2016 Denver Lake Monitoring Findings:
Overview and Update to Recycled Water Advisory Group

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City and County of Denver – Department of Environmental Health

This update summarizes the Denver Department of Environmental Health's (DEH) monitoring efforts on the City Ditch Lakes in 2016. This summary will focus on salt concentrations in the two Washington Park Lakes (Grasmere and Smith) and Ferril Lake in City Park. The 2016 monitoring events included the mid-summer visit to each lake in July as well as one additional visit to all three lakes in November. Ferril Lake was also sampled in June and October. The objectives of this monitoring were to:

- continue DEH's long term annual assessments of these lakes; and
- collect additional data on salts and other ions that can impact landscaping of the irrigated surroundings.

Because it had not historically been an issue in Denver Lakes, prior to 2016, DEH did not analyze samples for sodium. As a result of discussions within the Recycled Water Advisory Group meetings (2015/16), this was added to the suite of analytes in 2016. For this reason, the long term discussion on salts will focus on chloride. In that chloride and sodium demonstrated a fairly strong relationship when looking at all Denver Lakes (**Figure 1**), it should be closely representative of what was happening with sodium in the past as well.

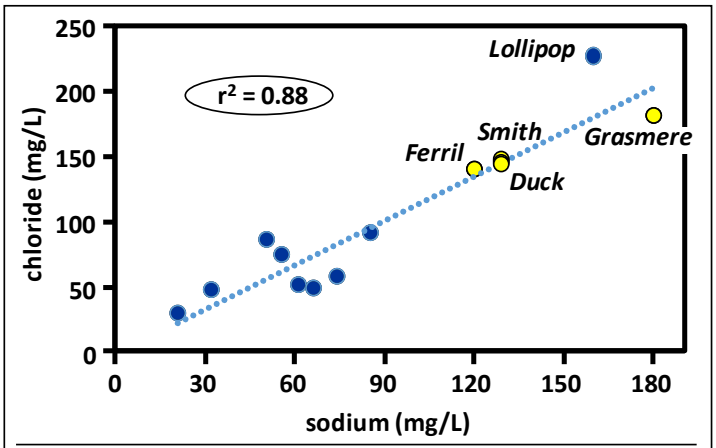

Fig 1. Chloride and sodium relationship in all sampled Denver Lakes, mid-summer 2016. The yellow circles represent the City Ditch Lakes. Of note, Lollipop is subsidized with deep ground water.

Comparison among all monitored Denver Lakes can provide some perspective on City Ditch Lakes salt levels. Chloride levels in the City Ditch Lakes over the past decade were relatively high compared with other Denver Lakes (**Figure 2**). The two lakes that had consistently comparable chloride levels were groundwater sustained lakes (Lollipop and Vanderbilt). Lollipop Lake is sustained with deep groundwater, while Vanderbilt sits within a basin that likely interacts directly with South Platte River alluvial groundwater.

The increase in chloride concentrations in the City Ditch Lakes in 2004 following transition to recycle water as source is evident in the long term data (Figure 2). Also of note is a gradual but steady increase in chloride concentrations over the past decade (**Figure 3**). This trend changed course in Grasmere Lake in 2015 with a 17% decrease from 2014, which was generally sustained in 2016. This response was also noted in down-ditch lakes, but at a more muted level.

