

## **Spring Forecast Based Operations, Folsom Dam, California**

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### **BIOGRAPHICAL SKETCH**

Graduate of Humboldt State University, 1975, B.S. Environmental Engineering and Utah State University, 1976, M.S. Civil Engineering, Specializing in Water Resources. Joined the Sacramento District, USACE in 1976 in the Reservoir Control Section. Performed and managed hydrology and reservoir operations portions of flood damage reduction and environmental restoration studies since joining the Sacramento District. Has been the Chief of Water Management for the Sacramento & San Francisco Districts since 1994.

Enjoys short travel experiences, restoring and judging Corvettes (National Corvette Restoration Society), and belt buckle & bolo collecting (Navajo & Zuni).

# California Weather Symposium - 2003

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## **Spring Forecast Based Operations, Folsom Dam, California**

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In August 2002, the U.S. Bureau of Reclamation (BOR) and the Sacramento Area Flood Control Agency (SAFCA) conducted the Lower American River Flow Fluctuation Workshop to identify and evaluate solutions to the adverse effects of flow fluctuations in the lower American River on anadromous fish. During the workshop, the Corps Sacramento District proposed the modification of the current flood control diagram, during mid- to late-spring, to define a flexible zone of operation around the allowable flood and water conservation storage lines. Definition of this flexible zone would be achieved by utilizing weather forecasts provided by the National Weather Service (NWS). By anticipating runoff conditions 24-48 hours in advance, reductions in flow fluctuations and increases in spring runoff storage could be achieved resulting in a balance between fishery preservation and flood risk.

# Outline

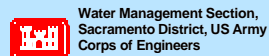
- ① Background
- ② Overview of Existing Flood Control Diagram
- ③ Purpose & Objectives of Spring Plan
- ④ Details of Plan
- ⑤ Flood Routings
- ⑥ Implementation of Plan



This presentation provides a short background on how this proposed plan came to fruition along with an overview of existing flood operation criteria, and objectives of the proposed plan. Discussion details concepts behind the plan's operational criteria and touches upon possible future refinements to these criteria.

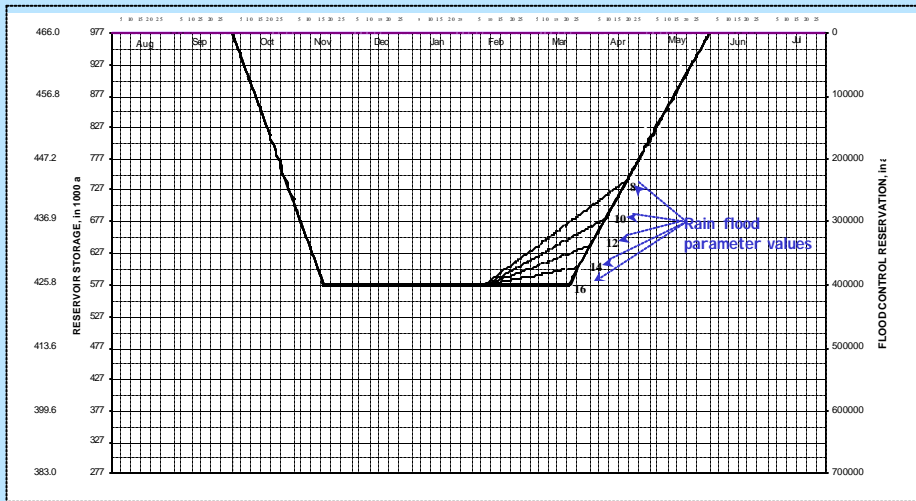
## Background

- Concept originated during the 2002 Lower American River Flow Fluctuation Workshop
- Participants from numerous agencies attended this workshop



