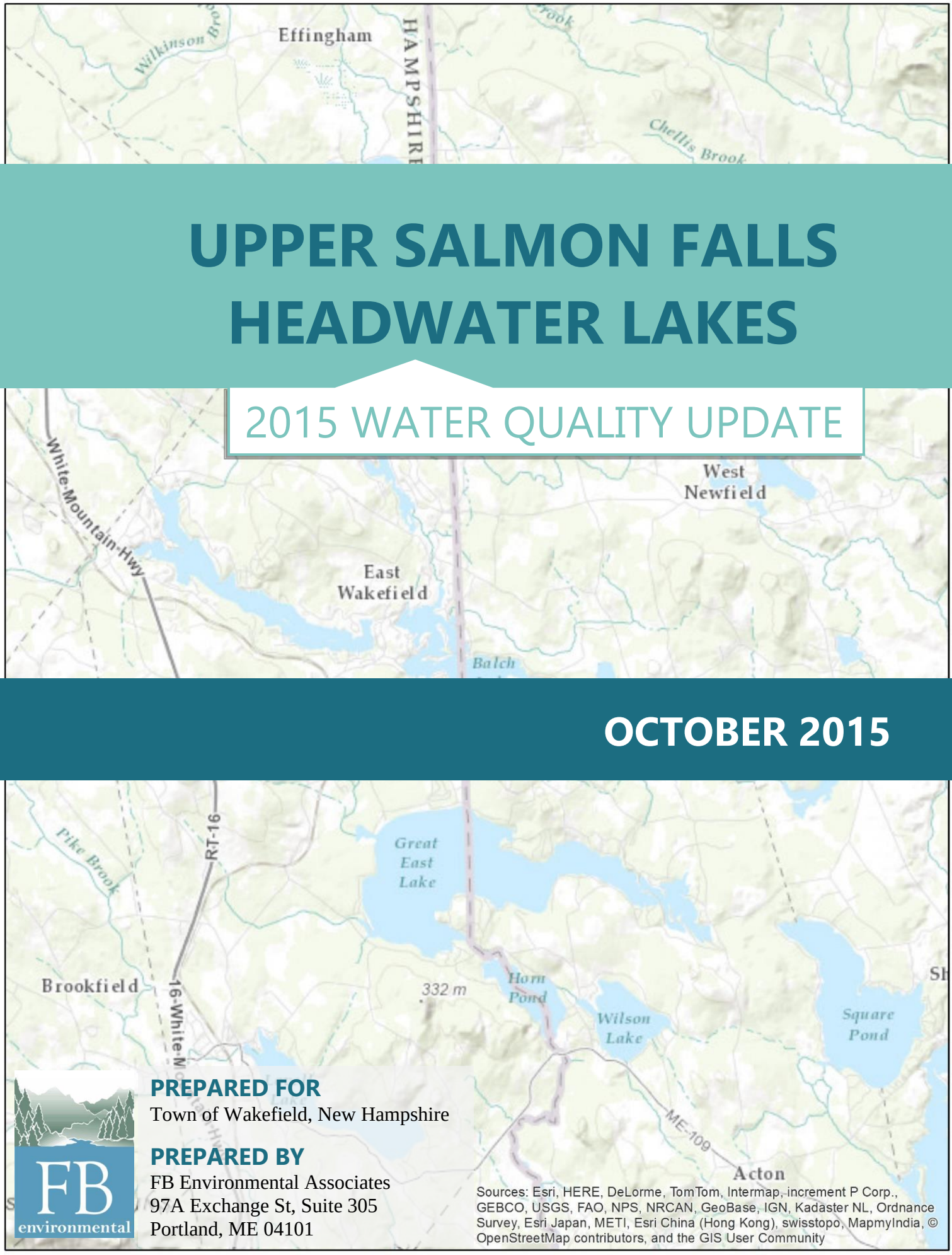
UPPER SALMON FALLS HEADWATER LAKES

2015 WATER QUALITY UPDATE

OCTOBER 2015



PREPARED FOR
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2015 Upper Salmon Falls Headwater Lakes Water Quality Update

INTRODUCTION

The Upper Salmon Falls watershed headwaters region includes Great East Lake, Horn Pond, Lovell Lake, Lake Ivanhoe (also known as Round Pond), and Wilson Lake and their associated tributaries (Figure 1). These waters flow to the Salmon Falls River and eventually to the Piscataqua River, which forms the southern border between Maine and New Hampshire. Province Lake and Pine River Pond flow to the Ossipee River and are located within the Saco River watershed. The region's lakes are threatened by phosphorus, particularly from existing development, road runoff, and other untreated sources of stormwater runoff. As a result, an Upper Salmon Falls Headwater Lakes Watershed Management Plan (WMP) was developed from 2008-2010 to provide recommendations for local decision-makers as they plan for future development and to offer other stakeholder strategies for minimizing impact to water quality. The Province Lake WMP was published in 2014, and there is no plan yet for Pine River Pond. The recommendations in these plans will help guide the communities of Acton and Wakefield and the Acton Wakefield Watersheds Alliance (AWWA) to maintain or achieve High Quality Water (HQW) status in each of these waterbodies.

This report provides an update to the 2012 and 2014 water quality reports that analyzed long-term trends in water quality data for four major waterbodies: Great East Lake, Lovell Lake, Lake Ivanhoe, and Horn Pond; 2014 only provided an update for Great East Lake and Lovell Lake. Water quality for Province Lake was updated since the 2014 Province Lake WMP. This is the first analysis of water quality data for Pine River Pond. These analyses will help determine how on-the-ground water quality improvement projects may be influencing in-lake water quality.

METHODS

Water quality data, including water clarity, total phosphorus, chlorophyll-a, and color, from as early as 1974 up to 2014 was collected by the University of New Hampshire (UNH) Center for Freshwater Biology (CFB) and Lakes Lay Monitoring Program (LLMP), the New Hampshire Department of Environmental Services (NHDES) Volunteer Lake Assessment Program (VLAP), and the Maine Department of Environmental Protection (Maine DEP) for ten stations across six lakes. The analysis included only epilimnetic core or grab samples collected between May 15 and October 15. Any duplicate samples were averaged and included as a single sample point. Surface grab samples were used in years without any epilimnetic samples for phosphorus. Mann-Kendall trend tests were performed on all median annual data to determine statistically significant trends over time.

