Technical Memorandum

RECEIVED
6/2/2025
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WATERSHED MANAGEMENT DIVISION

To: Vermont Agency of Natural Resources
From: Keith Pilgrim, Barr Engineering Co.
Subject: NPDES Permit Application for Lake Carmi-Supplemental Information
Date: May 7, 2025
Project: Lake Carmi Alum and Sodium Aluminate Treatment
c: City of Franklin, VT; Robert Evans and Peter Benevento

1 Sediment Inactivation Dosing Plan

Lake Carmi has been designated by the Vermont Agency of Natural Resources as a "Lake in Crisis." This designation led to the commissioning of a study to evaluate the feasibility of using aluminum sulfate (alum) and sodium aluminate to improve the water quality of Lake Carmi (see *Lake Carmi Feasibility Study on the Inactivation of Phosphorus in Lake Bottom Sediments* (Barr Engineering Co., 2024)). The study outcome was the development of a treatment plan designed to inactivate phosphorus in Lake Carmi bottom sediments by applying alum and sodium aluminate (a buffer) via a treatment barge (Figure 1). The two chemicals are added together as a 2 to 1 ratio (2 parts alum and 1 part sodium aluminate by volume) to maintain the pH of the lake in a near-neutral pH condition (e.g., minimize the change in lake pH from existing conditions). Minimal pH change is expected given the large size of the lake and the fact that only approximately 56% of the lake area will be treated. The treatment plan includes treatment of approximately 775 acres of Lake Carmi with alum and sodium aluminate at normal water depth of 19.2 feet (approximately 6 meters) and greater. The proposed treatment area is shown in Figure 2 (which is included at the end of Section 1). Bathymetry shown on Figure 2 was collected when Lake Carmi water levels were approximately 0.8 feet above normal water level (NWL). As a result, a lake depth of 20 feet on Figure 2 corresponds to a depth of 19.2 feet when Lake Carmi is at NWL.

Table 1 identifies the proposed alum and sodium aluminate application quantities that were recommended in the study. The treatment volume per acre is 532 gallons/acre of alum and 266 gallons/acre of sodium aluminate. The proposed treatment plan includes a triple-pass approach: one third of the total dose per acre (177.3 gallons/acre of alum and 88.7 gallons/acre of sodium aluminate) will be applied on a given treatment day. The contractor will determine how many acres can be treated in a given day. It is expected that the entire treatment will be conducted over three to four weeks.

The contractor will be required to treat no more than 177.3 gallons/acre of alum and 88.7 gallons/acre of sodium aluminate for a given area on one day (day 1). For the subsequent day, the contractor will be required to treat a different area (day 2). They can treat the day 1 treatment area on day 3 but they are not required to. Hence, 24 hours of no treatment will be required between treatment of the same area.

Table 1 Lake Carmi Alum and Sodium Aluminate Estimated Dose

Dose (g Al/m^2)	Total Alum[1] (gallons)	Total Sodium Aluminate[2] (gallons)	Total Mass of Aluminum Applied (kg)	Approximate Treatment Days
66.6	412,183	206,092	208,877	24

1. Gallons of alum calculated using a product density of 11.2 pounds per gallon and 4.4% aluminum by weight.
2. Gallons of sodium aluminate calculated using a product density of 12.1 pounds per gallon and 10.4% aluminum by weight.

Treatment is planned for the fall of 2025 (approximately mid-September to October). Fall treatment has several key benefits:

1. Avoidance of fish spawning periods.
2. Unencumbered use of Lake Carmi State Park as a staging area as it is closed in mid-September. The staging area is where alum and sodium aluminate are delivered via tanker truck and where the treatment barge is filled with alum and sodium aluminate. Use of Lake Carmi State Park in the fall of 2025 will reduce exposure to State Park campers, fishermen, and other recreators that use the boat dock at the State Park.
3. Recreational boating is reduced in the fall and there will be significantly reduced potential for public interaction with the treatment barge when it is conducting treatment on Lake Carmi.
4. Treatment in fall after intense summer algal blooms have ceased improves treatment efficiency and allows for more even distribution of the alum and sodium aluminate.

Figure 1 Example of a barge used to apply alum and sodium aluminate.