In August 2002, the U.S. Bureau of Reclamation (BOR) and the Sacramento Area Flood Control Agency (SAFCA) conducted the Lower American River Flow Fluctuation Workshop to identify and evaluate solutions to the adverse effects of flow fluctuations in the lower American River on anadromous fish. Participants from various agencies attended including: the BOR, SAFCA, California Department of Water Resources, California Department of Fish and Game, National Marine Fisheries Service, Fish and Wildlife Service, Save the American River Association, Sacramento Municipal Utility District, Western Area Power Administration, Water Forum, State Water Resources Control Board, and the Army Corps of Engineers. During the workshop, the Corps Sacramento District proposed the modification of the current flood control diagram, during mid- to late-spring, to define a flexible zone of operation around the allowable flood and water conservation storage lines. Releases from Folsom Dam would be contingent upon weather conditions, forecasted inflows, and operational plans to guarantee that the reservoir would be out of encroachment as quickly as possible in light of any significant runoff event. Following the workshop, several agencies, including the BOR, requested the Corps to proceed with the development and implementation of the flexible band of operation.

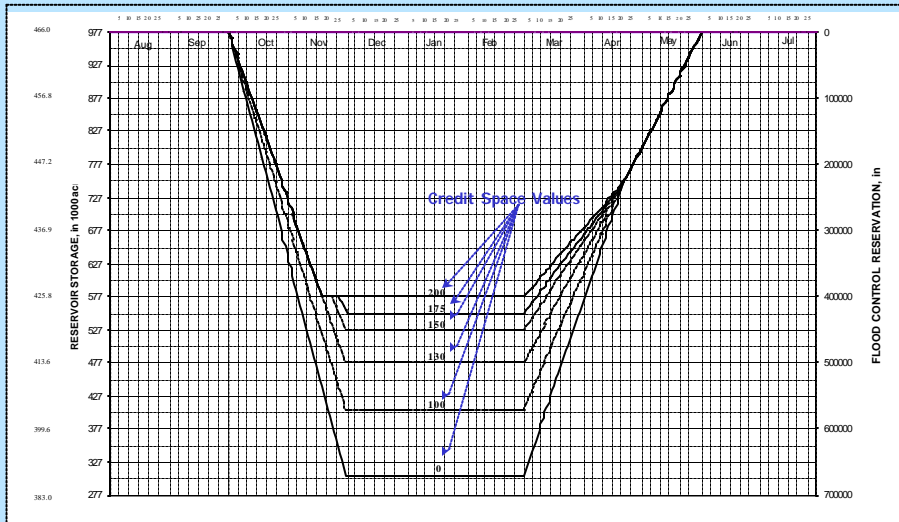
# Existing USACE Flood Control Diagram



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The amount of required flood space varies seasonally from October 1<sup>st</sup> through the end of May. It also varies depending on how wet the basin is during the months of February, March, and April. The basin wetness is defined by a rain flood parameter that is computed daily from the weighted accumulation of seasonal basin mean precipitation by adding the current day's precipitation in inches to 97% of the parameter computed the preceding day. The required flood space is then determined by taking the computed rain flood parameter and interpolating between the defined lines on the diagram.

## Existing SAFCA Flood Control Diagram



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In December of 1993 SAFCA established an interim flood control diagram in order to provide additional flood protection. The BOR currently operates to this diagram. The amount of flood space required by the SAFCA diagram varies seasonally from October 1<sup>st</sup> through the end of May. It also varies depending on available space in upstream reservoirs (French Meadows, Hell Hole, and Union Valley) from October first through mid April. The creditable flood transfer space is computed by combining the available space for each of the three upstream reservoirs. The amount of required flood space is then determined by taking the total creditable transfer space and interpolating between the values specified on the diagram. A maximum credit space for French Meadows, Hell Hole, and Union Valley are 45,000, 80,000, and 75,000 acre-feet respectively. As the various phases of the Folsom Dam Modifications Project become implemented, interim Water Control Plans will be developed. This diagram will replace the existing USACE diagram during the development of the first interim Water Control Plan.