Photo Credit: John Wilson

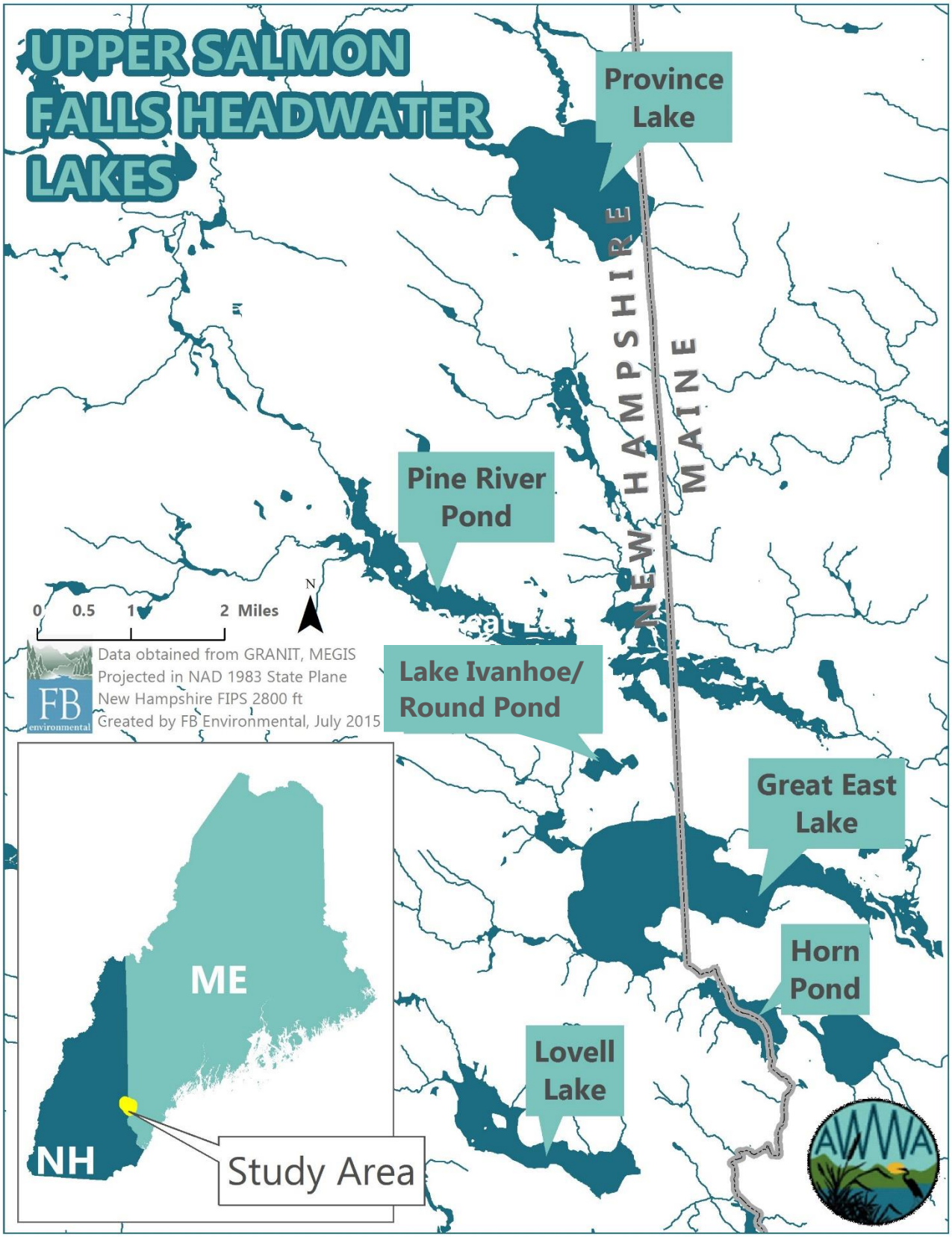


FIGURE 1. *Map of six major Upper Salmon Falls Headwater Lakes.*

RESULTS

Water quality trend analyses and summary statistics for each waterbody are presented below (Table 2; Attachment 1). Great East Lake, Horn Pond, Lovell Lake, and Lake Ivanhoe are oligotrophic lakes in New Hampshire; Province Lake and Pine River Pond are mesotrophic lakes in New Hampshire. All of these waterbodies fall under the aquatic life nutrient criteria established by NHDES (Table 1). A brief analysis of precipitation during the study period (1975-2014) is also included (Figure 2). A historical analysis of dissolved oxygen and temperature profiles will be completed at a later date, pending the development of the "anoxic factor" for multi-lake comparisons.

TABLE 1. *Lake water quality parameter definitions and applicable standards or guidelines for New Hampshire oligotrophic and mesotrophic lakes.*

PARAMETER	DEFINITION	STANDARD
WATER CLARITY	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 (a.k.a Secchi disk transparency). Measuring water clarity 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.	Greater than 2.0 meters
TOTAL PHOSPHORUS	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. 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.	Less than 8.0 ppb (oligotrophic); Less than 12.0 ppb (mesotrophic)
CHLOROPHYLL-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 chlorophyll-a equates to greater amount of algae in the lake.	Less than 3.3 ppb (oligotrophic); Less than 5.0 ppb (mesotrophic)
COLOR	The influence of suspended and dissolved particles in the water as measured by Platinum Cobalt Units (PCU or CPU). 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 CPU) can have reduced transparency readings and increased phosphorus values. When lakes are highly colored, the best indicator of algal growth is chlorophyll-a.	Less than 25 CPU

PARAMETER	DEFINITION	STANDARD
DISSOLVED OXYGEN	The concentration of oxygen that is dissolved in water. Oxygen is critical to the healthy metabolism of many creatures that reside in the water. Oxygen levels in lake water are influenced by a number of factors, including water temperature, concentration of algae and other plants, 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. Oxygen concentrations may change dramatically with lake depth as oxygen is produced in the top portion of a lake (where sunlight drives photosynthesis) and oxygen is consumed near the bottom of a lake (where organic matter accumulates and decomposes).	Shall not fall below 5 mg/L or 75% saturation
WATER TEMPERATURE	Measure of the degree of heat in a waterbody	Coldwater fish species thrive under maximum weekly and instantaneous temperatures of 19° and 24° C, respectively

PRECIPITATION ANALYSIS

Precipitation totals ranged from 34.1 to 71.9 inches during the time period of 1975-2014, as measured by the Sanford weather station obtained from NOAA National Climatic Data Center (NCDC) online (Figure 2). Record rainfall amounts in 2005 were documented in many areas of the northeast. These heavy rains and flooding contributed to turbulent waters and caused uprooted trees and scoured shorelines as floodwaters overflowed river banks. In May of 2006, New Hampshire received record amounts of rainfall once again, also known as the "Mother's Day Storm," which resulted "in excessive soil erosion and increased nutrient loading to surface waters throughout the State" (NHDES, 2006). In general, rainfall can play a large role in surface water quality by affecting its physical and chemical composition as runoff from the landscape can influence temperature, pH, and nutrient and sediment loading.

Total annual precipitation did not significantly increase or decrease from 1975 to 2014 near the study area, but has been steadily declining since the record high in 2005. A seasonal analysis of precipitation shows only a significantly increasing trend in precipitation in fall (September-November); the other seasons were too variable for trend detection. The reader should be aware that water quality data were not normalized (adjusted for) levels of precipitation, nor were correlations between water quality measurements and precipitation calculated for this report. **A more in-depth analysis that accounts for precipitation should be conducted, particularly to assess trajectory of water quality changes since restoration efforts began in 2008.**

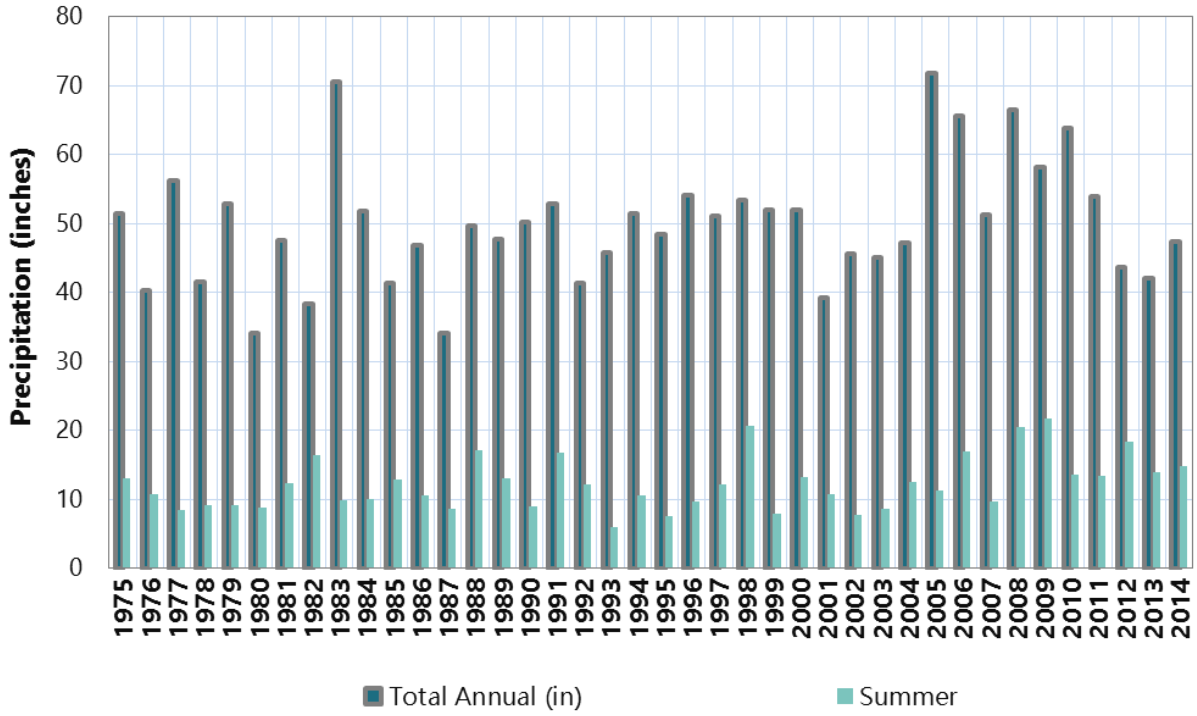


FIGURE 2. *Total annual precipitation and summer precipitation from 1975 to 2014. Precipitation data was obtained from NOAA NCDC Sanford, ME weather station.*

