GARY FISKE AND ASSOCIATES, INC.
Water Resources Planning and Management

Date: February 4, 2015
From: Gary Fiske
To: Water Supply Advisory Committee
Re: Baseline System Reliability

This memorandum describes the results of my analysis of baseline system reliability. Because the Santa Cruz water system is primarily dependent on surface water, its performance in any year is a function of that year's and immediately prior years' hydrology. Since rainfall in any year is highly uncertain, the question of "how reliable is the system?" is a complicated one to answer. Several approaches are used in this memo; other suggestions by the committee would be welcome.

DEFINING THE BASELINE

The baseline is defined by:

- Current supplies and infrastructure
- The interim demand forecast

The Confluence® model was used to assess the performance of the baseline against each of three flow regimes. The second and third of these are the two HCP flow assumptions which bound the current discussions with the California Department of Fish and Wildlife and the National Marine Fisheries Service (collectively the "agencies"):

- Natural flows, which assume no HCP instream requirements
- City Proposed (Tier 3/2) flows
- DFG-5 flows

System performance with each of these three flow assumptions is assessed against forecasted 2020 and 2035 demands.

All of these flow sets are based on historic hydrology. Daily flows at each of the City's points of diversion have been either gauged or estimated over a 73-year historic period (1937-2009). <u>All of the baseline results that follow assess future system performance assuming that the distribution of future hydrology will look like this historical record</u>. This is a very big assumption. Climate change may make future hydrology drier than this 73-year period, with different seasonal patterns of rainfall, and longer and more severe droughts. As we continue to work with the WSAC, we will be modeling various alternative assumptions about how climate change may modify historical flow patterns.

EXISTING SUPPLY ASSUMPTIONS

As described by Heidi's memo to the committee, the existing system consists of the following supply sources, listed in the order that they are dispatched to meet demand on any day:

- North Coast diversions

- Tait Street diversion and wells
- Live Oak wells
- Loch Lomond reservoir

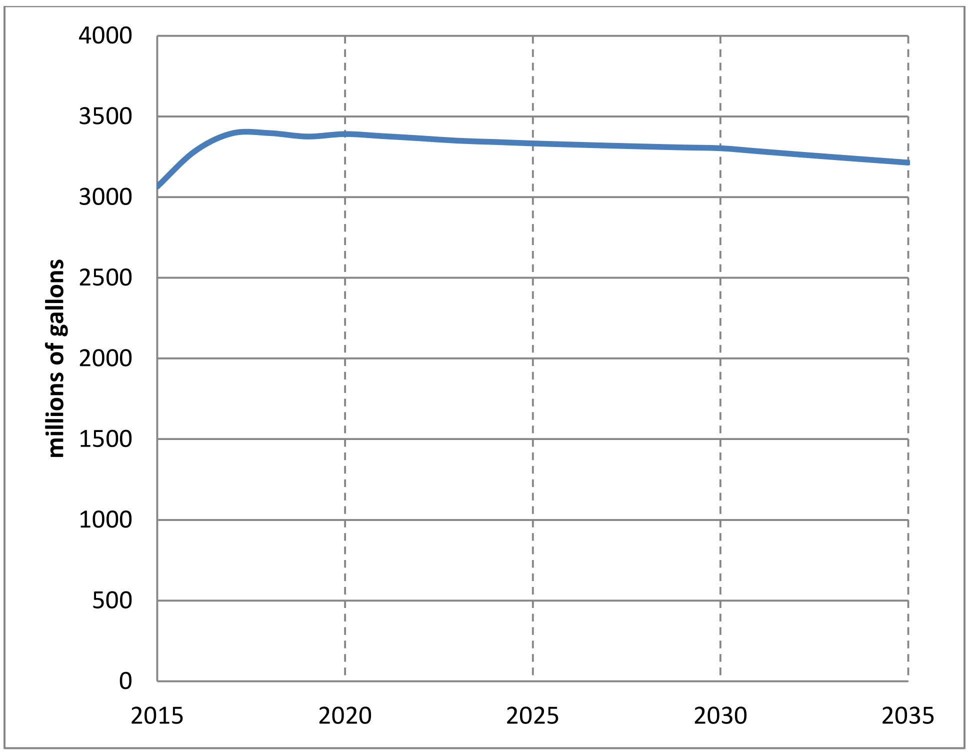
In addition, whenever possible, water is diverted from Felton to Loch Lomond.

DEMAND FORECAST

As described in David Mitchell's memorandum to the committee, the 2015-2035 demand forecast is as shown in Figure 1. This is a forecast of unconstrained demand, i.e., the volume of water that Santa Cruz municipal and industrial customers would use without any curtailments or other restrictions imposed by the utility.

After increasing for the next several years, annual demand is forecast to slowly decrease between 2020 and 2035 (by a total of about 175 mg). Thus, we would expect baseline system reliability to slightly improve between these years.

