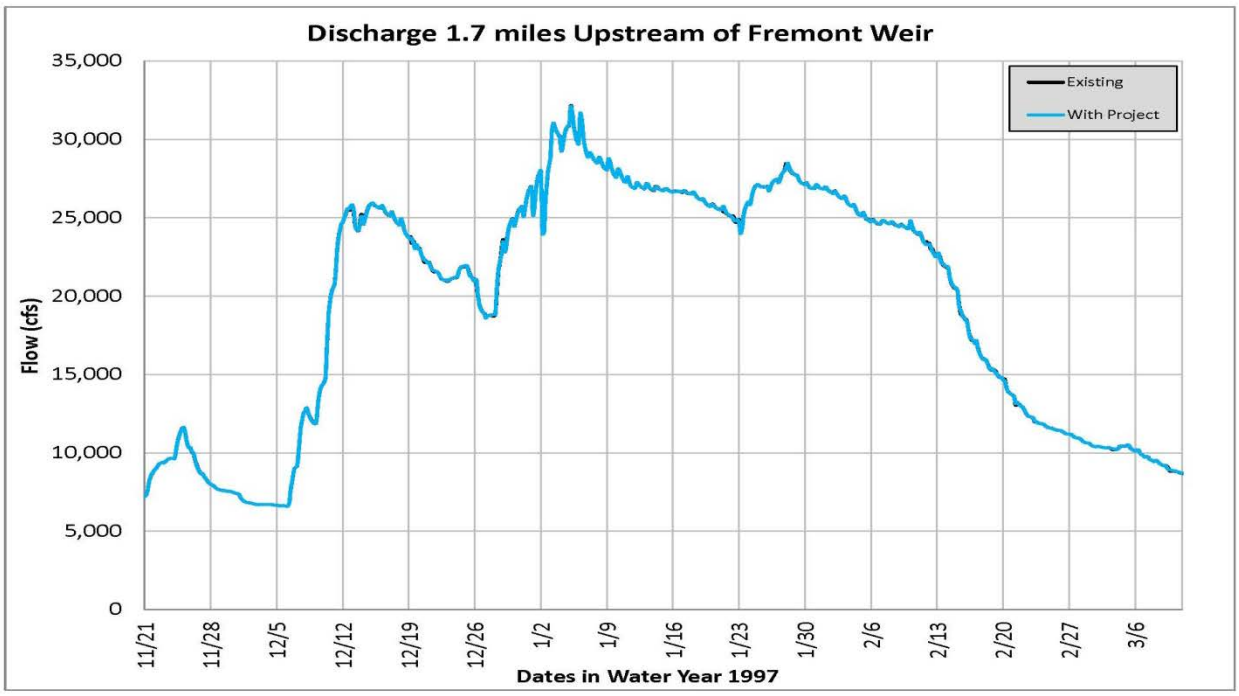

Figure 13. Comparison of flows between existing and proposed project conditions (Scenario 1) for water year 1997 in the Sacramento River at 1.7 miles upstream of Fremont Weir