MAJOR FINDINGS

- **Water clarity** at most stations was deeper than 2.0 meters with the exception of Province Lake at a minimum of 1.3 meters. Two stations (Great East Lake – Station 2 Canal and Horn Pond – Station 1) showed statistically significant improving trends in median water clarity. In particular, Great East Lake – Station 2 Canal had the deepest median value at 10 meters, indicative of high quality water.
- Three stations (Great East Lake – Basin 2, Province Lake – Station 1, and Lake Ivanhoe – Station 2) had median **total phosphorus** greater than their respective criteria for total phosphorus. One station (Lovell Lake – Station 1 North) showed a statistically significant degrading trend in total phosphorus.
- All waterbodies had median **chlorophyll-a** better than their respective criteria for chlorophyll-a. Three stations (Great East Lake – Station 1 Center, Great East Lake – Basin 2, and Lovell Lake – Station 1 North) showed statistically significant improving trends in chlorophyll-a.
- All waterbodies had median **color** better than the threshold of 25 CPU. No significant trends were found for color at these stations.

TABLE 2. *Summary of water quality data for each waterbody. Red text indicate exceedance of water quality standard or threshold. Great East Lake, Lovell Lake, Lake Ivanhoe, and Horn Pond are oligotrophic lakes; Province Lake and Pine River Pond are mesotrophic lakes.*

		Water Clarity (m)					
Waterbody	**Station**	Years	Min	Median	Max	Trend*	Standard
Great East Lake	1 (Center)	35	6.0	9.6	13.3	0	
Great East Lake	2 (Canal)	18	4.2	10.0	12.6	+	
Great East Lake	3 (Mmann)	18	4.2	9.3	10.7	0	
Great East Lake	Basin 2	14	3.3	5.5	10.5	0	
Lovell Lake	1 (North)	26	3.8	6.3	7.6	0	2.0
Lovell Lake	2 (South)	26	3.4	6.4	9.0	0	
Province Lake	1 (Deep)	26	**1.3**	2.5	4.3	0	
Lake Ivanhoe	2 (Deep)	20	2.8	5.0	7.0	0	
Horn Pond	1 (Deep)	17	5.3	7.0	8.9	+	
Pine River Pond	1 (Deep)	4	4.5	6.0	7.4	**NS**	

		Total Phosphorus (ppb)					
Waterbody	**Station**	Years	Min	Median	Max	Trend*	Standard
Great East Lake	1 (Center)	26	0.9	6.0	**17.8**	0	
Great East Lake	2 (Canal)	13	2.7	5.9	**17.8**	0	
Great East Lake	3 (Mmann)	13	2.5	5.9	**16.2**	0	
Great East Lake	Basin 2	12	3.5	**10.0**	**25.6**	0	
Lovell Lake	1 (North)	26	0.7	6.6	**12.8**	-	**8.0 (oligo)**
Lovell Lake	2 (South)	26	1.3	7.3	**16.4**	0	**12.0 (meso)**
Province Lake	1 (Deep)	27	5.0	**15.0**	**46.0**	0	
Lake Ivanhoe	2 (Deep)	19	2.0	**8.0**	**12.3**	0	
Horn Pond	1 (Deep)	13	2.6	7.0	**12.1**	0	
Pine River Pond	1 (Deep)	4	4.3	6.2	**12.8**	**NS**	

		Chlorophyll-a (ppb)					
Waterbody	**Station**	Years	Min	Median	Max	Trend*	Standard
Great East Lake	1 (Center)	26	0.3	1.0	**5.2**	+	
Great East Lake	2 (Canal)	16	0.4	0.9	**3.3**	0	
Great East Lake	3 (Mmann)	15	0.4	1.0	2.4	0	
Great East Lake	Basin 2	12	0.4	2.1	**6.2**	+	
Lovell Lake	1 (North)	23	0.4	2.3	**15.6**	+	**3.3 (oligo)**
Lovell Lake	2 (South)	23	0.4	2.4	**5.5**	0	**5.0 (meso)**
Province Lake	1 (Deep)	26	0.8	3.5	**10.6**	0	
Lake Ivanhoe	2 (Deep)	19	0.2	2.5	**7.8**	0	
Horn Pond	1 (Deep)	8	0.3	1.9	**3.6**	**NS**	
Pine River Pond	1 (Deep)	4	1.9	3.0	3.9	**NS**	

Improving (+), degrading (-), stable (0), or not significant because too little data (NS**) trends for all available data*

TABLE 2 (CONTINUED). *Summary of water quality data for each waterbody. Red text indicate exceedance of water quality standard or threshold. Great East Lake, Lovell Lake, Lake Ivanhoe, and Horn Pond are oligotrophic lakes; Province Lake and Pine River Pond are mesotrophic lakes.*

		Color (CPU)					
Waterbody	**Station**	Years	Min	Median	Max	Trend*	Threshold
Great East Lake	1 (Center)	26	6.0	11.9	**39.5**	0	
Great East Lake	2 (Canal)	14	3.8	11.9	24.9	0	
Great East Lake	3 (Mmann)	14	6.0	11.8	22.5	0	
Great East Lake	Basin 2	10	9.9	22.5	**34.8**	0	
Lovell Lake	1 (North)	24	0.9	11.3	**35.2**	0	**25.0**
Lovell Lake	2 (South)	24	6.0	11.2	**30.1**	0	
Province Lake	1 (Deep)	11	12.0	22.4	**48.0**	0	
Lake Ivanhoe	2 (Deep)	12	5.0	9.1	**33.0**	0	
Horn Pond	1 (Deep)	13	4.6	12.6	**38.0**	0	
Pine River Pond	1 (Deep)	4	12.7	18.2	23.5	**NS**	

Improving (+), degrading (-), stable (0), or not significant because too little data (NS**) trends for all available data*

SUMMARY

These analyses revealed three stations (**Great East Lake – Basin 2, Province Lake – Station 1, and Lake Ivanhoe – Station 2)** that have water quality parameters (i.e., total phosphorus, water clarity) exceeding State standards for oligotrophic or mesotrophic lakes (Table 3). Only one station (**Lovell Lake – Station 1 North**) showed a statistically significant degrading trend in total phosphorus, but interestingly also a statistically significant improving trend in chlorophyll-a. This station should be targeted for a more in-depth study of nutrient and algae dynamics; algae communities at Lovell Lake may be limited by a different key element other than phosphorus. These four stations should be priority targets for future restoration efforts.

