WATER QUALITY ANALYSIS | MEMORANDUM

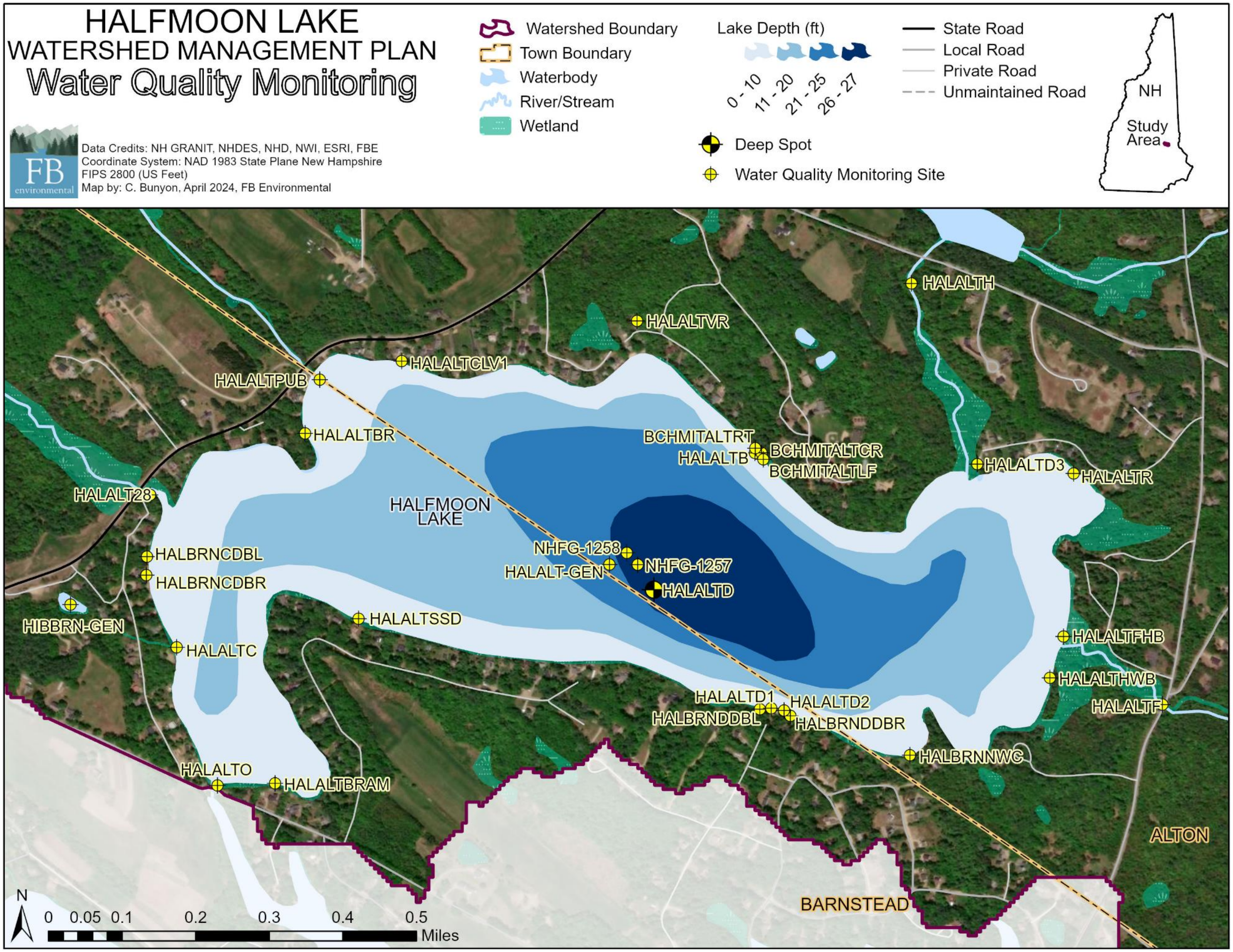
TO: Nina Kelly, Halfmoon Lake Association
FROM: Christine Bunyon, FB Environmental Associates
SUBJECT: Halfmoon Lake Water Quality Analysis
DATE: April 30, 2024
CC: Forrest Bell, Laura Diemer, and Evan Ma, FB Environmental Associates

This memo summarizes water quality data available for Halfmoon Lake in Alton and Barnstead, NH through 2023 and proposes additional water quality data to be collected in 2024 to fill in gaps needed for assessment and modeling as part of the development of a watershed management plan.

PROBLEM BACKGROUND

According to the 2022 Data Summary of the New Hampshire Volunteer Lake Assessment Program (VLAP) Individual Lake Report for Halfmoon Lake, the lake has total phosphorus and chlorophyll-a levels higher than the NH Department of Environmental Services (NHDES) threshold for oligotrophic lakes, though concentrations of each parameter appear to be improving. NHDES designated Halfmoon Lake as a Class B water, impaired for Aquatic Life Integrity due to elevated total phosphorus and chlorophyll-a, low pH, and low dissolved oxygen saturation. Halfmoon Lake is also listed as impaired for Primary Contact Recreation due to the presence of cyanobacteria hepatotoxic microcystins. Multiple inlets, including the Fern Hill Inlet, Dugan's Inlet, and an unnamed brook north of Crescent Beach (Route 28 Inlet) are assessed as impaired for Aquatic Life Integrity due to low pH. The 1978 NHDES Lake Trophic Survey Report assessed the lake as oligotrophic, noting aquatic weeds were common along the shoreline. By the next assessment in 1992, the lake was re-classified as mesotrophic due to depleted dissolved oxygen in bottom waters. It was noted that aquatic plants were less abundant, though reports of nuisance filamentous algae in bottom waters were more frequent.

The deep spot of Halfmoon Lake experiences periods of anoxia. Anoxia in bottom waters of lakes can trigger the release of phosphorus from bottom sediments into the water column. This phenomenon, known as internal loading, is already evident in Halfmoon Lake. Once present in the water column, phosphorus can be used by phytoplankton such as cyanobacteria. Beyond this, cyanobacteria commonly found in the epi- and metalimnia can take advantage of higher hypolimnion phosphorus levels due to their ability to regulate their buoyancy in the water column. This movement is seen through elevated hypolimnion turbidity levels and the presence of cyanobacteria in hypolimnion water samples noted in the 2022 VLAP Individual Lake Report. Enhanced loading of phosphorus to surface waters, whether from internal or external sources, particularly when compounded by the impacts from climate change, can stimulate excessive plant, algae, and cyanobacteria growth and degrade mean annual water quality.



MAP 1. Map of water quality sampling sites within the Halfmoon Lake watershed and the bathymetry of Halfmoon Lake.

WATER QUALITY SUMMARY

Phytoplankton and Zooplankton

Bloom History

Halfmoon Lake has had three officially reported NHDES cyanobacteria bloom advisories, the first of which was issued in 2011. The 2011 advisory lasted for nine days and was dominated by the taxon *Oscillatoria*, with a cell count of 859,833. The next advisory was issued in 2018 and was dominated by *Oscillatoria* and *Planktothrix*. The bloom had a cell count of 1,450,000 and lasted for fourteen days. One year later in 2019, the most recent advisory was issued for seven days. The bloom was dominated by *Dolichospermum* (formerly *Anabaena*) with a cell count of 137,000 cells/mL. *Oscillatoria* and *Planktothrix* can form benthic mats, and *Dolichospermum* are potentially a toxin producing species. No cyanobacteria bloom advisories were issued by NHDES from 2020-2023.

