Collaborate, Plan, and Prepare – A Utility's Role in Source Water Protection

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In Boulder, Colorado, the tap water comes from mountain streams and reservoirs fed predominantly by snow melt. To maintain water quality, most raw water is piped directly from the source to the water treatment plants. Boulder owns a portion of the watershed near the Continental Divide and public access has been prohibited in that area since 1920. Therefore, we can sit back, relax, and let the pure water nourish our community without a second thought, right? Not so much. Maintaining this high quality water involves water quality monitoring and evaluation, planning and preparation, and most importantly, a lot of collaboration.

The portion of the watershed owned by the city only represents 12 percent of the land area. Like other communities, water quality can be impacted by a variety of sources such as wastewater effluent; leaking septic systems; discharges from abandoned mines; lawn, road, and agricultural runoff; post-fire erosion and sediment transport; atmospheric deposition; and climate change. Boulder staff works with local, state, and federal land managers to implement projects and policies that help to provide operational flexibility and ensure a resilient, reliable, and high quality water supply for residents.

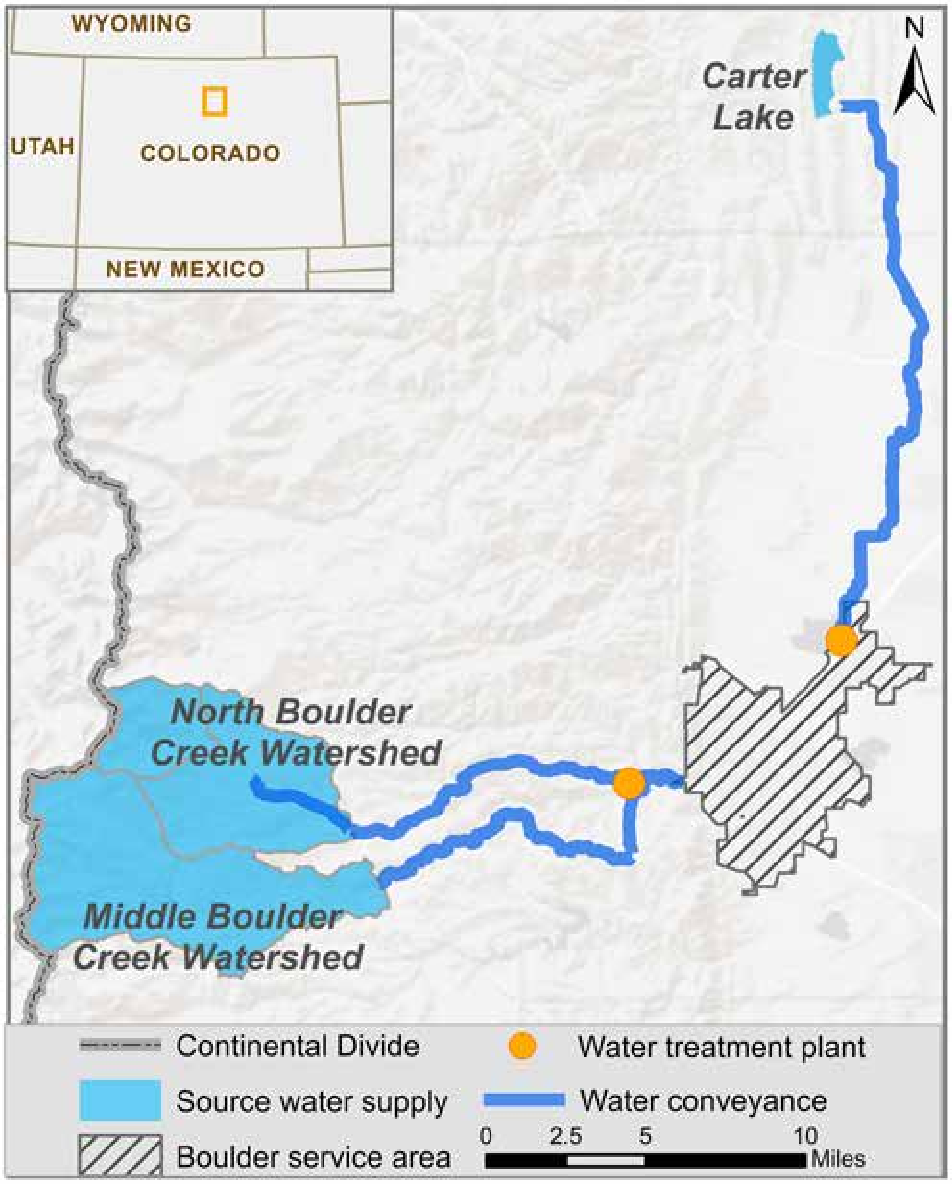


Figure 1. Boulder's source water supply watershed map.

