Proceedings of the25th Climate Diagnostics & Prediction Workshop, Palisades, NY, October 2000, pp 219-222 (2001)

Demand-side perspective on climate services for reservoir management

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Introduction: The implementation of a national climate service will require the regular and systematic communication of climate information to users. There are a number of barriers to use of the climate information currently available, among them, the timing of the forecast, the need for locally specific information or other kinds of information, and need for procedures to incorporate climate information in decisions (Pulwarty and Redmond, 1997; Stern, 1999; Chagnon 2000). We are conducting a systematic effort to effectively remove some barriers by providing focused climate information that address users= needs for reservoir management in the Interior West. This effort is an example of pilot or prototype implementation of climate services. In addition, we are interviewing users to determine their climate information needs and current uses. Finally, we are observing how the information is used in decisions. We anticipate that implementation of climate services on a national scale will be improved by first conducting regional-scale prototype activities, focused on users who are susceptible to climate variations and who are willing to work in a partnership to help design effective information systems for products useful to them. This study is part of the NOAA/Univ. of Colorado Western Water Assessment as well as the Climate Diagnostic Center=s activities as a NOAA Applied Research Center.

This effort focuses on the potential for climate information to improve reservoir management decisions, e.g., annual reservoir operating plans, and providing water for specific goals. In contrast to the frequently used sector focus, we are using a problem-oriented approach to identify issues sensitive to climate variability, the decision processes which are associated with these issues, and thus the users to target and their demands for information. Reservoir managers in the Interior West are currently faced with providing water for new uses (in stream flows, recreation) while still meeting the needs of traditional rights holders. Several legal mandates could require changes in water distribution unless another way is found to meet an increasing number of multiple uses. Improved use of climate information represents one tool for reservoir mangers to meet these uses while minimizing conflicts.

Our approach relies on direct interaction with regional reservoir managers. We are building on several years of CDC interaction with the U.S. Bureau of Reclamation (USBR) which began with providing climate input for the management of Glen Canyon Dam/Lake Powell during the 1997/98 El Niño. That year, managers were concerned about the potential for high runoff (see Pulwarty and Melis, 2001). In this case, the need for climate information in reservoir management is driven by expanded operational goals to meet multiple uses that now include recreation and environmental needs in addition to irrigation, municipal, and industrial uses, and hydropower.

Climate information and multi-purpose reservoir management decision-making: Our interactions over the past year with water managers have revealed a number of key decision points for which both forecasts and historical relationships of ENSO and local conditions which might be useful, i.e., the demand for climate information. The USBR now is being asked to support the Recovery Implementation Plan (RIP) for endangered fish in the Upper Colorado River, by engaging in efforts to achieve a more natural hydrograph by augmenting spring peak flows and maintaining target minimum flows at other times (USFWS, 1999). Before large dams were built, natural peak flows of the Colorado River above Grand Junction averaged over 25,000 cubic feet per second (cfs), and almost always exceeded the 12,500 cfs threshold to move sediment and rework the channel to build and maintain endangered fish habitat (Pitlick, et al, 1998). Since the large dams were built, peak flows have averaged 17,500 cfs and many years failed to exceed the 12,500 cfs threshold. Reservoir managers are incorporating into their operating plans an effort to augment the peak flows along reaches of the Upper Colorado River in order to exceed the threshold for habitat building. Efforts to augment natural peak flows with water from large reservoirs depend on:

1) Confidence of reservoir managers in water supply and demand forecasts in order to justify decisions to release water prior to the high demands period, and still meet contracts to supply water,
2) forecasting the peak to time releases to ensure raising the flows above the threshold.

Critical questions for deciding whether to attempt to augment peak flows are: How much water is stored in the snowpack? How quickly will it will melt, how much runoff will be produced? When will the peak flow occur? And what will subsequent warm season water demands be?

Reservoir annual operating plans are often graphed as reservoir elevation curves (related to volume). The elevation curve for the USBR Green Mountain Reservoir is representative of reservoirs in the Colorado River headwaters region (Figure 1). A "start of fill" target is set for April 1st, depending on the inflow volume expected during the runoff season from April-July. As early as February, operators may begin to draw down the reservoir if high inflow volumes are expected (lower dotted line); on the other hand, if a low volume is expected, reservoir volume will be conserved (upper dotted line). The consequence of drawing down the reservoir, without getting the expected inflow, is that the manager may not fill the reservoir to capacity. On the other hand, if a high inflow volume is received but the reservoir was not drawn down, the manager may be forced to "spill" the reservoir, and also risks downstream flooding. In both cases, the manager loses hydropower revenues later in the season as well as water for irrigation; in the former because the reservoir is not filled to capacity, and in the later because the water was released when not needed for irrigation or hydropower demand.

