CLIMATE CHANGE AND FLOOD CONTROL OPERATIONS IN THE SACRAMENTO BASIN

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ABSTRACT

Shasta, Oroville and New Bullards Bar reservoirs are being studied to determine how Northern California's flood control projects respond to "climate changed" inflows. The goal of this project is to identify why flood control curves should be based on data-gathering and technological improvements that have occurred since the curves were created in the mid-1900s. In collaboration with the Institute for Water Resources, the Bureau of Reclamation, the California-Nevada River Forecast Center (CNRFC) and the Hydrologic Engineering Center, the U.S. Army Corps of Engineers is using climate projections for the year 2030 to test how flood control rule curves respond to changes in timing and magnitude. Preliminary research indicates that both temperature and precipitation changes will occur during that period and that they will alter historically observed flows. As California receives most precipitation between November and May, adapting to changes in peak flow timing and snowmelt runoff is not only crucial to reserve an adequate supply of water into the summer and fall, but also to ensure adequate flood storage.

INTRODUCTION

Flood control is the primary responsibility of the United States Army Corps of Engineers (USACE). Flood control curves exist for each reservoir and define how much water may be stored in a reservoir at any time during the year. This storage volume is determined based on hydrologic data from the early to mid 1900s and the functional objectives of each dam. To prepare for each flood season, the USACE looks at both climate conditions and flood control curves to forecast what releases should be made from reservoirs to prepare for the anticipated inflow. While climate trends have changed since the operating regulations for the dams were developed, the rule curves defining those operational releases have not. The rule curves for Shasta, Oroville and New Bullard's Bar dams will be tested against climate projections for the year 2030. The climate projections will simulate temperature increases of 0.8°F (0.4°C), 1.8°F (1.0°C) and 2.5°F (1.4°C); and precipitation changes of -6.6%, +4.5% and +16.8%. These changes will be applied to a 6-hour time step observed period of record for each basin from 1960 to 1999. Once new hydrologic flows for each combination of temperature and precipitation changes are developed, they will be used to test each reservoir's rule curve.

STUDY AREAS

Basins were chosen based on the expectation that their low mean elevations would be most sensitive to short-term climate changes. The mean elevation in the Shasta, Oroville and New Bullard's Bar watersheds is around 5000ft. Shasta is federally owned and operated by the Bureau of Reclamation. Its rule curve includes a decision parameter based on inflow and was last revised in 1977. Oroville is state-owned and operated by the California Department of Water Resources. Its rule curve includes a decision parameter based on precipitation and was last revised in 1971. New Bullard's Bar is locally owned and operated by the Yuba County Water Agency. Its rule curve has no decision parameter and still uses its original 1978 rule curve. All of these basins are rain-flood dominated.

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METHODOLOGY

Twenty-two Global Circulation Models (GCM) simulations were analyzed for downscaled temperature and precipitation changes under two IPCC climate scenarios, A2 and B1. These GCM simulations are based on observed monthly data from the 1963-1992 historical record. Temperature and precipitation projections are based on the 10th, 50th and 90th percentile values in each basin for the year 2030. These percentile values are used to perturb the 6-hour time step historical temperature and precipitation records from 1960-1999. Temperature scenarios simulate the observed record, +0.8^{o}F (0.4^{o}C), +1.8^{o}F (1.0^{o}C) and +2.5^{o}F (1.4^{o}C). Precipitation scenarios simulate the observed record, -6.6%, +4.5% and +16.8%. Reservoir inflows are generated using the National Weather Service River Forecast System (NWS-RFS). Inputs are perturbed temperature and precipitation records. Outputs are 6-hour time step inflow volumes. Flood control operations are simulated using HEC-ResSim 3.0 and 3.1 Alpha III. Inputs are the 6-hour time step inflows generated by the NWS-RFS. Outputs are 6-hour time step release decisions and reservoir-pool elevations.

SAMPLED EVENTS

Flood events are sampled to reflect a range of storm timings, intensities and rain to snow ratios. Events that are mostly snow are called cold events; events that are mostly rain are called warm events. Warm events are January 1963, January 1965, February 1986, and January 1997. Cold events include January 1969, January 1980, December 1982, March 1983 and March 1995.