## Existing Flood Release Requirements

- Required flood release – maximum inflow up to 115,000 cfs unless greater releases are required by the Emergency Spillway Release Diagram
- Releases will not be increased more than 15,000 cfs or decreased more than 10,000 cfs during any 2 hour period.



The current USACE Water Control Plan specifies that releases shall be equal to the maximum inflow up to 115,000 cfs, but not less than 20,000 cfs when inflows are increasing. Releases shall also not be increased by more than 15,000 cfs or decreased more than 10,000 cfs during any two hour period. In addition, there is a release schedule recommended by NMFS in the September 20, 2002 Biological Opinion that pertains to the rate at which releases are decreased. This release schedule requires sustained higher than normal releases for fish migration and to limit fish stranding, even though the high releases were initially made to evacuate the flood pool. The sustained releases can cause the reservoir to drop well below the bottom of the flood pool or top of conservation pool, even farther than under minimum flow requirement conditions.

## Reasons for Change

Depending on storm timing and magnitude during the late spring, strict adherence to the existing Water Control Plan could result in:

- 1) *Significant flow fluctuations resulting in devastating effects on fall-run Chinook salmon and Central Valley steelhead*
- 2) *Folsom Reservoir not filling after the flood season*
- 3) *Spilling of cold water at the bottom of the reservoir, which is needed for maintaining adequate temperatures for fall-run Chinook salmon and Central Valley steelhead*

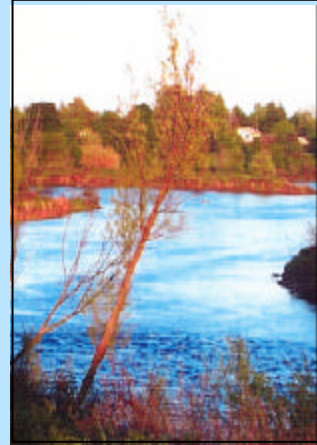


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Central Valley steelhead are listed as a threatened species and fall-run Chinook salmon are a candidate species for listing, pursuant to the federal Endangered Species Act. The purpose of the plan is to provide additional protection to salmon and steelhead by minimizing flow fluctuations and conserving storage of water, especially cold water, in Folsom Reservoir while maintaining the level of flood protection downstream.

## Objectives of Plan

- Reduce magnitude and frequency of flow fluctuations in late spring that can result in Chinook salmon and steelhead losses due to isolation and beach stranding
- Achieve a balance between fishery preservation and flood risk by applying more flexible flood and conservation operations



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A flexible zone of flood control operations between mid March and the end of May will assist in minimizing downstream flow fluctuations and maximize conservation of spring runoff storage. By minimizing flow fluctuations and conserving storage, additional protection to salmon and steelhead will be provided.

## Objectives of Plan

- Increase mid-to-late spring storage levels to meet summer and early fall water supply allocations
- Increase volume of cold water pool by enabling releases through spillway gates when possible



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Although the Folsom Dam river outlets are not of sufficient size to evacuate a considerable volume of water in advance of a storm, during the spring, the reservoir level would be sufficient to utilize the spillway gates for moderate flood control releases. When making these spring flood releases, the spillway gates would be utilized rather than using the river outlets. This would be done to conserve cold water for later downstream releases, when colder water is needed for salmon and steelhead