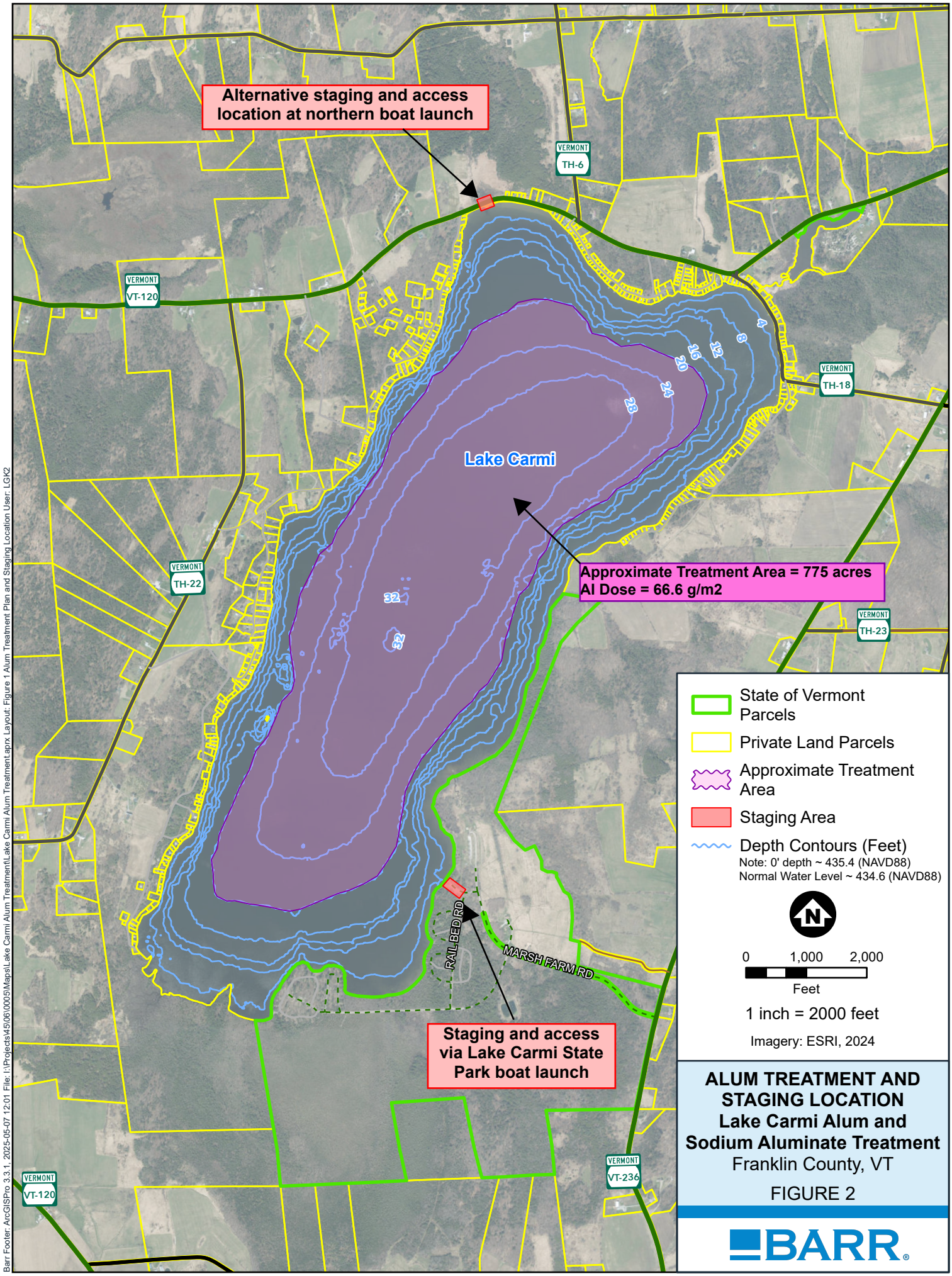
Spring treatment is not recommended to avoid conflicting with the fishing opener, to reduce potential adverse effects to spawning and newly hatched fish, and to avoid complications with other recreators. Summer treatment is also not recommended to avoid disrupting recreation and to avoid treating the lake during more intense algal blooms which can lead to treatment inefficiencies and uneven distribution of the alum and sodium aluminate. As a result, fall treatment is preferred. Fall treatment will mitigate logistical and safety issues while providing technical benefits as well.