Boulder's water supply

Boulder, Colorado, located 30 miles northwest of Denver, has a service area population of 120,000, expected to grow to 136,000 by the year 2040. Boulder's water supply comes from the following sources (one-third each): the North Boulder Creek Watershed, the Middle Boulder Creek Watershed, and Upper Colorado River diversions (Figure 1). The trans-mountain diversions are part of the Colorado-Big Thompson Project, which transfers water through a series of reservoirs, canals, and pipelines from the Upper Colorado River to eastern slope communities. Boulder's share of the diversions is delivered via Carter Lake, 20 miles north of Boulder. By 2020, the open channel delivery system from Carter Lake to Boulder's water treatment plant will be replaced with a pipeline to maintain water quality and improve resilience.

Monitoring and analyzing source water quality

Water quality monitoring is the cornerstone of Boulder's source water protection program. Water supply reservoirs and tributaries are sampled routinely for a suite of constituents including basic chemistry, nutrients, metals, organic carbon, total suspended solids, volatile organic compounds, and phytoplankton (Figure 2). Staff also monitor for more than 100 pesticides, pharmaceuticals, personal care products, hormones, and other unregulated organic chemicals on a less frequent basis through a multi-utility collaborative to reduce costs. A team of water staff evaluate and update the monitoring program annually.

Throughout the year, staff analyze water quality data to understand trends or changes, and report on key findings to Utility's staff via a Monthly Water Quality Update. The mini-newsletter is developed in PowerPoint and filled with bullet point text, figures, maps, and infographics to inform water treatment, monitor changes during spring runoff and fall reservoir stratification, and educate staff more broadly about the water supply and reservoir health (Figure 3). Data are also used to assess event-related changes (e.g., reservoir chemistry changes caused by the 2013 flood), or evaluate the effectiveness of source water protection investments (e.g., reductions in reservoir nutrient levels since investing in phosphorus removal at a small upstream wastewater treatment facility). The updates also provide a record of issues, actions, and outcomes.

Figure 2. Boulder staff collecting reservoir samples. After lab analyses, staff analyze water quality data to understand trends and changes in the source water.

Developing a source water protection work plan

Over the years, Boulder has developed a number of watershed management plans, a Source Water Master Plan, and reservoir impact assessments. To better coordinate and prioritize watershed protection efforts, Boulder embarked on a stakeholder-driven process to develop a Source Water Protection Plan (SWPP), finalized in 2017. Over the course of a year, staff and dozens of stakeholders met monthly to identify potential sources of contamination to the water supply, delineate protection zones, and prioritize specific strategies and programs to minimize or prevent water quality impacts. The SWPP identified key threats to the water supply (e.g., post-wildfire erosion and climate change), and potential sources of contamination (e.g., abandoned mine discharges, illegal hazardous waste dumping). The benefits of the SWPP process are two-fold: first, the SWPP has helped staff prioritize efforts and more efficiently allocate resources; second, and perhaps more importantly, the process was stakeholder-driven and allowed staff to further develop working relationships with local, state, and federal agencies, businesses, and landowners in the watersheds. Contact your state's environment or public health agency to learn about SWPP grant funding availability. A list of state source water contacts is maintained here: https://www.asdwa.org/sourcewatercontacts/.

Planning and preparing for wildfire

Like many communities in the West, wildfire is a key threat to Boulder's forested water supply. Specifically, erosion and sediment transport during post-fire rain events can fill reservoirs and reduce water storage capacity (a critical component of western water supply management), cause short- and long-term water quality issues, and increase water treatment costs. While forest thinning projects are a common approach to reducing or preventing severe wildfires, they take years to implement and a variety of factors make any large-scale forest thinning projects not practical in Boulder's source watersheds in the near term.