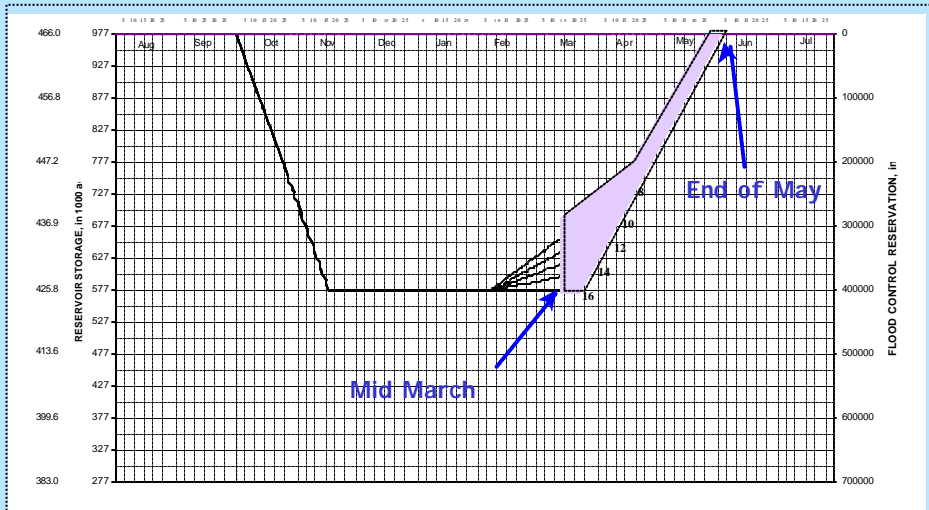
## Details of Plan

- Apply a flexible zone of flood operations starting in mid March and ending on the first of June
- Band extends 30,000 acre-feet above and 10,000 acre feet below the existing top of conservation
- Allow storage to encroach above the existing top of conservation for an extended period of time
- Releases within the band are triggered by forecasted 48-hour volumes into Folsom



A flexible flood operations zone would be applied to the flood control diagram starting in mid March and ending on June 1<sup>st</sup>. The zone has an upper and lower limit. The upper limit, or band, extends 30,000 acre-feet above the TCS line, and the lower band extends 10,000 acre feet below. The main objective of this band is to strike a balance between fishery preservation and flood risk. The potential for reduced flow fluctuation and storage conservation will be made possible by allowing storage to encroach between the TCS line and the upper band for an extended period of time. Evacuation of this additional storage will be contingent upon forecasted inflow volumes over a 24-48 hour period and the percent at which the storage is currently encroached into the flood space. During extreme events flood risk will be reduced by allowing the reservoir storage to dip below the TCS line, but not below the lower band. However, even in such situations, the magnitude of flow fluctuations and the amount of storage evacuated due to the flood releases will be less than what would have occurred under the existing rules.

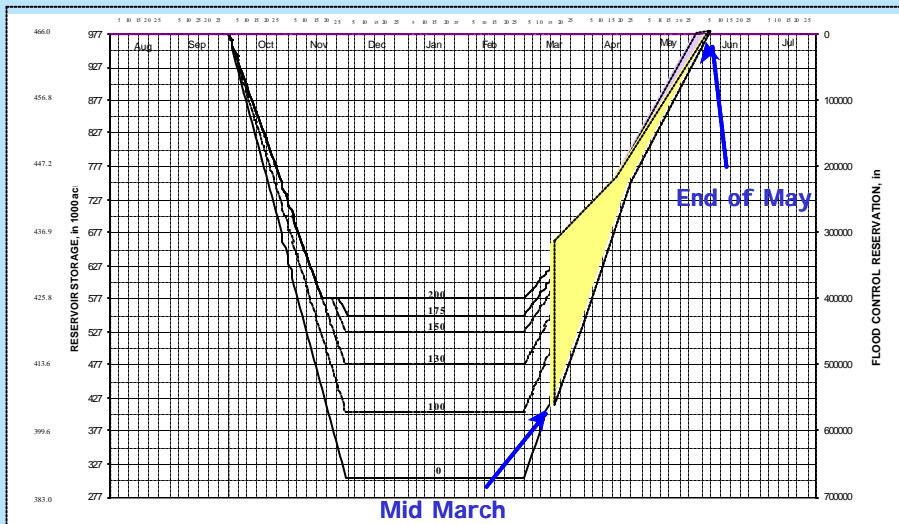
# Modified USACE Flood Control Diagram



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The band would encroach 30,000 acre-feet above and 10,000 acre-feet below the existing top of conservation storage (TCS) line. The TCS line varies seasonally from the October 1<sup>st</sup> through the end of May. It also varies depending on antecedent moisture conditions for the months of February, March, and April.

