# INCORPORATING SEASONAL STREAMFLOW FORECASTS INTO OPERATIONAL DECISIONMAKING

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## ABSTRACT

*Note: This paper is a companion to 'SEASONAL STREAMFLOW FORECASTING USING CLIMATE INFORMATION" (Baldwin, this volume).*

Explosive population growth in the western U.S. and the resulting new demands on water systems require water system operators to squeeze more efficiency from their existing water systems. In mountainous areas of the west, most of the available water comes from snowmelt runoff. Improving snowmelt forecasting, including the lead-time of forecasts, can help meet the water challenges of population growth.

One technique, developed by Utah State University for the city of Denver, shows promise. Based on climate indices from the Pacific and Atlantic oceans, probabilistic forecasts of the April through July runoff volume on the South Platte and Colorado rivers are made in the autumn. These forecasts have the potential to increase operating efficiency particularly to benefit secondary operating priorities such as hydropower generation, water-based recreation, and aquatic restoration programs. The forecasts are now being evaluated for use in operational decisionmaking. Forecasts made in the fall of 2000 along with the low water conditions prompted system operators to reduce winter hydropower generation and redistribute storage water. Spring runoff will show if these were good decisions. Research will continue this year into how to make the forecasts more understandable and useable by the water system operators.

## INTRODUCTION

Growth and water management are hot topics in the mountain regions of the American West. As demonstrated by the 2000 Census, this area has experienced explosive population growth -- creating demand for not only more municipal water supply, but also for more water for recreation, hydropower, and aquatic restoration (Olinger 2001). Along with the population growth comes a stronger environmental ethic, closing the door on the classic solution of more dams, tunnels, and canals to meet growing water demands. Water historian and Colorado Supreme Court Justice Greg Hobbs has mused that water supply planning is the toughest job in the New West (Hobbs 1998). Rather than building new facilities, today's emphasis is on maximizing the efficiency of existing water systems. Many municipal water suppliers now rely upon aggressive water conservation and water reuse projects. Improvements in snowmelt runoff forecasting, particularly longer lead time forecasting, can also play an important role in improving the efficiency of water systems.

Climate indices representing the El Niño/Southern Oscillation (ENSO) phenomena have highlighted the potential for forecasting spring runoff even before the snow falls. Runoff forecasts made in the fall of the year may help water operators squeeze more benefits and efficiency out of their existing water systems. While forecasts from ENSO phenomena may have helped many water systems in the American West, there is not a strong correlation between ENSO phenomena and springtime runoff in central Colorado (Baldwin 2000). In the companion paper, "Seasonal Streamflow Forecasting Using Climate Information," Connely K. Baldwin describes how ENSO and Atlantic Ocean indices were used in central Colorado to develop probabilistic forecasts, in autumn, to predict the snowmelt runoff volume in the City of Denver's watersheds. Along with the technique, the accuracy and reliability of the forecasts are described in that paper. The emphasis of the project was to develop forecasts that would be practical and useful in the actual operation of Denver's water system. Careful attention was given to meeting the water system operator's needs. This paper describes the need for and the usefulness of the autumn forecasts in the operation of the Denver water system.

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## BACKGROUND

### The Lay of the Land

The Continental Divide is the backbone of Colorado, dividing the state in many ways. Approximately 75 percent of the state's precipitation falls on the Western Slope, but nearly 90 percent of the state's population lives on the semi-arid Eastern Slope (Paulson 1991). The discovery of gold caused the first population boom to the Eastern Slope of Colorado. To feed the miners, by the 1880's, farmers had claimed most of the reliable streamflow along the Eastern Slope. To meet their customers' water needs, growing Eastern Slope cities such as Denver built reservoirs to capture spring runoff and later tunnels under the Continental Divide to tap West Slope sources. As environmental concerns grew, the dams and tunnel projects were halted but the region's population continued to boom.

The Front Range of eastern Colorado has three of the ten fastest growing counties in the United States. Douglas County, on the southern end of the Denver metropolitan area and the fastest growing county in the U.S., nearly doubled in population during the last ten years (Olinger 2001). Front Range municipal water suppliers are straining to keep up with water demand. Plus, the booming population is demanding more than just water taps creating new and unexpected challenges for water managers. Reservoir owners are asked to augment the natural streamflow to meet the spawning needs of non-native trout species. Start-up rafting companies are clamoring for reservoirs to release more water and, in some cases, augment natural streamflow conditions. Ski resorts now borrow water from cities in the wintertime for artificial snowmaking. Hydropower is back in vogue as a clean, reliable energy source. Flood protection is needed for the trophy homes built along scenic mountain streams. Forest fire suppression for the protection of homes on the Front Range has led to a huge buildup of fuels, resulting in devastating forest fires that clog water intakes with sediment and debris (USDA 2000). On top of these growth demands, many water systems are past their prime, requiring long-term outages for replacement. Global warming is threatening to change the entire streamflow regime. To respond, water managers are squeezing as much efficiency from their water systems as possible.

### Water Efficiency and Forecasting

Rather than building more dams and tunnels to meet the challenges of population growth, water providers along the Colorado Front Range now focus on efficiency. They rely heavily on aggressive water conservation measures, building water reuse systems, and making physical improvements to their existing systems. Improvements in snowmelt runoff forecasting can also help make water systems more efficient.

Unfortunately, long lead time snowmelt forecasting for central Colorado, where Denver collects its water, can be complex. Apparently by being in the middle of the continent far from the Pacific moisture sources and protected by numerous mountain ranges, the spring runoff volume in central Colorado does not correlate well with ENSO conditions alone (Baldwin 2000). Also, weather on the Eastern Slope is strongly influenced by Atlantic moisture sources (McKee 2000).

