2015

KEZAR LAKE WATER QUALITY REPORT

A Report on the Water Quality of Kezar Lake, Two Tributaries, and Six Watershed Ponds

FB Environmental Associates
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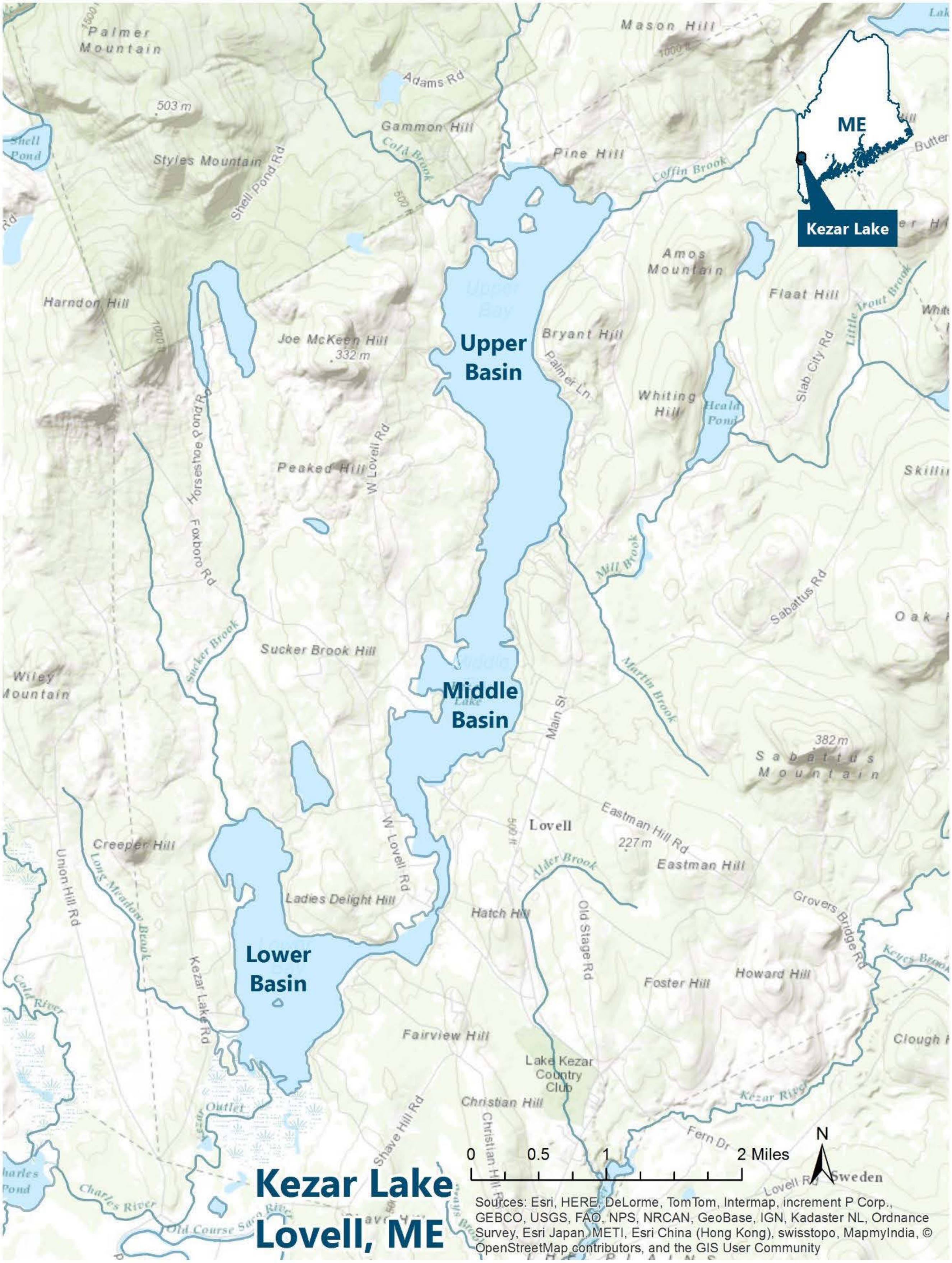
Kezar Lake
Lovell, ME
ME
Kezar Lake
Upper Basin
Middle Basin
Lower Basin
Lovell
Palmer Mountain
Mason Hill
Adams Rd
Gammon Hill
Cold Brook
Pine Hill
Coffin Brook
Shell Pond
Styles Mountain
Shell Pond Rd
Amos Mountain
Flaat Hill
Harndon Hill
Joe McKeen Hill
332 m
503 m
Bryant Hill
Palmer Ln
Whiting Hill
Heald Pond
Slab City Rd
Little Trout Brook
Peaked Hill
W Lovell Rd
Horseshoe Pond Rd
Foxboro Rd
Mill Brook
Sabattus Rd
Sucker Brook Hill
Sucker Brook
Wiley Mountain
Martin Brook
Main St
382 m
Sabattus Mountain
Eastman Hill Rd
227 m
Eastman Hill
Creeper Hill
Union Hill Rd
Long Meadow Brook
Alder Brook
Ladies Delight Hill
Hatch Hill
Old Stage Rd
Grovers Bridge Rd
Keyes Brook
Kezar Lake Rd
Foster Hill
Howard Hill
Cold River
Fairview Hill
Clough Hill
Lake Kezar Country Club
Christian Hill
Christian Hill Rd
Kezar River
Outlet
Shave Hill Rd
Fern Dr
Lovell Rd
Sweden
Charles Pond
Charles River
Old Course Saco River
0 0.5 1 2 Miles
N
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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Kezar Lake Water Quality Report

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January 2016

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Special thanks to KLWA volunteers Jim Stone (KLWA President), Heinrich Wurm and Don Griggs (Boat Captains on Kezar Lake), Terri Mulks (Camp Susan Curtis - Trout Pond), Ralph Tedesco (Farrington Pond), Mrs. Sundsrom (Heald Pond), and the Emond family (Horseshoe Pond) for providing access, time, and equipment for the 2015 water quality monitoring season.

Cover photo: FBE, 2015

Table of Contents

List of Tables

List of Figures

Glossary of Key Terms Used in this Report

Chlorophyll-a (Chl-a): A measurement of the green pigment found in all plants, including microscopic plants such as algae. It is used as an estimate of algal biomass; higher Chl-a equates to greater amount of algae in the lake.

Color: The influence of suspended and dissolved particles in the water as measured by Platinum Cobalt Units (PCU). A variety of sources contribute to the types and amount of suspended material in lake water, including weathered geologic material, vegetation cover, and land use activity. Colored lakes (>25 PCU) can have reduced transparency readings and increased TP values. When lakes are highly colored, the best indicator of algal growth is chlorophyll-a.

Dissolved Oxygen: The concentration of oxygen that is dissolved in the water. DO is critical to the healthy metabolism of many creatures that reside in the water. DO levels in lake water are influenced by a number of factors, including water temperature, concentration of algae and other plants in the water, and amount of nutrients and organic matter that flow into the waterbody from the watershed. Too little oxygen severely reduces the diversity and abundance of aquatic communities. DO concentrations may change dramatically with lake depth. Oxygen is produced in the top portion of a lake (where sunlight drives photosynthesis), and oxygen consumption is greatest near the bottom of a lake (where organic matter accumulates and decomposes).

Epilimnion: The top layer of lake water that is directly affected by seasonal air temperature and wind. This layer is well oxygenated by wind and wave action, except when the lake is covered by ice.

Escherichia coli (E. coli): An indicator of the presence of fecal contamination in the watershed. By itself, *E. coli* is generally not a threat to human health, but it can be associated with disease-causing organisms.

Eutrophication: Refers to lakes with high productivity, high levels of phosphorus and chlorophyll, low Secchi disk readings, and abundant biomass with significant accumulation of organic matter on the bottom. Eutrophic lakes are susceptible to algal blooms and oxygen depletion in the hypolimnion.

Integrated Epilimnetic Core: A water sample that is taken with a long tube in order to determine average nutrient concentration in the epilimnion.

pH: The standard measure of the acidity or alkalinity of a solution on a scale of 0-14. Most aquatic species require a pH between 6.5 and 8. As the pH of a lake declines, particularly below six, the reproductive capacity of fish populations can be greatly impacted as the availability of nutrients and metals changes. pH is influenced by bedrock, acid rain or snow deposition, wastewater discharge, and natural carbon dioxide fluctuations.

Platinum Cobalt Units (PCU): A unit of measurement used to determine the color of lake water. Lake water with 30 PCU will look slightly brown or tea-colored. (Formerly reported as SPU- Standard Platinum Units).

Glossary of Key Terms (*Continued*)

Sample Station: Location where water quality readings and samples are taken. Some of the larger lakes or basins are sampled at more than one location, resulting in multiple station numbers. In lakes with more than one basin, at least one station is usually located in each basin.

Secchi Disk Transparency (SDT): A vertical measure of water transparency (ability of light to penetrate water) obtained by lowering a black and white disk into the water until it is no longer visible. Measuring SDT is one of the most useful ways to show whether a lake is changing from year to year. Changes in transparency may be due to increased or decreased algal growth, or the amount of dissolved or particulate materials in a lake, resulting from human disturbance or other impacts to the lake watershed area. Factors that affect transparency include algae, water color, and sediment. Since algae are usually the most common factor, transparency is an indirect measure of algal populations.

Thermocline: The uppermost point in the water column where the temperature drops at least a degree Celsius per meter of depth.

