Storage Developments for California Water

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12 March 2013

Water storage Capacity in California

- Surface water – 42 MAF; Groundwater – 150-1,450 MAF, depending on how you count it
- Onstream surface storage – best for catching floods, most good sites already have dams
- Offstream surface storage – most new surface storage for water supply
- Groundwater is better storage for droughts, but requires pumping and recharge capacity

Recent developments

- Los Vaqueros (CCWD) – added 60 taf storage capacity in 2012, potential to expand more
- San Vicente Dam, San Diego County WA – adding 152 taf of emergency storage capacity
- Sites (1.3-1.8 maf), Shasta expansion (0.63 maf), Temperance Flat (0.43 – 1.3 maf), Merced R. (70 taf) – proposals pending; Most of Shasta expansion depends on winter run salmon benefits.
- Delta Wetlands - private proposed 215 taf storage on two Delta islands, seasonal storage
- Groundwater – steady increase in local management; continued Tulare basin overdraft

Markets help local agencies coordinate use of underground and surface storage: Folsom flood, GCID, YCWD, KWB, Semitropic, Arvin-Edison, MWD, etc. Significant improvements in storage operation for water supply and flood protection

Greater environmental flow requirements for Delta and tributaries will leave less water available to store, but making stored water more valuable.

Urban conservation reduces the value of expanded reservoirs (See Table 1).

Less water export ability from Delta significantly lowers the value of expanding storage capacities north of the Delta, and raises most storage values south of the Delta (See Table 1).

Water Storage with Climate Change

- With loss of snowpack, moving drought storage in surface reservoirs to groundwater storage can allow existing reservoirs to better capture winter flows and floods (Buck, et al. 2011). Warmer drier climate often raises, but sometimes reduces, the value of increasing surface storage capacity (See Table 1).
- Flood operating rules should be formally examined with a warmer climate. Rules based on the current wetness of the watershed seem to perform better with climate change (Willis, et al. 2011).
- Warmer temperatures are likely to constrain operation of cold water for salmon in some reservoirs.

Useful directions for storage

- Make the best use of existing storage: Facilitate water market agreements for better use of surface and groundwater storage; ease long-term water market contracts/dry-year options.
- Reduce barriers to local districts in a region developing and funding joint facilities.

Water Bond Implications

Important for agencies to view storage investments evenhandedly with other investments. State funding for storage has historically been mostly via revenue bonds, repaid by beneficiaries.

Table 1: Estimated average marginal water supply and hydropower benefit of expanding storage capacity ($/af/year) (Ragatz 2013)

