

MEMORANDUM

TO: Rick Dulin, Sonya Reiser, ECI
FROM: Lee Rozaklis, Hydrosphere, Hydrosphere Resource Consultants, Inc.
SUBJECT: City of Boulder Hydropower Water Availability
DATE: March 9, 2005

This memo and the accompanying spreadsheets summarize our most recent work estimating water availability to Boulder's hydropower units.

As before, we utilized the Boulder Watershed Model to simulate the operation of Boulder's water supply system over a hydrologic study period of 1950-1998. Using output from the model, we developed spreadsheets to complete the analysis of specific aspects of hydropower operations that could not be easily incorporated into the model itself.

Based upon the outcome of our January 31, 2005 meeting with ECI and Carol Ellinghouse, we have analyzed three scenarios described below in order to provide a valid basis for economic analysis of alternative courses of action being contemplated by Boulder regarding raw water facility improvements and associated hydropower development opportunities.

Scenario 1: Existing Facilities – Normal 63rd Street WTP Operations

This scenario simulates the normal operation of Boulder's water supply system with existing facilities. Specific assumptions include:

- Municipal treated water demand is set to 25,000 acre-feet per year.
- In meeting its treated water demands, Boulder first uses its direct flow rights (including its Farmers Ditch rights that divert to Boulder Reservoir), then its exchange rights, then it delivers water from its 63rd Street WTP and from its mountain reservoirs.
- Betasso WTP - 45 MGD capacity.
- 63rd Street WTP - 10 MGD capacity. The 63rd Street WTP normally operates at a minimum level of 5 MGD from November through March each year as an ongoing drought protection measure. During the remaining months, the 63rd Street WTP operates up to its capacity to meet demands not met from direct flow rights and exchange rights. Typically, the 63rd Street WTP delivers an average of 8.3 MGD during April, September and October, and an average of 5 MGD during November

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- through March, in order to minimize draw-down of Boulder's mountain reservoirs during these months.
- Barker gravity line - 43 cfs net capacity after 3% seepage losses
 - Lakewood and Silver Lake pipelines - 20 MGD capacity.
 - Farmers Ditch to Boulder Reservoir "municipal" conveyance capacity – 12.17 cfs
 - Barker Reservoir bypasses a minimum of 5 cfs during May-September and 4 cfs during October-April.
 - Silver Lake Hydro: 3.1 cfs – 31 cfs flow range. Silver Lake Hydro receives all of Boulder's water supply-related diversions and reservoir releases taken from North Boulder Creek at the Silver Lake Pipeline headgate, as well as any additional natural flow in North Boulder Creek, subject to instream flows below the Silver Lake Pipeline headgate of 4 cfs April-October and 1.5 cfs November-March. Additional Silver Lake Hydro diversions not usable by Lakewood Hydro are returned to North Boulder Creek at the Lakewood reservoir spillway.
 - Lakewood Hydro: 3.1 cfs – 31 cfs flow range. Lakewood Hydro receives all of Boulder's water supply-related diversions and reservoir releases taken from North Boulder Creek at the Silver Lake Pipeline headgate or the Lakewood North Boulder Creek and Como Creek Inlets.
 - Betasso Hydro: 3.9 cfs – 35 cfs flow range. Betasso Hydro receives all of Boulder's water supply-related diversions and reservoir releases from Middle Boulder Creek.
 - Boulder Canyon Hydro: 16.6 - 83 cfs flow range. Boulder Canyon Hydro receives Barker outflows to Middle Boulder Creek subject to remaining capacity in the Barker Gravity Line after deliveries to the Betasso WTP and also subject to instream flow bypass targets below Barker of 5 cfs May-September and 4 cfs October-April. No Barker storage releases are made to supply Boulder Canyon Hydro. Water used for generation at Boulder Canyon Hydro returns to Boulder Creek near Orodell.

The results of Scenario 1 are presented in the attached workbook. These results are suitable as a baseline from which to compare costs and revenues associated with Scenarios 2, 3 and 4.

We understand that Boulder receives additional hydropower revenue in any month when the combined generation of its Silver Lake, Lakewood and Betasso hydro units averages at least 50% of their combined nameplate capacities, which would occur whenever the monthly flow through these three units averages at

least 46.2 cfs. A summary of results for this scenario related to Boulder's capacity-related hydropower targets is shown in Table 1 at the end of this memo. Table 1 shows the percent of time the target was achieved in each month, and the average volumetric shortfall for the years in which the target was not met. Boulder could choose to meet these shortfalls by releasing water from its reservoirs, although such releases could reduce the reliability of Boulder's municipal supply system and could have water rights implications.