Total Alkalinity: A measure of the buffering capacity of a lake, or the capacity of water to neutralize acids. It is a measure of naturally-available bicarbonate, carbonate, and hydroxide ions in the water, which is largely determined by the geology of soils and rocks surrounding the lake. Alkalinity is important to aquatic life because it buffers against changes in pH that could have dire effects on animals and plants.

Total Phosphorus (TP): The total concentration of phosphorus found in the water, including organic and inorganic forms. TP is one of the major nutrients needed for plant growth. It is generally present in small amounts and limits plant growth in freshwater ecosystems. As phosphorus increases, the amount of algae generally increases. Humans can add phosphorous to a lake through stormwater runoff, lawn or garden fertilizers, and leaky or poorly maintained septic tanks.

Trophic State Indicators: A scale from 0 to 100+, which ranks lakes for productivity. The low (zero) end of the scale supports very little algae, has excellent water quality (oligotrophic) and the high end 100+ is eutrophic and very productive. TSI can be calculated from the Secchi disk, Chl-a or TP results and requires at least five months of data per year. Lakes with TSI values greater than 65 may support algal blooms while values over 100 indicate extreme productivity and annual algae blooms. TSI values can be used to compare lakes with similar water color and track water quality trends within a lake.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

1. Background and Historical Information

This report documents the results of water quality monitoring conducted by FB Environmental Associates (FBE) for the Kezar Lake Watershed Association (KLWA) in 2015. In addition to monitoring water quality in the three basins of Kezar Lake, FBE also collected water quality data at six ponds in the Kezar Lake watershed: Bradley, Cushman, Farrington, Heald, Horseshoe, and Trout Ponds (Figure 1). Several of the six ponds are hydrologically connected, and they all ultimately drain to Kezar Lake. Additionally, FBE monitored two tributaries of Kezar Lake: Great Brook and Boulder Brook. Great Brook drains to the upper basin at the north end of Kezar Lake, and Boulder Brook flows into Kezar Lake between the middle and upper basins on the east side of the lake.

Background and historical information about Kezar Lake, Great Brook, Boulder Brook, and the six ponds has been presented in detail in previous reports (listed below), as well as online at klwa.org where historical water quality data, maps, and waterbody descriptions can be found.

- Kezar Lake 2013 Water Quality Report (January 2014) - S*ummarizes the results of the 2013 water quality monitoring for Kezar Lake, Boulder Brook, Great Brook, and the six ponds.*
- Kezar Lake Nutrient Modeling (June 2013) - *Estimates Phosphorus Loads using Lake Loading Response Modeling.*
- Kezar Lake Watershed Ponds NPS Survey Report (January 2013) - S*ummarizes the watershed survey conducted for the subwatersheds of the six ponds surrounding Kezar Lake: Bradley, Cushman, Farrington, Heald, Horseshoe, and Trout Ponds.*
- Historical Trend Analysis: Kezar Lake & Ponds (July 2012) - *Provides a 40-year analysis of water quality monitoring data for Kezar Lake and six ponds within the Kezar Lake watershed.*

2. Methods and Parameters

The sample stations at the three basins of Kezar Lake were sampled on June 24, August 19, and September 16, 2015. The four tributary stations in Great Brook (GB-1) and Boulder Brook (BB-1, BB-3, and BB-4) were sampled on June 24 and September 16, 2015, and the six ponds (Bradley, Cushman, Farrington, Heald, Horseshoe, and Trout Ponds) were sampled on June 24 and August 19, 2015 (Table 1). Sampling was conducted in accordance with standard methods and procedures for lake monitoring established by the Maine Department of Environmental Protection (Maine DEP), the US Environmental Protection Agency (USEPA), and the Maine Volunteer Lake Monitoring Program (VLMP). All lab samples were analyzed at the Health and Environmental Testing Lab (HETL) in Augusta.

KLWA volunteer Heinrich Wurm (above) assisted FBE with sample collection in 2015.

Table 1. 2015 sampling summary of Kezar Lake, six ponds, and two tributaries in the Kezar Lake watershed.

	Weather				
Date	Prior 24 hr Precip (in)*	Prior 48 hr Precip (in)*	Prior 96 hr Precip (in)*	Sampling Day Conditions	Sampling Sites
6/24/2015	1.56	1.8	2.52	Bright	KEZA-0097-01,-02,-03 HORS-3196-01 FARR-3200-01 HEAL-3222-01 CUSH-3224-01 BRAD-3220-01 TROU-3212-01 BB-1, BB-3, BB-4, GB-1
8/19/2015	0	0	0	Cloudy	KEZA-0097-01,-02,-03 HORS-3196-01 FARR-3200-01 HEAL-3222-01 CUSH-3224-01 BRAD-3220-01 TROU-3212-01
9/16/2015	0	0.47	0.81	Bright	KEZA-0097-01,-02,-03 BB-1, BB-3, BB-4, GB-1

* Source: Weather Underground, Fryeburg, ME weather station (KIZG)

With the help of KLWA volunteers, FBE collected temperature and dissolved oxygen profiles at the deep spots of the three basins at Kezar Lake and six ponds in the Kezar Lake watershed. This information is used to determine where the epilimnion (or upper part of the thermocline) occurs, and at what depth an integrated epilimnetic core will be taken. The water collected from this core is analyzed for natural color, total alkalinity, pH, total phosphorus (TP), and chlorophyll-a (Chl-a). In addition, water clarity is also measured by Secchi disk transparency (SDT) readings. Three of these parameters (SDT, TP, and Chl-a) are trophic state indicators, or indicators of biological productivity in lake ecosystems. The combination of these parameters helps determine the extent and effects of eutrophication in lakes, and helps signal changes in lake water quality over time.

The tributary stations on Great and Boulder Brooks were sampled for dissolved oxygen, temperature, TP, pH, and *E. coli.*

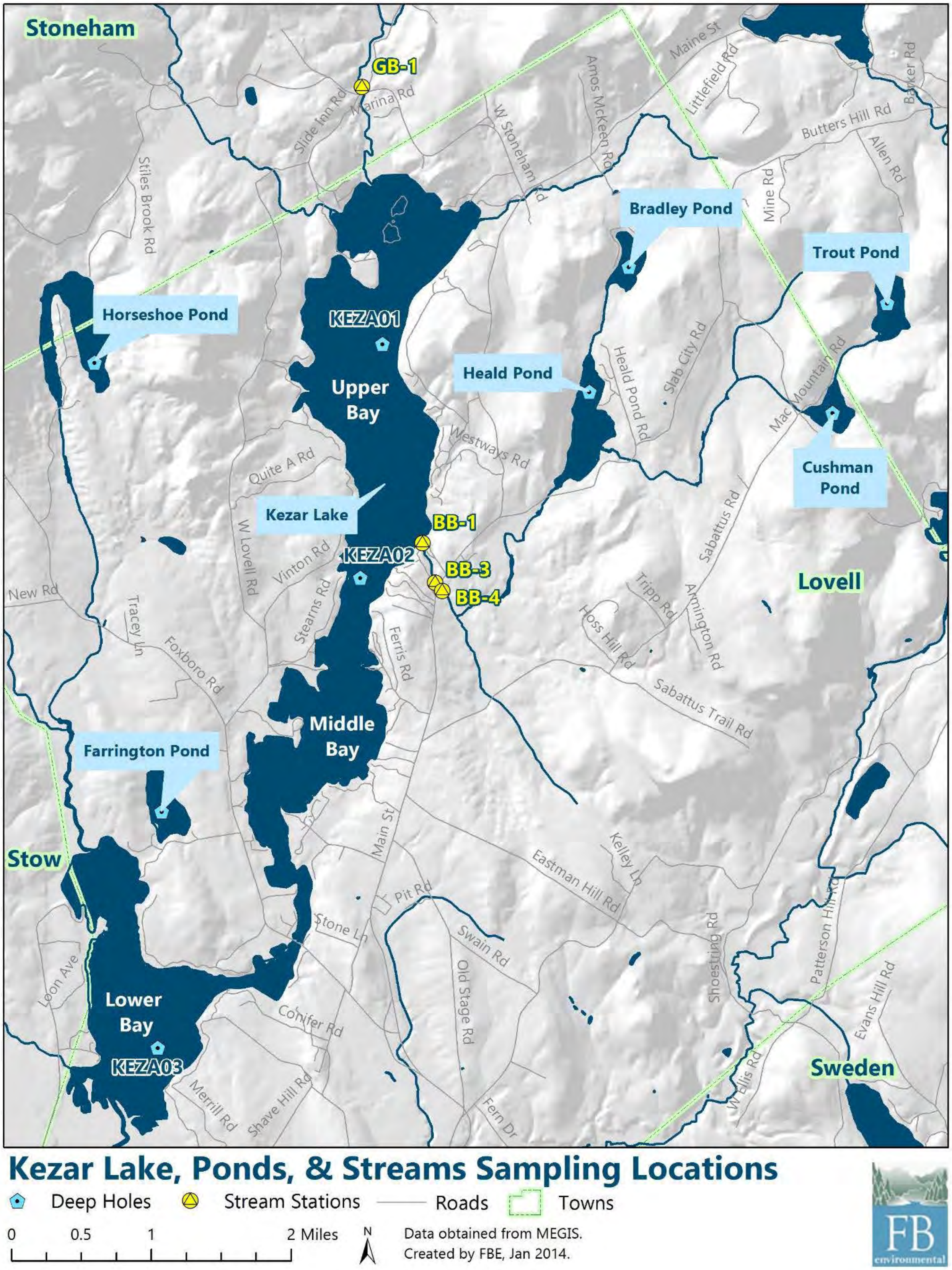


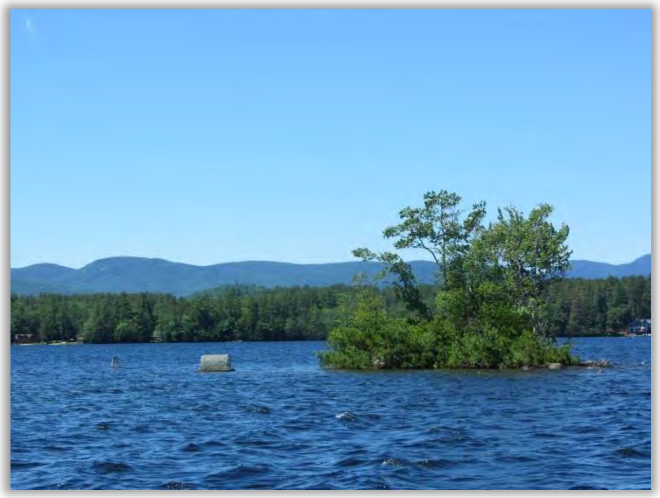
Figure 1. Map of 2015 sampling locations.