		Historical Climate						Warmer, Drier Climate					
		0% Urban Conserv.		30% Urban Conservation				0% Urban Conserv.		30% Urban Conservation			
		Full Exports	No Exports	Full Exports	50%	25%	No Exports	Full Exports	No Exports	Full Exports	50%	25%	No Exports
North of Delta	Clair Engle Lake	3	3	3	3	3	3	39	30	32	40	33	32
	Whiskeytown Lake	8	6	6	7	6	6	65	34	49	62	46	34
	Shasta Lake	8	8	8	8	8	8	67	34	51	66	49	34
	Black Butte Lake	9	4	6	6	5	4	250	63	146	163	100	62
	Lake Oroville	15	11	13	13	12	10	78	18	56	66	43	17
	Folsom Lake	13	10	11	11	10	9	153	20	85	94	49	15
	Camp Far West Reservoir	6	2	3	3	2	1	171	19	93	115	66	14
	Clear Lake & Indian Valley Reservoir	2	0	1	1	1	0	48	2	25	29	14	2
	Englebright Lake	44	44	44	44	44	44	326	44	184	209	116	44
	Lake Berryessa	0	0	0	0	0	0	2	0	0	2	2	0
	New Bullards Bar Res	18	17	17	17	17	17	156	19	90	104	55	19
South of Delta	New Hogan Lake	2	2	1	1	1	0	49	38	26	39	30	20
	Pardee Reservoir	2	5	1	1	1	1	14	32	20	23	25	41
	Los Vaqueros Reservoir	16	0	0	0	0	0	13	10	34	37	2	34
	Camanche Res	2	1	1	1	1	0	14	33	20	24	25	42
	EBMUD aggregate	0	1	0	0	0	0	12	17	19	21	21	39
	New Melones Reservoir	9	10	9	10	10	10	3	3	3	2	3	5
	San Luis Reservoir	0	0	0	0	0	0	11	0	13	0	0	0
	Lake Del Valle	0	0	0	0	0	0	5	0	3	0	0	0
	Millerton Lake	6	95	5	5	20	62	37	120	56	34	22	33
	Lake McClure	9	18	8	9	18	18	20	22	12	15	20	24
	Hensley Lake	13	53	10	13	53	53	64	75	39	52	68	79
	Eastman Lake	6	26	5	6	26	26	7	7	4	5	7	8
	New Don Pedro Reservoir	8	9	8	8	9	8	4	3	4	2	3	5
	SF aggregate	0	0	0	0	0	0	0	0	0	0	0	0
	Hetch Hetchy Reservoir	6	7	5	5	7	7	7	6	5	3	5	7
	Lake Lloyd/Lake Eleanor	15	17	15	15	17	17	2	2	3	1	2	4
	Santa Clara Aggregate	0	0	0	0	0	0	3	0	0	0	0	0
	Turlock Reservoir	7	7	6	6	7	7	3	3	3	2	3	5
	Lake Isabella	4	46	1	1	6	15	32	76	32	12	1	5
	Lake Kaweah	56	457	47	52	261	379	269	263	225	235	254	254
	Lake Success	49	403	42	47	241	340	361	361	308	333	357	357
	Pine Flat Reservoir	5	47	4	4	20	31	20	103	51	47	62	95
	Silverwood Lake	0	0	0	0	16	1	1	8	24	9	8	2
	Lake Perris	0	0	0	0	0	0	0	0	9	0	0	0
	Pyramid Lake	0	0	0	0	0	0	2	14	8	0	0	0
	Castaic Lake	3	0	0	1	1	0	8	18	12	1	0	2
	Eastside Reservoir (Diamond Valley)	0	0	0	0	0	0	0	0	0	0	0	0
	Grant Lake	52	116	44	44	57	76	0	0	0	0	0	0
	LAA Storage	10	26	8	8	11	16	0	0	0	0	0	0
	Long Valley Reservoir (Lake Crowley)	10	26	7	8	11	16	0	0	0	0	0	0
	Lake Mathews of MWDSC	0	0	0	0	0	0	0	0	3	0	0	0
	Lake Skinner	816	1	0	0	0	0	148	0	2	0	0	0

Further reading

"Water Storage in California" http://californiawaterblog.com/2011/09/13/water-storage-in-california-2/

"Expanding Water Storage Capacity in California" http://californiawaterblog.com/2012/02/22/expanding-water-storage-capacity-in-california/

Water Storage in California

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September 13, 2011 CaliforniaWaterBlog.com (abridged 9 March 2013, references in original)

"With a larger reservoir, there is some increasing gain with further size, but in a diminishing ratio." – Alan Hazen (1914)

Water storage capacity is important in California's water system for capturing lower-value water for higher-value uses later. Such storage aids water supply, flood protection, hydropower, and recreational uses and helps regulate downstream water quality and supply cold water flows for fish. California has about 42 million acre-feet (maf) of surface reservoir storage capacity and much more storage capacity in underground aquifers (150 million to 1.45 billion acre-feet, depending on how you count it).

Seasonal water storage: In normal years, about 8-14 million acre-ft of water is stored in the wet season and used in the dry season. This compares to roughly 34 maf/yr of average net agricultural and urban water use. Human water use is highest in California's dry summer, so crops and landscapes must be watered from stored winter and spring flows. Roughly 5-8 maf of seasonal storage is held in surface reservoirs and 3-6 maf is held in groundwater basins.

Drought water storage: Water also is stored in wet years for use in dry years. The amount stored varies with the drought's intensity and length. Stored surface water is mostly used in the initial drought years, while stored groundwater plays a larger role in longer droughts. I'm unaware of anyone with data on statewide drought storage use, but from our modeling results, about 35-43 maf is ideally carried over from wet to dry years for droughts lasting 3-6 years. Of this total, some 15-18 maf is held in surface reservoirs and 20-25 maf in aquifers.