As shown on Figure 2, the preferred access and staging location is at the public boat launch at Lake Carmi State Park because it provides clear access to Lake Carmi, has ample surface area for material storage and staging, and it is not in a high traffic area during the fall. An alternative location is on the north end of the Lake Carmi near the boat launch and Highway 120 (also shown on Figure 2). The location on the north end of the lake is less preferable because of its smaller footprint and it's located immediately adjacent to a 45-mph highway.

It will be the responsibility of the awarded contractor to:

- safely furnish, deliver, and store the liquid alum and sodium aluminate within the designated staging area;
- have a spill prevention and containment plan;
- follow all local and federal storage and spill prevention regulations;
- obtain any additional and necessary permits;
- maintain and protect access routes, the boat launch area, and any roads used for access, storage, or staging; and
- restore any areas impacted by the work to existing conditions.

Barr Engineering Co. (Barr) has entered into an Engineering Services Agreement with the Town of Franklin (Town) (the project owner) to provide design, permitting, and construction support for the alum and sodium aluminate treatment of Lake Carmi. Barr will develop bid documents, provide recommendations for contractor selection, and assist the Town with contracting with the awarded treatment contractor. Barr will also facilitate communication between the Town, the Lake Carmi Campers Association, the State, and the selected contractor during all stages of the treatment.



ALUM TREATMENT AND STAGING LOCATION
Lake Carmi Alum and Sodium Aluminate Treatment
Franklin County, VT

FIGURE 2

BARR

2 Effect of Treatment on In-Lake Aluminum Concentrations

The Environmental Protection Agency (EPA) Aluminum Criteria Calculator was used by the Vermont Agency of Natural Resources to calculate the aluminum criteria for Lake Carmi based on the pH, hardness, and dissolved organic carbon (DOC) measurements currently collected from the lake from September through November (US EPA, 2018; Vermont, 2018). Table 2 summarizes the acute (Criterion Maximum Concentration or CMC) and chronic (Criterion Continuous Concentration or CCC) aluminum criteria calculated by the Vermont Agency of Natural Resources.

Table 2 Aluminum Criteria Calculated for Lake Carmi

CMC Acute Criterion	CCC Chronic Criterion
1.6 mg/L (1-hour average)	0.59 mg/L (4-day average)

Calculations were performed to estimate the Lake Carmi aluminum concentrations during alum and sodium aluminate application for comparison to the acute and chronic criteria (Table 2). For this analysis, the area and volume of lake water treated in one day are considered to be the "treatment zone" for that day. Since the total application of 66.6 g Al/m^2 will be applied using a triple-pass approach, it is assumed that it will take 24 working days (and approximately 28 total days or 4 weeks) to apply the total volume of alum and sodium aluminate (i.e., 4 weeks of treatment, treatment conducted 6 days a week, 12 hours of application time each day, and one-hour break at mid-day is assumed). The actual time to conduct the treatment will depend on weather, on-time delivery of the alum and sodium aluminate, contractor equipment capabilities, and other factors. Regardless, calculations of the maximum, average, and final aluminum concentration during a treatment day are based upon the following:

- Average daily treated area: 96.89 acres (392,090.4 m^2)
- Average treated volume per day: 3,043,315 m^3
- Average mass of aluminum applied daily: 8,703 kg
- Assumed duration of alum and sodium aluminate application: 12 hours/day (5 hours of application, 1 hour break, followed by 7 hours of application)

Conceptually, as the treatment barge travels across the daily treatment zone and delivers liquid alum and sodium aluminate below the lake surface (tubes from the barge deliver the chemicals subsurface), floc will form instantaneously and start to settle as soon as the alum and sodium aluminate contact the lake water. Because treatment is planned for fall, Lake Carmi will be completely mixed (see Figure 3 at the end of this section for a plot showing a temperature profile from September 18, 2018) and it may be expected that the floc will readily mix and distribute throughout the water column. During treatment days, the floc will be at different stages of settling within the treatment zone. Based on a literature-reported aluminum floc settling rate (Gorczyca, B. and J. Ganczarczyk, 2001), it can be expected that the aluminum floc ($Al(OH)_3$) will settle to the bottom of Lake Carmi at a rate of approximately 8.2 feet/hour (2.5 meters/hour).