3. Water Quality Monitoring Results

Kezar Lake Basins

Water Clarity

In 2015, average SDT readings for the upper, middle, and lower basins of Kezar Lake were 10.1, 9.1, and 3.4 m, respectively (Figure 2). Using all available data, annual water clarity for the upper, middle, and lower, basins of Kezar Lake are 7.8, 7.0, and 3.2 m, respectively (Table 3). Water clarity at the lower basin is less than at the other basins; however, the lower basin is very shallow and the Secchi disk is usually still visible on the lake bottom. Because of this, SDT for the lower basin is not an accurate reflection of water clarity when compared to the other stations. The 2015 season set record depths for water clarity in both the upper basin and middle basin (Figure 2). The 2015 average SDT of 10.1 m at the upper basin exceeded the next highest historical annual average of 9.7 m in 2003. The exceptional water clarity during the 2015 season was driven by a high reading in August of 10.7 m, likely a result of low rainfall in August and therefore, less stormwater runoff to the lake.



A sunny day with choppy waters at Kezar Lake in June of 2015.

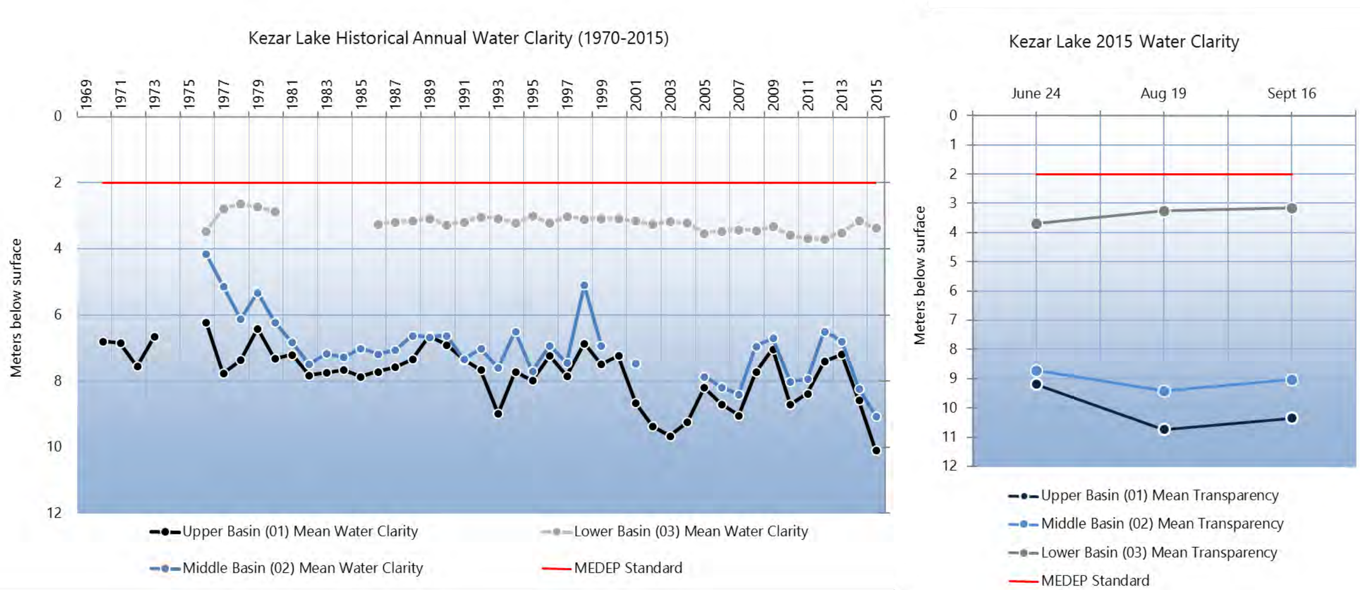


Figure 2. Kezar Lake historical water clarity (1970-2015) for the three basins (left) and Kezar Lake 2015 water clarity (right). Red line denotes Maine DEP water quality standard of 2 m for water clarity. The lower basin (03) is limited by its shallow depth and the Secchi disk typically hits bottom during readings (all three 2015 readings hit bottom).

In Maine, SDT values vary from 0.5 m to 15.5 m, with an average of 4.8 m (VLMP, 2013). Average SDT readings are related to algal productivity using the following guidelines:

- **< 4 m = productive**
- **4-7 m = moderately productive**
- **> 7 m = non-productive**

According to these guidelines, the upper and middle basins of Kezar Lake are non-productive.

Dissolved Oxygen

A common problem in Maine lakes is the depletion of dissolved oxygen (DO) in the deepest part of the lake throughout the summer months. This occurs when thermal stratification prevents the oxygenated surface water from mixing with deeper water in the lake, and chemical or biological processes use up the available DO at the bottom of the water column. DO levels below 5 mg/L can stress some species of cold-water fish and reduce habitat for sensitive cold-water species over time. In addition, anoxia (usually defined as <2 mg/L of dissolved oxygen) at the lake bottom can result in the release of sediment-bound phosphorus, which becomes a readily-available food source for algae.

Historically, Kezar Lake has experienced some DO depletion in the upper and middle basins in spring, late summer, and early fall. Evidence of DO depletion (near or below 5 mg/L) was not documented at Kezar Lake during the 2015 season, with the lowest recorded DO of 6.2 mg/L at 40 m depth in the upper basin on June 24 (Figure 3). Typically, during the hottest summer months, DO concentrations in the middle basin are less than 5 mg/L, as was seen in 2011 and 2009. In 2014 and 2015, DO in the middle basin remained high, never measuring below 7.4 mg/L. Overall, DO is excellent at Kezar Lake, and it was especially good during the 2015 season.

Temperature profiles in 2015 are in line with historic temperature profiles for all stations. Formation of the metalimnion occurred between 5 and 8 meters below the surface at the upper and middle basins (Figure 3). A thermocline cannot develop at the lower basin due to the shallow depth of the water. The middle basin experienced a record depth reading of 45 ft. due to unknown reasons since the other basins were in line with historical depths. In addition to baseline temperature collection presented above, the KLWA has been working with Dr. Dan Buckley at the University of Maine at Farmington (UMF) to collect continuous in-lake temperature data using HOBO data loggers in Kezar Lake. KLWA deploys 3 loggers in Kezar Lake and 1 in Horseshoe Pond in the spring and sends them to UMF in the fall. Dr. Buckley uses the KLWA data as part of a Statewide climate change study of Maine lakes. In that sense, changes in lake temperature in Kezar Lake and Horseshoe Pond can be compared to other lakes across the State.