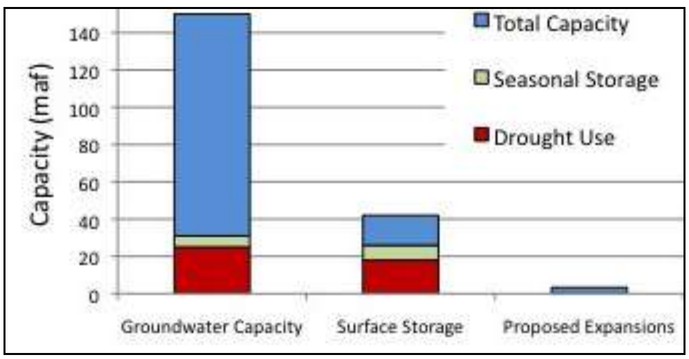

Figure 1: Statewide capacities and approximate use of surface and groundwater storage, and proposed surface storage expansion.

Should we pay for more water storage? All combined, proposed state expansions of surface storage facilities would add less than 3.9 maf of new capacity (Sites: 1.3-1.8 maf, Shasta expansion (634 taf), Temperance Flat: 0.43-1.3 maf, Los Vaqueros: 60-175 taf). This is not much relative to existing capacities (Figure 1). In evaluating cost and effectiveness of proposed facilities, size, connections, and location matter, among other things.

Storage effectiveness decreases with size: Reservoirs only store water, they cannot create it. No reservoir can reliably deliver more than the reservoir's average annual inflow (minus evaporation). Enlarging a reservoir always increases water deliveries by a smaller proportion (Hazen 1914). Similarly for flood management, larger reservoirs provide more control, but with decreasing incremental effectiveness. Most cheap and effective reservoir locations in California already have reservoirs.

Flexibility varies with storage type: Traditional surface reservoirs (on-stream storage behind a dammed river) fill directly with stream flow. Today most new surface storage is off-stream (e.g. Sites, Los Vaqueros, Eastside), which fills more slowly with pumps, increasing costs and reducing ability to manage floods. Groundwater storage usually fills slowly by infiltration, making it less directly useful for floods. Groundwater must be pumped at some cost.

Location, location, location: The value of storage depends on its location. Storage is most valuable when releases can be connected to users. If Delta conveyance is "broken", north of Delta storage (e.g., Sites reservoir) becomes less valuable.

Storage should be examined and used as part of a system.

- *Storage investments should be a business decision*. Water managers will always prefer more storage capacity, if it is free. But surface storage has substantial costs (financial, environmental, legal), and political controversy. Is more storage at a particular location a good system investment, relative to other uses of scarce money (and political attention)?
- *Storage has somewhat different roles from the past*. Water markets, conservation, reuse, conjunctive use of ground and surface waters, and other innovations change the best use storage assets. Water demands also have grown and become more diverse. Water markets and conjunctive use, in particular, increase the value of coordinated operation. Expanding storage will be less effective without other, perhaps greater, changes in water use and management.
- *Better management can improve the value of storage*. Coordinated operation of storage and other water management activities can improve overall performance by making more effective use of existing or new storage. Increases in conjunctive management of water surface and groundwater storage in California since the 1980s have already greatly improved system performance. There remains potential for improvement.
- *Climate change might affect the value of storage*. Climate warming is reducing the ability of California's snowpack to store water seasonally. Fortunately, downstream reservoirs on many streams are already large compared to seasonal changes in streamflows and flood peaks. Model results show that with the right management, climate warming might be inconvenient, not catastrophic, for most water uses.
- *Warming will increase difficulties in managing stream temperatures for salmon. Larger reservoirs or changed operations might preserve cold water for fish*. Reduced precipitation reduces water for water supplies and ecosystems. But larger reservoirs might not help much; with a much drier climate, there could be too little water to fill even existing storage capacity.
- *Some places are more promising for new storage*. Additional storage seems most promising at or above Folsom (for floods), Los Vaqueros (improving delivered water quality), Kaweah and Tule mostly (reduces operating costs), and improved groundwater recharge and storage in metropolitan areas, the Sacramento Valley, and elsewhere. Other places might be promising if investments and management are coordinated systemwide for human and environmental purposes. A system-wide business case is needed. Few expansion proposals will pass this test.
- *Most storage expansion costs must be borne locally*. Federal and state budget problems mean that most future water infrastructure will need to be financed by local beneficiaries. Historically, state support for storage has been by revenue bonds repaid by beneficiaries.

Water storage is important for human and environmental objectives, but has large costs and fits within a large and diverse system. We should be thoughtful and creative in thinking about storage or other major investments, and ultimately cold and calculating about their value.