Using the above application and settling rates, the lake volume for the treatment zone, and the proposed total dose of 66.6 g Al/m^2, the average concentration in the treatment zone water column was calculated for each hour of a 24-hour period as shown in Figure 4 at the end of this section. Over a 24-hour period, the average and one-hour maximum aluminum concentrations in the treatment zone are approximately 0.31 and 0.59 mg/L, respectively (Table 3). These concentrations are below the calculated acute (1-hour) and would also meet the chronic (4-day average) criteria. The average residual aluminum concentration within the treatment zone 24 hours after the start of application is calculated to be less than 0.01 mg/L. In

essence, the treatment zone, and correspondingly the entire lake, should "reset" after each treatment day with respect to in-lake total aluminum concentration.

Table 3 Calculated concentration of aluminum in the daily treatment zone.

Condition	Predicted Aluminum Concentration (mg/L)	
	Treatment Zone on Day of Application	*Full Lake*
Maximum 1-Hour Concentration	0.59	0.057
Average Concentration	0.31	0.030

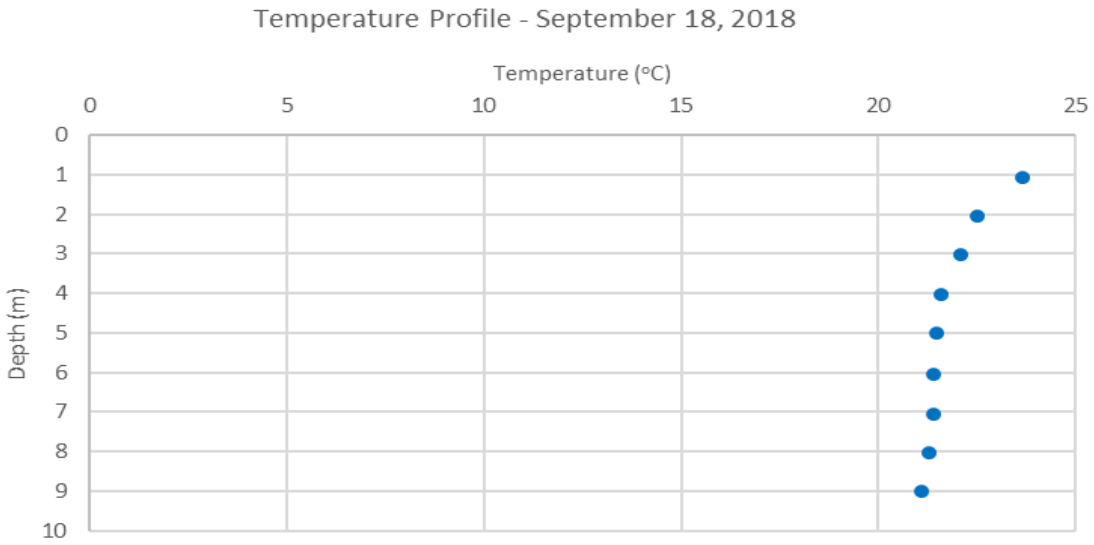


Figure 3 Temperature Profile for Lake Carmi measured at mid-lake monitoring location on September 18, 2018