Overall, most stations are in good to excellent condition for the measured water quality parameters with some stations showing significantly improving trends in water clarity (**Great East Lake – Station 2 Canal and Horn Pond – Station 1**) and chlorophyll-a (**Great East Lake – Station 1 Center, Great East Lake – Basin 2, and Lovell Lake – Station 1 North**). Trend analyses could not be completed for Pine River Pond due to insufficient data years for statistical significance. Most lakes included in the 2010 Upper Salmon Falls Headwater Lakes WMP are meeting their water quality goals. Great East Lake – Station 1 Center, Horn Pond – Station 1, and Lovell Lake – Station 1 North are better than their water quality goals for total phosphorus. **Great East Lake – Basin 2, Lovell Lake – Station 1 South, and Lake Ivanhoe – Station 2 are worse than their water quality goals for total phosphorus and will require more targeted restoration work.**

It is important to note that lake water quality changes naturally over hundreds or thousands of years, gradually transforming from less productive (oligotrophic) to more productive (eutrophic) systems;

human disturbances within a watershed can accelerate this transformation within only a few decades, which is why remedial steps should be sought to mitigate and manage this change.

Water quality information empowers communities to make informed planning and resource-protection decisions. Results of the analyses completed for this report can be used by AWWA and the watershed towns to prioritize and direct future monitoring and water quality protection efforts. Communities can address water quality issues by adopting NHDES, NHLA, and UNH-recommended Best Management Practices (BMPs) and Low Impact Development (LID) techniques as parts of their local land-use planning and development regulations. Towns can also incorporate shoreland and aquifer protection priorities into their local planning and regulatory structures. The Town of Wakefield and AWWA have already taken significant steps to implement these restoration techniques at multiple lakes in the region.

Since water clarity, total phosphorus, and chlorophyll-a are intricately linked, it is critical that long-term monitoring continue on an annual basis, and that data analysis is completed at a minimum of every five years to help guide management activities in the watershed. It is recommended that a common database other than Excel is used to store these water quality data. In this way, data can be easily updated and accessed to query information about a given station or parameter.

TABLE 3. *Summary of water quality data for each waterbody. The current status of each water quality condition or trend is presented as "stoplights" or directional arrows, respectively (refer to legend). This display provides a visual means of comparing water quality parameters across multiple waterbodies.*

Waterbody	Station	Clarity	TP	Chl-a	Color
Great East Lake	1 (Center)	→	→	↑	→
Great East Lake	2 (Canal)	↑	→	→	→
Great East Lake	3 (Mmann)	→	→	→	→
Great East Lake	Basin 2	→	→	↑	→
Lovell Lake	1 (North)	→	↓	↑	→
Lovell Lake	2 (South)	→	→	→	→
Province Lake	1 (Deep)	→	→	→	→
Lake Ivanhoe	2 (Deep)	→	→	→	→
Horn Pond	1 (Deep)	↑	→	NS	→
Pine River Pond	1 (Deep)	NS	NS	NS	NS

LEGEND	Historical Trend		Overall Condition	
	↑	Improving		Excellent
	→	Stable		Good
	↓	Degrading		Poor

Clarity = water clarity
TP = total phosphorus
Chl-a = chlorophyll-a
***NS** = not significant; too little data*

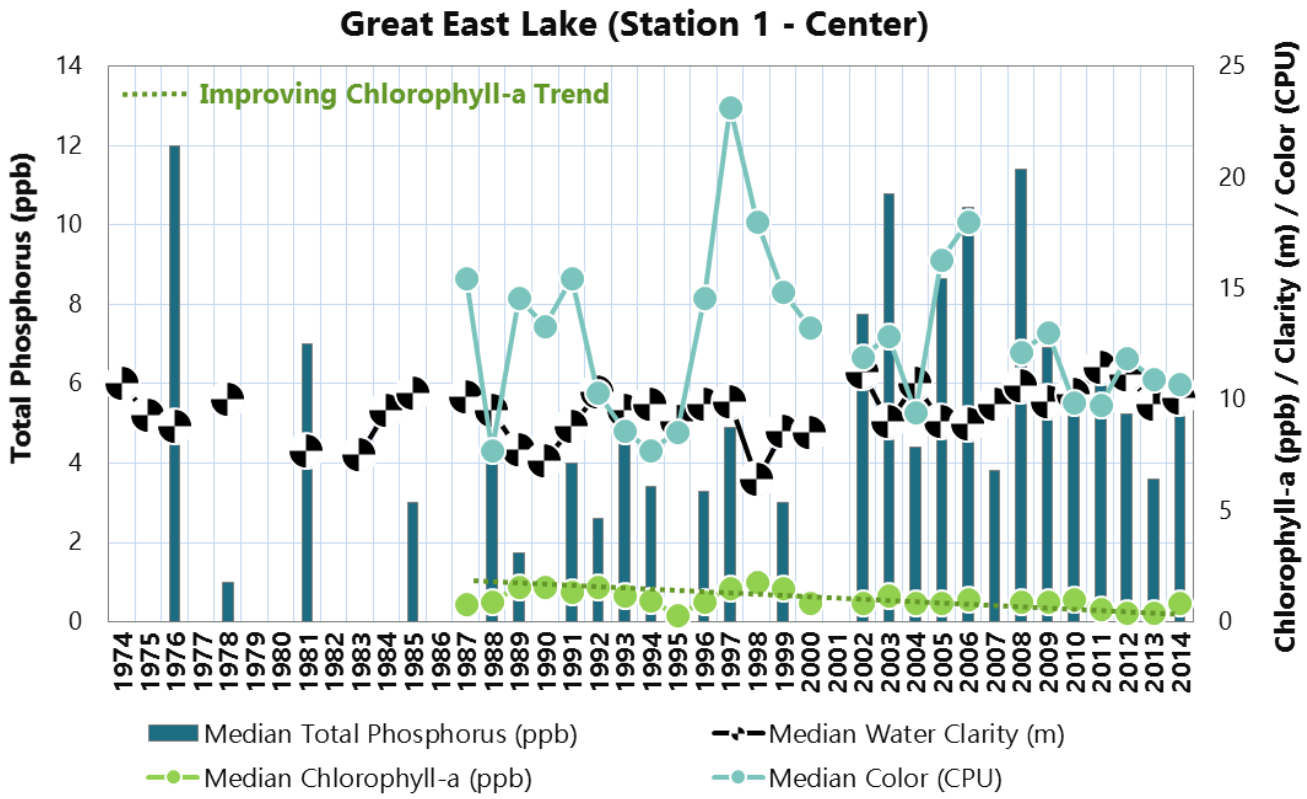
REFERENCES

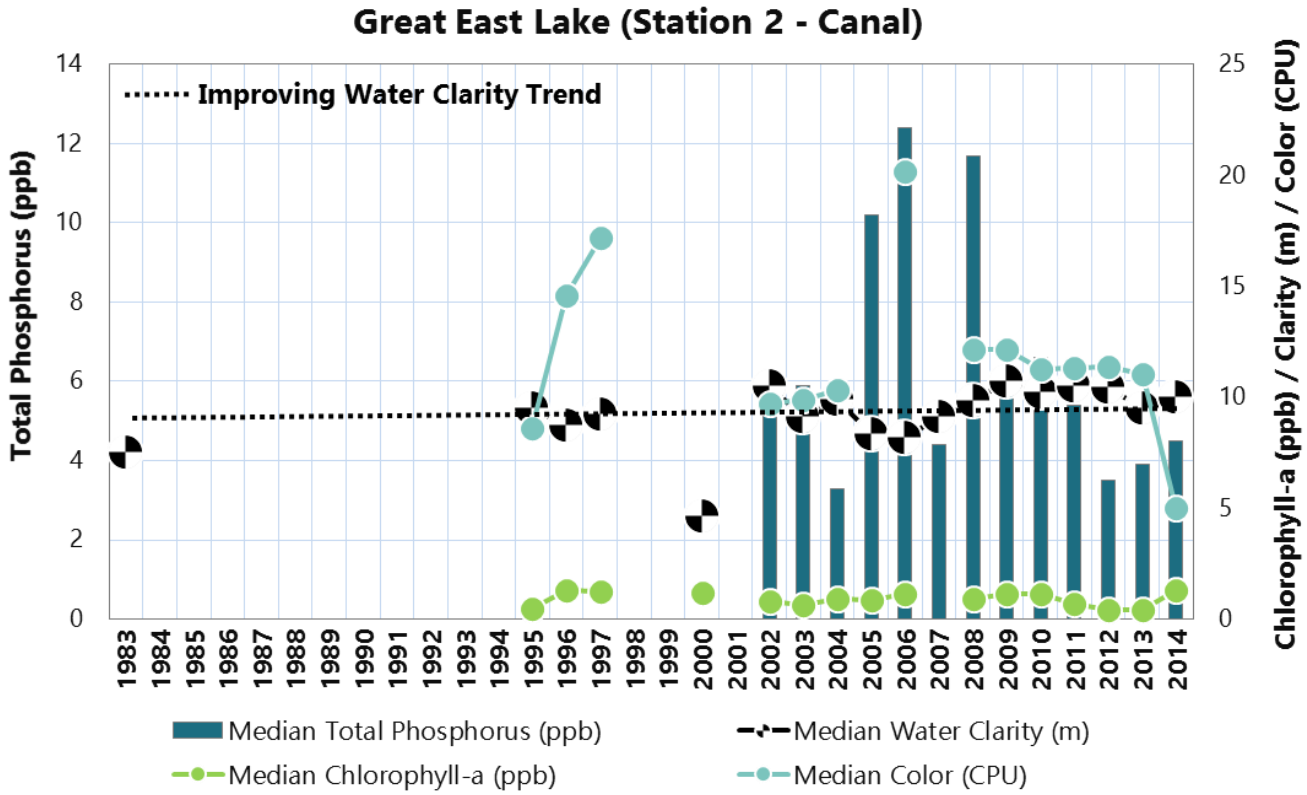
FB Environmental Associates. 2010. Salmon Falls Headwater Lakes Watershed Management Plan. Prepared for the Acton Wakefield Watersheds Alliance (AWWA).