Phytoplankton/Zooplankton Results

The 2022 Data Summary of the NH VLAP Individual Lake Report for Halfmoon Lake shows phytoplankton population (relative percent cell count per taxa) for 2014, 2016, 2018, and 2021. In 2021, golden-browns dominated over other taxa after cyanobacteria dominated in 2016 and 2018. However, in 2022, cyanobacteria were also observed at 8 meters in August, indicating their continued presence in Halfmoon Lake. This continuing shift from diatoms and golden-browns to cyanobacteria is also evident when analyzing older trophic surveys as well. Phytoplankton and zooplankton samples were collected and analyzed during the 1979 and 1992 NHDES Trophic Surveys of Halfmoon Lake. The dominant phytoplankton species were *Chrysosphaerella* (golden-brown), *Ceratium* (diatom), and *Asterionella* (diatom).

The dominant zooplankton species in the 1979 and 1992 surveys were *Nauplius* larvae (copepod), *Kellicottia* (rotifer), and *Gastropus* (rotifer). Copepods are small crustaceans that eat phytoplankton and provide an important food source to fish. Rotifers are small zooplankton whose population can respond quickly to environmental changes. *Daphnia* are among the most efficient grazers of phytoplankton but were not shown to be a dominant zooplankton in Halfmoon Lake. Maintaining a balance of phytoplankton and zooplankton are necessary components of a healthy lake ecosystem.

Trophic State Indicator

Total phosphorus, chlorophyll-a, and Secchi disk transparency are trophic state indicators, or indicators of biological productivity in lake ecosystems. The combination of these parameters helps determine the extent and effect of eutrophication in lakes and helps signal changes in lake water quality over time. For example, changes in Secchi disk transparency may be due to a change in the amount and composition of algae communities (typically because of greater total phosphorus availability) or the amount of dissolved or particulate materials in a lake. Such changes are often the result of human disturbance or other impacts to the lake's watershed.

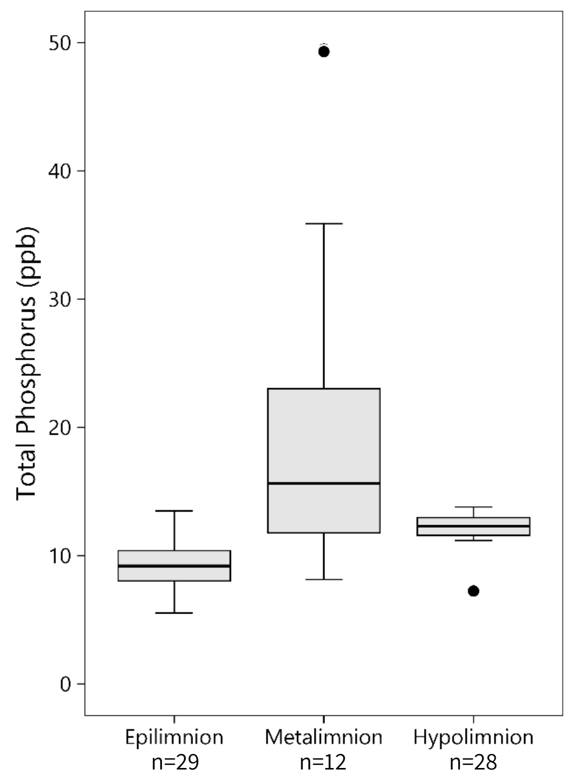


FIGURE 1. Boxplots showing median total phosphorus concentration in the epilimnion, metalimnion, and hypolimnion of the deep spot of Halfmoon Lake (HALALTD) from the past 10 years, 2014-2023.

At Halfmoon Lake from 1914-2023, higher total phosphorus concentrations were most often measured in the metalimnion and hypolimnion compared to the epilimnion, indicating some amount of internal phosphorus loading is occurring (Figure 1). Phosphorus concentrations are also more variable in the metalimnion than the epilimnion and hypolimnion. While the cause of elevated meta- and hypolimnion turbidity at Halfmoon Lake is unknown, it suggests the possibility that cyanobacteria may be taking advantage of this additional phosphorus source and transporting it to other areas of the water column, resulting in the observed cyanobacteria blooms.

For the available time period, 1978-2023, no statistically significant trends were found for median epilimnetic total phosphorus, chlorophyll-a, or Secchi disk transparency at the deep spot of Halfmoon Lake (HALALDT) (Figure 2). The 2022 Data Summary of the NH VLAP Individual Lake Report for Halfmoon Lake found stable trends for total phosphorus and Secchi disk transparency, and improving trends in chlorophyll-a, though higher concentrations of chlorophyll-a were observed in 2023.

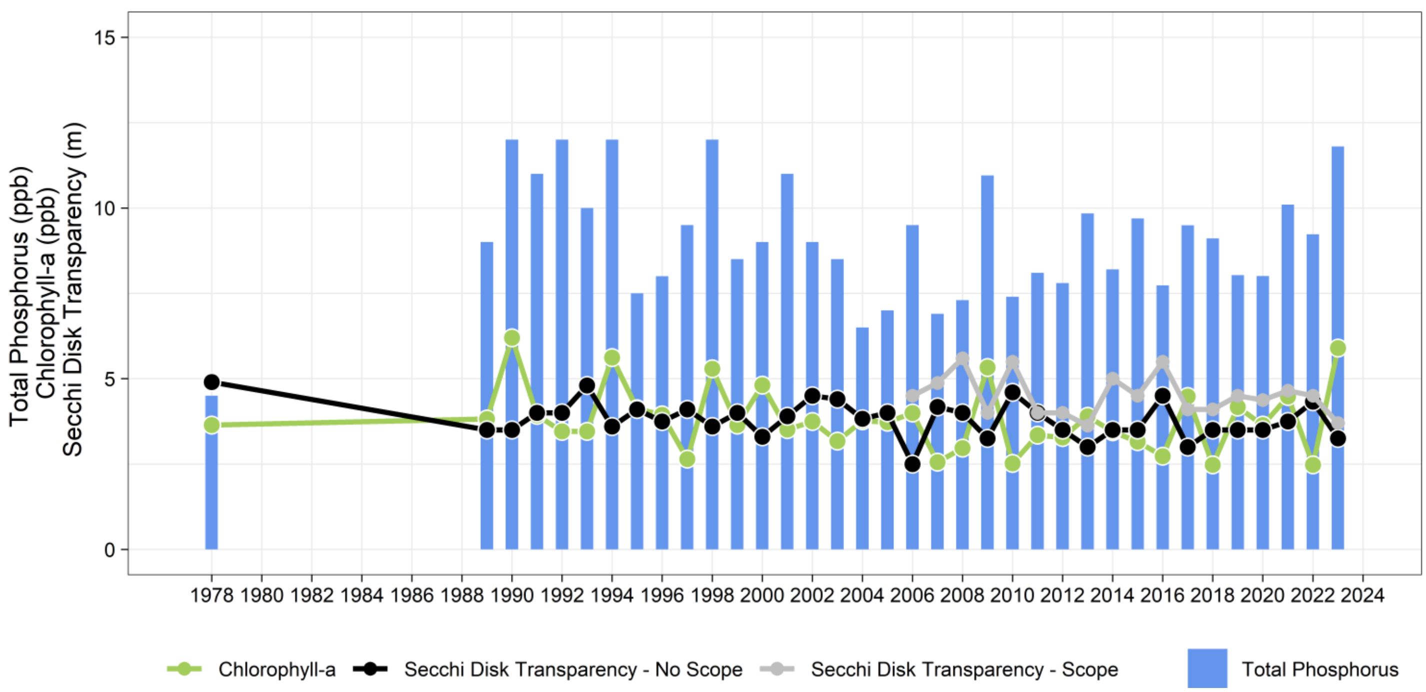


FIGURE 2. Median epilimnion grab samples (0-3 meters) total phosphorus, median composite epilimnion (0-5 meters) chlorophyll-a, and median water clarity (Secchi Disk depth for scope and no scope methods) measured at Halfmoon Lake largely in June-September from 1978-2023 for the deep spot station (HALALTD). No statistically significant trends were detected from the Mann-Kendall nonparametric trend test using *rkt* package in R Studio.