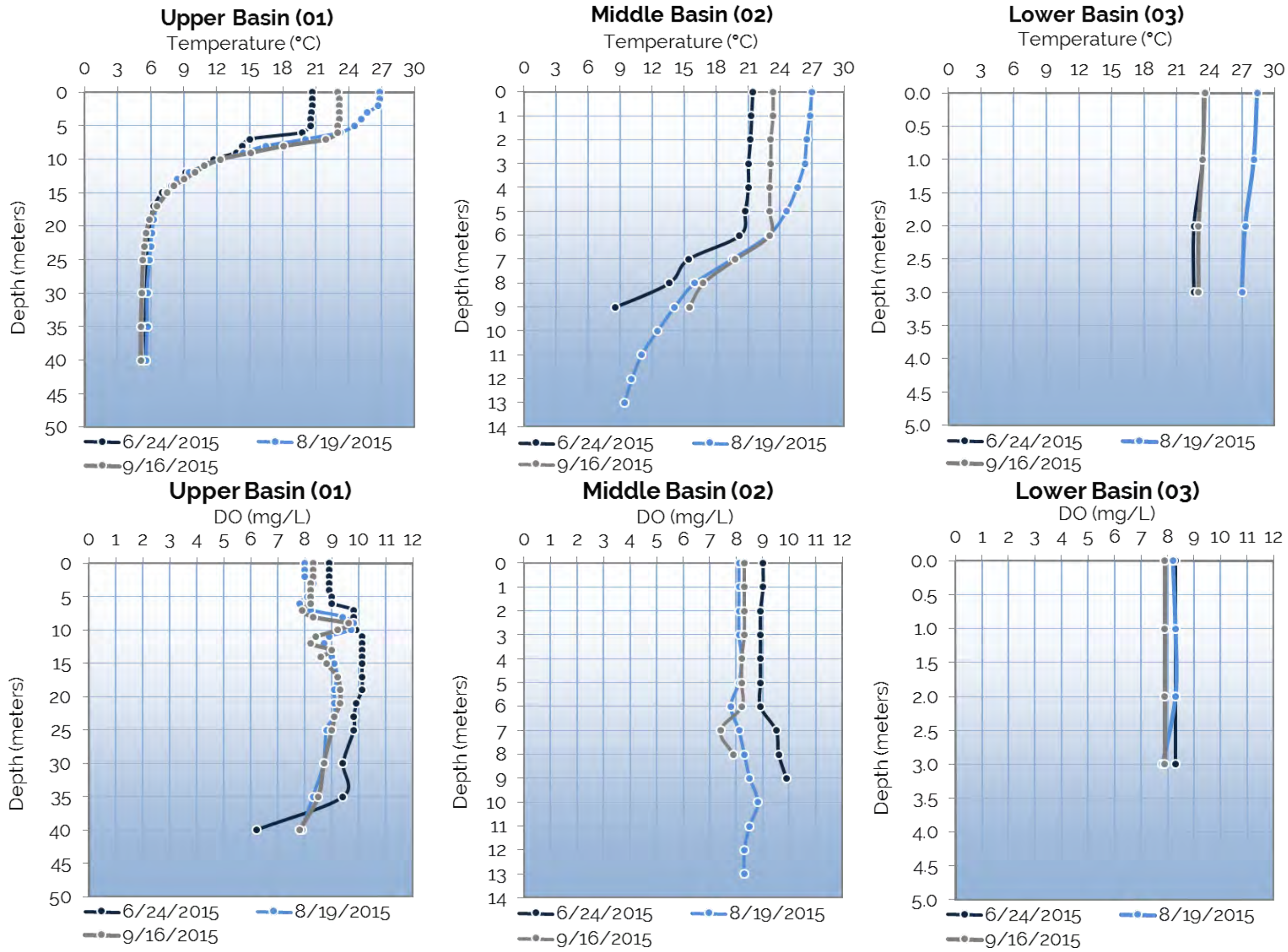


Figure 3. 2015 temperature (top panel) and dissolved oxygen (bottom panel) profiles for the upper, middle, and lower basins of Kezar Lake. The middle basin experienced a record depth reading of 45 ft. due to unknown reasons since the other basins were in line with historical depths.

Total Phosphorus

In Maine lakes, total phosphorus (TP) varies from 1 ppb to 139 ppb with an average of 12 ppb (VLMP, 2013). In 2015, TP averaged 4.3, 4.0, and 7.3 ppb at the upper, middle, and lower basins of Kezar Lake, respectively (Table 2). TP results at the upper basin in 2015 (4.3 ppb) were significantly lower than in 2014 (6.0 ppb) and 2013 (6.7 ppb; Table 3). TP results for the middle basin in 2015 (4.0 ppb) were unchanged from the 2014 season (4.0 ppb) and still lower than in 2013 (6.3 ppb). TP results for the lower basin in 2015 (7.3 ppb) were lower than in 2014 (8.7 ppb), and 2013 (8.3 ppb). TP samples collected over the course of the summer from 2010-2015 show decreasing TP concentrations from late spring to early fall at the upper basin except for a spike in TP in August of 2014 of 11 ppb. In 2015, the upper basin resumed the decreasing trend with a TP value of 6.0 ppb in June and TP values of 3.0 and 4.0 ppb in August and September, respectively. Individual samples and seasonal averages in 2015 were far below the Statewide average for TP at all three basins on Kezar Lake.

Color

In Maine lakes, color varies from 2 to 493 Platinum Color Units (PCU) with an average of 28 PCU (VLMP, 2013). In 2015, color averaged 9.0, 9.0, and 10.3 PCU at the upper, middle, and lower basins of Kezar Lake, respectively (Table 2). These results were lower than the averages observed in 2014 and 2013 (Table 3). Historical data indicate that high color values are positively correlated to high precipitation years, as a result of increased runoff (Figure 4). Overall, Kezar Lake is a non-colored lake with an average color that is less than the average for Maine lakes.

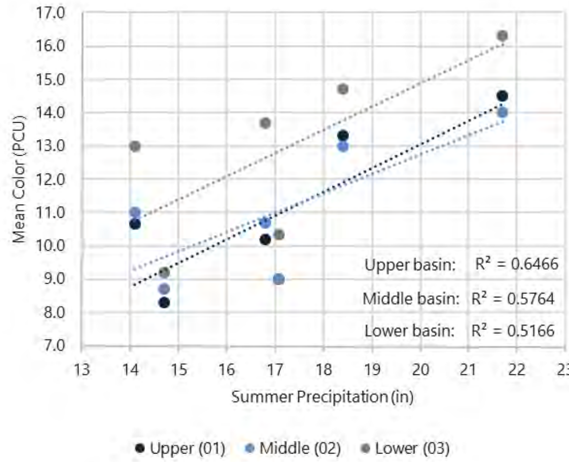


Figure 4. 2015 had the lowest color values since 2010. Note the scale on the x and y axes.

Chlorophyll-a

Chlorophyll-a (Chl-a) in Maine lakes ranges from 0.7 ppb to 182 ppb, with an average of 5.4 ppb (VLMP, 2013). In 2015, Chl-a averaged 1.7, 1.4, and 2.1 ppb at the upper, middle, and lower basins of Kezar Lake, respectively (Table 2). These results were virtually unchanged compared to mean annual Chl-a results since 2010 (Table 3). The lower basin commonly shows a higher average Chl-a concentration than the upper and middle basins. This basin is more at risk to algal growth than other areas of the lake due to its shallow nature. Chl-a concentrations in all basins of Kezar Lake are still roughly half the Maine average.

Alkalinity

Kezar Lake has low alkalinity (or buffering capacity) as a result of its contributing geology (i.e., granite) that lacks carbonates, bicarbonates, and carbonic acid. Alkalinity in Maine lakes ranges from -0.3 to 155.7 mg/L with an average of 11.8 mg/L (VLMP, 2013). Since 2012, all three basins in Kezar Lake have averaged about 4.0 mg/L over the course of each sampling season (Tables 2 and 3). These low values indicate that Kezar Lake is susceptible to changes in pH, particularly from acidic deposition in the form of rain or snow. Alkalinity is important to aquatic life because it protects organisms against changes in the acidity of the water (pH). Without adequate buffering capacity, the lake is subject to both natural and anthropogenic swings in pH values that can jeopardize the health of freshwater fish species.

pH

Most aquatic species require a pH between 6.5 and 8. Measurements of pH at all three basins at Kezar Lake were 6.3 in 2015, which was only slightly more acidic than in 2014 at 6.5 (Tables 2 and 3). Water becomes acidic when pH is less than 7.0 and is alkaline above a pH of 7.0. In Maine lakes, pH varies from 4.2 to 9.5 with an average of 6.8. This year, Kezar Lake was slightly more acidic than the average pH for Maine lakes.

Table 2. 2015 water quality monitoring results for the upper, middle, and lower basins of Kezar Lake.

Date	Station	Total Phosphorous (ppb)	Color (PCU)	Alkalinity (ppm)	Chlorophyll-a (ppb)	pH
6/24/2015	Upper	6.0	10.0	4.0	2.4	6.3
	Middle	5.0	10.0	4.0	2.1	6.3
	Lower	9.0	11.0	4.0	2.7	6.3
8/19/2015	Upper	3.0	9.0	4.0	1.2	6.3
	Middle	3.0	9.0	4.0	<1	6.3
	Lower	6.0	10.0	4.0	1.8	6.5
9/16/2015	Upper	4.0	8.0	4.0	1.5	6.3
	Middle	4.0	8.0	4.0	1.7	6.3
	Lower	7.0	10.0	4.0	1.9	6.2
2015 Mean (Kezar Lake)	Upper	4.3	9.0	4.0	1.7	6.3
	Middle	4.0	9.0	4.0	1.4	6.3
	Lower	7.3	10.3	4.0	2.1	6.3
Maine Lakes	Mean	12.0	28.0	11.8	5.4	6.8

Summary

Kezar Lake remains one of Maine's cleanest and clearest lakes, with above average water quality and clarity. Historically, Kezar Lake's TP and Chl-a results have been well below Statewide averages. Similarly, the long-term average SDT for the lake's upper and middle basins is 7.8 m and 7.0 m, respectively, compared to an average of 4.8 m for all Maine lakes (Table 3).

Lauren Bizzari (FBE; right) and Chelsea Berg (2015 KLWA Intern; left) during sampling of the three Kezar Lake basins.

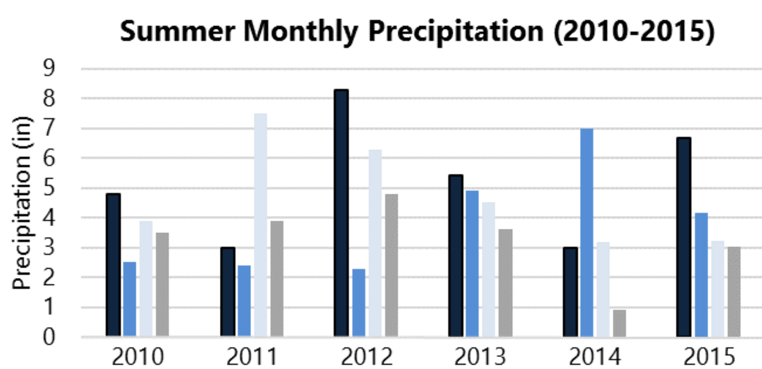
Water quality measures (SDT, TP, Chl-a, and color) in 2015 indicate that Kezar Lake's water quality is close to or better than historical averages (Table 3). Year to year fluctuations in TP and transparency readings can be due to weather influences, such as stronger winds or increased rainfall that can decrease water clarity and increase TP by increasing the amount of particles (e.g., sand, silt, and clay) suspended in the water column. Summer 2015 had some rainfall in June and July, with a very dry spell through August and early September. The low rainfall is most likely responsible for the high clarity (deep SDT readings) at the upper and middle basins during the 2015 sampling season.

