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Water Resources Planning and Management

Date: April 19, 2015
From: Gary Fiske
To: Water Supply Advisory Committee
Re: Modeling Results: Harvesting Winter Flows

This memo reports the results of the Confluence modeling of the Consolidated Alternatives (CAs) that are based on harvesting and storing excess winter San Lorenzo River flows, specifically:

- CA-9: Winter Flows Capture
- CA-16: Aquifer Restoration/Storage
- CA-18: Off-Stream Water Storage

These three alternatives all divert winter flows that are surplus to fish requirements, current customer demands, and storage in Loch Lomond to another surface or groundwater storage facility (called a Virtual Reservoir or VR in this memo) for use in dry years when current supplies are insufficient to meet customer demands.

Objectives

The ultimate objective of this modeling is to estimate how well any of the winter flow harvesting CAs deals with projected system shortages. In order to better understand those reliability impacts, we must also look at these key operating parameters:

1. Fill and drawdown of the VR
2. Increased diversions at Felton and Tait to fill the VR
3. VR production to meet demand

All of these will be discussed below.

Modeling Approach

To the current supply sources I added the VR, which can be filled with excess flows either at Felton or Tait Street. On any day, the VR will fill only after available flows have been used either to meet demands (Tait Street) or to fill Loch Lomond (Felton). The VR is drawn on in conjunction with Loch Lomond to meet demands on any day that cannot be met by the North Coast and Tait Street diversions to GHWTP. The revised Confluence system schematic is shown in Figure 1.

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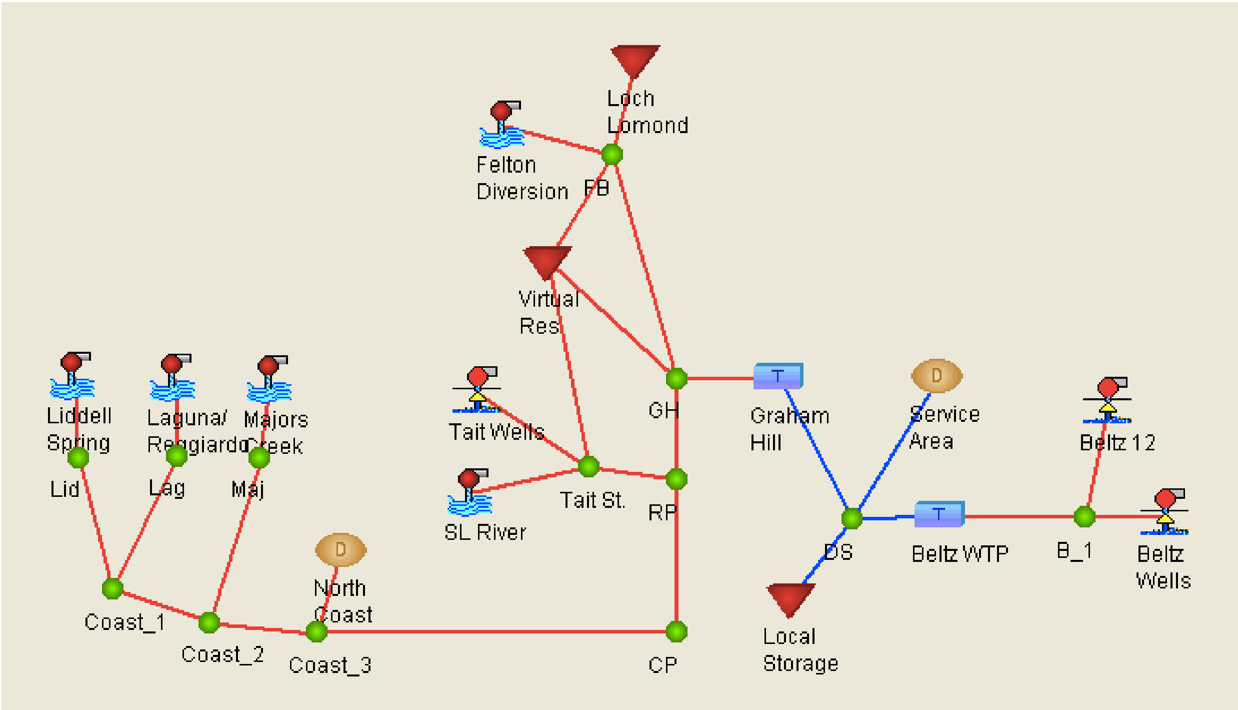
Figure 1. Confluence System Schematic with Virtual Reservoir