As shown in Table 1, with existing facilities and normal 63rd Street WTP operations, Boulder would meet its capacity targets 100% of the time in June through August, 96% of the time in May, and 22% of the time in September.

It should be noted that the May capacity shortfalls would occur only in certain types of wet years (with lower-than-normal downstream demands and greater-than-normal downstream inflows) when Boulder's reservoirs are in priority to store all inflows. It is the State Engineer's policy that reservoirs must store all available in-priority water or else be "paper filled" by the amount bypassed. Once they are "paper filled", reservoirs cannot physically fill at a later time in the same year except under free river conditions or by exchange.

Accordingly, in such situations, the Boulder Watershed Model simulates Boulder's reservoirs as storing all inflows other than those needed to meet Boulder's treated water demands. In practice, Boulder could bypass sufficient water while filling its reservoirs to meet its capacity targets. Boulder would have to carefully examine the water rights implications of such a practice.

The amounts of additional reservoir water that would be needed to consistently achieve capacity targets in the other shortfall months (September through April) are significant and would have to be carefully evaluated from the perspective of risk to the reliability of Boulder's water supply system.

Scenario 2: Existing Facilities – Modified 63rd Street WTP Operations

In order to increase the frequency of meeting its hydropower capacity targets in April and September, Boulder could reduce deliveries from the 63rd Street WTP during these months to minimal levels (2 MGD is assumed), and increase its storage releases from its mountain reservoirs to offset reduced 63rd Street WTP deliveries. This would result in greater flows through the Silver Lake, Lakewood and Betasso hydro facilities during these months. In order to compensate for increased April and September draw-downs of its mountain reservoirs, Boulder could increase deliveries from the 63rd Street WTP during November through March such that the 63rd Street WTP's overall delivery volume for September through April is maintained.

Scenario 2 simulates such a modified operation of the 63rd Street WTP. In all other respects, Scenario 2 is identical to Scenario 1.

The results of Scenario 2 are presented in the attached workbook. A summary of results for this scenario related to Boulder's capacity-related hydropower targets is shown in Table 1. As shown in Table 1, modifying the operations of the 63rd Street WTP would increase the frequency of meeting Boulder's September capacity targets from 22% to 100% of the time. It would also significantly reduce the average target shortfall in April (from 1,242 AF/year to 460 AF/year).

Scenario 3: Proposed Facilities Including Tram Hill Discharge Line

Scenario 3 modifies Scenario 2 by assuming the addition of a new 30-inch-diameter City of Boulder Pipeline No. 3, conversion of the existing 20-inch Pipeline No. 3 into a discharge line from the Betasso Water Treatment Plant to Boulder Creek, and a new Hannah Barker hydro facility. Specifics of this scenario are:

- A new 30-inch-diameter City of Boulder Pipeline No. 3 would replace the 20-inch line. This would reduce head losses at Betasso Hydro and would facilitate one-hour hydro unit capacity tests.
- The existing 20-inch line would be converted into a discharge line (the Tram Hill discharge line from the Betasso WTP to Boulder Creek). This would allow for increased hydropower generation from additional diversions from North and Middle Boulder Creeks. The Tram Hill discharge line is assumed to have a 35 cfs capacity.
- Silver Lake Hydro: 3.1 cfs – 31 cfs flow range. As in Scenario 1, Silver Lake Hydro receives all of Boulder's water supply-related diversions and reservoir releases taken from North Boulder Creek at the Silver Lake Pipeline headgate, as well as any additional natural flow in North Boulder Creek, subject to instream flows below the Silver Lake Pipeline headgate of 4 cfs April-October and 1.5 cfs November-March. Additional Silver Lake Hydro diversions not usable by Lakewood Hydro are returned to North Boulder Creek at the Lakewood reservoir spillway. Because of the operational changes to the 63rd Street WTP, the hydropower revenues from Silver Lake Hydro would be different than Scenario 1.
- Lakewood Hydro is assumed to divert additional flows from North Boulder Creek, subject to instream flows below the Lakewood North Boulder Creek Inlet of 5 cfs April-September and 2 cfs October-March. Lakewood diversions in excess of water supply deliveries to Betasso WTP would generate hydropower at Lakewood Hydro. Excess Lakewood deliveries would be returned to Boulder Creek near Orodell via the Tram Hill discharge line.