### Denver's Water System

Denver Water supplies water to approximately one million people, or about one-half of the metropolitan Denver area (DBWC 1997). One-half of the customers are in the city of Denver and the other half are in the surrounding suburbs. Nearly 80 percent of the streamflow in Denver's watershed comes during springtime runoff. Approximately one-half of Denver's water supplies comes from the South Platte River flowing through this city. Much of that supply is obtained from storing the springtime snowmelt runoff in a series of upstream reservoirs. The other half of Denver's water supply comes from collecting, storing, and conveying the headwaters of the Colorado River under the Continental Divide to the South Platte basin through a series of reservoirs, canals, and tunnels. Denver has a storage capacity of 820,000,000 $m^3$ (665,000 acre-feet), about half of which is located on the Western Slope of Colorado. Denver's current system water use is approximately 327,000,000 $m^3$ (265,000 acre-feet per year). The system has a firm annual yield of approximately 425,000,000 $m^3$ (345,000 acre-feet). Projected buildout demand for Denver's service area is over 549,000,000 $m^3$ (445,000 acre-feet per year). Denver's system is somewhat unique in the West in that it is fully owned by the municipality. There are no federal facilities. Even though the system was designed and built for a single purpose — municipal water supply – it is now operated for many secondary benefits.

## USING SEASONAL STREAMFLOW FORECASTS IN OPERATIONAL DECISIONS

### The Potential

In autumn, Denver's water operators make critical operating decisions. Decisions are made based on two criteria: (1) the current water levels in reservoirs and streams, and (2) the amount of water the system will yield in a drought compared to the current water use levels. Without knowledge of the upcoming snowpack, operators must assume the worst — that the next year will bring a drought. This assumption sometimes leads to winter operations that maximize the probability of refilling reservoirs during the runoff. Assuming the next year will be try tends to reduce secondary benefits the water system can provide such as hydropower generation, flood control, and streamflow augmentation for sport fisheries, endangered fish recovery programs, and whitewater recreation.

Fall and winter is the time to redistribute water in reservoirs in order to maximize the capture of spring runoff. In some years, Denver can have below normal runoff on one side of the Continental Divide and above normal runoff on the other side. Runoff forecasts would help better position water prior to runoff. Much of Denver's water system has passed its design life expectancy, requiring large parts of the system to be shut down for rehabilitation. Forecasting the probability of upcoming droughts would help avoid having critical parts of its system out for repair when they are needed during a drought. In wet and average years Denver has water available to make hydropower through the fall and winter months. However, should it over release it would lose valuable water supply if the next year turns out to be dry.

Runoff forecasts made in autumn might help recover endangered fish in the Grand Valley area of the Colorado River. Upstream water users, including Denver, voluntarily release water from reservoirs for the fish. Fall releases can provide critical flow habitat for the fish (Brown and Caldwell 2000). If forecasts favor wet conditions, reservoir operators might be willing to release more water for the endangered fish. Denver's reservoirs create many renowned tailwater trout fisheries. The non-native rainbow and brown trout spawning cycles can be disrupted by the naturally low wintertime flow in Colorado (Conklin 1997). Favorable forecasts could help operators augment wintertime flows for sport fish. During droughts city water suppliers must make tough decisions about how much to restrict water use. Insight into next year's water supply would help best allocate water during droughts.

Not surprisingly, there are numerous potential operational benefits from forecasting in autumn what the spring snowmelt runoff will be. Whether forecasts are used and to what success depends of course on how accurate and understandable they are. That test is underway.

### 2000-2001 Operating Experience

In September and November of 2000, Connely Baldwin provided April through July runoff volume forecasts of streamflow of the Colorado River and the South Platte River. The November forecasts favored higher than normal runoff on the Colorado River and lower than normal runoff on the South Platte River. In November, Denver's reservoirs were lower than normal particularly in the South Platte Basin. As a result, operators decided to move water from reservoirs in the Colorado River Basin to reservoirs in the South Platte Basin. This operation probably would have been performed without the forecasts; however, the forecasts added more justification. Denver opted not to make releases from its Colorado River reservoirs solely for hydropower purposes. Even though the forecast was for better than normal runoff on the Colorado, the low storage, particularly on the South Platte, dictated the need for conservative operations.

Although it is too soon to test the April through July runoff forecasts, it is interesting to look at current snowpack. After a below normal winter snowfall, March precipitation was above normal, bringing April 1 snowpack to near-normal conditions. Actual runoff can still be heavily influenced by springtime weather.

### What's Next?

Utah State and Denver Water are developing a second phase for this forecasting project. New technology and operational aids must be understood and trusted by system operators, or they will not be used. The next phase of research will focus on documenting and explaining the forecasting methods to system operators in terms that they can understand. By better understanding the method and accuracy of the forecasts, operators can better determine how best to incorporate the forecasts and how much weight to put on the forecasts.

## CONCLUSIONS

Explosive population growth in the western U.S. and the resulting new demands on water systems require water suppliers to be able to operate their system in the most efficient manner. And the new demands on water systems are not just for more domestic supply. Other benefits are sought. Improving snowmelt forecasting can help meet the challenge. One technique, developed by Utah State University for the city of Denver, shows promise. Based on Pacific and Atlantic Ocean climate indices, probabilistic forecasts of the April though July runoff volume on the South Platte and Colorado Rivers are made in the fall of the year. These forecasts have the potential to increase operating efficiency and benefit secondary operating priorities such as hydropower generation, water-based recreation, and aquatic restoration programs. Research will continue into how to make the forecasts more understandable and useable by the water system operators.

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