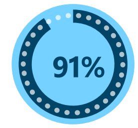
Recognizing that there could be a wildfire in the watersheds at any time, Boulder teamed up with the Colorado Forest Restoration Institute to build a pre- and post-wildfire planning tool for water supply protection. The Wildfire Erosion and Sediment Transport Tool (WESTT), simulates wildfires; predicts post-fire sediment transport under varying fuel dryness conditions and rain intensities; recommends rehabilitation plans to stabilize hillslopes and trap sediment upstream from intakes; and estimates the cost of implementing the watershed rehabilitation efforts such as wood mulch, straw mulch, and installing wattles. Staff members from U.S. Forest Service (USFS) and U.S. Geological Survey (USGS), among other partners were involved throughout WESTT development to help ensure the tool is scientifically sound and useful to all partners including any USFS Burned Area Emergency Response Team that may be activated post-fire.

Monthly Water Quality Update — April 2018

General Updates

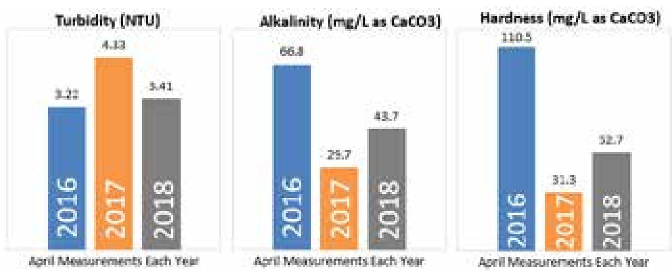
- During the week of April 30th, Betasso will run performance tests on the new basins and 63rd will shut down for ~2 weeks. 63rd is expected to come back online on May 14th and begin treating Boulder Feeder Canal (BFC).
- Northern Water has set the Colorado-Big Thompson Project quota at 80%, meaning that 80% of C-BT water will be available to allottees this year. The allocation is based on high C-BT storage levels and below average winter precipitation. Learn about the quota system here.

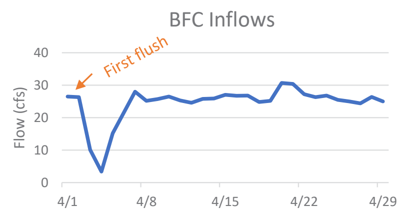
University Camp Snowpack
(% of Median)



Boulder Feeder Canal

- Boulder Feeder Canal flow has been steady in recent weeks, with a current discharge rate of 25 cfs.
- BFC basic water chemistry is shown for 2018 and the previous two years in the figures below.





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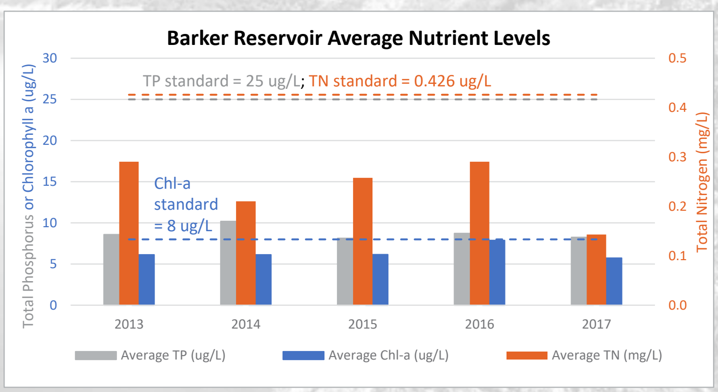
Nutrient Interim Values

- The Colorado Department of Public Health and Environment (CDPHE) performs basin-wide water quality assessments on a four-year rotational cycle. The South Platte River Basin will be assessed in 2019.
- CDPHE reviews water quality data to determine whether waterbodies are achieving their designated use (e.g., recreation, water supply) through attainment of water quality standards. 2019 will be the first year the South Platte River Basin is assessed for total phosphorus (TP) and chlorophyll-a (chl-a), which is a measure of algal growth.
  - Total nitrogen (TN) will be considered for adoption in the South Platte River Basin in 2027.
- Waterbodies will be classified as impaired or on the monitoring and evaluation list if summer average* concentrations exceed the standards more than once in five years.

How do nutrient levels stack up in Barker Reservoir?

- Barker Reservoir is in compliance with the TN, TP, and Chl-a interim values.
- While not readily visible from the summer average values shown in the figure, TN and TP have been significantly declining since the Nederland WWTF upgrades in 2013.



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** Summer = July 1 to Sept. 30 for TP and TN or March 1 to Nov. 30 for Chl-a.*

Figure 3. A-D above and on following page. Examples of information conveyed in monthly water quality updates.