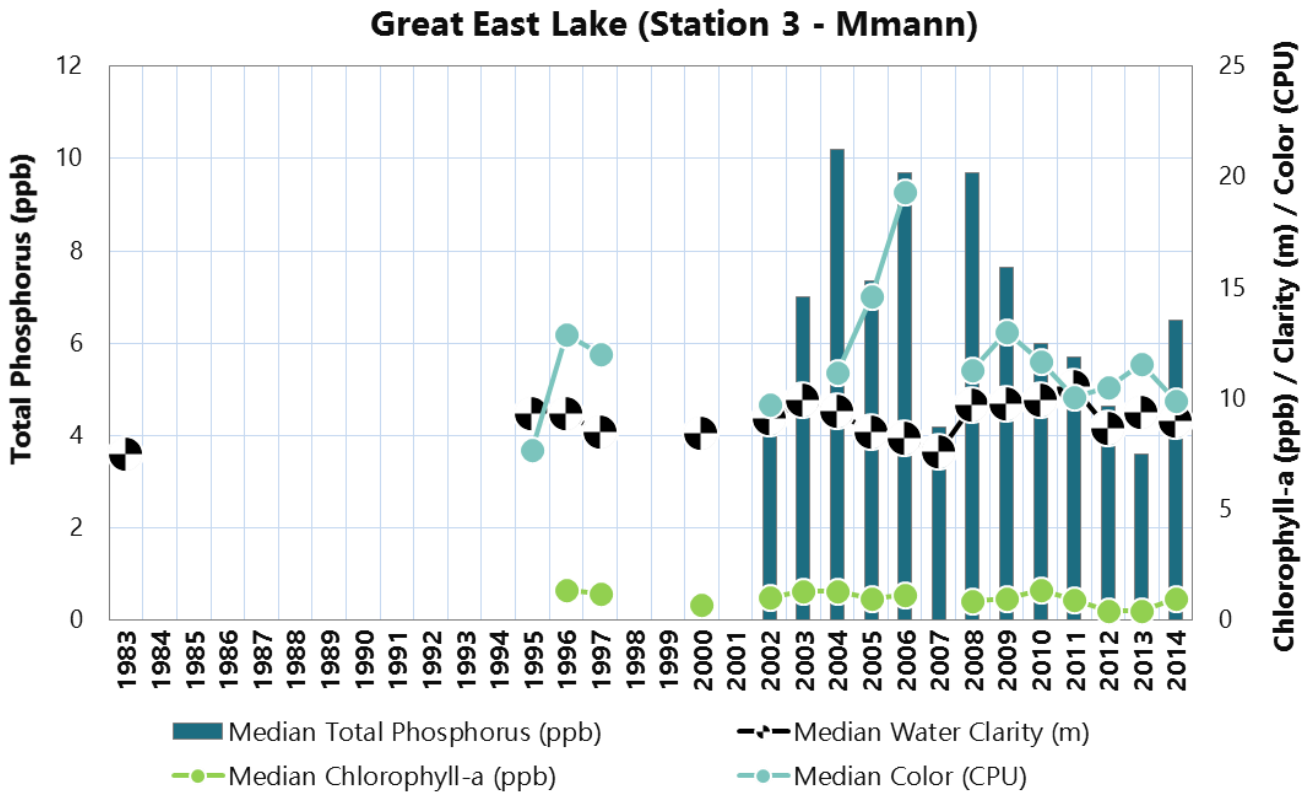
NHDES. 1999. New Hampshire Environmental Services Department. State of New Hampshire surface water quality regulations, Chapter 1700, 1999. NT 628.16

NHDES. 2006. Volunteer Lake Assessment Program (VLAP) Annual Report. New Hampshire Department of Environmental Services. Online: http://des.nh.gov/organization/divisions/water/wmb/vlap/2006/index.htm

ATTACHMENT 1: WATER QUALITY FIGURES






Great East Lake (Station 3 - Mmann)
Total Phosphorus (ppb)
Chlorophyll-a (ppb) / Clarity (m) / Color (CPU)
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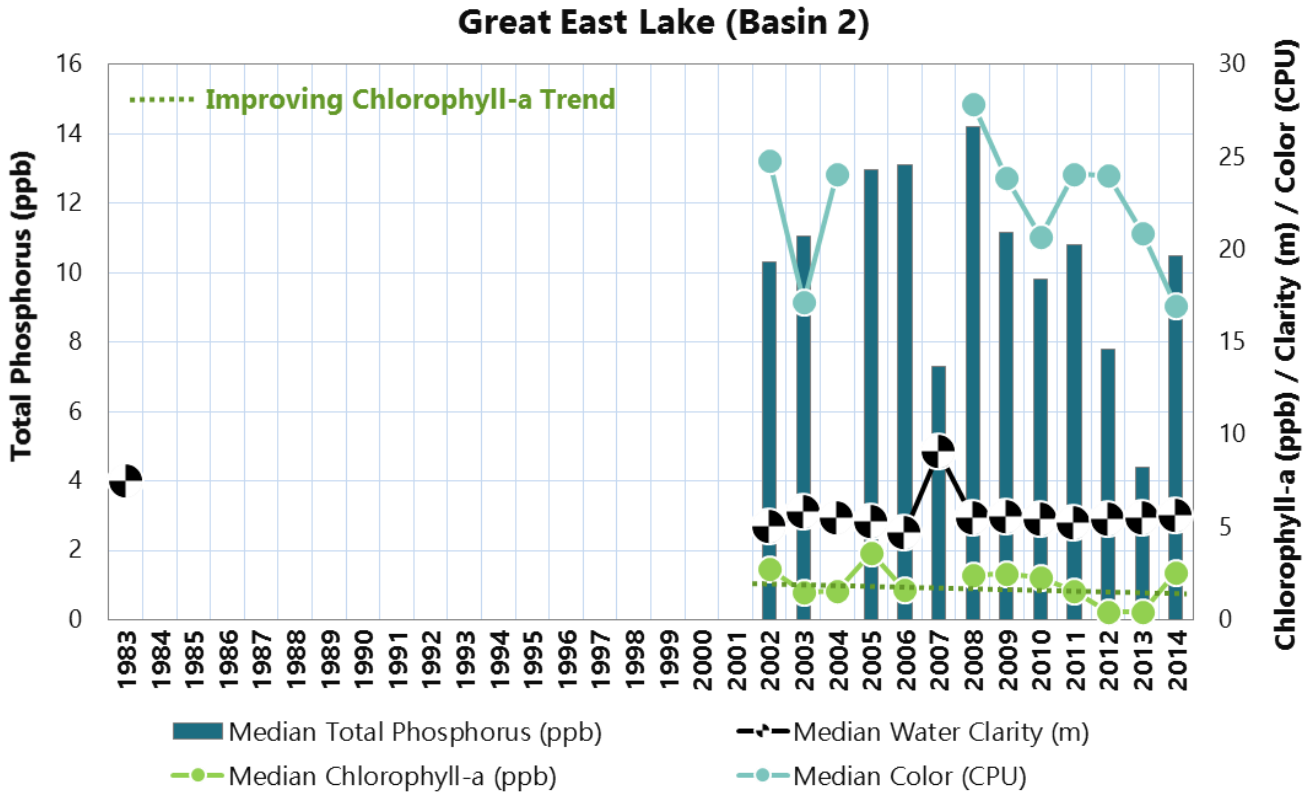
Median Total Phosphorus (ppb)
Median Water Clarity (m)
Median Chlorophyll-a (ppb)
Median Color (CPU)