The hypolimnion of the upper and middle basins were well-oxygenated throughout the 2015 sampling season. A well-oxygenated hypolimnion can help cold-water fish species survive the warmest months of the year.

Table 3. Kezar Lake historical and recent water quality averages.

Year	Basin	SDT (meters)	TP (ppb)	Chl-a (ppb)	pH	Alkalinity (ppm)	Color (PCU)
2015	Upper (01)	10.1	4.3	1.7	6.3	4.0	9.0
	Middle (02)	9.1	4.0	1.4	6.3	4.0	9.0
	Lower (03)	3.4	7.3	2.1	6.3	4.0	10.3
2014	Upper (01)	8.6	6.0	1.8	6.5	4.0	10.7
	Middle (02)	8.2	4.0	1.4	6.5	4.0	11.0
	Lower (03)	3.2	8.7	2.1	6.5	4.0	13.0
2013	Upper (01)	7.2	6.7	1.8	7.0	4.0	13.3
	Middle (02)	6.8	6.3	2.1	7.0	4.0	13.0
	Lower (03)	3.5	8.3	2.4	7.0	4.0	14.7
2012	Upper (01)	7.4	4.0	2.2	6.9	4.0	14.5
	Middle (02)	6.5	4.7	2.3	6.9	4.0	14.0
	Lower (03)	3.7	9.7	2.1	6.9	4.0	16.3
2011	Upper (01)	8.3	5.3	2.0	--	3.7	10.2
	Middle (02)	7.9	5.7	2.2	--	3.3	10.7
	Lower (03)	3.7	8.3	2.6	--	3.7	13.7
2010	Upper (01)	8.7	9.3	2.1	--	3.7	8.3
	Middle (02)	8.0	3.3	1.8	--	4.0	8.7
	Lower (03)	3.6	10.2	2.4	--	3.8	9.2
Historical Average[a]	Upper (01)	7.8	5.9	2.7	6.7	4.5	11.3
	Middle (02)	7.0	5.0	2.0	6.6	3.7	11.7
	Lower (03)	3.2	8.8	2.4	6.6	4.5	14.2
Maine Lakes Average[b]		4.8	12.0	5.4	6.8	11.8	28.0

[a] Includes FBE data from 2015, but does not include any 2015 Maine DEP or VLMP data
[b] 2013 Maine Lakes Report (Maine VLMP)



	2010	2011	2012	2013	2014	2015
June	4.8	3.0	8.3	5.4	3.0	6.7
July	2.5	2.4	2.3	4.9	7.0	4.2
August	3.9	7.5	6.3	4.5	3.2	3.2
September	3.5	3.9	4.8	3.6	0.9	3.0

Figure 5. Summer monthly precipitation amounts from 2010-2015. Data sourced from Weather Underground for the Fryeburg, ME weather station.

Tributaries

Boulder Brook was sampled at the outlet to Kezar Lake on the Boulder Brook Club property (BB-1), as well as upstream (BB-4) and downstream (BB-3) of the Route 5 crossing. Great Brook was sampled upstream of the Adams Road crossing adjacent to Hut Road (GB-1). Temperature, dissolved oxygen (DO), pH, total phosphorus (TP), and *E. coli* were measured at each sampling event (Table 4).

Table 4. 2015 water quality monitoring results for Kezar Lake tributaries (Great Brook and Boulder Brook). Red text indicates an exceedance of applicable water quality criteria.

Date	Site Code	Temp (°C)	DO (mg/L)	pH	*E. coli* (col/100mL)	TP (ppb)
Great Brook						
6/24/2015	GB-1	16.5	9.4	5.8	24	5
9/16/2015	GB-1	17.8	8.8	6.1	36	5
2015 Average		**17.2**	**9.1**	**6.0**	**30**	**5**
2014 Average		*14.8*	*9.5*	*6.4*	*21*	*5*
Boulder Brook						
6/24/2015	BB-1	18.6	8.1	5.8	71	19
6/24/2015	BB-3	20.3	7.1	5.7	59	16
6/24/2015	BB-4	20.6	6.9	5.6	67	16
9/16/2015	BB-1	18.0	8.7	6.2	8	7
9/16/2015	BB-3	20.2	6.3	5.8	11	18
9/16/2015	BB-4	21.4	5.9	5.8	11	25
2015 Average		**19.9**	**7.2**	**5.8**	**38**	**17**
2014 Average		*18.6*	*7.7*	*6.3*	*26*	*14*

DO concentrations in both streams in 2015 were generally above 7 mg/L, which is the Maine DEP standard for Class A streams and a threshold required by most aquatic species for survival and growth. Exceptions included BB-4 on both sampling dates and BB-3 on 9/16/2015. Great Brook averaged 9.1 mg/L and Boulder Brook averaged 7.2 mg/L (Table 4). These patterns were consistent with 2014. Average water temperatures were higher in 2015 compared to 2014, which may account for lower DO concentrations in 2015 compared to 2014.

pH in the tributaries ranged from 5.6 to 6.2, with an average of 6.0 for Great Brook and 5.8 for Boulder Brook (Table 4). These average values were lower (more acidic) in 2015 compared to 2014 averages for both streams and all readings fall below recommended pH range of 6.5 to 8.0.

TP is one of the most important nutrients to monitor in streams that drain to lakes because it is generally the limiting nutrient in freshwater systems. This means that the amount of phosphorus in the water usually governs biological productivity, such as algal and plant growth. High phosphorus concentrations often result in greater biomass of algae and aquatic plants. TP concentrations in the tributaries ranged from 5 to 25 ppb with an average of 5 ppb for Great Brook and 17 ppb for Boulder Brook (Table 4). These values remained slightly higher for Boulder Brook (14.4 ppb for Boulder Brook) for two consecutive years (2013-2015), however, TP in Great Brook was the same this year as the previous year (5 ppb). Boulder

Brook is potentially contributing more TP to Kezar Lake than Great Brook. These TP concentrations are still considered low for typical New England streams.

E. coli results in the tributaries were well below the Maine DEP standard of 194 col/100 mL at both Great Brook and Boulder Brook in 2015, though numbers were slightly elevated at all stations in Boulder Brook during the June sampling. The higher values in June could be attributed to precipitation prior to sampling (Table 1). In 2012, elevated *E. coli* levels were measured at Boulder Brook stations BB-3 (461 col/100mL) and BB-4 (548 col/100mL) in September. High *E. coli* measurements under low flow conditions may indicate fecal contamination from septic systems, wildlife, or pets. Further sampling and reconnaissance is needed under both dry and wet weather conditions, as well as during peak summer months (July-August) to refine potential sources at this site, specifically targeted during wet weather time periods. In general, the water quality in Great Brook appears to be better than in Boulder Brook.

Continuous Loggers

Funded by the Sally Mead Hands Foundation, the Climate Change Observatory (CCO) was established for the Kezar Lake watershed with the mission to evaluate potential impacts of climate change on watershed resources and identify actions to mitigate climate change in the watershed. As part of this mission, the CCO purchased and deployed five HOBO temperature loggers in Coffin, Boulder, Bradley, Sucker, and Long Meadow Brooks and two HOBO water level/temperature loggers in Beaver and Great Brooks in 2014. Two water level/temperature sites were added at the lower basin and outlet stream of Kezar Lake in 2015 (Figure 8). These data will serve as a baseline for future comparisons of water quality to assess long-term temperature and flow trends.

The water temperature loggers were deployed on 4/8/15 at five sites (Coffin, Boulder, Bradley, Sucker, and Long Meadow Brooks) and retrieved on 12/9/15 for a total of 245 days. These sites were checked on 4/22/15, 6/29/15, 8/19/15, 9/16/15, and 10/28/15. In most cases, loggers were submerged and in good condition. If a deeper spot was nearby, loggers were repositioned. The logger at Coffin Brook on 8/19/15 and 10/28/15 was found out of water. The temperature sensor on the stage logger at the lower basin was also found out of water from 7/29/15 to 9/29/15.

The stilling well at Great Brook on 4/8/15 was bent and needed replacement. The stilling well at Beaver Brook on 4/8/15 was full of sediment and other debris and also needed replacement. FBE returned on 6/29/15 to replace stilling wells at Great and Beaver Brooks and install new stilling wells at the lower basin (Heinrich Wurm's property) and at the fish control structure in the Kezar outlet stream upstream of the Harbor Road crossing. The stilling well at Beaver Brook was moved slightly upstream to get above a large woody debris pile blocking the stream. The stilling well at Great Brook was also moved slightly upstream away from a large downed tree. Water level loggers were checked on 8/19/15 and 10/28/15 before being taken out on 12/9/15. Water level loggers were deployed for a total of 163 days. The water level at the lower basin was extremely low; only one inch of water was covering the bottom of the well and sensor on 8/19/15. The stilling well at Great Brook on 10/2/15 was found slightly bent, but FBE righted the well and made necessary adjustments to readings. The stilling well at Great Brook on 12/9/15 was severely bent over and unstable. The well was taken out for the winter. All other stilling wells were found in good condition throughout the season.