So....what's driving algal growth in Barker Reservoir?

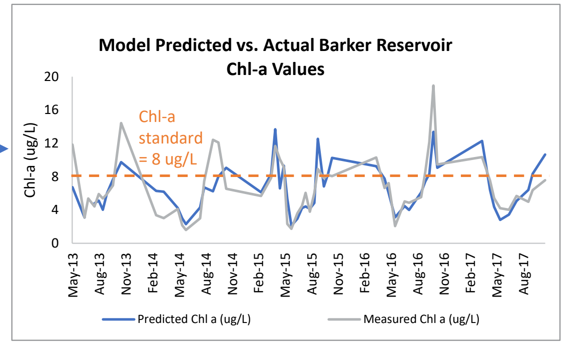
3C

Analyses suggest that Barker Reservoir chl-a (i.e., algal growth) is most strongly influenced by **reservoir residence time** and **TP concentrations** (*see methods in footnote*). Residence time is the amount of time a molecule of water stays in Barker Reservoir before being flushed out.

What Do the Model Results Mean?

The model can be used to predict Barker chl-a levels (see close alignment of grey and blue lines on the figure). Peak chl-a measurements are typically in November, or April.

Reservoir residence time is a function of water rights, season, and water demand. Therefore, it's not something that can be easily manipulated.



Model Results:

P value = <0.0001	Probability value – this means that there is less than a 0.01% chance that the relationship is due to chance. P values <0.05 indicate statistically significant relationships.
R^2= 0.68	R-squared value – this means that residence time and TP concentrations explain 68% of the variation in chl-a levels in the reservoir. The R^2 value assesses how well the model fits the data. Values closer to +1 or -1 (positive or negative relationship) indicate stronger models. 0.68 is a very good R^2 value.
Spearman Rho • *Res. Time = 0.63* • *TP = 0.38*	Rho – these measure the strength of the relationship to chl-a within the model (similarly to R^2, values closer to +1 or -1 indicate a stronger relationship). The higher rho value for residence time indicates that it explains more variation in chl-a than TP (i.e., it's a more important component of the model).

Methods: *Ran non-parametric spearman rank correlations between log-transformed water quality and environmental data from the 2013-2017 period (post-WWTF upgrades). Parameters included: reservoir and WWTF nitrogen (NH4+, NO3-, TKN) and phosphorus (ortho, dissolved); reservoir contents (acre-ft); air temperature; snow-water equivalent; precipitation. Then ran multiple linear regression models using the significantly correlated parameters (p<0.05) to find the best fit model that explains chl-a concentrations. Checked for autocorrelation – TP and residence time were not correlated with each other (p = 0.773). Contact Kate Dunlap if you have more questions about the methods and results.*

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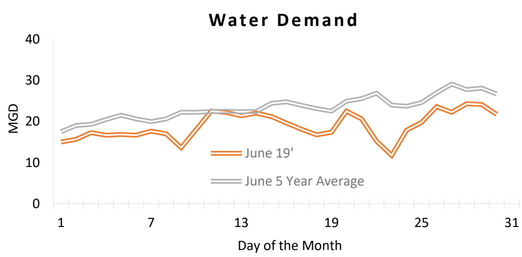
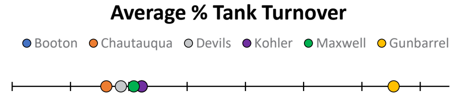
Distribution System Characteristics