## Modified SAFCA Flood Control Diagram



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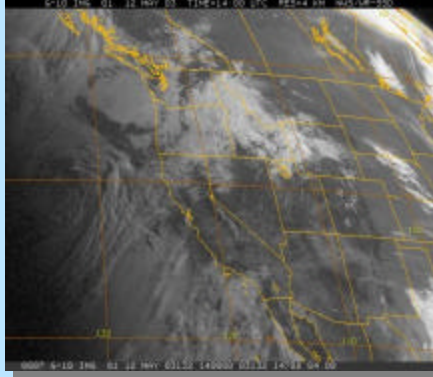
The band would encroach 30,000 acre-feet above and 10,000 acre-feet below the existing top of conservation storage (TCS) line. The band will increase at the same linear rate as the TCS line during late spring when the credit space agreement is not in effect. However, during early spring, the elevation of the upper and lower bands will vary not only by time, but also by available upstream storage. However, the thickness of the band will always be a constant 40,000 acre-feet.


By allowing storage to encroach 30,000 acre-feet above the TCS line up to June 1<sup>st</sup>, the risk of filling the reservoir too soon is increased. In such a case, larger flood releases would have to be made in order to prevent the reservoir from spilling which could result in adverse environmental impacts that would not have occurred under the existing operating rules. One possible solution would be to gradually decrease the thickness of the band so that the band would disappear by the end of May. The rate at which the thickness of the band decreases could be tied to hydrologic conditions in the basin. For example, the rate of decrease would be greater during a “wet year” than a “dry year”. The interim WCPs that will be developed during the implementation of the Folsom Dam Modifications Project will provide the opportunity to make such refinements.

# Weather Forecasting

National Weather Service issues 5-day forecasts, updated normally every 6 hours.

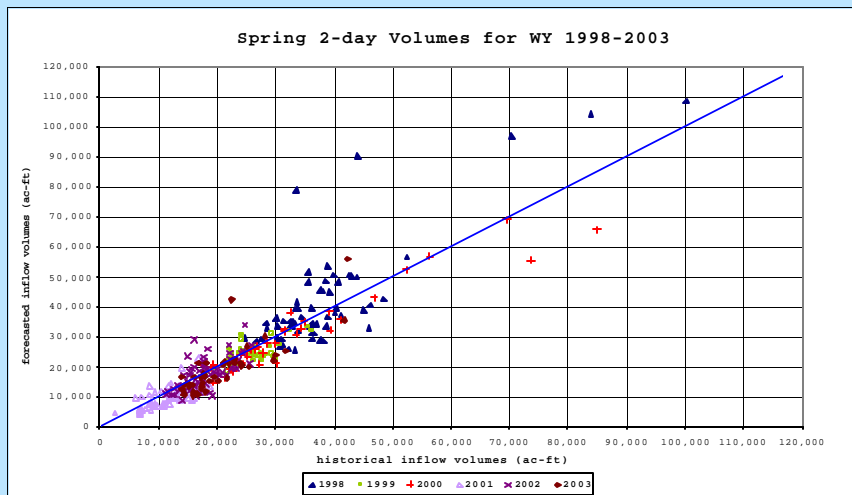
Advance release, 24-48 hours in advance of arrival of spring storms



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The California Nevada River Forecast Center issues 5 day inflow forecasts into Folsom at 6 hour intervals. This information will be utilized when scheduling advanced releases during the spring. Flood releases will be initiated 24-48 hours in advance of the storm. By doing so, the magnitude of flow fluctuations will be reduced. In addition, the volume of cold water will be conserved because the spillway gates will be used to make the advanced releases.