Water level data were corrected for atmospheric pressure, temperature, and reference field measurements using the Onset HOBO® Barometric Compensation Assistant. Measurement error (i.e., sensor drift) was accounted for by comparing the difference between the logger end point and the reference water level measurement at time of collection; differences greater than or equal to 0.004 m were corrected for, assuming a constant rate of drift for the calibration period (Wagner et al. 2006). Any data flagged as suspect for being out of water or interfered in some way as to not reflect true stream conditions were deleted from the record. Any stilling wells found bent where corrected with a constant offset from the nearest large storm. Four stage-discharge measurements were collected at Great and Beaver Brooks, but a more robust stage-discharge relationship will need to be made to convert water level to flow.

Water level logger locations from left to right: Great Brook, Beaver Brook, lower basin, and Kezar outlet stream.

The following presents the processed (QA/QC) data from 2015 logger monitoring in the Kezar Lake watershed. Until more data are collected over the next few years to begin to account for interannual variability, no major conclusions or analyses can be made on this limited dataset aside from general patterns. Precipitation data were obtained from a weather station located on Creeper Hill near northwest cove on Kezar Lake.

Water level at the lower basin gradually declined from June to September (due to summer evaporation) up until the large 4.55-in precipitation event on 9/30/15 that increased the lake level of the lower basin by 0.65 ft. (Figure 6). Water level at the lower basin responded to two other fall storms on 10/29/15 and 11/20/15. Water level at the fish control structure on the Kezar outlet stream responded to precipitation in a similar manner throughout the deployment period; due to the larger volume of water flowing from the lake through the outlet stream, the water level increased and decreased much more slowly compared to the smaller headwater streams: Great and Beaver Brooks. Water level in Great and Beaver Brooks responded quickly to precipitation. Both streams experienced the greatest flows during two major fall storm events on 9/30/15 and 11/20/15.

Water temperature increased at all sites from April to August and then steadily declined until retrieval in December, which follows closely with observed air temperature (Figure 7). Water temperatures at all sites converged from October to December. This likely represents leaf senescence in the fall after which all streams were exposed to similar light and air temperatures. Kezar outlet stream, the lower bay, Boulder

Brook, and Long Meadow Brook experienced higher water temperatures than the other streams, likely due to having more open canopies or shallower water depths compared to the other sites. It would be interesting to conduct a brief survey of canopy cover in the summer at each of the sites to confirm this hypothesis.

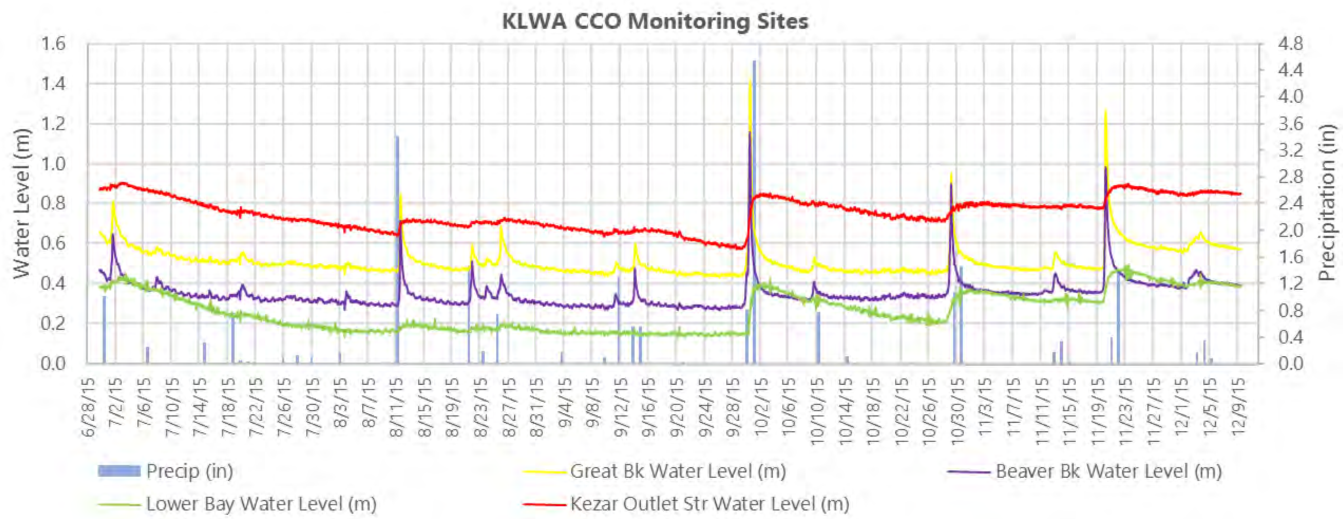


Figure 6. Water level data for Great Brook, Beaver Brook, the lower basin, and the Kezar outlet stream from 6/29/2015 to 12/9/2015. Precipitation data were obtained from Weather Underground Creeper Hill station at northwest cove on Kezar Lake (KMEFRYEB2).

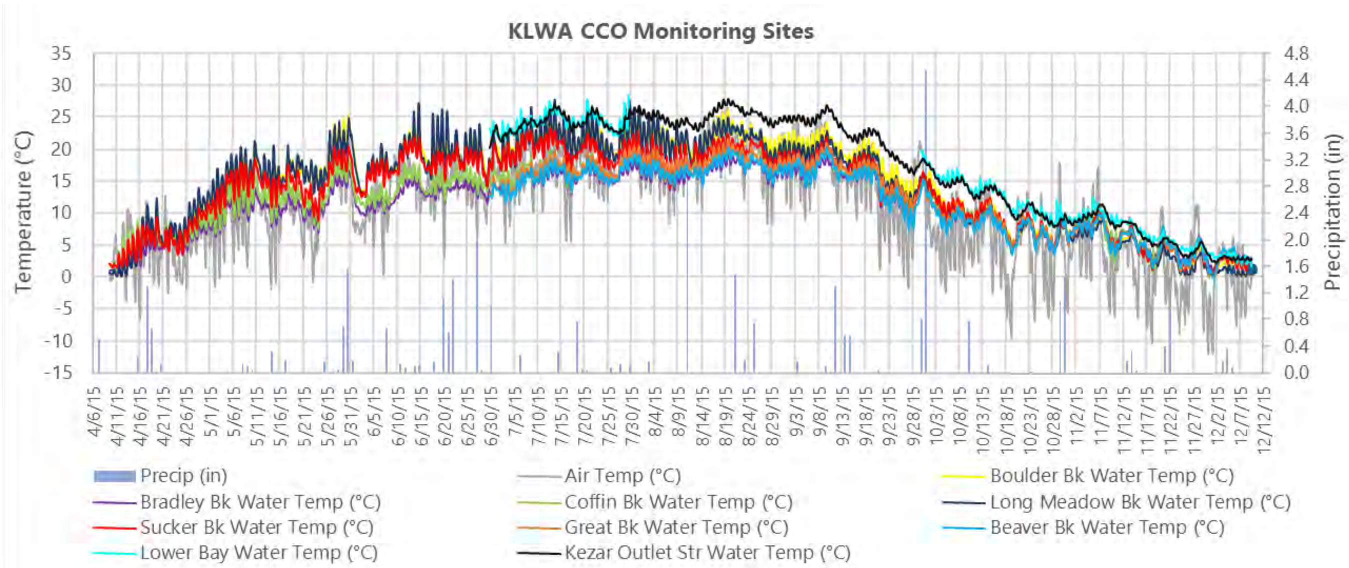


Figure 7. Water temperature data for all nine KLWA CCO sites from 4/8/2015 to 12/9/2015. Precipitation data were obtained from Weather Underground Creeper Hill station at northwest cove on Kezar Lake (KMEFRYEB2). Air temperature data were obtained from NOAA NCDC (Fryeburg, ME).