Key Assumptions

I analyzed this group of alternatives under two DFG-5 flow scenarios, one based on historic hydrology and one based on the climate change scenario we have so far focused on. For each of these distributions of available flows, I made the following key modeling assumptions:

- Unlimited infrastructure capacity. The objective in this analysis is to assess the potential to harvest winter flows, without regard to current infrastructure capacity limitations. Thus, the modeling assumes unlimited capacity as follows:[1]
    - Diversion capacity at Felton and Tait Street; and
    - Transmission capacity between Felton and the VR, between Tait and the VR, and between the VR and Graham Hill;
- Current water rights. While not limited by infrastructure, diversions at Felton and Tait Street are limited by current water rights. At Felton, this water right limits daily diversions to 20 cfs in all months other than September (in September the right is 7.8 cfs). There is also an annual diversion limitation at Felton of 3,000 AF (978 mg). At Tait, the diversion right is 12.2 cfs year-round with no annual limit.

[1] The modeling enables us to get rough estimates of how much capacity is needed. This will be discussed below.

- Storage capacity. Based on discussions with Bill Faisst, I assumed a maximum virtual reservoir storage capacity of 5 billion gallons. This draws on preliminary work done by Pueblo.

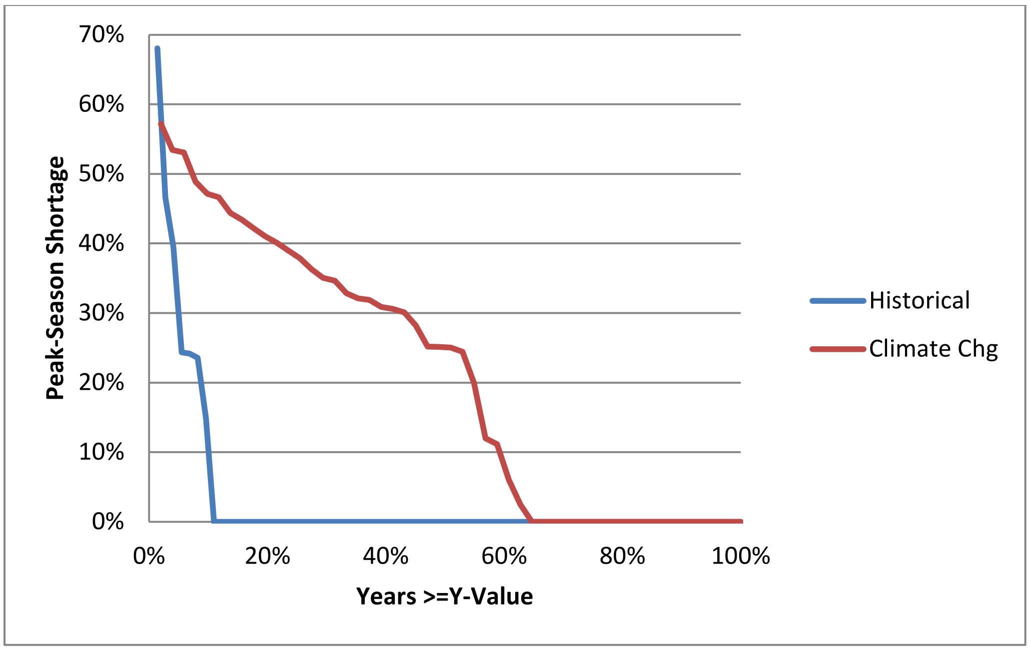
- Storage losses. At Bill's suggestion, I assume that 80% of stored water is recoverable. That is, for each 100 gallons stored, the City can withdraw 80 gallons.

Beyond these, I retained all other current modeling assumptions regarding operation of the current sources (e.g., turbidity constraints, flush flows, etc.)