Great East Lake (Basin 2)
Improving Chlorophyll-a Trend
Total Phosphorus (ppb)
Chlorophyll-a (ppb) / Clarity (m) / Color (CPU)
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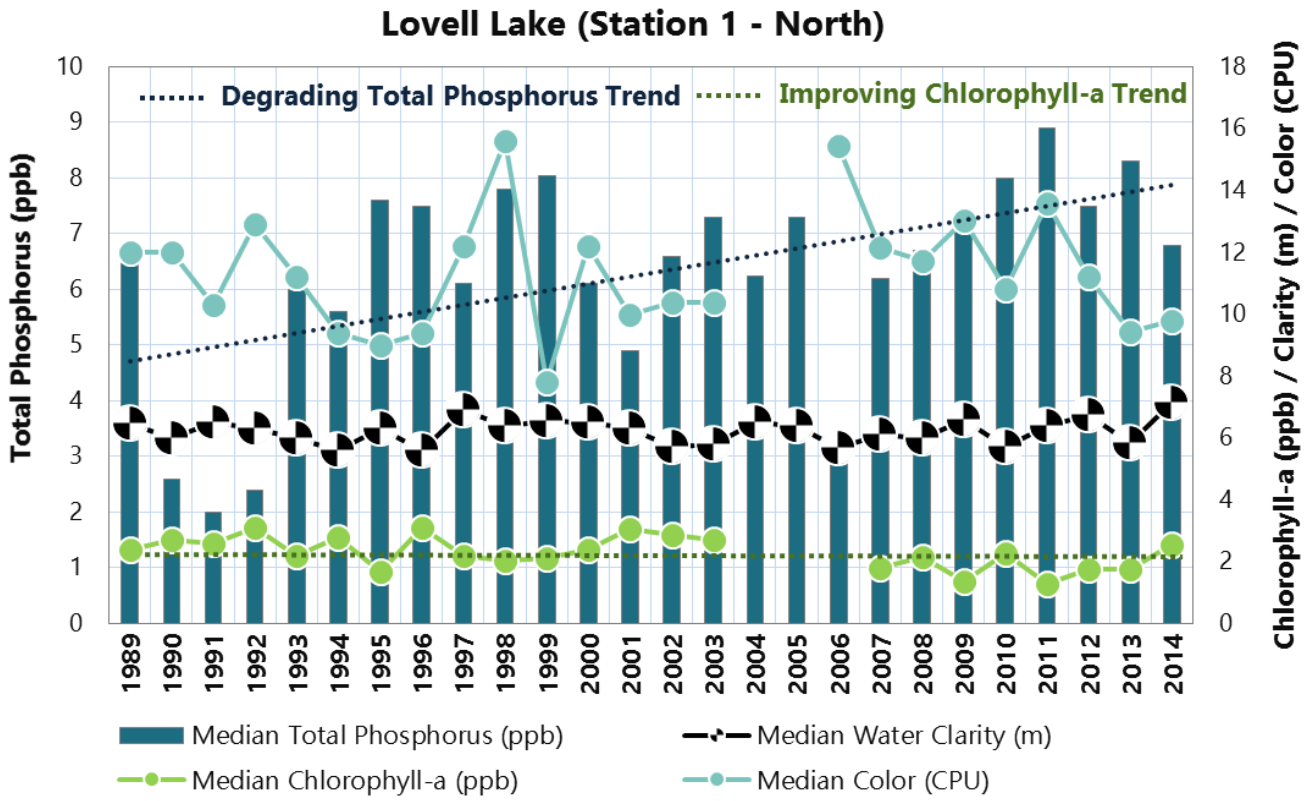
Median Total Phosphorus (ppb)
Median Water Clarity (m)
Median Chlorophyll-a (ppb)
Median Color (CPU)


Lovell Lake (Station 1 - North)
Degrading Total Phosphorus Trend
Improving Chlorophyll-a Trend
Total Phosphorus (ppb)
Chlorophyll-a (ppb) / Clarity (m) / Color (CPU)
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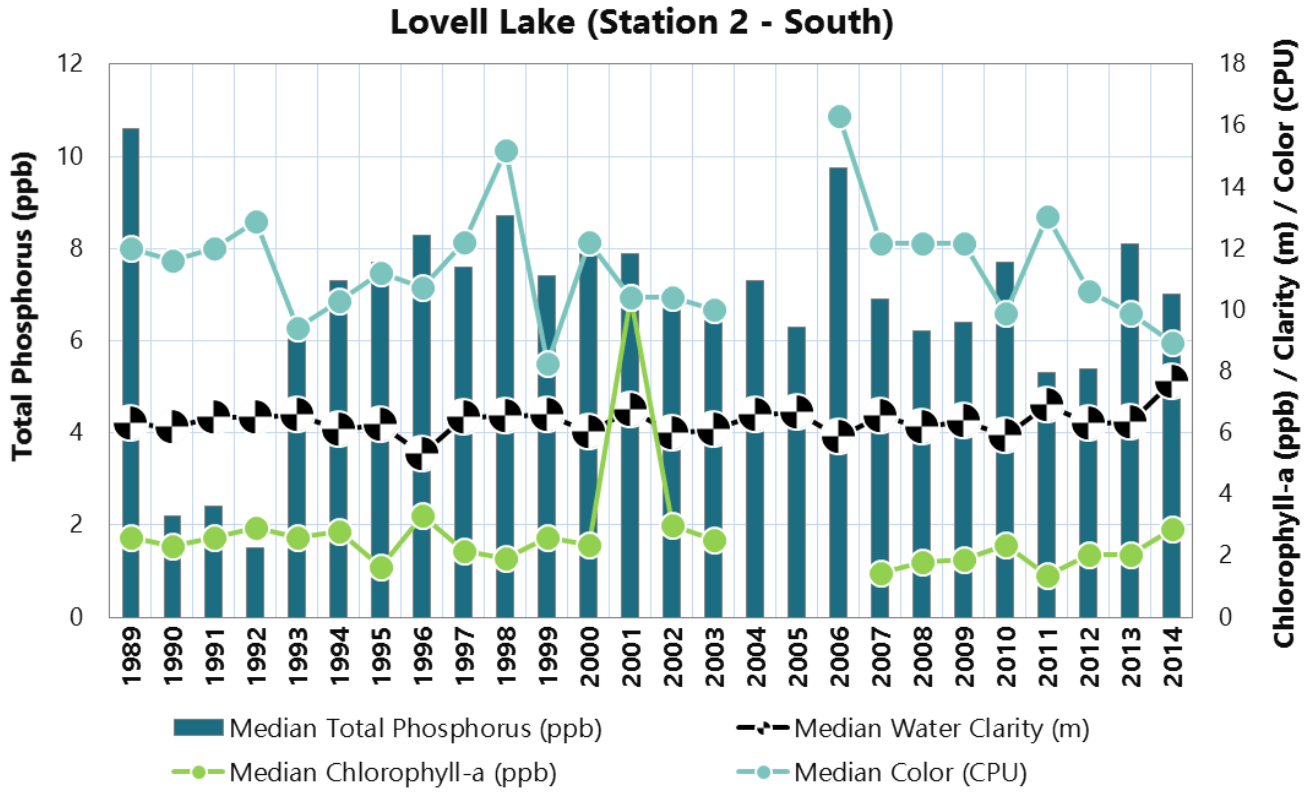
Median Total Phosphorus (ppb)
Median Water Clarity (m)
Median Chlorophyll-a (ppb)
Median Color (CPU)