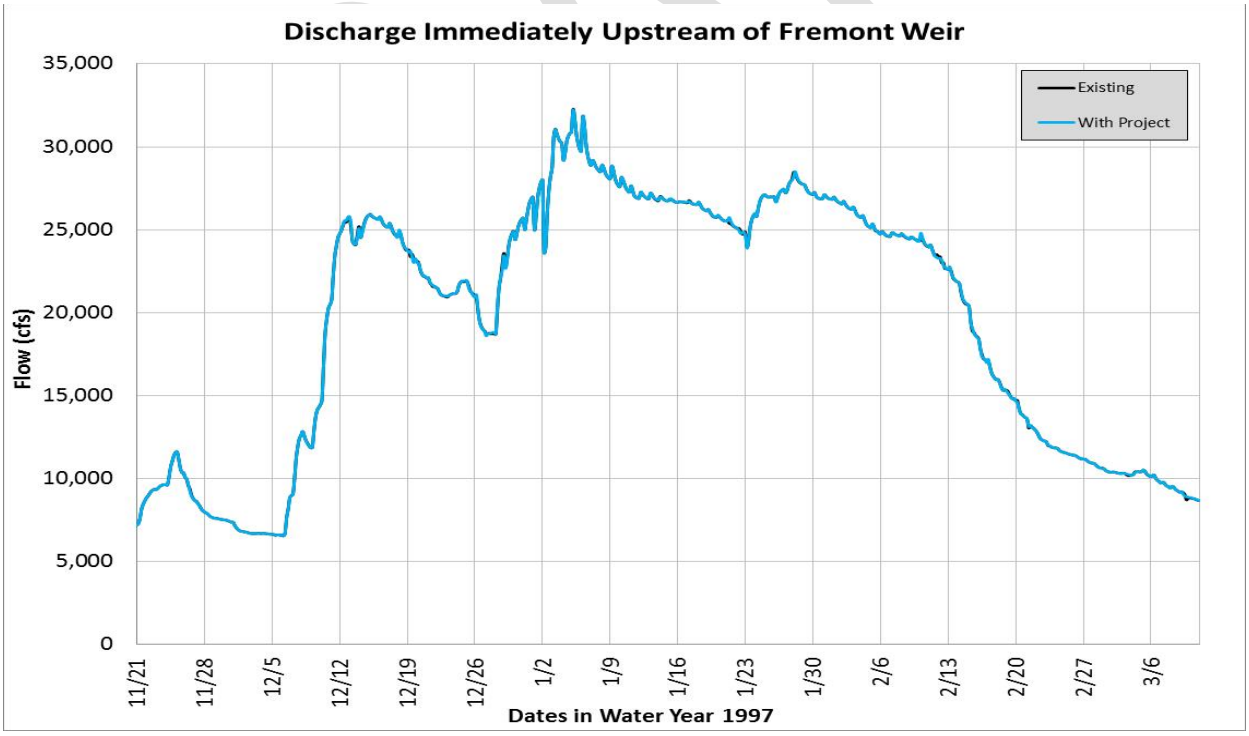

Figure 14. Comparison of flows between existing and proposed project conditions (Scenario 1) for water year 1997 in the Sacramento River at Fremont Weir