The Bottom Line: Impacts on System Reliability

Figure 2 shows the peak-season shortage duration curves assuming DFG-5 flows with current supplies that we have seen before (see my March 9 memo). This is one depiction of the reliability "problem" that we want to solve with these CAs.

Figure 2. Peak-Season Shortage Duration Curves with Base Supplies: DFG-5 Flows



The modeling results lead to the following conclusion:

> ***If the City had a way to store winter flows as described above and developed the necessary infrastructure to store and to withdraw water as needed, these shortages go to zero. That is, all demands can be served, even in the driest years with DFG-5 flows and even assuming climate change.***[2]

The remainder of this memo helps understand why this is the case.

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[2] This conclusion holds after the VR reaches a "steady state", i.e., once a sufficient number of years have passed to fill the empty VR. As will be illustrated below, even with the reduced flows of climate change, this does not require many years.

Virtual Reservoir Fill and Drawdown

Figure 3 shows the VR fill and drawdown in the 5 years leading up to the worst drought events in the historic and climate change records.[3] In each case, the VR starts at zero. There is somewhat more fill with historic flows, but in neither case does the VR fill completely before being drawn down. However, there is sufficient fill to ensure that the VR is not completely drawn down before the drought event ends; it is therefore able to meet demands throughout the sequence.

Figure 3. Virtual Reservoir Fill and Drawdown with 5 Years Fill Before Worst Drought Event

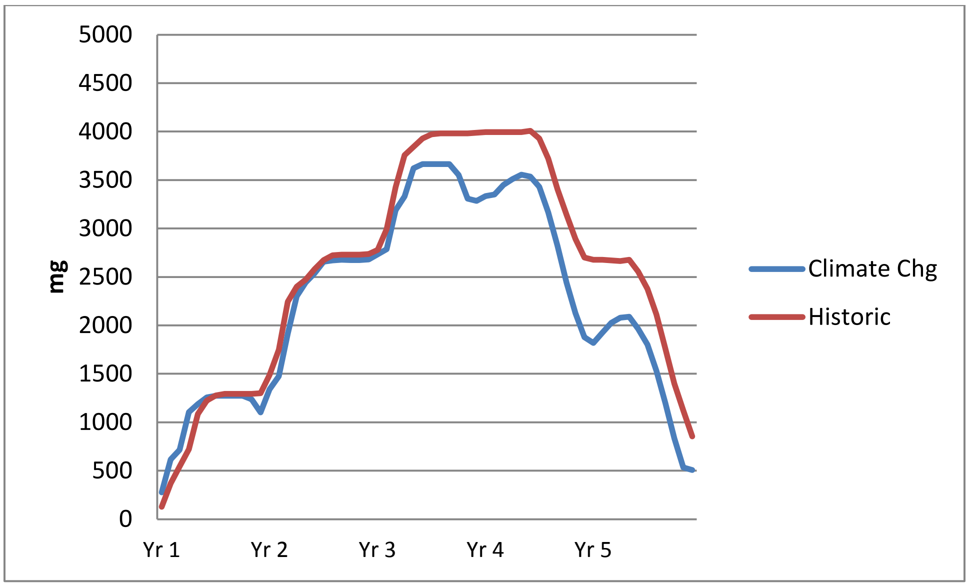
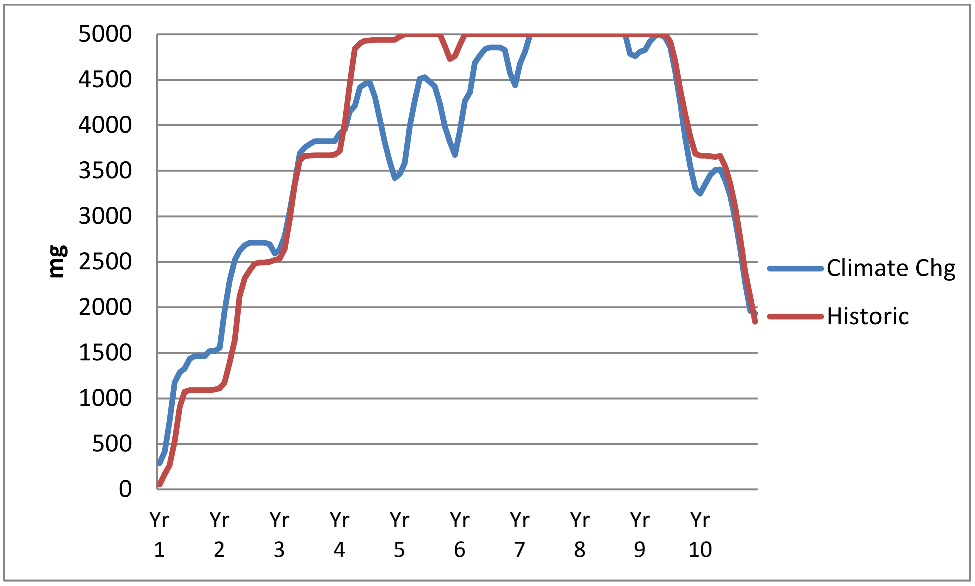