Reservoir managers have identified some operational flexibility in facilities such as Green Mountain reservoir that could be used in peak augmentation. This figure also shows how adding peak augmentation affects management planning. In the peak augmentation effort, more of the inflow is captured before and after the anticipated natural peak (thin gray line); during the natural peak all inflows are "bypassed" through the reservoir (gray shading). In some recent years 2000-2500 cfs have been added to the peak for 7-10 days (Smith and Wilson,1999).

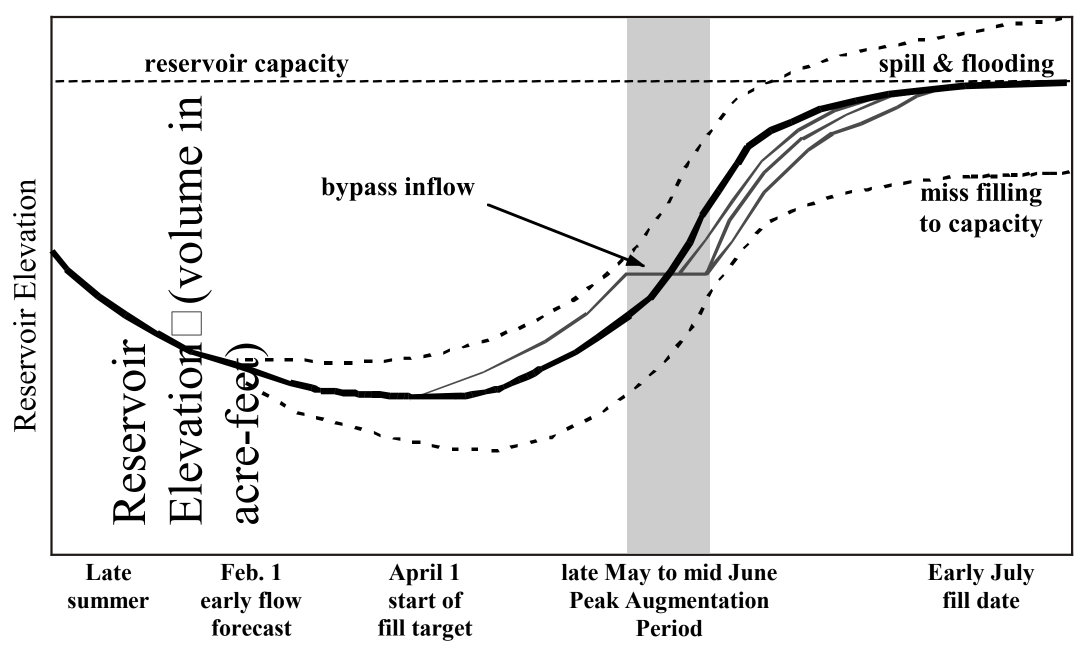

Figure 1. Idealized elevation curve for Green Mountain Reservoir, Blue River, north central Colorado.

We have collected information on planning processes and operational issues for the Upper Colorado River Basin reservoirs in a series of interviews and workshops. Our decision calendar

(Fig. 2) illustrates how planning processes and operational issues relate to the potential use of various types and timings of climate and weather forecasts.

The Reservoir Management Decision Calendar indicates the timing of select planning processes (shaded bars) and operational issues (dotted bars) for the Upper Colorado River Basin reservoirs. Also shown are the potential use of various types and timings of climate and weather forecasts (hatched bars) that could be used to address these concerns. The width and position of the bars indicate the intervals of relevant time periods. For example in the late winter (Feb-March), improved forecasts of the runoff volume, as well as forecasts of summer irrigation and hydropower demand, based on long-lead climate forecasts, could better help plan for both the start-of-fill target and the decision on whether to attempt peak augmentation. Improving forecasts of the timing of the peak is important, with lead times of 2-3 weeks. The lead time required is related to the coordination that is needed to achieve the peak augmentation as well as the transit times of several days from the reservoirs to the critical reaches of the river where the habitats are. Later in the summer, forecasts of the upcoming water year could be helpful in late summer management of irrigation, hydropower, and meeting target instream flows for environmental purposes. This topic is not discussed further in this paper.

Conclusions: Decisions within multipurpose reservoir operations could use a spectrum of climate information and forecasts to improve the efficiency of coordinated reservoir operations, including peak flow augmentation as part of endangered species recovery plans. The decision calendar has proven to be an effective as a framework to link planning processes and operational issues to potential uses of forecasts and climate information in understanding the needs of water managers.

As illustrated by the calendar, the users studied could use both improved climate forecasts and improved information on how climate influences weather and extreme events. Furthermore, these users view weather and climate events as a continuum. This finding supports the need to develop a truly "seamless suite" of forecasts, and a staged forecast strategy connecting forecasts of seasonal risks (one or more seasons in advance), threats assessments (days to weeks in advance) and weather forecasts. Finally, mutual education of scientist and users, and the development of partnerships between the researchers and users is critical to improve the usefulness of forecasts and climate information.

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