# Forecast Reliability



Note- spring time period is from March 15 – May 30

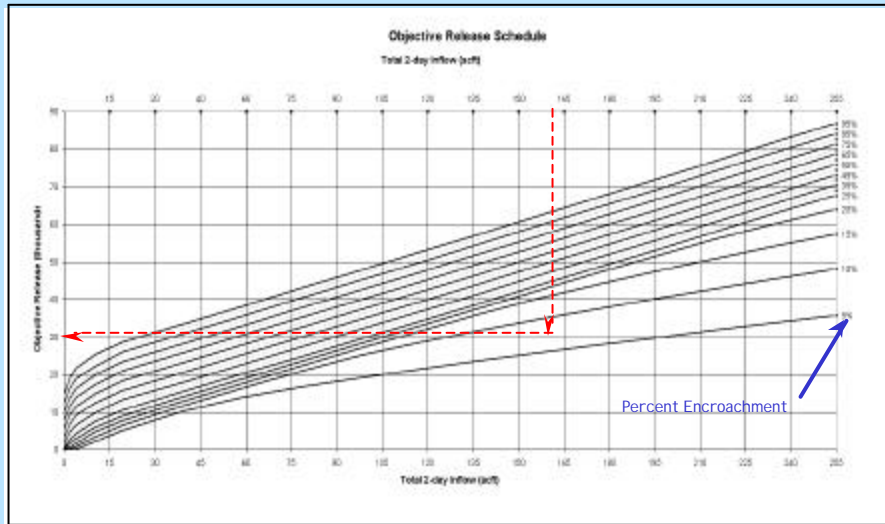


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The California Nevada River Forecast Center issues 5 day inflow forecasts into Folsom at 6 hour intervals. In order to assess the accuracy of these forecasts, a comparison plot between forecasted and recorded two-day inflow volumes was developed. Data was compiled from March 15<sup>th</sup> through May 30<sup>th</sup> for the past five years. Inflow volume calculations started at 10:00 PST each day and extended out 48 hours into the future. Days were not included if the forecast was missing or there was more than five consecutive hours of missing historical data. Influence of upstream reservoir regulation was not incorporated into these computations. The magnitude of forecasted two-day volumes during this time period ranged from 4,000 to 108,000 acre-feet. However, the majority of the forecasted volumes are less than 40,000 acre-feet. Understanding how forecast reliability relates to flow magnitude will continue to grow as additional years of analysis are gathered.

In the above plot, values on the blue line indicate a perfect match between what was forecasted and what came into Folsom. Values above the blue line represent forecasts that are larger than what occurred, and values below the line represent forecasts that are less than what occurred. The majority of the data points do not deviate from the line by more than 25 percent. In order to assess the impacts of how under and over estimated forecasts impact operations, hypothetical routings for such cases were performed. Based on these routings, the application of the modified release schedule still indicates benefits when compared to the use of the existing operating criteria.

# Modified Release Schedule



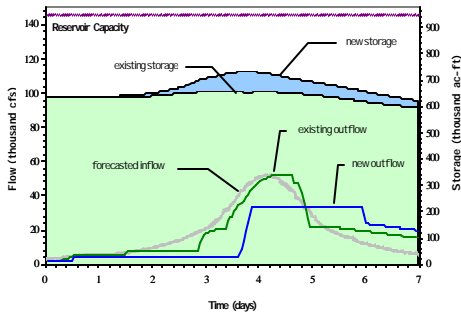
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This is an example of what the modified release schedule could look like. The goal of this objective release schedule is to maximize the use of the storage space in the band while minimizing required releases. The scheduled release is based upon the reservoir's current encroachment and what the two-day forecasted inflow volume is. This schedule would be followed until greater releases are specified by the Emergency Spillway Release Diagram. This release schedule would only be used to step up releases. The current National Marine Fisheries Service (NMFS) criteria specified in the September 20<sup>th</sup>, 2002 Biological Opinion would be applied as releases are decreased.

