Forecast Based Reservoir Flood Operation for Flood Management in California

Maurice Roos[1]

Synopsis

Current reservoir flood operation in California relies on maintaining sufficient space during the winter rainy season to contain possible flood runoff from a very large design flood and only release amounts regarded as safe for downstream areas. If reservoir storage during the flood season encroaches into the flood reservation pool, extra water is released to maintain a designated amount of empty storage space. Typically this means that, in some years of previous good runoff, extra fall season releases are made to achieve the required mid-winter pool. The maximum risk of a large flood in the northern California climate is during the winter months. Risks decrease during the spring and so space requirements are gradually reduced, enabling the foothill reservoirs to fill from snowmelt and late season rain runoff. These so-called rule curves are often adjusted for the dryness of the watershed, because a dry watershed will not produce as much storm runoff as a wet one. But often in the later portion of the flood season excess water above the rule curve is dumped when there is no immediate threat of a storm and when it would be very useful for power production and water later in the year.

Medium range (2 to 5 days) weather forecasts have improved greatly during the last two decades and it is less likely that we will be surprised by an extreme rain event on the watershed. Better satellite coverage is one reason for better forecasts. Forecast based flood operation, also known as forecast informed operation, and requires a high degree of weather and watershed monitoring to always be alert for a flood producing storm. Forecasters and reservoir operators need to check constantly to be sure that they have the capacity to lower the reservoir to its required pool level before inflow from a major storm arrives.

The payoff is that often there are no large flood events later in the season and the extra storage can be used for water supply, power production, and other needs.

In this paper, the author will provide an example from a large northern California multipurpose reservoir—Folsom reservoir on the American River east of Sacramento, the State capitol. Forecast based operation does require a high degree of coordination between weather and river forecasters and the reservoir operators.

Introduction

Chart 1 shows the location of Folsom Reservoir relative to the Sacramento Valley flood system in California. The Central Valley of California is probably one of the more flood prone regions on earth. It comprises a large flat low elevation area adjacent to high mountains, particularly on the east, with a plentiful source of moisture for storms in the adjacent Pacific Ocean to the west. In its natural state the Valley was often inundated by major storm events during the winter season and, sometimes, especially in the southern portion to snow melt fed spring floods during years of big Sierra snowpacks. Development in many parts of the Valley was made possible by long lengths of leveed banks along the major rivers,

[1] Chief Hydrologist, California Department of Water Resources, USA

supplemented later by major foothill reservoir operation for flood control on the Sacramento River and tributaries.

Most of the major instream reservoirs in northern California are multipurpose for water supply, hydroelectric power, recreation, flood control, and sometimes other purposes. Other than flood management, the other purposes prefer the highest level of storage possible. But for flood management, empty space is required to control a possible flood which can often arise in a matter of days during the wet season. Reservoir operators like to fill reservoirs as much as possible near the end of the wet season to obtain the most yield and revenue. Operational guidance in the form of rule curves have been worked out to allow increases in water storage in the spring. In the past, the melting mountain snowpack has provided a surge of runoff during the April-July season to allow filling; with global warming, temperate zone snowpack's are shrinking making it more difficult to refill foothill reservoirs.

The recent improvements in medium range weather forecasts out to 5 or 6 days offer the prospects for forecast based flood operation. Water in storage which would be dumped during the wet season can be held in storage for later dry season demands. With good monitoring of the watershed and better short term forecasting of precipitation on the watershed, operators can keep some of the reservoir water for future dry season use. Continual modeling of precipitation and runoff can show the amount of reservoir space needed to control releases to safe downstream levels as a part of routine operations. Allowances are made for the intensity of rain, snow levels, and timing of the storm. Routing of the water can be done for the next 5 or 6 days and adjusted operationally as needed, often two or more times a day during storm events.