Average residence time is
51 hours

a decrease from last month's 74 hours

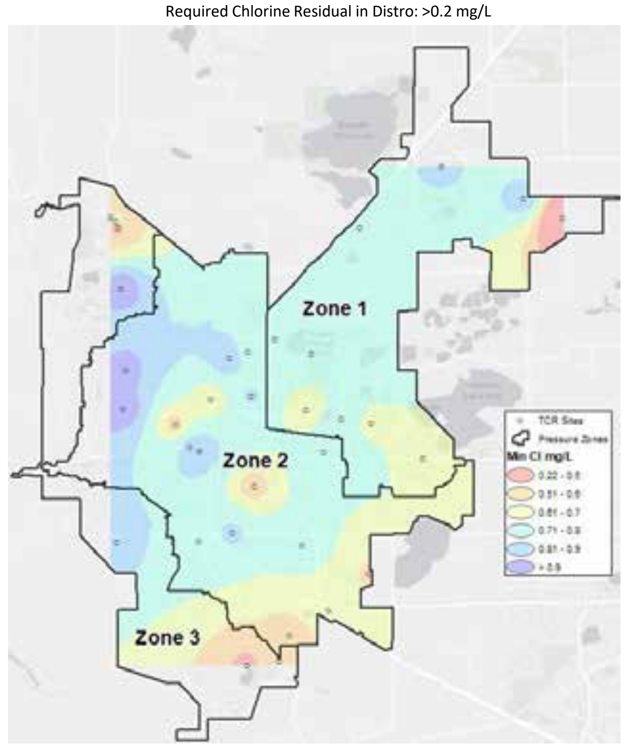
Average % Tank Turnover



*EPA recommends >20% Tank Turnover

Chlorine Residual in the Distribution System

Target Chlorine Residual Entering Distro: 1.1 mg/L.
Required Chlorine Residual in Distro: >0.2 mg/L



3D

*Click *here* for definitions and goals related to distro characteristics

Collaborating and sharing information

Despite all of the sampling and analyses Boulder staff do internally, we could never achieve any measurable level of source water protection without collaborating with external partners, landowners, and businesses. Water quality staff take advantage of the fact that Boulder is home to more than a dozen federal labs including the Institute of Arctic and Alpine Research, National Oceanic and Atmospheric Administration, and the National Weather Service, as well as key USFS and USGS offices and the University of Colorado, Boulder. When planning projects, Boulder staff frequently consult with and involve experts from these entities. For example, to characterize potential impacts from two discharging inactive mines, Boulder consulted with scientists from USGS and the Colorado Division of Reclamation and Mining Safety to design and implement the study. Due to the partnership in this effort, Boulder received a grant to fund the sampling and lab analysis costs for this project.

Staff time and monetary resources are limited, and we can all benefit by sharing information, lessons learned, and plans that can be used by others. Recently while we were evaluating and updating the water quality monitoring program, staff asked what other Colorado utility programs look like. What are other water providers monitoring? Where do they sample and how often? To what extent do they perform statistical analyses on their water quality data and report to staff and the public on findings? What are some key threats or pollutant sources to other water supplies and how are water providers planning and adapting?

To answer these questions, Boulder staff developed an online survey in Google Forms and sent it to water providers across the state. Twenty-one providers with service area populations ranging from 4,000 to 1.4 million, responded to the survey. Staff analyzed the responses and presented the survey results at a Colorado Lake and Reservoir Management Association (CLRMA) luncheon – a NALMS affiliate. Aggregate results have also been provided to interested water providers. Learning from others has helped Boulder improve the monitoring program and embark on source water protection projects recommended by other utilities.

Conclusion

No matter where your drinking water comes from, implementing a source water protection program is paramount. From one water provider to another, here are some thoughts:

- *Monitoring = Sampling + Analysis*. What good is a database of water data if no one is looking at it? Reviewing your data can help you understand baseline conditions, identify trends, and potential pollutant sources. Seek guidance from local university professors, USGS staff, or other water providers to formulate hypotheses and conduct analyses. At a minimum, preparing a timeseries scatterplot in Excel can tell you a fair amount about your source water.
- *Try not to reinvent the wheel*. More than likely, other water providers in your area are facing similar threats to their water supplies, developing similar plans, and encountering similar issues regarding source water protection. Contact them to share information and lessons learned, and perhaps collaborate on projects to spread out the costs.
- *Planning and stakeholder involvement.* Get to know the local, state, and federal staff who own or manage the land in the source watershed. Developing these relationships in advance will facilitate working together post-natural disaster to implement projects and secure funding.

And one last thought – always serve cookies or lemon bars at your meetings. We've analyzed it, and the chances that fellow staff and stakeholders will attend your meetings and offer insightful thoughts and ideas, significantly increases (p-value <0.001).

Kate Dunlap has 15 years of experience in water resource management in the private and public sectors and an M.S. in Water Resources. To protect and preserve Boulder's source water quality, she collaborates across sectors, analyzes environmental data, and communicates results to inform special projects and policies.

Michelle Wind manages the City of Boulder Drinking Water Quality Program that provides technical support to protect, maintain, and optimize the city's drinking water quality from source to tap. Michelle is an environmental engineer with 25 years of experience in water quality and watershed management.