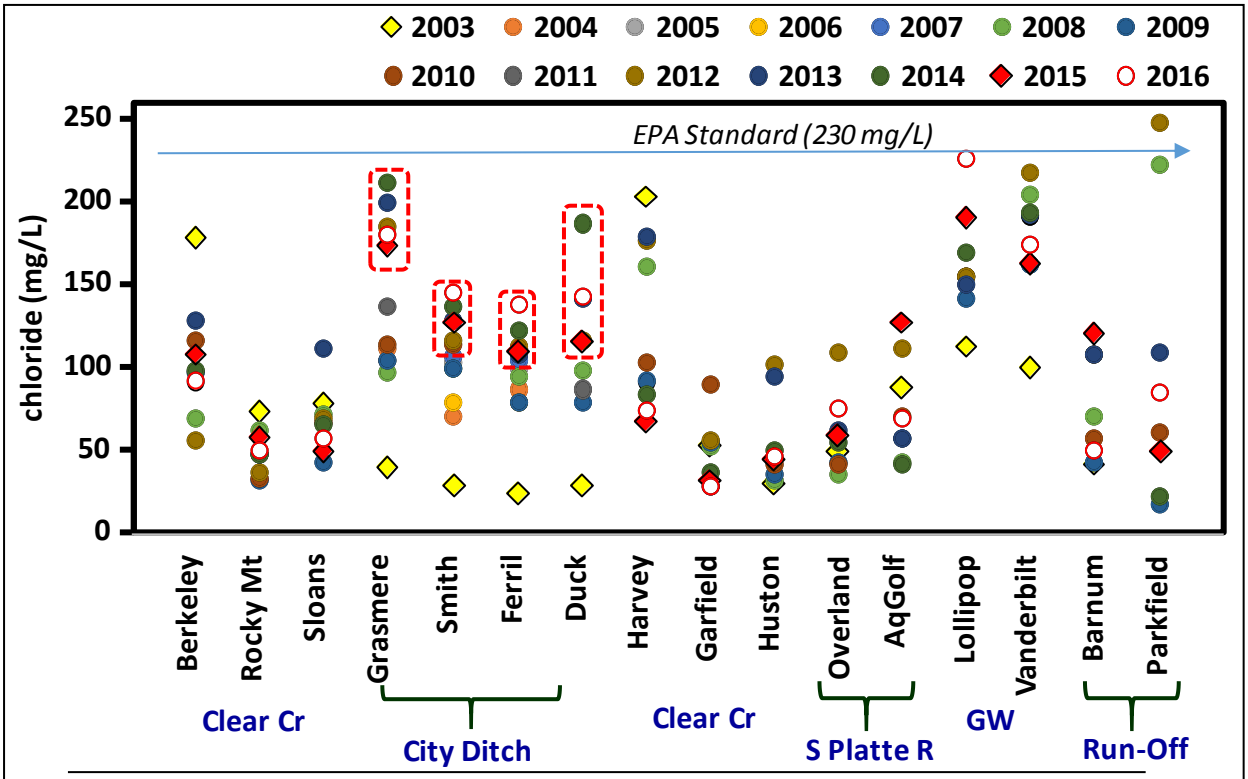

Fig 2. Chloride levels in Denver Lakes, 2003-2016. Source water is delineated in blue below lake designations. The red dashed rectangles delineate the past 5 years of data in the City Ditch Lakes, which received recycled water from 2004 – 2016.

Also of note from the long term data, Smith and Ferril Lakes both had notably lower chloride concentrations than Grasmere after 2011. Its not clear why there was an increase in Grasmere Lake chloride levels at this time. Measurements from the ditch do not indicate a correspondingly large change in source water concentrations over the same time period. However, source water chloride also increased over time with notable bumps in 2013 and 2015 (**Figure 3**).