Figure 4 shows the same comparison of VR levels, assuming that there is 10 years before the worst drought year. In both cases, the VR fills.

[3] Year 5 is the end of the worst drought sequence. For the historic record, the 5-year period shown is 1973-77.

Figure 4. Virtual Reservoir Fill and Drawdown with 10 Years Fill Before Worst Drought Event



Increased Diversion from San Lorenzo River

The next question is how much additional water is diverted at the two diversion points to charge the VR and refill it when it is drawn down.

Figure 5 shows, with historic flows, the average annual incremental production at the two diversion points over a 10 year period beginning with an empty VR.[4] The initial year diversions are high as the VR fills. Then they settle into a steady state of about 250 mgy.

Figure 6 shows similar curves assuming climate change. The steady state annual average diversion is around 700 mgy. Despite the fact that river flows are lower with climate change, the average river diversions are considerably higher. This is because the system requires much more frequent VR drawdown which in turn requires more refill.

Figure 7 shows the duration curves of the steady state incremental combined Felton and Tait Street annual production with and without climate change. In each case, the maximum added diversion is about 1500 mg. But as expected, there are many more hydrologic years with significant added diversions with climate change.

[4] Note that the diversions at Tait draw not only on the mainstem flows after diversion at Felton, but also on tributary inflows between the two diversion points.

Figure 5. Incremental River Diversions in First 10 Years of VR Fill: Historic Flows

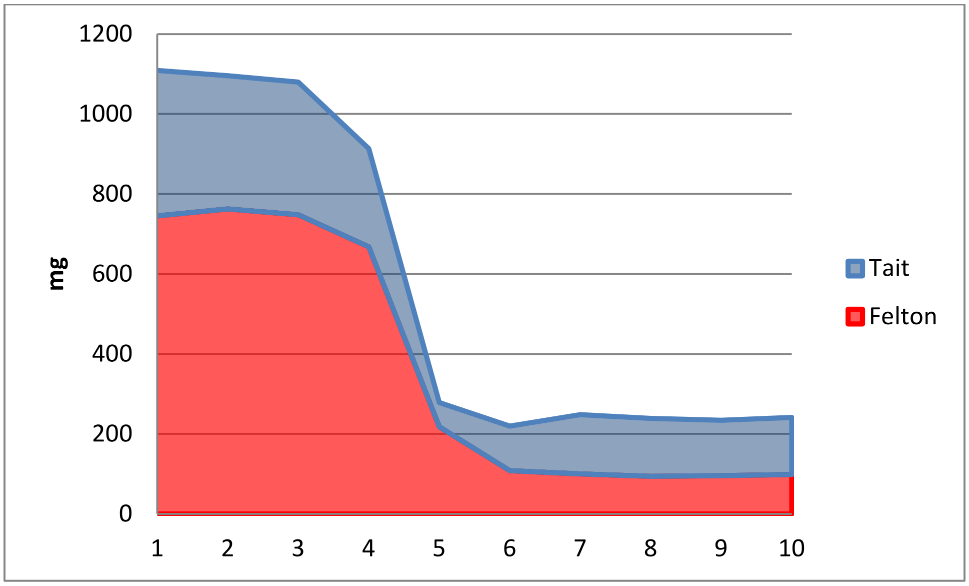


Figure 6. Incremental River Diversions in First 10 Years of VR Fill: Climate Change