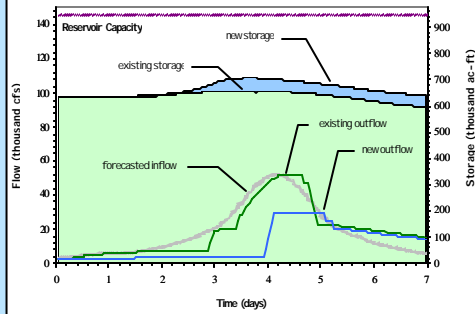
The dotted flow lines indicate an example of a hypothetical event that will be discussed later in the presentation. Reservoir releases will be approximately 30,000 cfs when forecasted 48-hour inflow volumes are 160,000 acre-feet, and percent encroachment is between 5 and 10 percent. Under existing operating rules, maximum outflow would be approximately 50,000 cfs.

# Typical Flood Routings

## Forecast is 100% Accurate...



## Forecast over estimates...

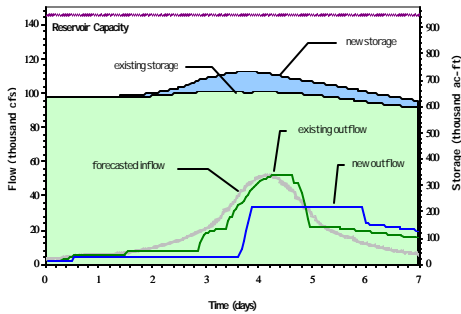


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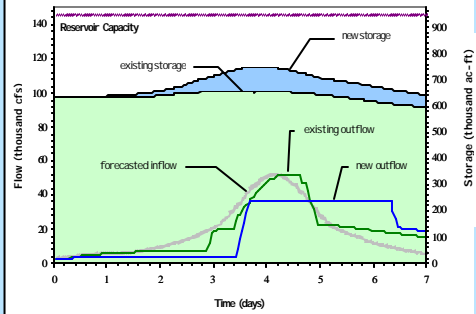
The purpose of these hypothetical routings is to provide a comparison between reservoir operations with and without the modified release schedule, and illustrate the operational impacts of over estimating inflow volumes. The plot on the left assumes that the forecast is 100 percent correct, and the plot on the right assumes that the two day volume that actually comes into Folsom is 25 percent less than what is forecasted. Results indicate application of the modified release schedule provides benefits in both flow fluctuation reduction and reservoir storage even if the forecast is over estimated. When the forecast is over estimated, the duration of maximum outflow is shorter, and outflow magnitude is slightly less than what would occur if the forecast was 100 percent accurate

# Typical Flood Routings

## Forecast is 100% Accurate...



## Forecast under estimates...



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The purpose of these hypothetical routings is to provide a comparison between reservoir operations with and without the modified release schedule, and illustrate the operational impacts of under estimating inflow volumes. The plot on the left assumes that the forecast is 100 percent correct, and the plot on the right assumes that the two day volume that actually comes into Folsom is 25 percent greater than what is forecasted. Results indicate application of the modified release schedule provides benefits in both flow fluctuation reduction and reservoir storage even if the forecast is under estimated. When the forecast is under estimated, the duration of maximum outflow is longer, and outflow magnitude is slightly larger than what would occur if the forecast was 100 percent accurate

## Implementation of Plan

- Will require update to the USACE Water Control Plan
- 3 to 7 interim Water Control Plans (WCPs) will be developed during the implementation of the Folsom Dam Modifications Project
- Refinements to the spring time advanced release plan will be included in these interim WCPs.
- Opportunity for public review of the advanced release strategy through NEPA compliance activities.



In order to change the flood operational criteria, Folsom's Water Control Plan (WCP) must be updated. This process requires NEPA compliance along with approval from the Sacramento District's Division Office. As the various phases of the Folsom Dam Modifications Project become implemented, three to seven interim WCPs will be developed. The opportunity to implement refinements to the spring advance release criteria will be provided prior to the issuance of each of these interim WCPs.

## **For Further Information**

**Point of contact:**

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Bill Fakes is the Program Manager for several of the Folsom Mods projects.

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