Dissolved Oxygen & Water Temperature

A common occurrence in New Hampshire's lakes is the depletion of dissolved oxygen in the deepest part of lakes throughout the summer months. This occurs when thermal stratification prevents warmer (less dense), oxygenated surface waters from mixing with cooler (denser), oxygen-depleted bottom waters in the lake. Chemical and biological processes occurring in bottom waters deplete the available oxygen throughout the summer, and because these waters are colder and denser, the oxygen cannot be replenished through mixing with surface waters. Dissolved oxygen levels below 5 ppm (and water temperature above 24 °C) can stress and reduce habitat for cold-water fish and other sensitive aquatic organisms. In addition, anoxia (low dissolved oxygen) at lake bottom can result in the release of sediment-bound phosphorus (otherwise known as internal phosphorus loading), which can become a readily available nutrient source for algae and cyanobacteria. While thermal stratification and depletion of oxygen in bottom waters is a natural phenomenon in dimictic lakes such as Halfmoon Lake, it is important to track these parameters to make sure the extent and duration of low oxygen does not change drastically because of human disturbance in the watershed resulting in excess phosphorus loading.

Figure 3 shows temperature and dissolved oxygen profiles for Halfmoon Lake averaged across sampling dates (1989-2022) during thermal stratification largely in summer (between spring and fall turnover). The change in temperature, seen most dramatically between 5 and 7 m, indicates thermal stratification in the water column. The average dissolved oxygen of <2 ppm at 7-9 m depth indicates the possibility of internal loading under anoxic conditions. Historic recording of temperature and dissolved oxygen profiles includes multiple water column profiles per sampling season which provide insight to seasonal changes in the lake. Additional profiles in the early autumn months (September and October) can provide additional insight into the possible internal loading in Halfmoon Lake.

Lake Stratification and Mixing

Halfmoon Lake is a dimictic lake, undergoing two cycles of stratification and mixing annually. Stratification takes place during summer, as surface waters warm, forming a thermal barrier due to differences in water densities. Additionally, winter months see stratification when the lake freezes over, with colder surface waters sitting atop warmer bottom waters. Dimictic lakes undergo both "fall turnover" and "spring turnover," characterized by the loss of these temperature gradients which enable water mixing once again.

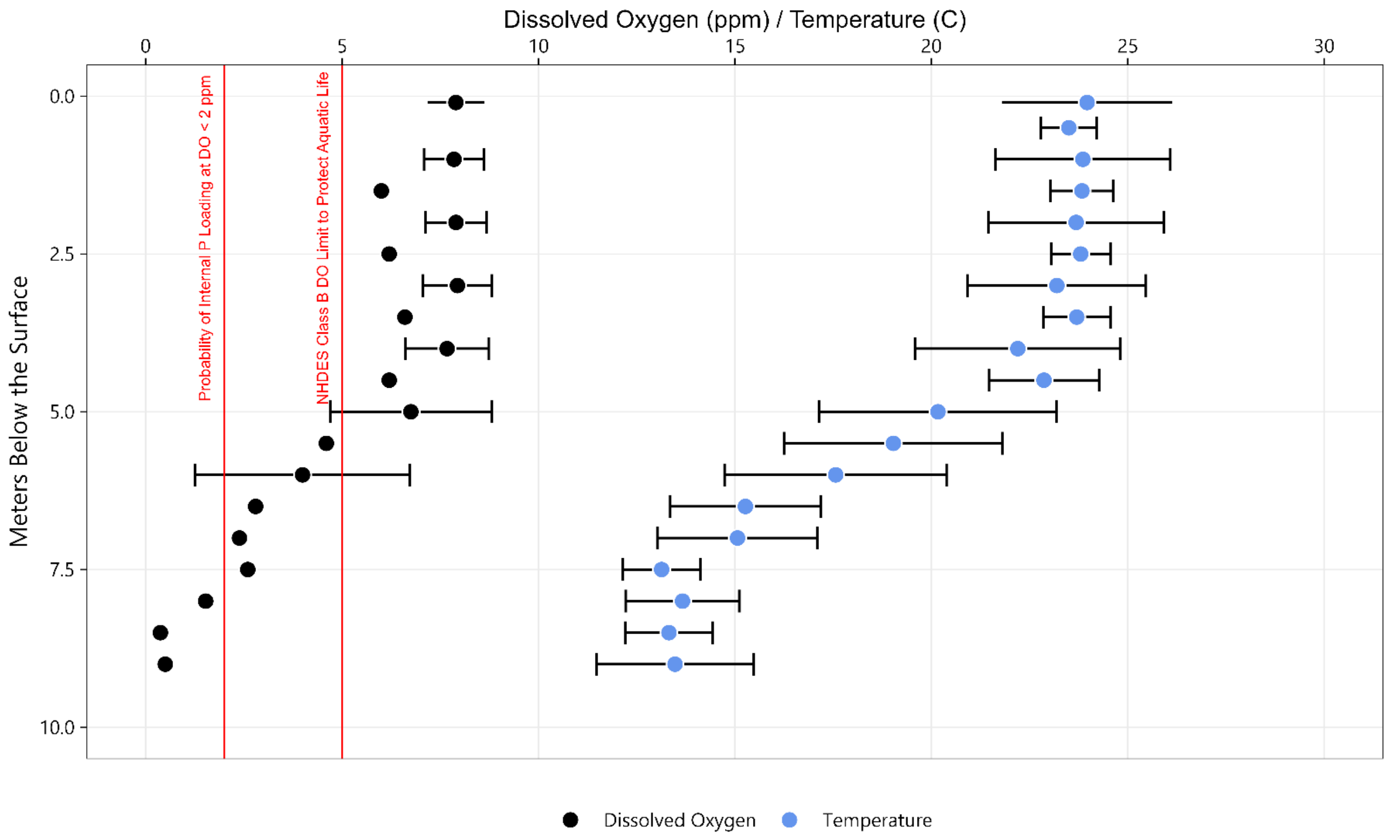


FIGURE 3. Dissolved oxygen (black) and water temperature (blue) depth profiles for the deep spot of Halfmoon Lake (HALALTD). Dots represent average values across sampling dates for each respective depth. Error bars represent standard deviation. Data represents profiles collected from 2014 to 2023 (n=20).

Chloride & Specific Conductivity

Chloride pollution can cause harm to aquatic organisms and disrupt internal mixing processes when concentrations reach toxic levels. The State of New Hampshire sets a chronic threshold of 230 ppm for chloride (which roughly equates to 835 µS/cm for specific conductivity). Chloride concentrations in Halfmoon Lake are well below the chronic threshold, with both chloride and specific conductivity low, which is typical for a high-quality lake (most New Hampshire lakes are around 4 ppm or 40 µS/cm). However, both chloride and specific conductivity show statistically significant increasing trends over the record from 1978-2023 across all depth zones (Figure 4). Upon further investigation in the dataset, the frequency and timing of specific conductivity sampling became less irregular in 2010. For example, before 2010, the epilimnion samples for specific conductivity ranged from June to September and from one to 4 samples per year. After 2010, three samples were collected each year – one in June, July, and August (except in 2020). Even when the data is analyzed before and after this change of sampling approach, an increasing trend remains evident, and the timing of sample collection does not account for the oscillation of the yearly median data plotted in Figure 4.

The increasing trends indicate that chloride from winter salting practices for deicing roads and other surfaces in the watershed may be contaminating the lake. Another potential source of chloride and specific conductivity is sediment loading from eroding, unpaved roads throughout the watershed. The steep slopes located in some areas of the watershed may make the watershed more susceptible to soil loss and road erosion. Other sources of pollution that may increase chloride and specific conductivity levels include wastewater inputs from septic systems and fertilizers. While not an immediate concern for the health of the lake, chronic chloride toxicity will likely become an issue in the future without a proactive reduction in salt use in the watershed.