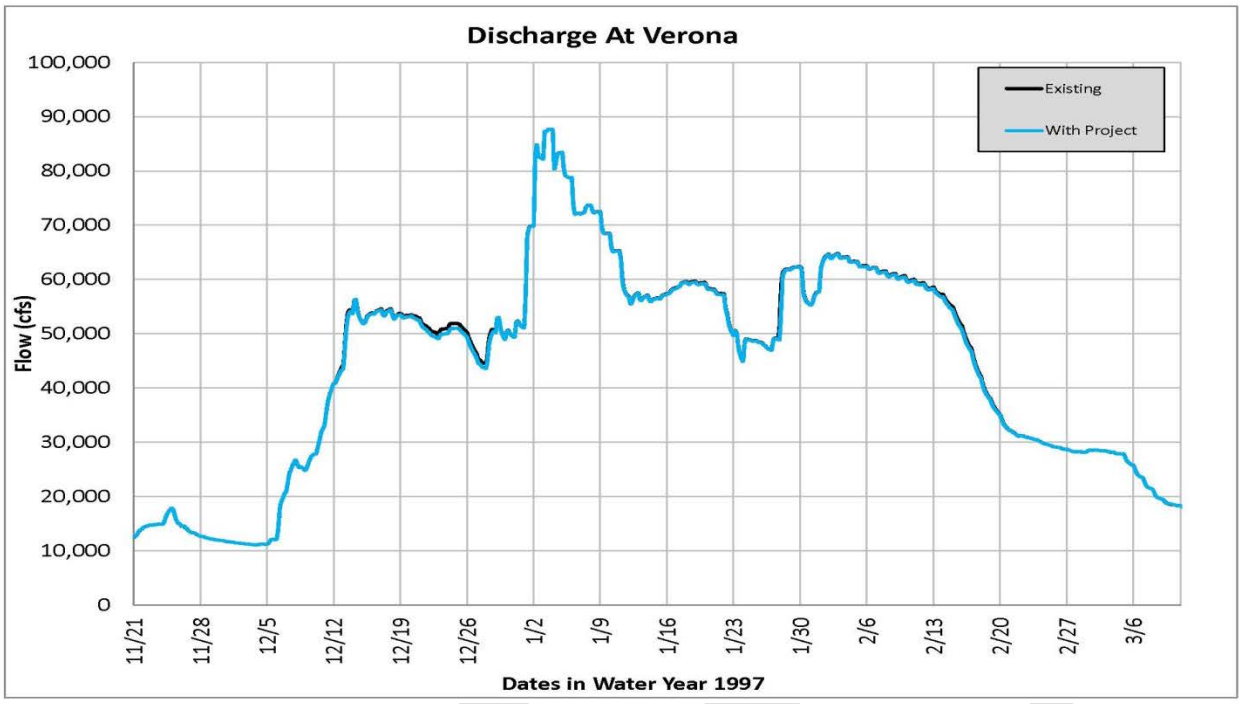

Figure 15. Comparison of flows between existing and proposed project conditions (Scenario 1) for water year 1997 in the Sacramento River at Verona Gage

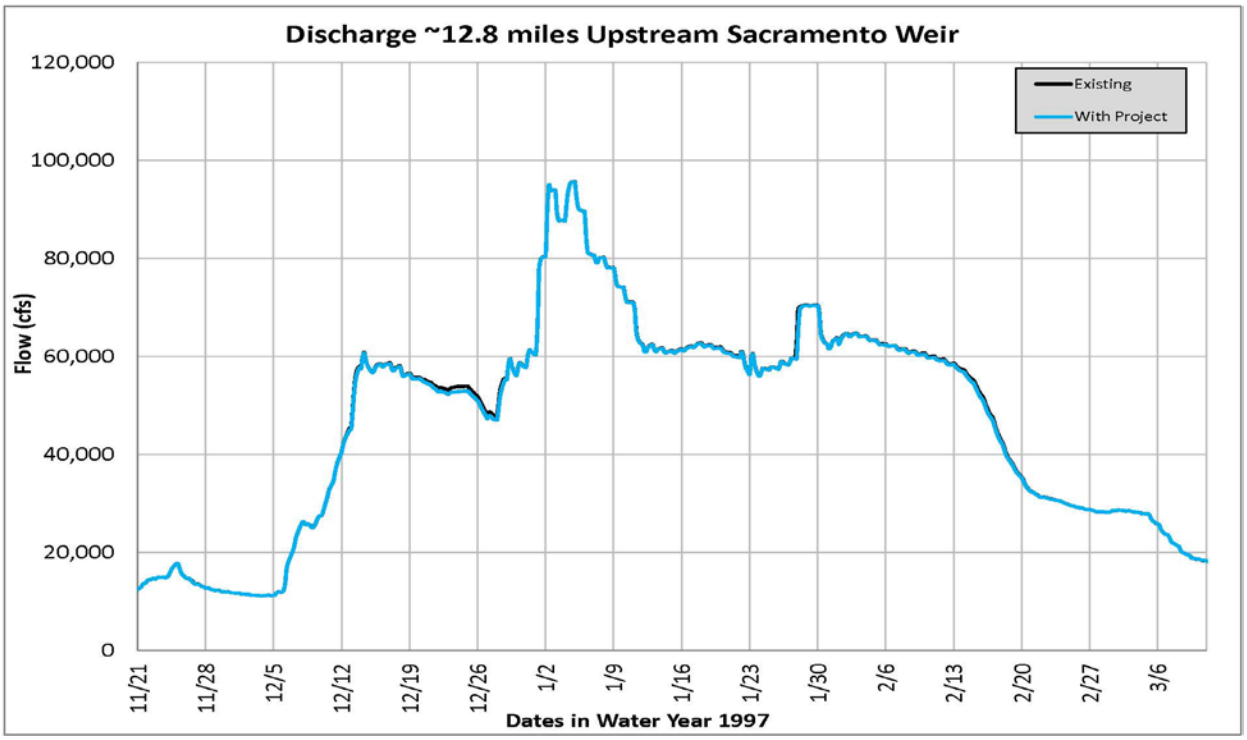

Figure 16. Comparison of flows between existing and proposed project conditions (Scenario 1) for water year 1997 in the Sacramento River at 12.8 miles upstream of Sacramento Weir