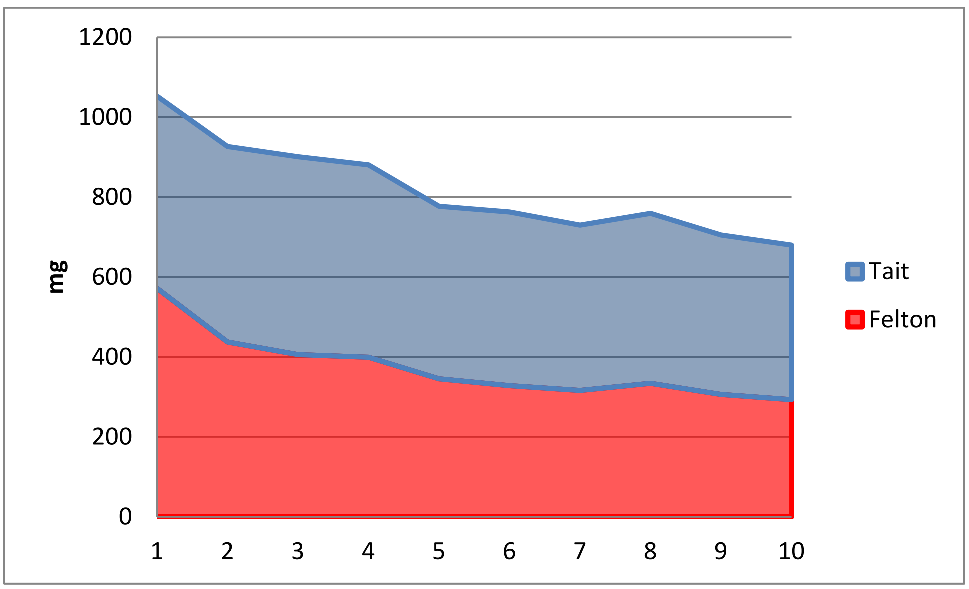
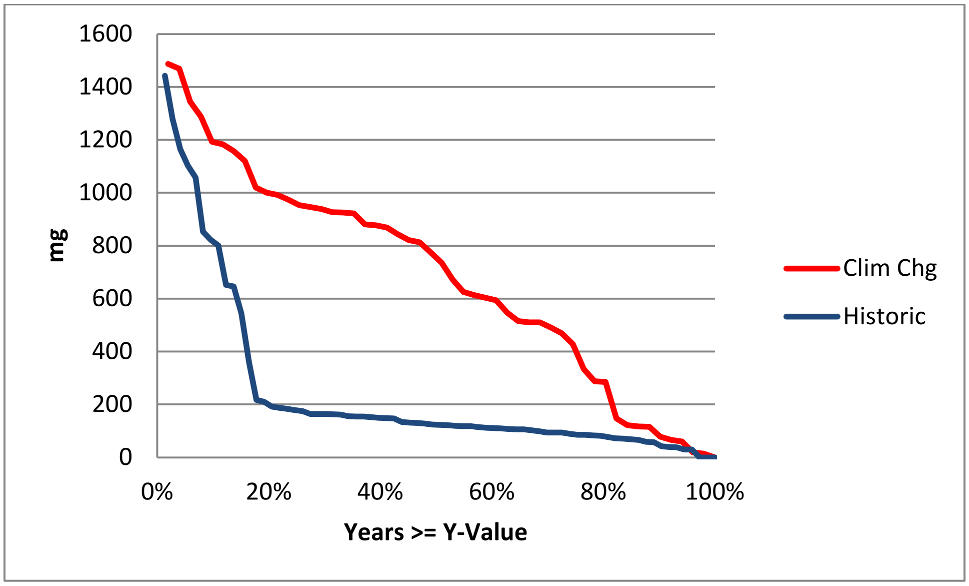


Figure 7. San Lorenzo River Annual Incremental Production Duration Curves



Project Yield

Since this alternative reduces shortages to zero, the worst-year yields of this alternative, i.e., how good a job this alternative does in reducing the worst-year peak-season shortages, are simply the highest points in the curves of Figure 2. Volumetrically, this is about 1360 mg with historic flows, and 1150 mg with climate change. Across all hydrologic conditions, the average reduction in peak-season shortage is about 60 mg with historic flows and 420 mg with climate change.