Lovell Lake (Station 2 - South)
Total Phosphorus (ppb)
Chlorophyll-a (ppb) / Clarity (m) / Color (CPU)
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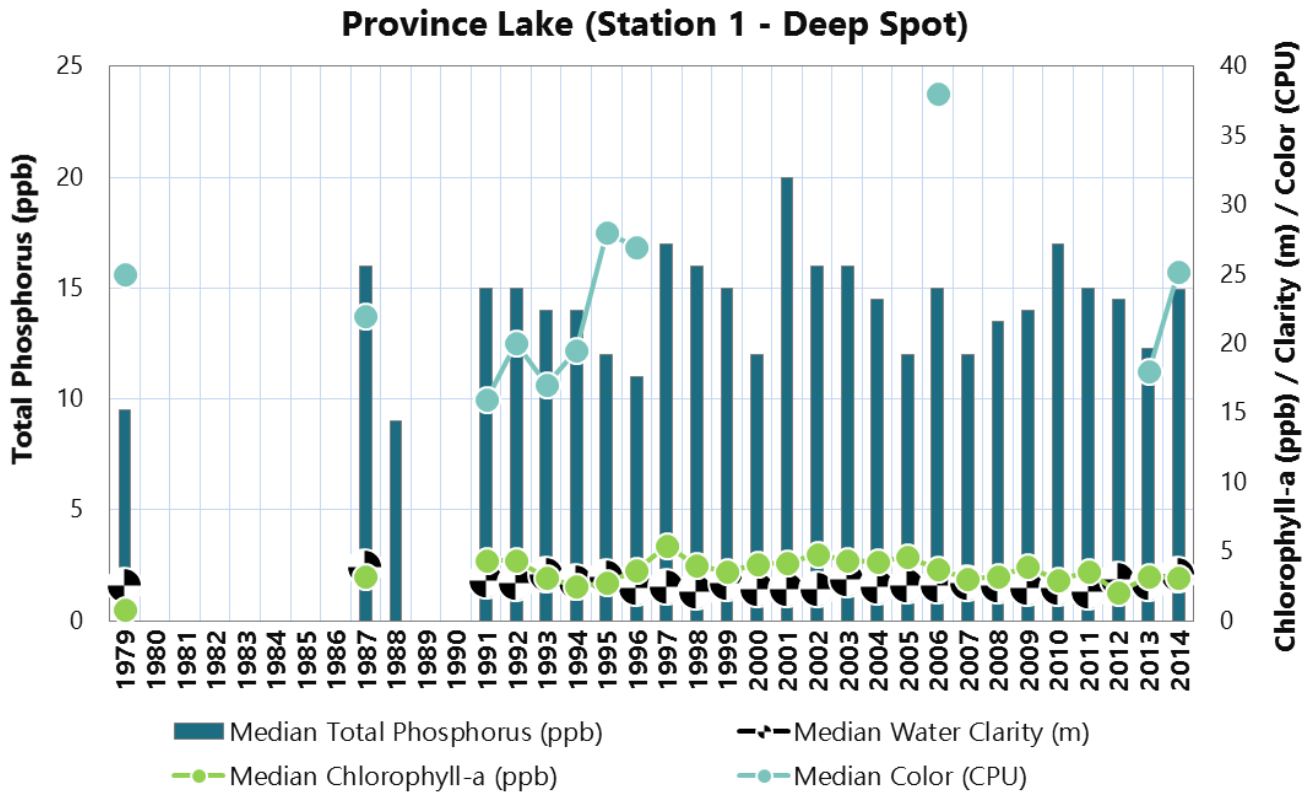
Median Total Phosphorus (ppb)
Median Water Clarity (m)
Median Chlorophyll-a (ppb)
Median Color (CPU)


Province Lake (Station 1 - Deep Spot)
Total Phosphorus (ppb)
Chlorophyll-a (ppb) / Clarity (m) / Color (CPU)
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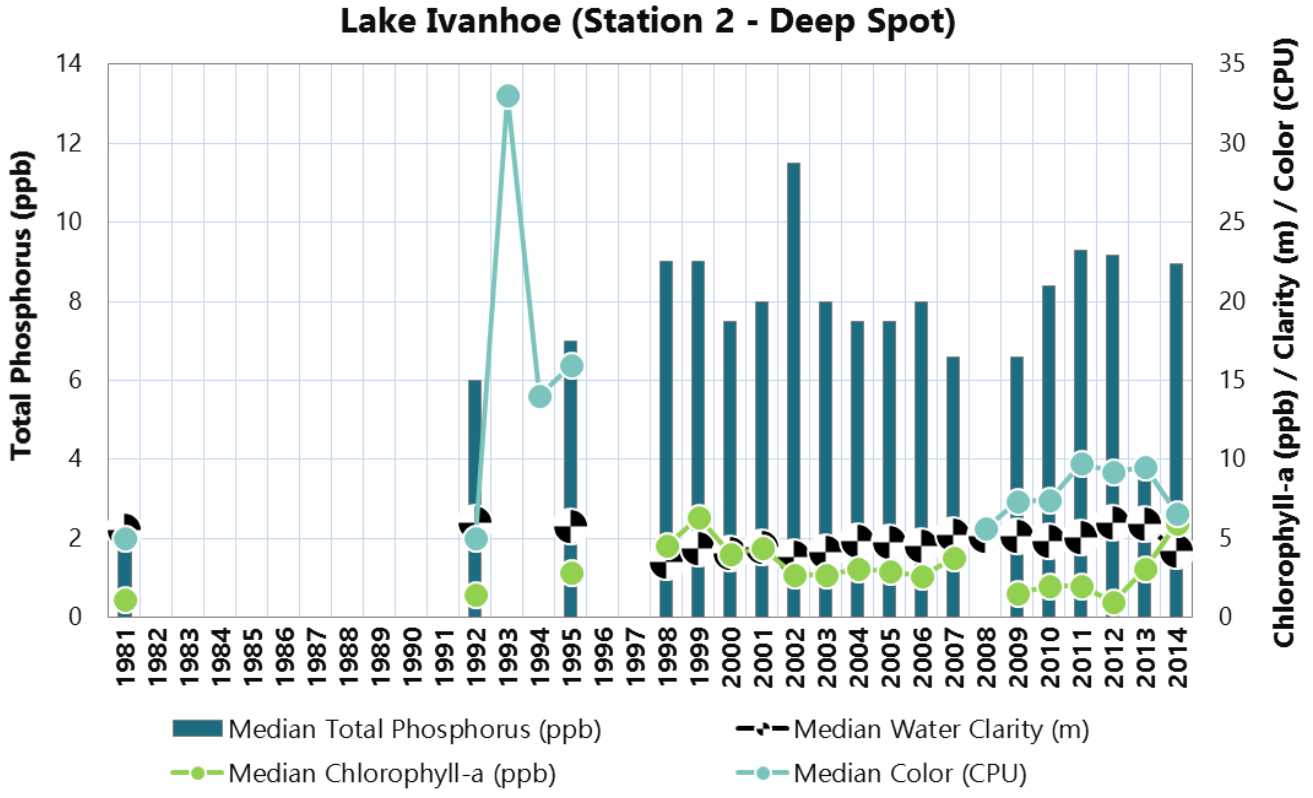
Median Total Phosphorus (ppb)
Median Water Clarity (m)
Median Chlorophyll-a (ppb)
Median Color (CPU)