RESULTS AND ANALYSIS

Research has been completed for New Bullard's Bar reservoir. Discharge volumes from warm events responded strongly to changes in precipitation intensities, but did not respond strongly to temperature changes (Figure 1). For cold events, discharge volumes responded strongly to both temperature and precipitation changes. This indicates that, because cold events were mostly snow, they were more sensitive to warming temperatures than warm events, which are predominately rain.

Scenarios simulating decreased precipitation intensities and increased temperatures showed unexpected results. Despite decreased storm intensities, runoff volumes were sometimes greater than those in the observed event. A close look at the storm peaks shows that runoff volumes from lower-intensity events began to exceed those of the observed event towards the end of the storm (Figure 2-5). The January 1969 event is used to illustrate this concept. The observed record is illustrated using a heavier line than the other climate scenarios. The four lines below the observed record each represent decreased precipitation scenarios with various temperature increases. The first peak shows that the flow volumes generated by the four decreased precipitation scenarios are less than the flow volume in the observed event (Figure 2). Eleven days into the event, only two scenarios peak below the observed event – both simulate decreased precipitation and the two lowest temperature scenarios (Figure 3). By the end of the event, only one scenario – observed temperature combined with decreased precipitation – generates flow volumes below the observed event (Figure 4). Though the decreased precipitation lowers the intensity of the storm, warmer temperatures increase the amount of precipitation falling as rain. This increased rainfall saturates the basin more quickly, resulting in increased surface flow.

CONCLUSIONS

Decreased precipitation scenarios may decrease storm intensities, but they will not always result in decreased flow volumes. Two factors that seem to have a greater impact on discharge volumes are temperature and basin wetness. Increasing temperatures increase runoff volumes for observed cold events. As warm events are already mostly rain, increasing temperatures do little to impact the snow-rain ratio. Cold events that contain more snow are more sensitive to increased temperatures. It is unclear to what extent basin wetness influences runoff volumes, though the graphs above suggest that increased temperature scenarios combined with decreased precipitation will not immediately yield increased runoff volumes.

Preliminary ResSim runs indicate that the existing rule curves cannot always route "climate-changed" flood volumes successfully; occasionally, inflows encroach the surcharge pool and sometimes overtop the dam. The refill schedule set by the curves must be tested next to determine whether the earlier, increased runoff volumes affect our ability to fill the conservation pool at the end of the season.

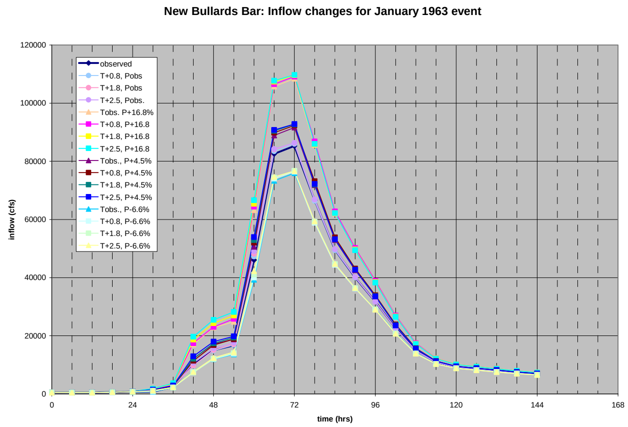

Figure 1. Runoff ensemble of 16 climate scenarios of the January 1963 event. Each grouping corresponds to changes in precipitation intensity. Temperature changes do not have a significant impact on discharge volumes.

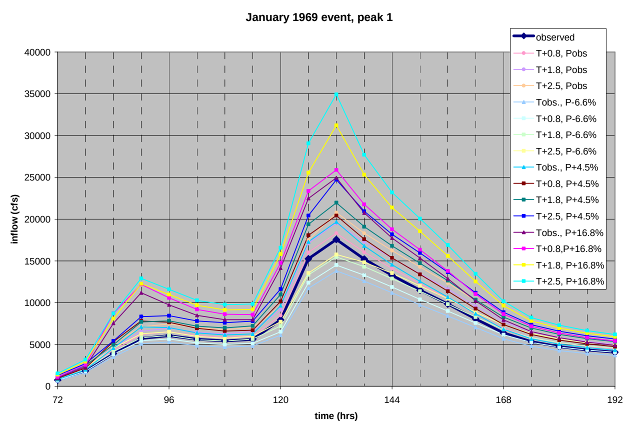

Figure 2. An early peak in the January 1969 event. The observed record is illustrated using the heavy line. Other climate scenarios are represented using thinner lines. The four lines below the observed record all represent scenarios in which temperature varies, but precipitation is decreased by 6.6%