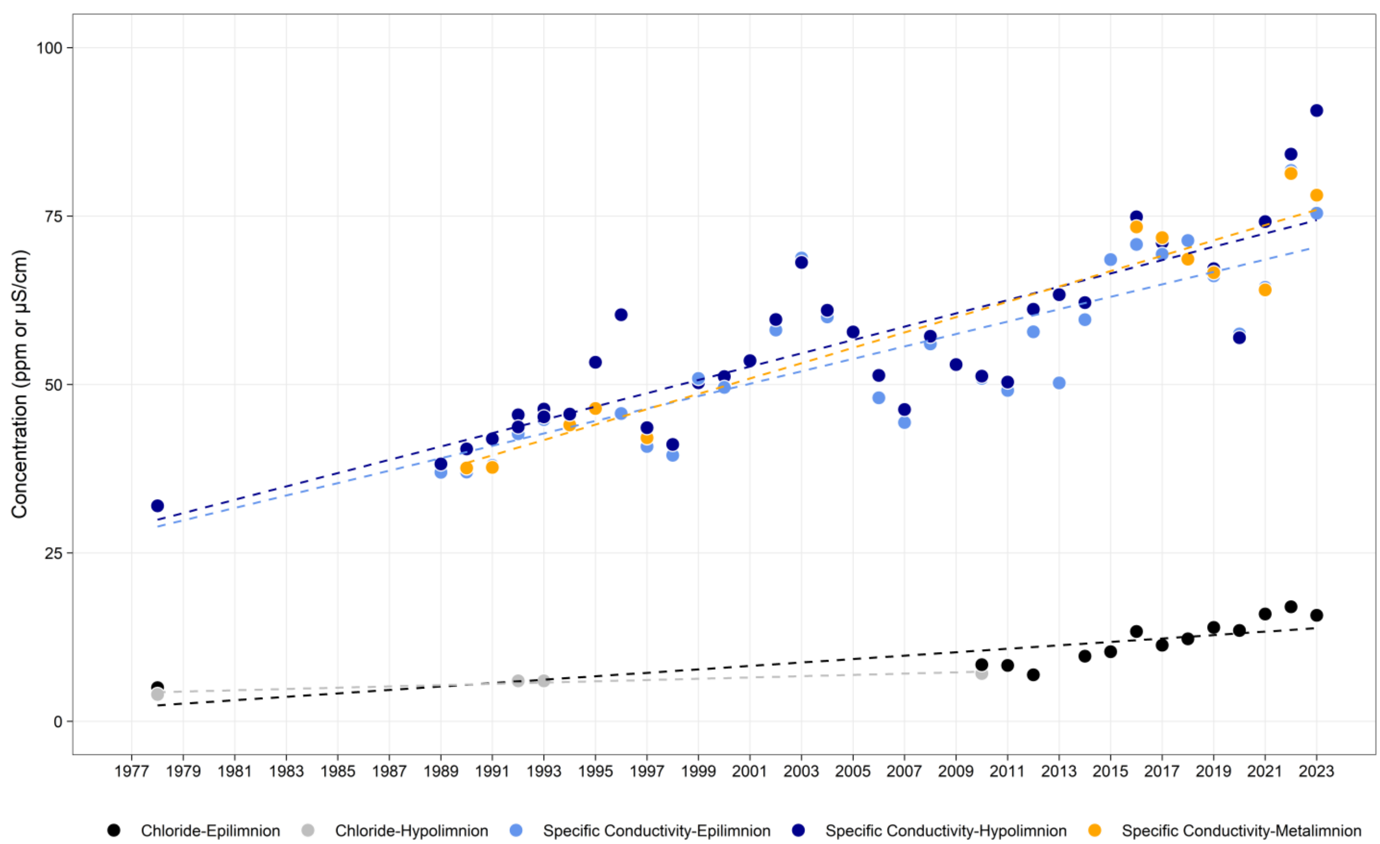


FIGURE 4. Yearly median of monthly medians for chloride and specific conductivity in the deep spot of Halfmoon Lake (HALALTD). Dashed lines indicate a statistically significant increasing (degrading) trend.

Turbidity

Turbidity is a measure of the cloudiness or murkiness of water, caused by the absorption or scattering of light by particulates in the water column. Various factors affect the turbidity of a lake or stream, such as algal and/or cyanobacterial colonies, organic matter, and sediment. High levels of turbidity can decrease water clarity, inhibiting photosynthesis and limiting the growth of aquatic plants, harm filter feeders, and damage the gills of fish. Turbid waters tend to be warmer and have lower levels of dissolved oxygen as suspended particles absorb sunlight and photosynthesis is decreased.

Turbidity values are low (<1NTU) at the deep spot of Halfmoon Lake (HALALTD); particularly in the epi- and metalimnions. The water quality standard in New Hampshire for turbidity in Class B waters is <10 NTU above naturally occurring levels, above which a violation occurs. Although a specific value for "natural" turbidity has not been set by the New Hampshire Department of Environmental Services, it is generally accepted that natural turbidity is low if less than 1 NTU[1]. The epilimnion and metalimnion of Halfmoon Lake show turbidity levels well below the NHDES threshold of 10 NTU (Figure 5). Turbidity is likely higher in the hypolimnion due to the ability of cyanobacteria to regulate their buoyancy using gas-vesicles. Cyanobacteria may descend into the hypolimnion during high light intensity conditions, or to take advantage of bio-available phosphorus at these depths. This phenomenon was observed in 2022 as noted in the Volunteer Lake Assessment Program Individual Lake Report for that year.

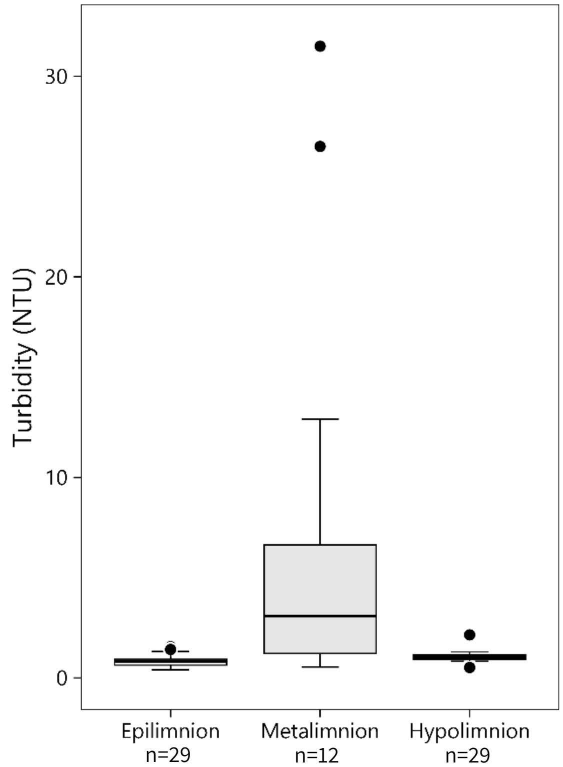


FIGURE 5. Boxplots showing median turbidity in the epilimnion, metalimnion, and hypolimnion of the deep spot of Halfmoon Lake (HALALTD) for the past 10 years (2014-2023).

[1] In the 2020/2022 Consolidated Assessment and Listing Methodology (CALM), NHDES provides reference values aimed to represent natural turbidity that differ based on the month, derived from other streams. The reference values for streams in June, July, August, and September are 0.875, 0.831, 0.813, and 0.800 NTU, respectively.

pH

The pH of a water body describes how acidic or basic the water is, with lower values representing more acid conditions, and a value of 7 representing neutral. The habitable range of pH for aquatic organisms is near neutral, with NHDES setting the standard for Class B waterbodies to have a pH between 6.5 and 8.0 to protect aquatic life. Monitoring the pH of Halfmoon Lake is especially important as multiple inflows to the lake are classified as impaired for low pH and may affect the water quality of the lake itself.