Figure 1. Interim Annual Demand Forecast



BASELINE SYSTEM RELIABILITY

Definition of Terms

To understand what follows, two terms must be defined:

> <u>Shortage</u>: A shortage occurs when the system is unable to provide sufficient water to serve unconstrained customer demand.

System reliability: The projected frequency and magnitude of future system shortages.

System Reliability Metrics

In Santa Cruz, since the vast bulk of shortages occur in the peak-season (May-October), all of our reliability measures are for that period.[1] There are many ways to portray system reliability. For purposes of this presentation, we use the following three approaches, which are in increasing order of complexity and completeness:

- Worst-year peak-season shortage. This is a single number that represents the expected peak-season shortage under the worst historical hydrologic conditions. (These worst conditions occurred in the 1977 drought.) While very important and easily understood, such a single number only provides information about shortages under one of the 73 historic hydrologic conditions. It does not tell us about what magnitudes of shortage, if any, might occur under less severe conditions.

- Peak-season shortage profile. This shows the likelihood of peak-season shortages within different ranges.

- Peak-season shortage duration curve. Such a curve provides a complete graphical depiction of how often different size peak-season shortages can be expected to occur.

In what follows, these measures are expressed both as volumes (millions of gallons) and as percentages of unconstrained peak-season demand.

Worst-Year Peak Season Shortages

Table 1 compares the worst-year peak-season shortages under the three flow regimes for forecast years 2020 and 2035. With Natural flows (i.e. without any HCP requirements for enhanced fish flows), the baseline system could fully serve future demands even under worst hydrologic conditions. The City Proposed (Tier 3/2) HCP flows result in a worst-year peak season shortage in 2020 of more than 600 mg or 32%; by 2035 this is forecast to decrease to 500 mg. The DFG-5 flow proposal would result in extremely severe worst-year peak-season shortages, approaching 1.4 billion gallons in 2020.

Table 1. Expected Worst-Year Peak-Season Shortages

FLOWS	2020		2035	
	Volume (mg)	Percent	Volume (mg)	Percent
Natural	0	0%	0	0%
City Prop	630	32%	500	26%
DFG-5	1360	68%	1220	64%

[1] In some years, there are small additional shortages immediately following the peak season (i.e., in November) before the fall rains begin in earnest. It is possible that these off-peak shortages may become more significant if future flows are different due to climate change.

Peak-Season Shortage Profiles

Table 2 and Table 3 show respectively the forecasted peak-season shortage profiles in 2020 and 2035.[2]

Table 2. 2020 Shortage Profiles

FLOWS	Likelihood of Peak-Season Shortages				
	0%	**<15%**	**15%-25%**	**25%-50%**	**>50%**
	0	**<300 mg**	**300-500 mg**	**500-1000 mg**	**>1000 mg**
Natural	100%	0%	0%	0%	0%
City Prop	92%	7%	0%	1%	0%
DFG-5	90%	1%	4%	3%	1%

Table 3. 2035 Shortage Profiles

FLOWS	Likelihood of Peak-Season Shortages				
	0%	**<15%**	**15%-25%**	**25%-50%**	**>50%**
	0	**<285 mg**	**285-475 mg**	**475-950 mg**	**>950 mg**
Natural	100%	0%	0%	0%	0%
City Prop	97%	1%	0%	1%	0%
DFG-5	90%	1%	4%	3%	1%

Several conclusions can be drawn from these profiles:

- With Natural flows, there are no shortages of any magnitude under any hydrologic condition. Since we saw above that there are no expected shortages under worst-year conditions, this is not surprising.

- As expected, the DFG-5 profile is worse (i.e. results in a higher likelihood of larger shortages) than the profile for City Proposed flows. For example, in both forecast years, there is about an 8% likelihood (6 out of 73 years) of a peak-season shortage larger than 15% under DFG-5. This compares to around 1% (1 out of 73 years) under the City Proposal.

- Even under the most stringent flow regime (DFG-5), there are no expected shortages in 90% of historic hydrologic conditions. The City's supply reliability challenges are in the driest years.

- While similar, the 2035 profiles are slightly more favorable than the 2020 profiles due to the somewhat lower forecast demand.

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[2] Note that the totals in any row may not add to 100% due to rounding.

Peak-Season Shortage Duration Curves

Figure 2 compares the 2020 peak-season shortage duration curves across all 73 historic hydrologic conditions for the three flow sets. Figure 3 shows the same comparison for 2035.