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- Betasso Hydro is assumed to divert additional flows in Middle Boulder Creek below Barker, but only as needed to help meet capacity targets, and subject to instream flows below Barker of 5 cfs May-September and 4 cfs October-April. Water in excess of Betasso WTP deliveries would be used for hydro generation at Betasso Hydro and would be returned to Boulder Creek near Orodell via the Tram Hill discharge line.
 - Boulder Canyon Hydro: 3.7 - 37 cfs flow range. Boulder Canyon Hydro receives Barker outflows to Middle Boulder Creek subject to remaining capacity in the Barker Gravity Line after deliveries to Betasso Hydro and the Betasso WTP and also subject to instream flow bypass targets below Barker of 5 cfs May-September and 4 cfs October-April. No Barker storage releases are made to supply Boulder Canyon Hydro. Water used for generation at Boulder Canyon Hydro returns to Boulder Creek near Orodell.
 - The production schedule for the 63rd Street WTP is assumed to be modified as described in Scenario 2, in order to increase April and September deliveries from Boulder's upper system to the Betasso WTP, thereby increasing the frequency of meeting capacity targets in these months.
 - During October through March, the 1906 Barker hydropower storage right was assumed to be used to limit outflows from Barker Reservoir to Boulder's water supply deliveries to Betasso WTP, plus bypasses required to satisfy downstream senior direct flow rights, plus any additional bypasses needed to meet the 4 cfs instream flow target in Middle Boulder Creek. All other inflows were stored, up to an 800 acre-foot limit. (Note: this limit was reduced from 1,000 AF in our previous analysis to 800 AF because it produced a more optimal result in terms of meeting April capacity targets while minimizing April-May hydropower spills.) This stored water was then released in April and May, first to meet April capacity targets, then to generate hydropower at Boulder Canyon Hydro.
 - Hannah Barker Hydro: 7.9 cfs minimum flow range, to unlimited maximum flow range. A new Hannah Barker Hydro facility is assumed at the base of Barker Reservoir. Hannah Barker Hydro is assumed to receive all Barker outflow (including deliveries to the Barker Gravity Line). No maximum flow limit was assumed for Hannah Barker.

The results of Scenario 3 are also presented in the attached workbook, and in Table 1 below. Compared to Scenario 2, Boulder's ability to meet its capacity targets would increase significantly in April (from 0% to 94% of the time), and slightly in May (from 96% to 98% of the time). Moreover, the average April shortage-to-target would drop from 460 AF per month to 122 AF per month. The

remaining April shortages are very minor and Boulder could easily meet these shortages by making additional releases from Barker Reservoir.

Scenario 4: Proposed Facilities Including Tram Hill Hydro

This scenario is the same as Scenario 3 except that the Tram Hill discharge line would serve a Tram Hill Hydro unit with a 1.74 cfs-to-17.4 cfs flow range. The Tram Hill discharge line's capacity would therefore be limited to 17.4 cfs.

In terms of hydropower water availability, the results of Scenario 4 are nearly identical to those of Scenario 3.

Table 1: Summary of Hydropower Revenue Target Operations

	Scenario 1: Existing Facilities, Normal 63rd Street WTP Operations		Scenario 2: Existing Facilities, Modified 63rd Street WTP Operations		Scenario 3: Proposed Facilities (with Tram Hill discharge pipeline), Modified 63rd Street WTP Operations		Scenario 4: Proposed Facilities (with Tram Hill Hydro), Modified 63rd Street WTP Operations	
	% of Years Capacity Target Met	Average Shortfall in Remaining Years, AF	% of Years Capacity Target Met	Average Shortfall in Remaining Years, AF	% of Years Capacity Target Met	Average Shortfall in Remaining Years, AF	% of Years Capacity Target Met	Average Shortfall in Remaining Years, AF
Oct	0%	1359	0%	1294	0%	1182	0%	1192
Nov	0%	1370	0%	1735	0%	1663	0%	1673
Dec	0%	1555	0%	1968	0%	1967	0%	1968
Jan	0%	1647	0%	2065	0%	2063	0%	2063
Feb	0%	1351	0%	1745	0%	1745	0%	1745
Mar	0%	1514	0%	1909	0%	1909	0%	1909
Apr	0%	1242	0%	460	94%	122	92%	98
May	96%	160	96%	160	98%	213	98%	213
Jun	100%	0	100%	0	100%	0	100%	0
Jul	100%	0	100%	0	100%	0	100%	0
Aug	100%	0	100%	0	100%	0	100%	0
Sep	22%	379	100%	0	100%	0	100%	0