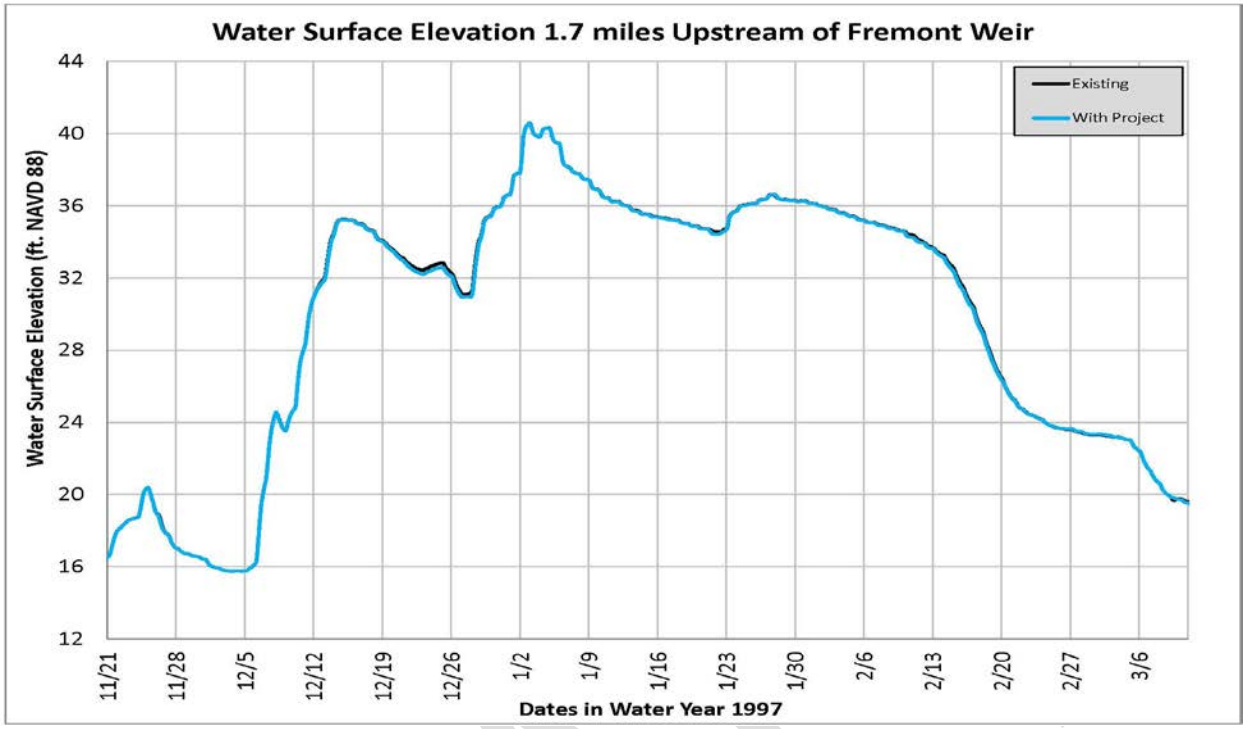

Figure 17. Comparison of stages between existing and project conditions (Scenario 1) for water year 1997 in the Sacramento River at 1.7 miles upstream of Fremont Weir