Proposed Forecast Based Flood Operation

This paper shows an example of how forecast based operations would work for the American River and Folsom Reservoir, a major tributary of the Sacramento River system. The State Capitol, Sacramento, relies on the 1,200 million cubic meter (mcm) or 977,000 acre-feet (AF) Folsom foothill reservoir for flood protection. Downstream flood channels are designed to pass 3260 cms (115,000 cfs). Estimated peak historic floods have been as high as 8,500 cms (300,000 cfs) in 1997 and take only about 6 - 8 hours from falling on the watershed to reach the Folsom dam. If the forecasted amount can be estimated several days in advance, the operators can make early releases at moderate rates to provide enough space to contain the predicted flood without excessive releases downsream.

In many years with smaller snowpacks, there is not enough late season runoff to fill the reservoir at the end of the wet season. If previously stored water can be held during the middle of the winter this would assure higher late spring levels in the lake and more water supply and power. There is a range of uncertainty in any forecast, so operators will tend to be on the conservative side, with daily (or more often)

Note: 1 AF = 1233.5 cubic meters and 1 cubic meter/sec = 35.3 cfs

adjustments in status. Operators will need to choose a margin of error in providing flood storage space—but at the same time there should be time to make adjustments in releases for differing storm scenarios. The NWS hydrometeorlogical forecasters provide 6 day predictions of precipitation and temperature (which affects snow level in mountain basins) by 6 hour time steps as part of the routine wet season operation. The hydrologists then model the basin runoff to generate inflow to Folsom reservoir. Release schedules are then adjusted and reservoir storage determined.

Historical Progression of Operational Rules

Chart 2 shows the 1986 flood storage diagram for Folsom Reservoir. Normally empty space is required starting in October with the maximum by mid November continuing to March 21, then gradually relaxed during the spring until the end of May. In a drier year when snowmelt runoff is decreased some encroachment can start in early February if the watershed is dry. Basin wetness is computed every day during the flood season from a set of precipitation stations in or near the basin. The current day index is computed as 97 percent of yesterday's index plus today's basin precipitation. The basin average daily precipitation is estimated from 4 telemetered precipitation stations in or near the watershed.

After the big February 1986 flood it was evident that the amount of upstream reservoir space needed to be factored in and that the original 490 mcm (400,000 AF) flood reservation might not be big enough for a really large flood. For a big mid-winter flood abou t830 mcm (670,000 AF) would be required. However, 3 upstream power reservoirs with a capacity around 680 mcm (550,000 AF) usually were only partially filled during winter months. So a revised diagram called the Reclamation/SAFCA rule curve was developed to guide flood operations. It allows credit for the empty space upstream. Chart 3 shows how this modified rule curve looks. It is the one being used today.

Total upstream storage capacity in the 3 reservoirs is about 680 million cubic meters or 550,000 AF. Whether these are nearly full or nearly empty makes a difference in the space required at Folsom to contain a very large flood. In this diagram the available empty space in the 3 reservoirs on each day is entered into the diagram to see how much space is required in Folsom Reservoir. If the upstream reservoirs are full, a full 670,000 AF is needed. More normal winter upstream reservoir levels would be about half full in which case 400,000 AF in Folsom would be sufficient.

In a couple of years new spillway gates will be completed at Folsom Dam with higher outflow capacity at moderate Folsom Lake levels. This will trigger a different diagram and allow a more flexible forecast based flood operation. With the new gates much larger releases at Folsom Dam can be made at mid-levels of Folsom storage, enabling operators to more quickly follow the inflow hydrograph. Normal mid-winter storage then can be held at a higher level, saving this water for the following summer in a dry year. The third chart show how this forecast based operation could work. When the forecasted flood inflow is large, flood releases in the early stages of a very large flood would be made earlier targeting for a peak storage a bit under Folsom capacity at maximum buildup. Peak releases would stay within the downstream flood conveyance capacity. This process would be repeated at intervals during the storm event, adjusting to meet updated forecasted storm hydrographs.

To conclude, the use of weather and runoff forecasts in reservoir flood operation is expected to improve the degree of downstream flood protection and also provide drier year water supply at Folsom Reservoir compared to conventional fixed rule curve operation.

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