Median pH in the epilimnion of Halfmoon Lake at the deep spot (HALALTD) has been stable from 1989-2023 and has generally been at the lower (more acidic) end of the acceptable range set by NHDES (Figure 6). Across the different depth zones, pH has generally been higher (less acidic) in the epilimnion than in the metalimnion or hypolimnion. Higher pH in the epilimnion is typically expected because of the greater amount of photosynthesis occurring in the photic zone which raises the pH, and increased respiration occurring in lower depth zones has an acidifying effect on the water. The pH may be lowest in the hypolimnion due to the settling of detritus and other organic matter on the bottom sediments, which leads to increased respiration when oxygen is present. Both the metalimnion and hypolimnion have median pH values that are below the NHDES guidelines for supporting aquatic life (state value, and sample range/number) (Figure 6). Low pH can have adverse effects on aquatic biota, and extremely low pH can promote the release of iron or even aluminum bound phosphorus (pH < 5.5) from the bottom sediments.

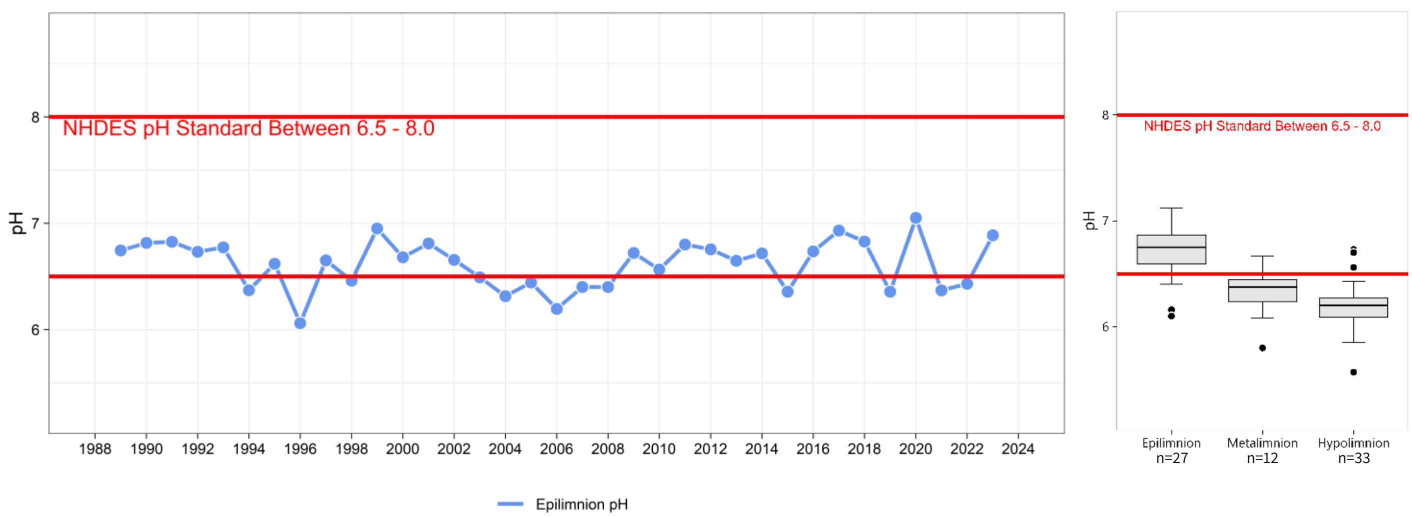


FIGURE 6. (Left) Yearly median of monthly medians for epilimnion pH in the deep spot of Halfmoon Lake (HALALTD). (Right) Boxplots showing median pH in the epilimnion, metalimnion, and hypolimnion of the deep spot of Halfmoon Lake (HALALTD) for the past 10 years, 2014-2023. Values were converted to the concentration of hydrogen ions before being summarized and logarithmically transformed back to the pH scale.

ASSIMILATIVE CAPACITY

The assimilative capacity of a waterbody describes the amount of pollutant that can be added to a waterbody without causing a violation of the water quality criteria based on lake trophic designation. Halfmoon Lake is a borderline oligotrophic/mesotrophic waterbody; however, the mesotrophic designation was largely attributed to a degradation in dissolved oxygen in the bottom waters. For enhanced protection of water quality, the oligotrophic designation was selected for running the assimilative capacity analysis for Halfmoon Lake. For oligotrophic waterbodies, the water quality criteria are set at 8 ppb for total phosphorus and 3.3 ppb for chlorophyll-a, above which the waterbody is considered impaired. NHDES requires 10% of the difference between the best possible water quality and the water quality standard be kept in reserve; therefore, total phosphorus and chlorophyll-a must be at or below 7.2 ppb and 3.0 ppb, respectively, to achieve Tier 2 High Quality Water status by NHDES. Support determinations are based on the nutrient stressor (phosphorus) and response indicator (chlorophyll-a), with chlorophyll-a dictating the assessment if both chlorophyll-a and total phosphorus data are available and the assessments differ.

Results of the assimilative capacity analysis show that Halfmoon Lake is impaired for the oligotrophic class designation (Table 1). The existing median total phosphorus and chlorophyll-a concentrations exceed the assimilative capacity threshold, indicating that reductions in the total phosphorus load are likely needed to reduce the chlorophyll-a concentration to meet the 3.0 ppb threshold and reduce the risk of possible cyanobacteria blooms.

TABLE 1. Assimilative capacity (AC) analysis results for Halfmoon Lake (station HALALTD).

Parameter	AC Threshold (ppb)	Existing Median WQ (ppb)*	Remaining AC (ppb)	Assessment Results
Total Phosphorus	7.2	9.2	-2.0	Impaired
Chlorophyll-a	3.0	3.6	-0.6	

** Existing water quality data truncated to May 24-Sept 15 in the previous 10 years (2014-2023) for composite, epilimnion, or upper samples (in order of priority on a given day). Data were summarized by day, then month, then year using median statistics.*

STREAM WATER QUALITY SUMMARY

Total Phosphorus & Turbidity

The water quality of streams that contribute water, nutrients, contaminants, and more, to Halfmoon Lake can reveal areas throughout the watershed contributing disproportionate amounts of certain parameters. Stream health is also critical because they often abut wetlands and serve as the home to various aquatic biota and macroinvertebrates. Of the streams around Halfmoon Lake, only Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28) have been sampled in the past 10 years. Although various other sites have been sampled in the past, this analysis focuses on streams with recent data. A summary of data for these three inlets is available in Table 2 on page 14.

Stream total phosphorus concentrations are relatively stable over time (1989 – present, Figure 7), with the Route 28 Inlet consistently having the highest total phosphorus concentration with a median of 58.4 ppb over the past ten years (Table 2). The Fern Hill Inlet historically had the lowest total phosphorus concentration, though levels have risen since 2013. However, statistically significant stable trends were found for total phosphorus and turbidity for the Fern Hill Inlet from 1989 (TP) or 1997 (turbidity) to present. The EPA's Ambient Water Quality Criteria Recommendations for Rivers and Streams recommends a reference total phosphorus level of 5 ppb for the sub-ecoregion containing the Halfmoon Lake watershed. All three stream inlets were above this reference threshold.

Turbidity is relatively low in the streams that feed Halfmoon Lake, with median values below 10 NTU for all streams over the past ten years. In 2022, a turbidity spike was observed at the Route 28 Inlet concurrent with a spike in total phosphorus (Figure 7). Turbidity is highly variable and often weather dependent. The timing and severity of storms is likely to have a large impact on turbidity readings due to the delivery and flushing of sediment and suspended particles through a stream. High turbidity is often caused by soil erosion and sediment loading associated with unpaved roads, agriculture, and residential development. Managing sources of turbidity often also addresses sources of phosphorus as phosphorus is adsorbed to soil particles that ultimately end up in streams. Low turbidity paired with high total phosphorus concentrations at the Route 28 Inlet suggest that sources of phosphorus other than soil erosion may be drivers of phosphorus loading to the stream. Although turbidity is generally low in the streams around Halfmoon Lake, the turbidity spike in 2022 serves as evidence that turbidity has the potential to increase in the absence of stormwater management and sediment control practices, especially as the frequency and severity of storm events have increased.