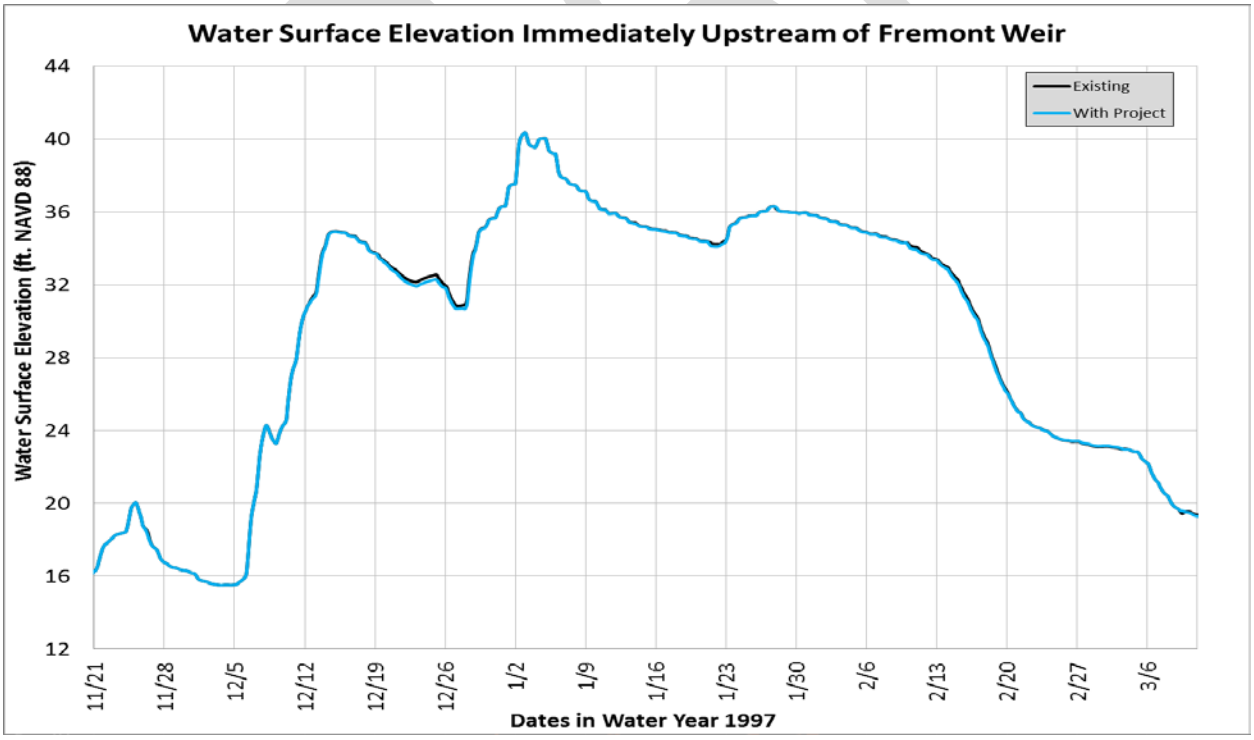

Figure 18. Comparison of stages between existing and proposed project conditions (Scenario 1) for water year 1997 in the Sacramento River at Fremont Weir