Lake Ivanhoe (Station 2 - Deep Spot)
Total Phosphorus (ppb)
Chlorophyll-a (ppb) / Clarity (m) / Color (CPU)
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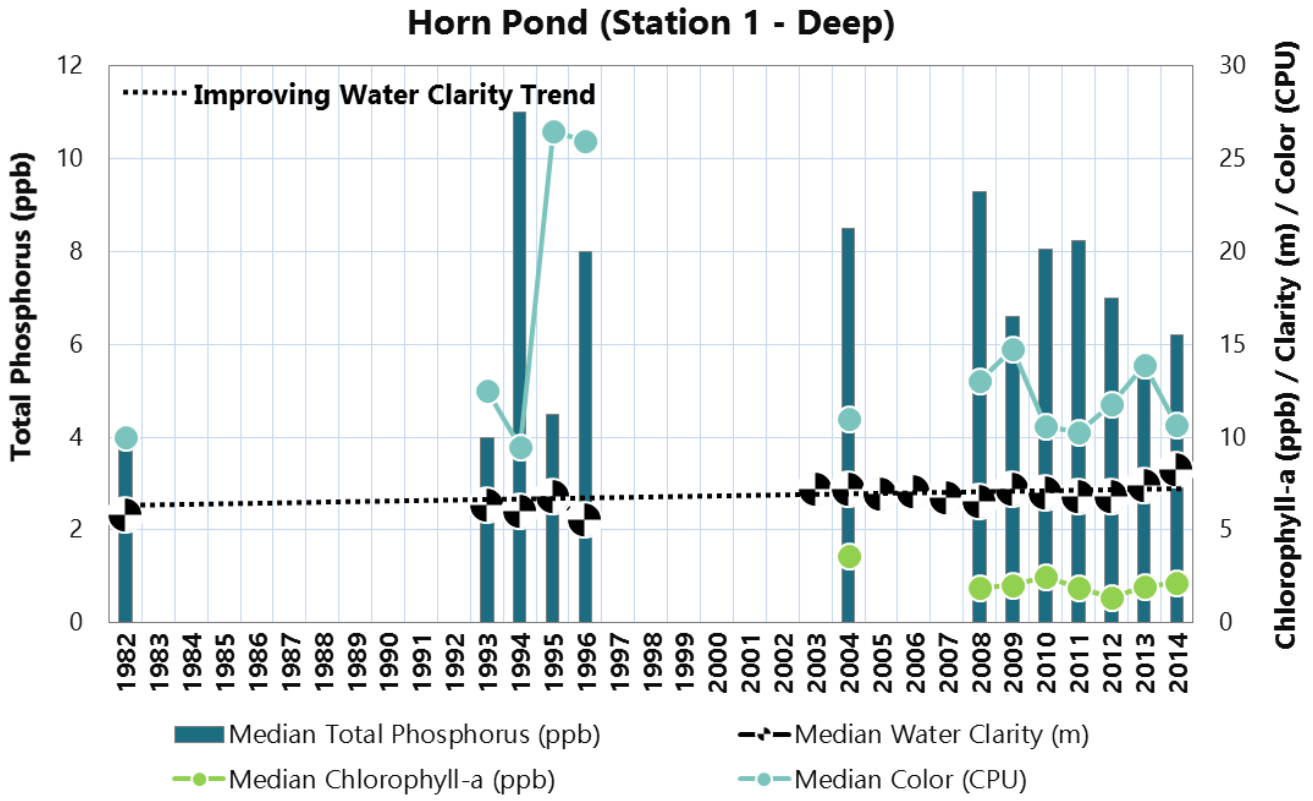
Median Total Phosphorus (ppb)
Median Water Clarity (m)
Median Chlorophyll-a (ppb)
Median Color (CPU)


Horn Pond (Station 1 - Deep)
Improving Water Clarity Trend
Total Phosphorus (ppb)
Chlorophyll-a (ppb) / Clarity (m) / Color (CPU)
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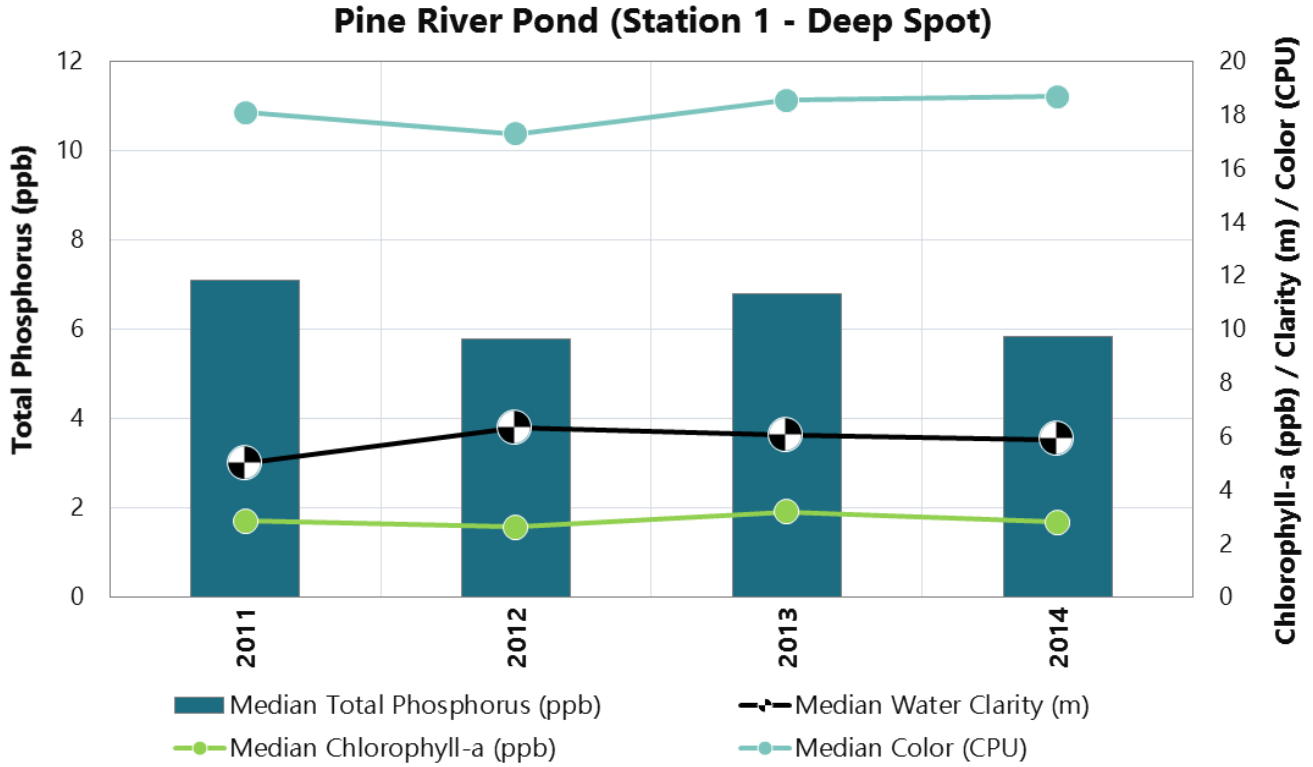
Median Total Phosphorus (ppb)
Median Water Clarity (m)
Median Chlorophyll-a (ppb)
Median Color (CPU)


Pine River Pond (Station 1 - Deep Spot)
Total Phosphorus (ppb)
Chlorophyll-a (ppb) / Clarity (m) / Color (CPU)
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2
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18
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2011
2012
2013
2014
Median Total Phosphorus (ppb)
Median Water Clarity (m)
Median Chlorophyll-a (ppb)
Median Color (CPU)