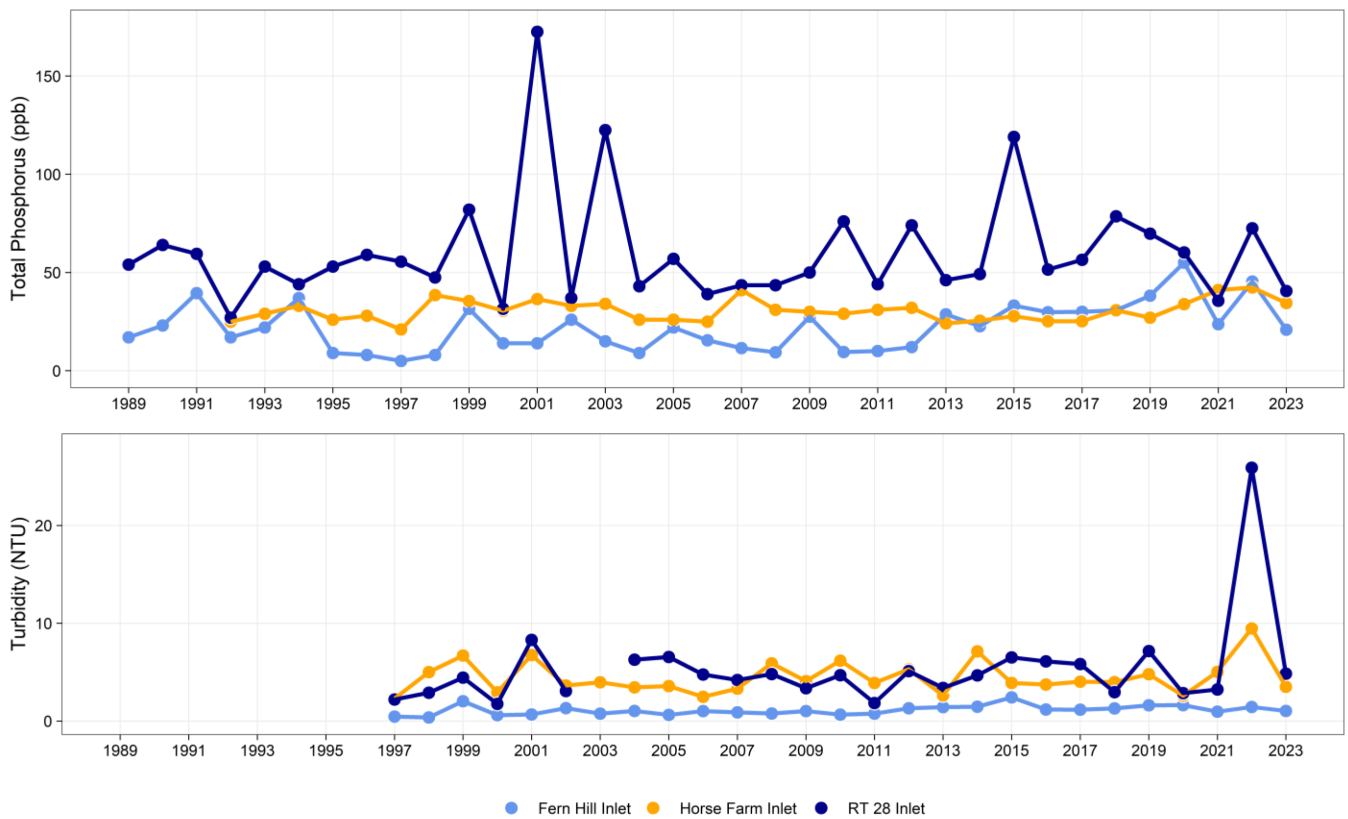


FIGURE 7. [Top] Yearly median of monthly medians for total phosphorus at the Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28). [Bottom] Yearly median of monthly medians for turbidity at the Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28).

Chloride & Specific Conductivity

Specific conductivity is a measure of the water's ability to conduct an electrical current. In the context of streams, specific conductivity relates to the concentration of ionic compounds in the water. Inputs to streams that affect specific conductivity include various types of salts (road salt), ions bound in soil, and ions found in wastewater and agricultural runoff. Chloride and specific conductivity levels are not approaching the chronic toxicity threshold of 230 ppm for chloride (which roughly equates to 835 µS/cm for specific conductivity). However, statistically significant increasing trends were found for specific conductivity at Horse Farm Inlet and Route 28 Inlet from 1989-2023 (Figure 8, top). A statistically significant increasing trend for chloride can be observed at the Route 28 Inlet from 2013-2023 (Figure 8, bottom). Increasing trends in these parameters indicate that pollution from each respective sub-watershed is likely reaching the streams and ultimately Halfmoon Lake. The Fern Hill Inlet has had lower specific conductivity concentrations and chloride levels historically and in recent years (Figure 8).