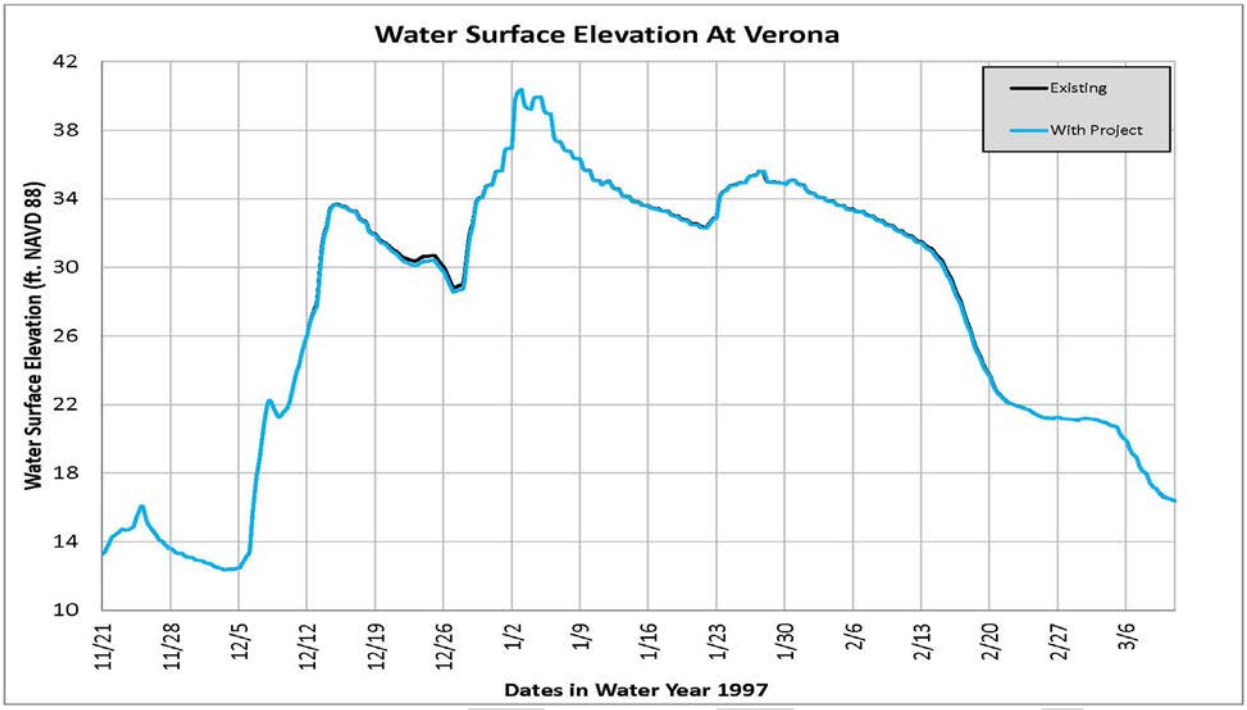

Figure 19. Comparison of stages between existing and proposed project conditions (Scenario 1) for water year 1997 in the Sacramento River at Verona Gage

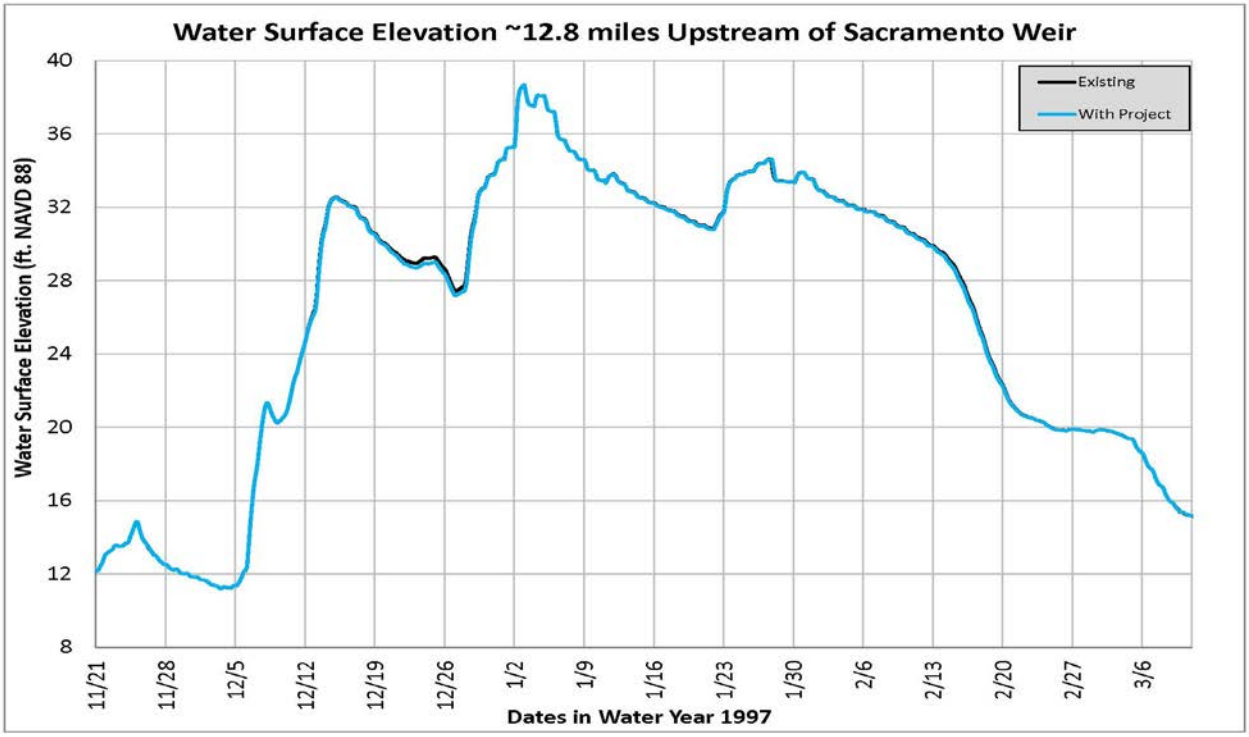

Figure 20. Comparison of stages between existing and proposed project conditions (Scenario 1) for water year 1997 in the Sacramento River at 12.8 miles upstream of Sacramento Weir