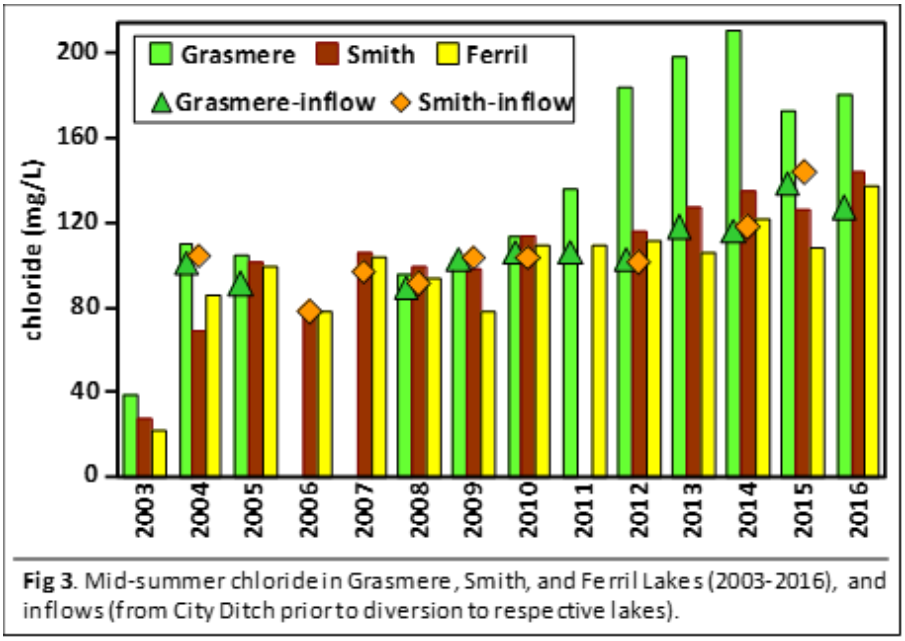

Fig 3. Mid-summer chloride in Grasmere, Smith, and Ferril Lakes (2003-2016), and inflows (from City Ditch prior to diversion to respective lakes).

Other factors that could have impacted chloride levels include changes in structural management strategies or climatic factors. SolarBee mixing units[1] were placed in Grasmere Lake shortly after the transition to recycled water in 2004/05. This was not a new development, and there were no known additional management changes over this sample period.

It is also possible that non-anthropogenic driven impacts such as interactions with groundwater, or evaporation influenced chloride levels. It is expected that groundwater interactions in Grasmere would be minimal due to a bentonite layer that was set in 2003. Variation in precipitation may also be playing a role, but its unlikely that annual variation could be attributable to five years of increased chloride levels.

An additional factor that theoretically makes sense would be a chronic buildup of salts in the surrounding soils that eventually flushed into the lake via groundwater infiltration. However, as mentioned previously, Grasmere does have a bentonite layer, so this is less likely. Also, if this were a factor, it would be expected that this route of entry would be noted in Smith and Ferril as well. While there is indeed an increase in these lakes over the same period, it is not as dramatic, and may be attributable to increased chloride concentrations entering the source water from the Grasmere discharge (back to City Ditch).

Sodium and SAR: Sodium imbalance in irrigation water can result in problems with park vegetation through a reduction in water infiltration. Sodium was added to the suite of analytes assessed by DEH during our 2016 mid-summer monitoring events for most of the Denver Lakes. Results from this were consistent with long term trends previously discussed for chloride concentrations. The City Ditch Lakes had relatively elevated sodium levels (**Figure 4**). As with the chloride concentrations, the one groundwater subsidized lake assessed for sodium (Lollipop) did have comparable levels to those in the City Ditch Lakes.

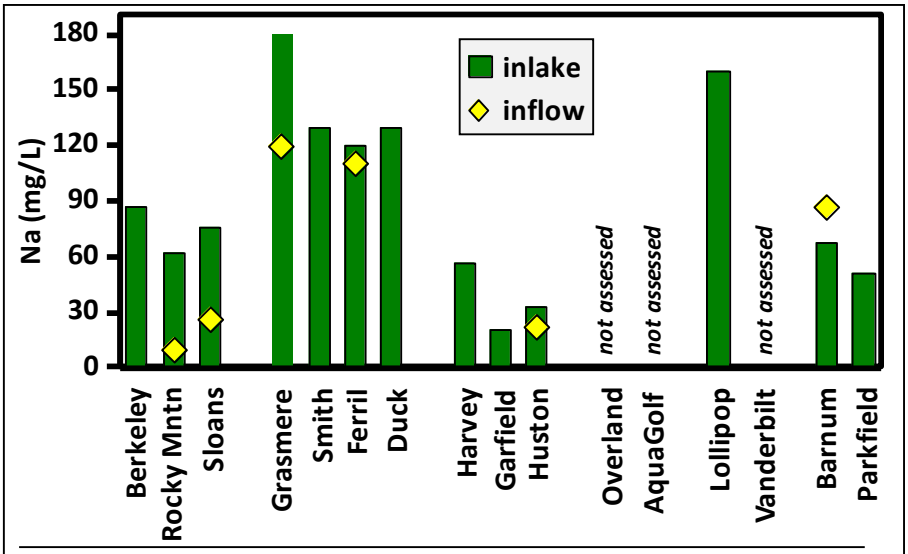

Fig 4. Mid-summer sodium levels in Denver Lakes and inflows (2016).