Figure 2. Peak-Season Shortage Duration Curves: 2020

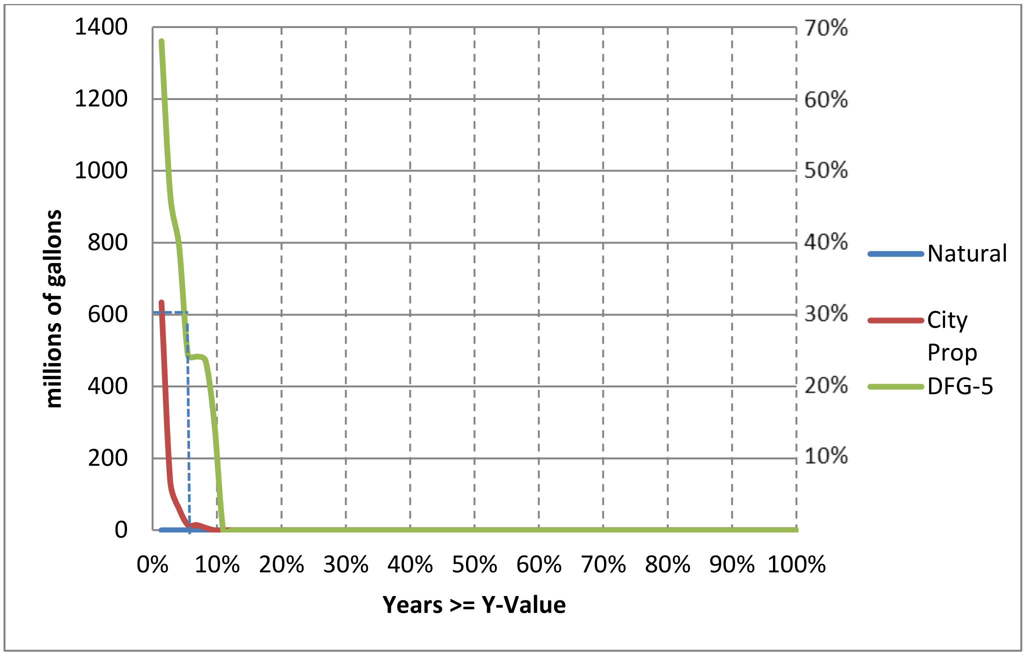
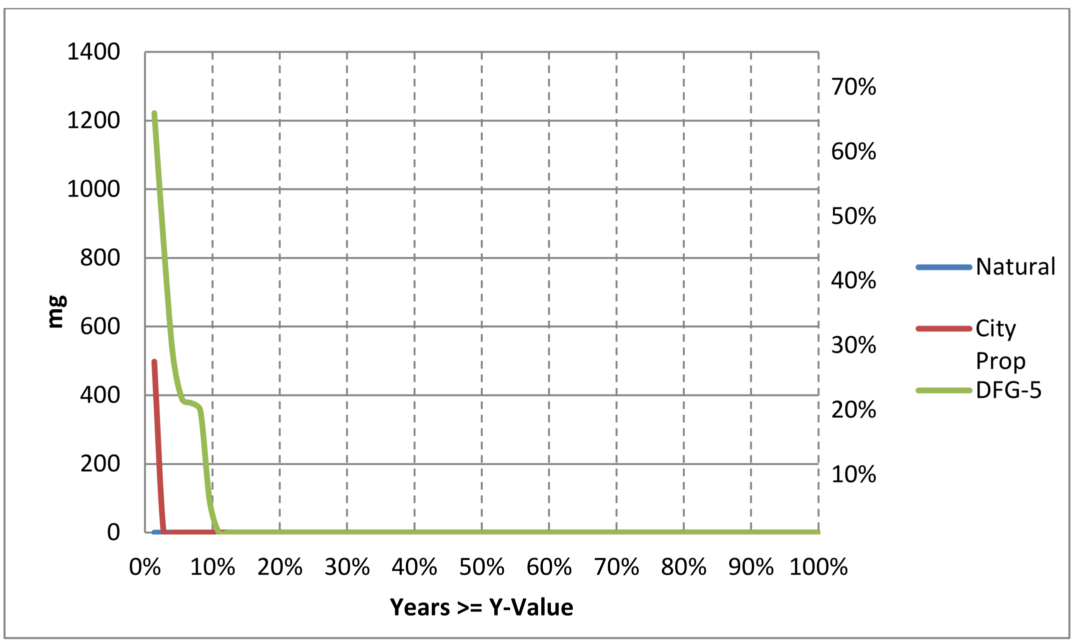


Figure 3. Peak-Season Shortage Duration Curves: 2035



Thus, for example, in 2020 under DFG-5 flows, there is about a 5% likelihood of a peak-season shortage of 600 mg or more (see blue-dashed lines in Figure 2). The curves clearly illustrate how much more severe the supply reliability challenges would be under DFG-5 than under the City Proposal. Moreover, when the two charts are compared, the slight improvement between 2020 and 2035 is evident.