These benefits accrue for two reasons:

- The production (less losses) of the VR itself <u>plus</u>
- The change in production of Loch Lomond (which in many hydrologic years is negative)[5]

The second point is important. In dry years, the benefit of these alternatives derive not only from the VR itself but also from added production from Loch Lomond. In those years, Loch Lomond begins at higher elevations because use of the VR in previous years allowed the lake to "rest".

Needed Infrastructure Capacities

One of the pieces of information that we can draw from these runs is a sense of how much capacity is needed for some of the critical required infrastructure. Following are brief discussions of these.

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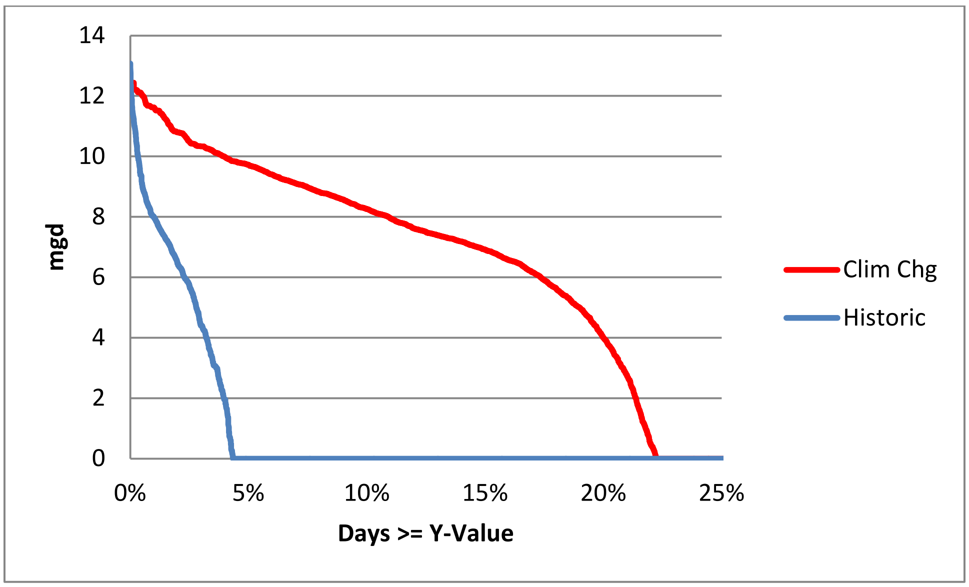
[5] The total also includes a slight increase in Tait Street production sent to GHWTP because of the assumed unlimited diversion capacity.

Diversions. The daily diversions at Felton and Tait Street are limited by the maximum water rights, 20 cfs at Felton and 12.2 cfs at Tait. Both of these are larger than the current capacities.

Virtual Reservoir Capacity. For this exercise, we assumed a 5 bg storage capacity. However, as illustrated in Figures 3 and 4, the drawdown in the worst year is just over 3 bg with both historic flows and climate change. That provides a preliminary estimate of the required storage capacity with DFG-5 instream flow requirements.

Virtual Reservoir Production. Figure 8 compares portions of the daily production duration curves for the VR. The maximum daily production with and without climate change is around 13 mgd. This provides an estimate the required delivery capacity of the VR itself and the transmission between the VR and the treatment plant.

Figure 8. Daily Production Duration Curves of Virtual Reservoir



Conclusion

The key outcome of this analysis is that the harvesting and storage of winter flows has the potential to completely address the City's water supply challenges and enable the City to meet projected future demands. This is the case even with current water rights, DFG-5 instream flows, and climate change. To achieve these benefits, the "virtual reservoir" used in the analysis would have to become real, i.e. suitable infrastructure improvements and institutional arrangements would have to be made to have a place to reliably store at least 3 billion gallons of water. In addition, the capacities of various current infrastructure would have to be increased.