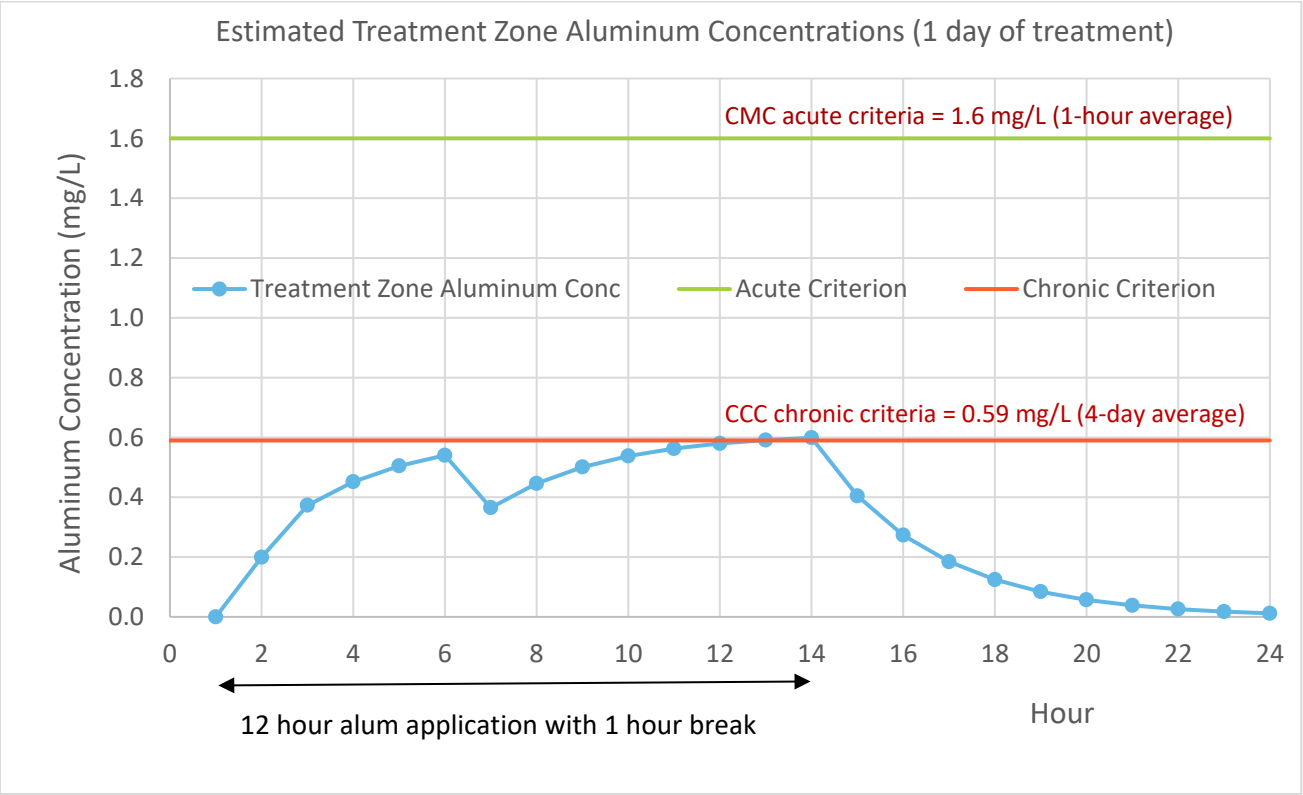


Figure 4 Estimated treatment zone aluminum concentrations as compared to acute and chronic criterion

3 Monitoring Plan

The final monitoring requirements will be developed by the Vermont Agency of Natural Resources as part of the NPDES permit but it is expected that it will be similar to that described below. The selected contractor will conduct the monitoring and reporting.

Potential parameters, monitoring frequency, and locations are summarized in Table 4. Barr will review monitoring reports provided by the contractor for compliance with the final NPDES permit monitoring requirements. It's anticipated that the contractor will be required to provide daily monitoring reports for field measurable parameters while monitoring data that requires laboratory analysis will be provided once results are published by the laboratory (note, turn-around time for aluminum analysis is subject to vary but anticipated to be approximately 2 weeks). The contractor will be required to provide immediate (same day) notification to the Owner and Barr for any exceedances. This includes notification if the pH violates permit conditions for the averaging period specified in the NPDES permit. If the pH falls outside specified permit conditions the contractor will be required to stop the treatment. Resumption of treatment would occur in accordance with NPDES permit conditions (if specified) but it is anticipated that resumption would occur after collection of pH measurements and a determination that it is safe to continue treatment.

Periodic construction observation and spot-checking of water quality monitoring during will also likely be completed by Barr's Resident Project Representative (RPR) and possibly volunteers of the Lake Carmi Campers Association during construction. .