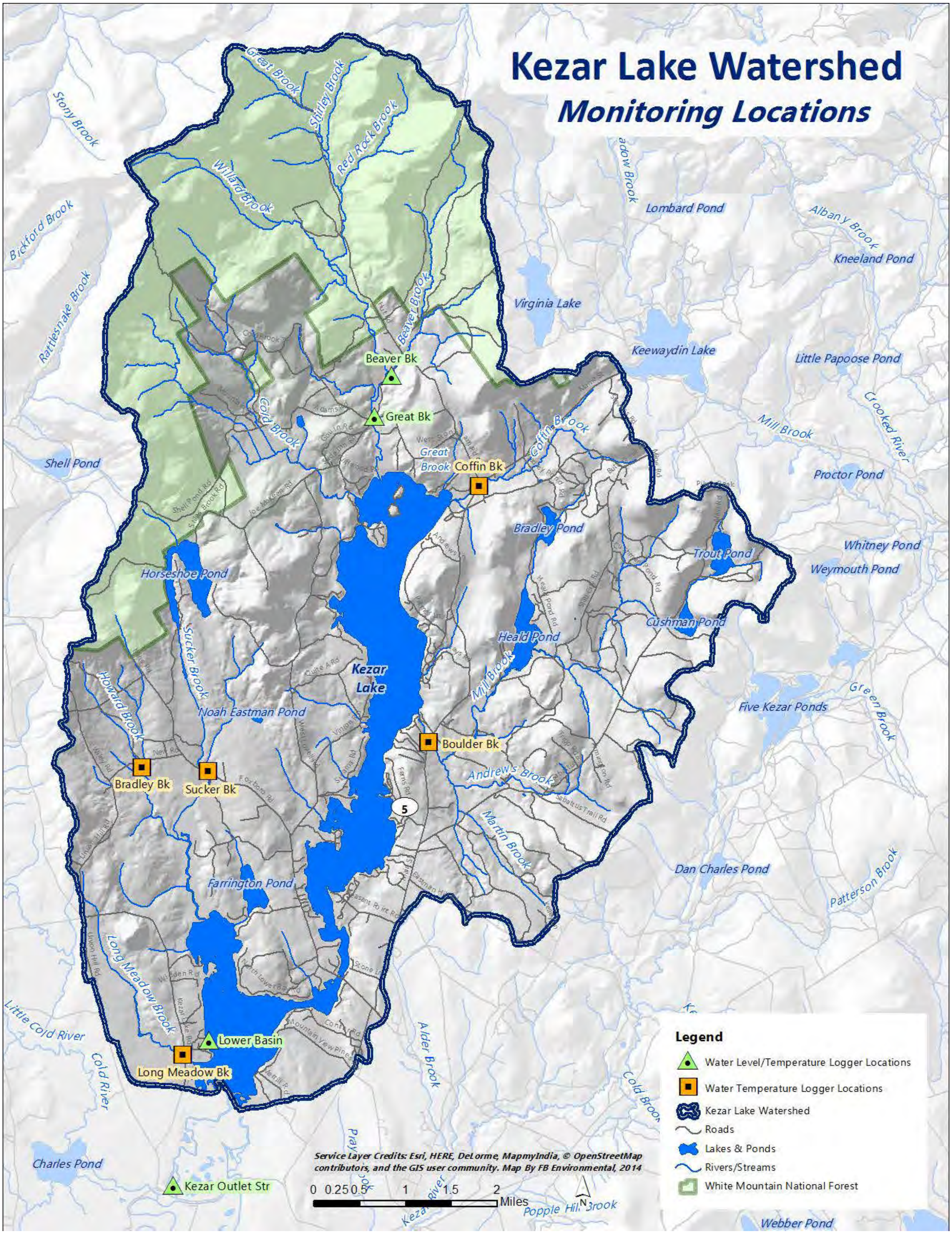


Figure 8. Continuous monitoring locations in or near the Kezar Lake watershed.

Ponds

In 2015, FBE continued baseline monitoring for six ponds that drain directly or indirectly to Kezar Lake (Table 5; Figures 9, 10). Water quality data for Bradley, Cushman, Farrington, Heald, Horseshoe, and Trout Ponds were collected on June 24 and August 19. June is the beginning of the "warm" season for Maine lakes, and August is generally the time when Maine lakes are most biologically productive and when indications of stress and water quality degradation are most apparent.

Water quality is generally good in the six ponds (Figure 10). According to 2015 sampling results, four of the six KLWA ponds had an average water clarity better than the Maine average of 4.8 m (Table 5). Farrington and Heald Ponds had transparency readings below the Maine average for both 2015 sampling and their historical averages. Historically, transparency readings are limited by depth at Farrington and Heald Ponds, as the Secchi disk is typically visible on the lake bottom for both of these lakes. In 2015, only Heald Pond had a transparency reading hit bottom during the August sampling event. None of the six ponds fell below the Maine DEP minimum water clarity standard of 2 m.

TP trends indicate lower TP concentrations in all ponds in 2015 compared to historical averages with the exception of Bradley and Farrington Ponds (Table 5). Historical averages are below the average TP concentration for Maine lakes (12 ppb), with the exception of Bradley and Farrington Ponds. Farrington Pond had the highest average TP in 2015 (16 ppb); this is in-line with Farrington Pond's historical TP average over the past several decades (15.3 ppb). Bradley Pond experienced a single high TP measurement in June 2015 (21 ppb) that increased the annual average to 14.5 ppb. Although samples were collected carefully, there is a possibility for human error in either sample collection, transport, or lab analysis. Otherwise, some yet-to-be-determined natural or anthropogenic event or process (over winter, during spring snowmelt, etc.) caused excess TP to either be washed off the landscape to the pond or resuspended from the bottom into the water column.

Chl-a was higher in 2015 compared to historical averages for Cushman, Farrington, and Heald Ponds. Farrington Pond experienced a high Chl-a reading in June 2015 of 17 ppb. Most ponds in 2015 fell below the Chl-a average for Maine Lakes (5.4 ppb), with the exception of Farrington Pond (Table 5). Farrington Pond maintains the highest historical Chl-a average of all the ponds.

In 2015, pH in the ponds were lower (more acidic) compared to their historical averages (Table 5). Historical averages for all ponds is slightly lower (more acidic) than the average for Maine lakes (6.8). Bradley Pond is the most acidic of the six ponds.

All ponds are consistently lower than the Maine average for alkalinity (11.8 mg/L), making these waterbodies highly sensitive to changes in pH. Changes in pH can be caused by acid rain or snow, or from polluted runoff entering the lake. Less productive lakes show pH between 6.5 and 7.5, suggesting that these ponds are on the low end of low-productivity lakes.

Color readings were generally lower in 2015 compared to historical averages for all ponds except for Farrington Pond. Heald, Farrington and Bradley Ponds are more colored (>16 PCU) compared to Cushman, Horseshoe, and Trout Ponds (<12 PCU).

Annual variability in water quality is common for freshwater lakes, which is why collection of annual baseline data for the KLWA ponds is important. This information will provide the KLWA with long-term water quality trends for the Kezar Lake watershed.

Table 5. Historical and recent (2015) averages for water quality parameters for six ponds of the Kezar Lake watershed.

Pond	SDT (m)		TP (ppb)		Chl-a (ppb)		pH		Alkalinity (mg/L)		Color (PCU)	
	Historical[b]	Recent 2015[c]	Historical[b]	Recent 2015[c]	Historical[b]	Recent 2015[c]	Historical[b]	Recent 2015[c]	Historical[b]	Recent 2015[c]	Historical[b]	Recent 2015[c]
Bradley	5.4	5.2	9.3	14.5	3.9	2.8	6.4	6.0	3.8	4.0	21.4	19.0
Cushman	5.5	5.8	7.3	6.5	2.6	2.8	6.7	6.2	4.7	4.5	12.0	10.3
Farrington*	4.4	4.0	15.3	16.0	7.7	12.2	6.7	6.6	4.3	5.0	16.0	20.0
Heald*	4.6	4.7	9.7	8.0	4.1	4.3	6.7	6.3	5.5	5.5	24.4	23.5
Horseshoe	6.9	6.7	6.5	6.0	3.6	3.1	6.7	6.2	3.8	3.5	10.4	9.5
Trout	7.8	7.3	4.6	4.5	3.0	1.4	6.7	6.3	3.5	4.0	9.4	7.0
Maine Lakes Average[a]	4.8		12.0		5.4		6.8		11.8		28.0	

* SDT Values limited by lake depth - secchi hits bottom

[a] Mean values obtained from the VLMP's 2013 Maine Lakes Report (http://www.mainevlmp.org/maine-lake-report/)

[b] Mean values calculated by FBE from all raw data sent by the MEDEP; duplicate values/days were averaged; only epicore samples were used in the analyses; includes all data up through 2014