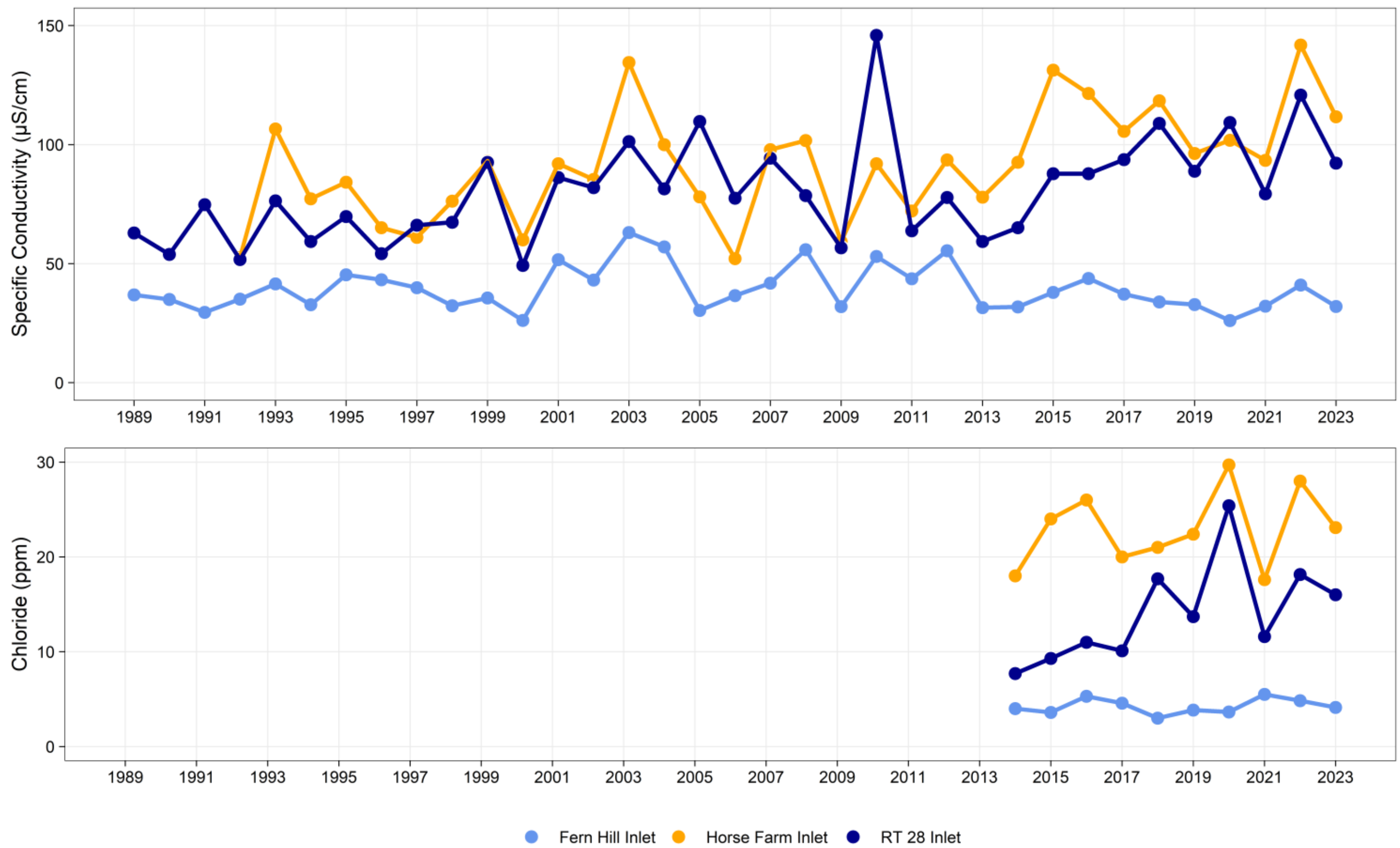


FIGURE 8. [Top] Yearly median of monthly medians for specific conductivity at the Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28). [Bottom] Yearly median of monthly medians for chloride at the Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), Route 28 Inlet (HALALT28), and Dugans Inlet (HALALTD3). Statistically significant increasing trends were found for specific conductivity for the Horse Farm Inlet and Route 28 Inlet from 2013 to 2023 using a Mann-Kendall nonparametric trend test.

pH

NHDES classified the Route 28 Inlet (HALALT28), Fern Hill Inlet (HALALTF), and Dugans Inlet (HALALTD3), and Horse Farm Inlet [HALALTH] as impaired for low pH. Dugans Inlet and the Horse Farm Inlet are located along the same stream—only the Horse Farm Inlet has data within the past 10 years, so the Horse Farm Inlet will be used for this analysis. The pH at all three inlets appears to be consistently low (acidic) from 1989-2023, with the Horse Farm Inlet having the lowest pH (Figure 10). Over the past ten years, the Horse Farm Inlet has had a median pH of 6.3, less than the NHDES standard which is between 6.5 and 8.0 (Table 2). The Fern Hill Inlet and Route 28 Inlet have median pH values of 6.6 and 6.5, respectively, meaning they are nearing the bottom of the NHDES threshold, and any further decreases in pH may lead to adverse effects on the biologic community.

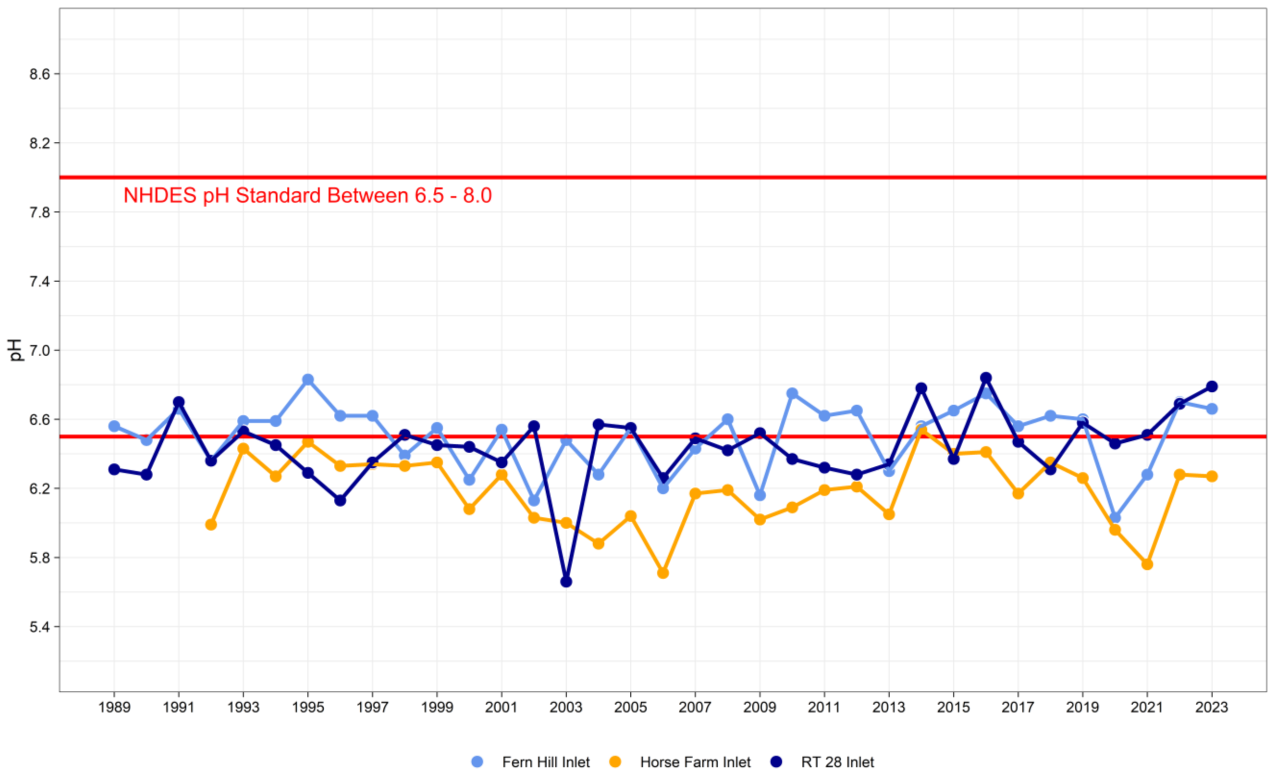


FIGURE 9. Yearly median of monthly medians for pH at the Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28). Values were converted to the concentration of hydrogen ions before being summarized and logarithmically transformed back to the pH scale.

BEACHES *E. COLI* DATA SUMMARY

Beaches on Halfmoon Lake are regularly sampled for fecal contamination using the indicator bacteria *Escherichia coli (E. coli),* to protect the health of swimmers and other users of the beach. Long-term *E. coli* data exists for a few sites along the shoreline, with other sites only having available data from 2012-2018. Fecal contamination in lake beaches may occur from various sources, such as wildlife/waterfowl, recreation, and nearby failing septic systems. NHDES sets the water quality criteria for a designated beach on a Class B waterbody at a geometric mean of 47 MPN/100mL and a single sample criterion of 88 MPN/100mL for *E. coli*. All sites fell below the NHDES geomean standard for all years, except for the left side of Crescent Drive Beach (HALBRNCDBL) in 2018. Despite meeting the NHDES criteria, all long-term sampling sites (Public Beach, Rustic Shores, Boys Camp, and Hollywood Beach) and one other site (Dalton Drive Beach – Left) showed statistically significant increasing trends in *E. coli* levels from 1995 to present or 2012 to present, indicating that fecal contamination has increased slowly over time. Numerous single samples exceedances have occurred since sampling began, including at the Public Beach (2012, 2022), Crescent Drive Beach – Left (2013, 2015, 2017, 2018), Crescent Drive Beach – Right (2013, 2017, 2018), Crescent Drive Beach – Center (2019), New Castle Beach (2017, 2018), Dalton Drive Beach – Left (2017, 2018), and Dalton Drive Beach – Right (2017). Increasing *E. coli* levels can pose a health risk to lake users and are often caused by sources of contamination that also lead to elevated nutrient levels, such as nuisance waterfowl or underperforming/failing septic systems.