The sodium absorption ratio (SAR) is a common way to assess source waters for a sodium imbalance. The equation calculates a value based on concentrations of sodium, magnesium, and calcium. The interaction between electrical conductivity and the SAR are important in determining the likelihood that an irrigation source can result in a problem with water infiltration due to a sodium imbalance (**Table 1;** Colorado State Extension 2016).

[1] Solar powered water column mixing device that keeps the lake from developing stratified layers, subsequently lacking oxygen on the lake bottom, which leads to release of nutrients and a more productive lake regarding algae.

Results from 2016 monitoring indicate that both Smith and Ferril, as irrigation source-water, fall between the "likely" and "unlikely" to create a water infiltration problem (in the irrigated soils) attributable to a sodium-calcium-magnesium imbalance (**Figure 5**). Calculated summer and fall SAR values for both lakes, ranged from 4.0 to 4.2. Conductivity values were in the grey area as to whether they could ameliorate impacts of elevated sodium concentrations (relative to calcium and magnesium) on water infiltration.

Future DEH Monitoring: In 2017, DEH will continue to collect data that provides insight into the status of salt concentrations in the City Ditch Lakes. This monitoring will be expanded to other lakes, particularly those that are utilized for irrigation to better understand all our irrigation sources.

DEH will also work with other stakeholders to assess storm water influence on City Ditch. While it is clear there is stormwater sharing the pipe with City Ditch downgradient of Washington Park, it is not clear to what extent. It is also not clear as to how much stormwater is entering the ditch south of Washington Park. Plans will be developed to do wet-weather and dry-weather monitoring of City Ditch to gain a better understanding on this.

Table 1. Potential for water infiltration problem; Guidelines for assessment of sodium hazard of irrigation water based on SAR and conductivity[1/].

Irrigation water **SAR**	Specific Conductivity (uS/cm)	
	unlikely	**likely**
0 – 3	>700	<200
3 - 6	**>1200**	**<400**
6 - 12	>1900	<500
12 - 20	>2900	<1000
20 - 40	>5000	<3000

1/ From Colorado State Extension website, which originally modified from R.S. Ayers and D.W. Westcot. 1994. Water Quality for Agriculture, Irrigation and Drainage Paper 29, rev.1, Food and Agriculture Organization of the United Nations, Rome.

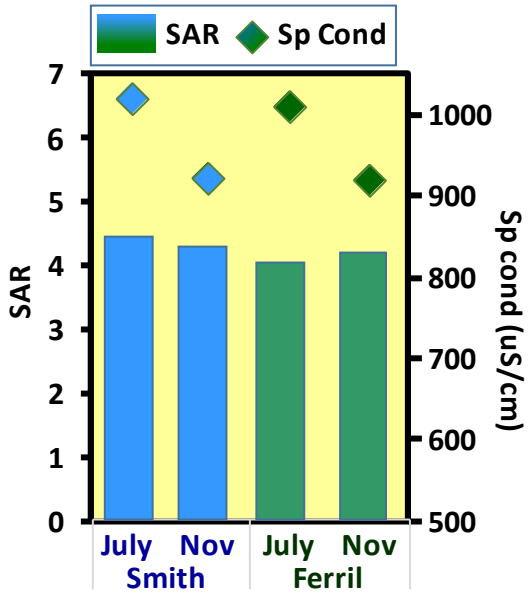

Fig 5. 2016 SAR values and specific conductivity in Smith and Ferril Lakes.

Reference

Colorado State University Extension – 2017 – Online: Irrigation Water Quality – 0.506.