[c] Mean values calculated by FBE from data collected by FBE in 2015

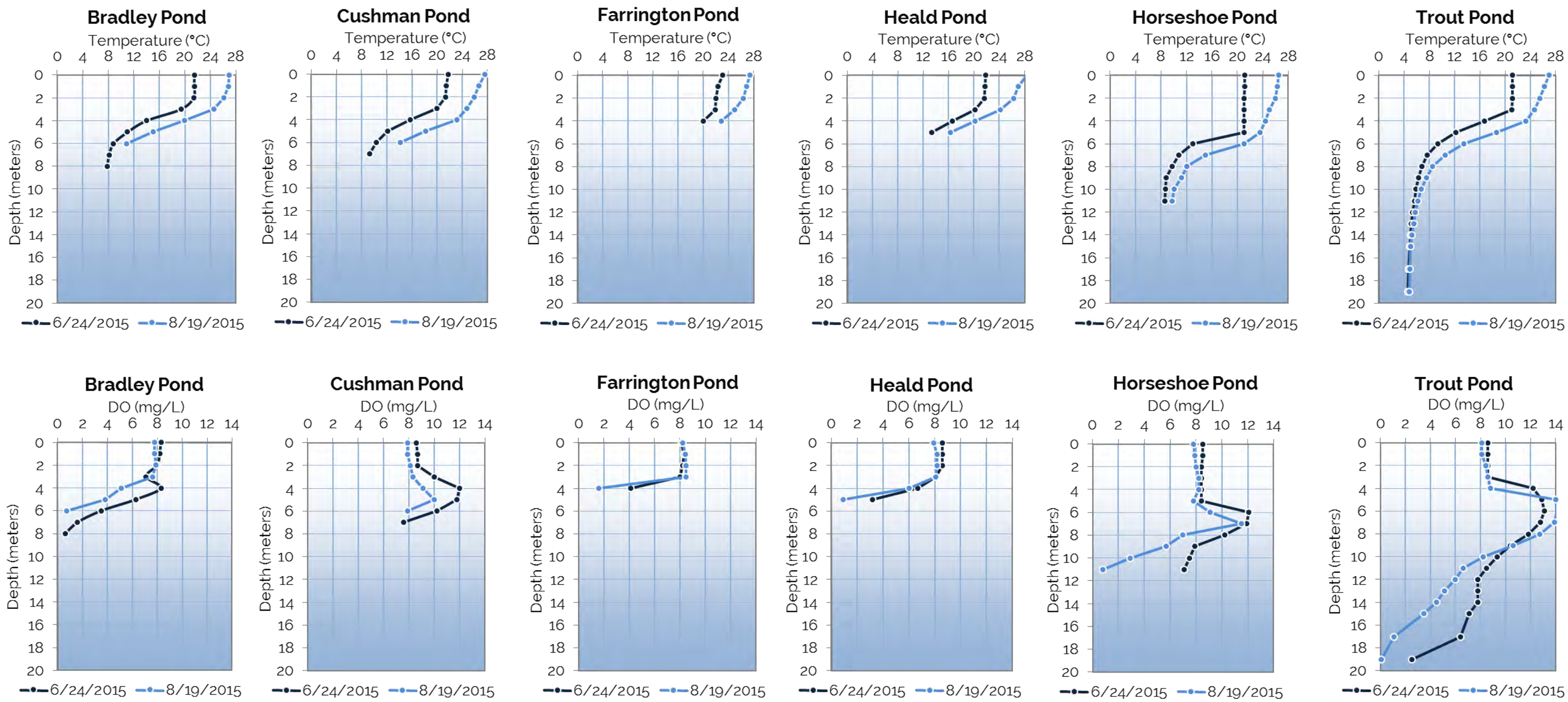


Figure 9. Temperature (top panel) and dissolved oxygen (bottom panel) profiles for six ponds of the Kezar Lake watershed.

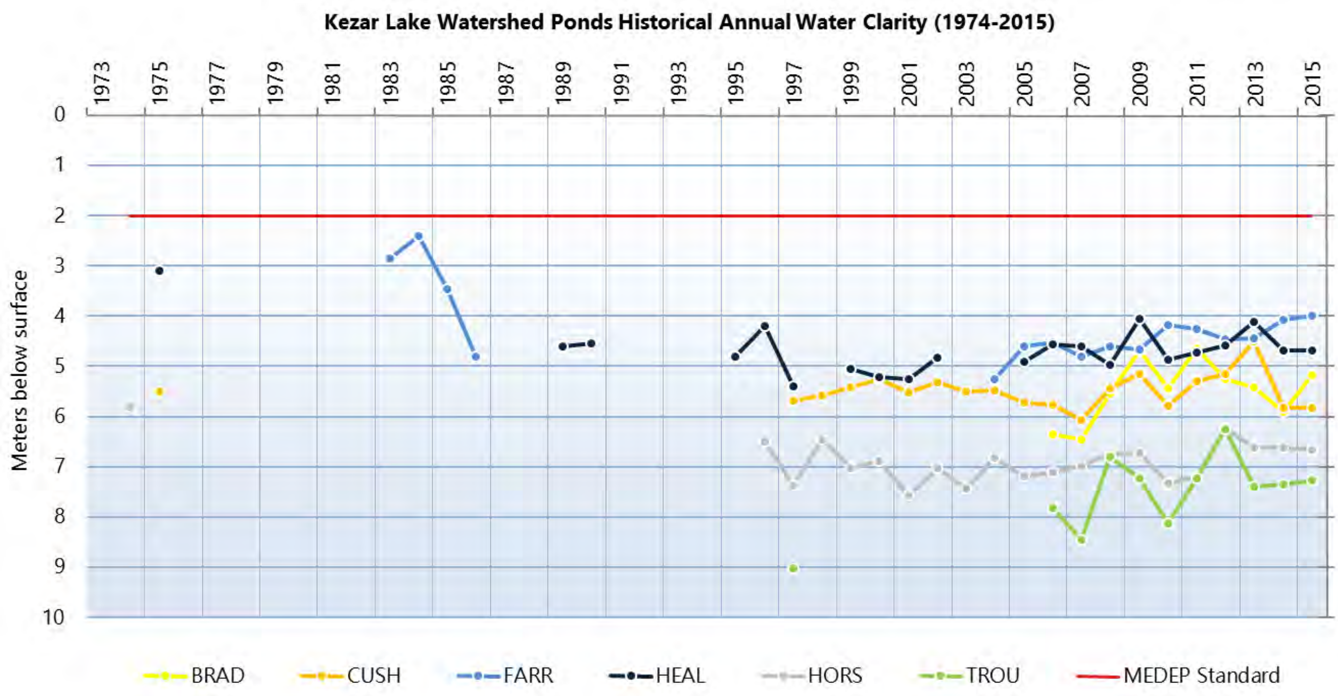


Figure 10. Kezar Lake watershed ponds historical water clarity (1974-2015).

Bradley Pond

- DO concentrations in Bradley Pond dropped below the aquatic life standard of 5 mg/L between 5 and 6 m depth on both sampling dates in 2015 (Figure 9). This is a continued concern for the pond.
- Bradley Pond experienced a record high TP (14.5 ppb) and a record low pH (6.0) in 2015 compared to historical data.
- All other water quality parameters have been relatively stable with no trend since 2006.

Cushman Pond

- No DO depletion below the standard was observed in Cushman Pond in 2015, and DO depletion hasn't been a significant problem historically.
- No trends were found for water clarity, TP, Chl-a, and color at Cushman Pond.
- Cushman Pond has experienced a decline in alkalinity since 1987, which may help explain the record low average pH of 6.2 in 2015.

Farrington Pond

- DO in Farrington Pond has not been a concern in the past. However, in 2015, low DO was recorded at 4 m on both sampling events (Figure 9). It is possible that the probe extended into the soft sediments at the bottom of the lake (which was very close to 4 m), resulting in low DO readings. Future monitoring requires sensitivity in readings close to the bottom due to the soft sediment in this pond. A reading at 0.5 m increments below 3 m may be needed to tease out the reported low DO this year.

- No trends were found for any of the water quality parameters measured at Farrington Pond.
- Farrington Pond continually exhibits the shallowest water clarity, highest TP, and highest Chl-a of all six ponds. The shallow nature of this pond makes is more vulnerable to sediment suspension as a result of heavy rainfall, wind storms, or watershed disturbances (e.g., shoreline development).

Heald Pond

- DO concentrations are consistently low (< 5 mg/L) below 4 m in the summer months (Figure 9). This is a continued concern for Heald Pond.
- Alkalinity has been declining at Heald Pond since sampling began in 1995, which may help explain the record low average pH of 6.3 in 2015.
- Transparency readings at Heald Pond are limited by the pond's shallow depth.
- Historical average TP and Chl-a at Heald Pond are the second highest after Farrington Pond; Heald Pond is also the most colored compared to the other ponds. Because of this, Heald Pond may be at risk for algal blooms.

Horseshoe Pond

- DO fell below 5 mg/L beginning at 10 m in August (Figure 9). The spring DO profile was well-oxygenated through the entire water column, similar to the 2014 profile. However, late summer DO depletion in the hypolimnion is still a concern for this pond.
- Alkalinity has been declining at Horseshoe Pond since sampling began in 1997, which may help explain the record low average pH of 6.2 in 2015.
- No trends were found for any of the other water quality parameters measured at Farrington Pond.
- Horseshoe Pond has the second deepest water clarity, lowest TP, and lowest color of the six ponds.

Trout Pond

- Similar to 2014, DO fell below 5 mg/L at 18 m (the bottom) in June 2015 and 14 m in August 2015 (Figure 9). Trout Pond is the deepest of the six ponds and is subject to thermal stratification that prevents oxygen at the surface from reaching the bottom.
- Water clarity at Trout Pond may be degrading by as much as 1 m in the last 10 years.
- No trends were found for any of the other water quality parameters measured at Trout Pond.
- Mean historical alkalinity (3.5 mg/L) is lowest at Trout Pond compared to the five other ponds, suggesting that Trout Pond is at risk for pH swings; this may help explain its record low average pH of 6.3 in 2015.
- Water quality at Trout Pond is considered the best among the small ponds in the Kezar Lake watershed. Mean historical TP, Chl-a, and color are lowest and SDT is deepest at Trout Pond. This may be the result of limited development along the shoreline compared to the other ponds in the watershed. Development around Trout Pond includes only a single large summer camp on the north end of the lake, known as Camp Susan Curtis.

Future Monitoring Recommendations

While the water quality of Kezar Lake and its tributaries and ponds is generally excellent, these waterbodies are sensitive to change. Continuing to monitor all three basins of the lake, two tributaries (Great Brook and Boulder Brook), and the small ponds that drain to Kezar Lake will help the KLWA better understand long and short-term trends and maintain the high quality of the water in the Kezar Lake watershed for future generations. The recent development of the Kezar Lake Climate Change Observatory (CCO) can help guide future water quality monitoring efforts that support on-going collection of long-term baseline data in the watershed.

The following is recommended for future monitoring of Kezar Lake, ponds and streams:

- Supplement monitoring efforts by adding a July sampling event for Kezar Lake and ponds to better assess seasonal (summer) water quality during the most productive time of the year.
- Expand in-lake monitoring to include spring and fall profiles during turn-over and include a geochemical analysis that may provide insight to the alkalinity and pH trends.
- Collect winter DO-temperature profiles and epilimnetic core sampling of key parameters in January and February (it has been shown that biological and chemical processes that occur over winter dictate the productivity of lakes in summer).
- Conduct stream macroinvertebrate analysis to determine macroinvertebrate richness and abundance during stream baseflow periods (late August - late September). This monitoring will provide baseline data for these streams, and can be replicated on a five-year (or more) cycle.
- Collect ongoing stream flow and continuous temperature data in targeted streams throughout the watershed.

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