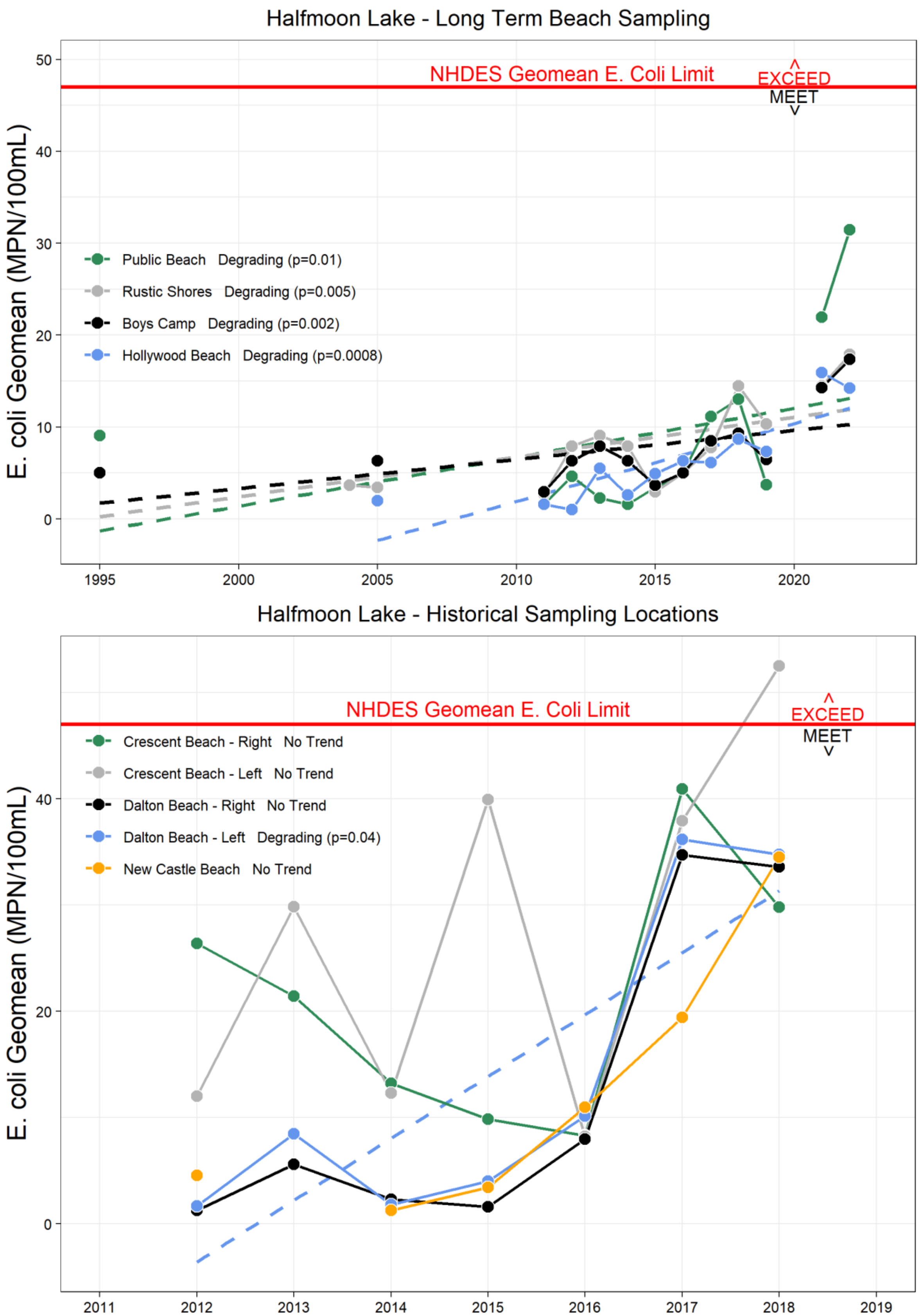


FIGURE 9. [Top] Yearly geomean of *E. coli* data at long-term sampling locations on Halfmoon Lake (1995-2022). [Bottom] Yearly geomean of *E. coli* data at additional sampling locations on Halfmoon Lake (2012-2018). No sampling was conducted in 2020. Statistically significant relationships were found using the Mann-Kendall nonparametric trend test.

TABLE 2. Median values of each water quality parameter for the three long-term stations. Existing water quality data summarized by day, then month, then year using the median statistic to create a recent data summary (2014-2023), historical data summary (1989-2013), and all data summary (1989-2023) Median pH values were determined by converting the value to the concentration of hydrogen ion before summarizing and logarithmically transforming back to the pH scale.

	Parameter	**Recent 10 Year Median**	**Historic Median**	**All Year Median**
Halfmoon Lake – Fern Hill Inlet (HALALTF)	Total Phosphorus (ppb)	30.4	15.0	22.0
	Turbidity (NTU)	1.4	0.8	1.0
	Chloride (ppm)	4.1	-	4.1
	Specific Conductivity (µS/cm)	33.4	39.9	36.9
	pH	6.6	6.5	6.6
Halfmoon Lake – Horse Farm Inlet (HALALTH)	Total Phosphorus (ppb)	29.3	30.3	30.3
	Turbidity (NTU)	4.0	3.9	4.0
	Chloride (ppm)	22.8	-	22.8
	Specific Conductivity (µS/cm)	108.7	81.1	92.9
	pH	6.3	6.2	6.2
Halfmoon Lake – Route 28 Inlet (HALALT28)	Total Phosphorus (ppb)	58.4	53.0	53.0
	Turbidity (NTU)	5.3	4.3	4.7
	Chloride (ppm)	12.7	-	12.7
	Specific Conductivity (µS/cm)	90.5	74.8	78.6
	pH	6.5	6.4	6.4

2024 MONITORING RECOMMENDATIONS

Given the available historic data summarized in this memorandum, the following monitoring efforts are recommended.

NHDES requires dissolved oxygen samples to meet stringent requirements in order to be included in State assessment. These requirements are intended to ensure that dissolved oxygen data is consistent and represents the highest stress periods of the year and time of day (June 1 to September 30 and between 10am and 2pm). Samples also must be collected from the epilimnion (defined as the surface to the first 1 or more *C change in temperature). To meet Class B standards, no more than two or 10% of samples (whichever is greater) that meet these requirements can have a dissolved oxygen concentration less than 5 mg/L. At Halfmoon Lake, 17 dissolved oxygen profiles were collected from the deep spot of Halfmoon Lake in the last 10 years but 10.5 of those 17 profiles were collected prior to 10am. The remaining 6.5 profiles were collected in June, July, or August, with no observations having a dissolved oxygen concentration < 5 mg/L within the epilimnion (though low DO was consistently observed in the hypolimnion). More frequent profile data collection throughout the season, particularly in August and September when stratification can reach its peak, is needed for assessment purposes and to thoroughly assess trophic conditions in the lake.

- If HMLA has access to a dissolved oxygen and temperature meter, we recommend that **profiles are collected biweekly at the deep spot** from May 15th to September 30 between the hours of 10am and 2pm for the 2024 season. Profiles should measure dissolved oxygen and temperature at each meter in the lake profile and be submitted to the Volunteer Lake Monitoring Program.

If additional funding is available, we also recommend the following to better characterize the contribution of phosphorus from internal loading:

- **Discrete grab samples for total phosphorus** collected every 2 meters from the surface (1 meter) to the bottom (8.5 meters) at the deep spot of Halfmoon Lake, for a total of 2-3 times in late July through September.
- **Sediment samples** (top 4 inches) collected from the deep spot of Halfmoon Lake to analyze elemental ratios of phosphorus, aluminum, and iron and characterize biologically labile fractions of phosphorus.

Continue routine monitoring for turbidity, pH, specific conductivity, and chloride at all long-term monitoring locations at a minimum.

Coordinate with NH VLAP to conduct another phytoplankton study to assess these population dynamics and investigate fi the shift from golden-browns and diatoms to cyanobacteria persists.