Both the worst-year shortages in Table 1 and the shortage profile tables in Tables 2 and 3 are based on the data underlying these charts.

Figures 4 and 5 are duration curves for 2020 (expressed as peak-season shortage percentages) broken down by year type. Figure 4 shows that in 2020, assuming City Proposed flows, there is about a 15% likelihood of a Critically-Dry year having at least a 15% shortage. Figure 5 shows that probability rising to about 55% with DFG-5 flows (plus about a 10% likelihood of such shortages in Dry years). Results in 2035 (not shown) are slightly more favorable.

Figure 4. 2020 Peak-Season Percent Shortage Duration Curves by Year Type: City Proposed Flows

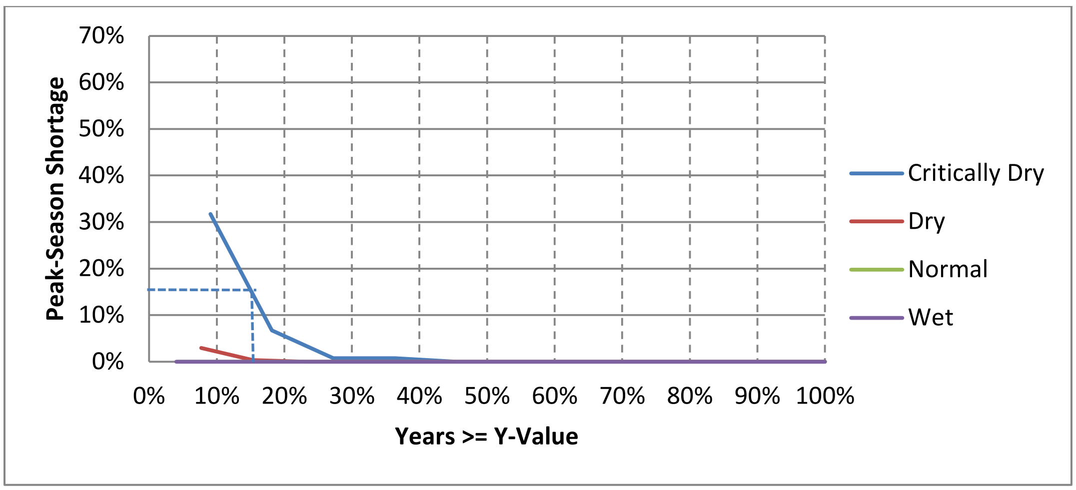
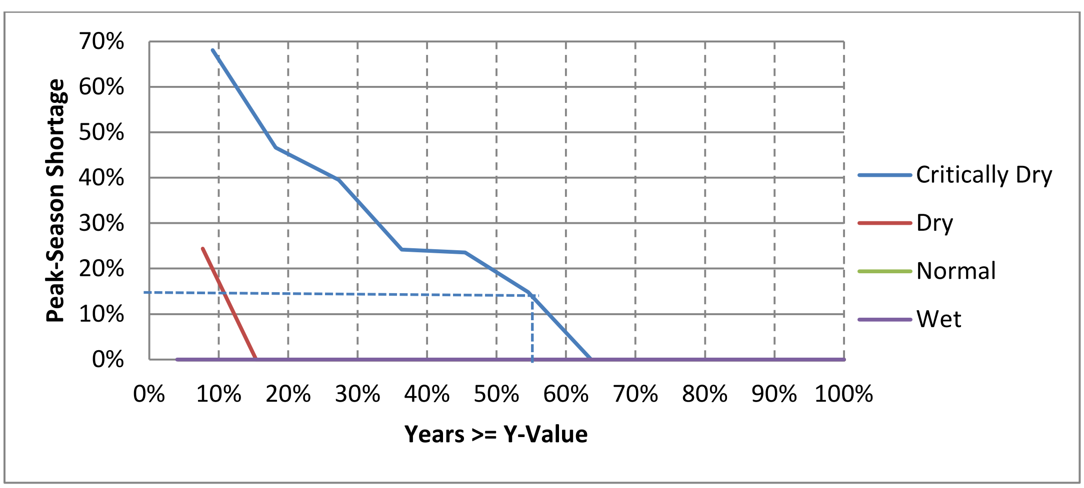


Figure 5. 2020 Peak-Season Percent Shortage Duration Curves by Year Type: DFG-5 Flows



Key Conclusions

Under baseline conditions, and assuming that future hydrology looks like the historic record, the City would have sufficient supply to serve its demands in the absence of any HCP flow restrictions. While the outcome of the HCP negotiations with the agencies is uncertain, we assume that the two flow proposals currently being discussed bound that outcome. Under either of those proposals, the City faces peak-season shortages in the driest hydrologic conditions. In those driest years, those shortages can be significant, around 600 million gallons under City-Proposed flows and close to 1.4 billion gallons under DFG-5 flows.