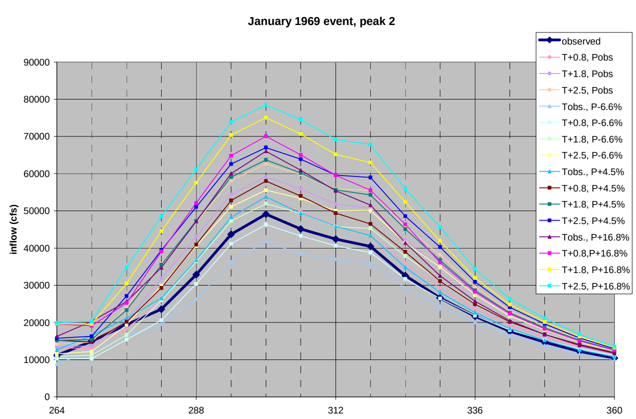

Figure 3. The main peak of the January 1969 event. This peak occurs 11 days after the start of the event. Notice how two of the decreased precipitation scenarios generate more runoff than the observed event. Though the storm is less intense, the high temperatures cause more rain than snow to fall. The increased rainfall saturates the basin sooner, increasing the amount of surface runoff.

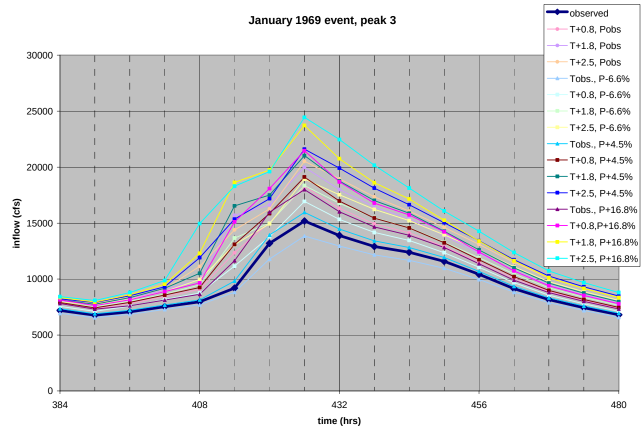

Figure 4. A small peak that occurs after the main storm runoff has passed. This peak occurs 16 days after the start of the event and five days after the main peak has passed. Now, only one decreased precipitation scenario results in less runoff than the observed event. This scenario simulates decreased precipitation with no temperature increase.

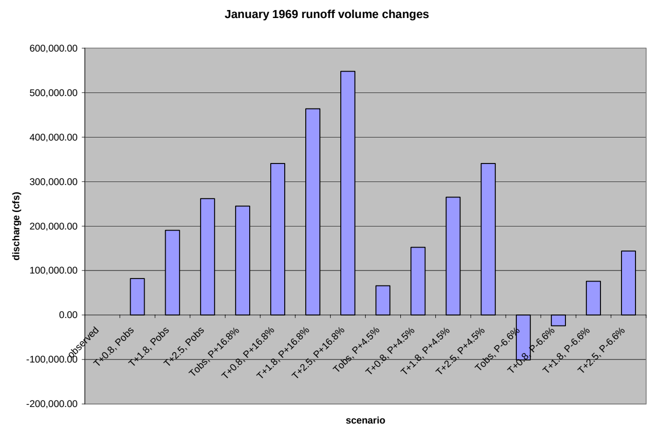

Figure 5. The difference in flow volumes compared to the observed January 1969 event. For total magnitudes, refer to Figures 1-3. The scenario labeled T+0.8, P-6.6% represents a temperature increase of 0.8°F (0.4°C) and precipitation decrease of 6.6%. Though this scenario eventually showed a runoff volume greater than the observed event (see Figure 3), this late runoff surge did not compensate for the earlier, lower runoff volumes.