Table 4 Example Monitoring Plan

Parameter	Location	Minimum Frequency	Depth(s)
Alum Discharge (gallons/day)	Each treatment zone	Daily total	n/a
Sodium Aluminate Discharge (gallons/day)	Each treatment zone	Daily total	n/a
GPS Tracking of Application	Treatment Zone	Continuous during treatment	n/a
Discharge Flow Measurement Accuracy	n/a	Weekly	n/a
In-situ pH, temperature, dissolved oxygen, turbidity, hardness, total aluminum	Center of Lake Carmi	Prior to the start of treatment	1 meter below surface, mid-depth, and 1 meter above sediment layer
In-Situ pH, turbidity, and total aluminum	Centroid of Treatment Zone	Daily, before treatment	1 meter below lake surface
Total Aluminum	Centroid of Treatment Zone	Daily, at end of treatment day and the daily, the next morning for the previous day's treatment zone	Composite of samples collected every meter starting at 1 meter below surface and ending 1 meter above sediment layer
In-situ pH, temperature, dissolved oxygen, turbidity, hardness, total aluminum	Centroid of Treatment Zone	Daily, at end of treatment day	1 meter below lake surface and 1 meter above sediment layer
Floc Formation (Visual)	Throughout Treatment Zone	At end of treatment each day in the treatment zone and following morning in the treatment zone completed the previous day	Qualitative observation from surface with photo record
Adverse Aquatic Impacts and Water Quality Violations (Visual)	General lake reconnaissance	Daily during treatment	Qualitative observation from surface for signs that the treatment has impacted biota or violated Vermont narrative criteria

Notes:
1. Record GPS location of all in-situ and water quality sample monitoring locations.
2. Photo log of qualitative observations shall be included in daily/weekly reporting.

4 Conclusions

The supplemental data provided in this technical memorandum supports the conclusion that treatment of Lake Carmi with alum and sodium aluminate can be conducted safely without impacts to aquatic life. The use of alum (an acid) and sodium aluminate (a base) together is expected to maintain pH in the near-neutral range in the localized treatment zone (pH can be expected to rapidly equilibrate with the greater Lake Carmi area and pH is expected to be largely unchanged compared to pre-treatment conditions) and monitoring will be used to confirm this expectation.

Lake Carmi is a large lake. As a result, the treatment area addressed each day will be a relatively small fraction of the entire lake. The proposed treatment will be conducted at lake depths of 19.1 feet (6.0 m) or greater. As a result, fish in deeper water will be able to readily avoid the treatment zone and small and young-of-the-year fish that frequent the littoral zone will not be directly exposed to the treatment floc. Further, it is expected that 24 hours after each treatment day all aluminum floc will have settled. Hence, there will be a reset to near zero with respect to average aluminum concentrations with each day of treatment (aluminum solubility is less than 0.1 mg/L in natural lake water near pH 7—see Pilgrim and Brezonik, 2005).

On average, for a given treatment day and within the daily treatment zone, it can be expected that the aluminum concentration will range from 0.01 and 0.59 mg/L. This concentration is below the acute criterion of 1.6 mg/L. The average and maximum lake-wide aluminum concentration is expected to be approximately 0.03 mg/L and 0.057 mg/L during the treatment, respectively, which is below the 4-day average chronic criterion of 0.59 mg/L.

The treatment will be managed through a combination of pre-treatment communication to adjacent property owners, on-site management of staging and work areas by the selected treatment contractor, performance monitoring and reporting by the contractor during monitoring, and review of monitoring data plus monitoring checks by Barr during field visits.

Expedited review and approval of this permit application will facilitate the execution of the treatment during the fall of 2025. Fall is the preferred treatment period as there will be greatly reduced complications with respect to the public use of Lake Carmi as well as reduced potential to impact fisheries. In addition, treatment in fall of 2025 is preferred to mitigate water quality impacts prior to summer 2026.

5 References

Barr Engineering Co. (2024). *Lake Carmi Feasibility Study on the Inactivation of Phosphorus in Lake Bottom Sediments.* Prepared for the Vermont Department of Environmental Conservation.

Gorczyca, B. and J. Ganczarczyk. (2001). Fractal Analysis of Pore Distributions in Alum Coagulation and Activated Sludge Flocs. *Water Quality Research Journal of Canada, 36*(10.2166/wqrj.2001.036.).

US EPA. (2018). *Aluminum Criteria Calculator*. Retrieved from Aquatic Life Criteria - Aluminum: https://www.epa.gov/wqc/aquatic-life-criteria-aluminum

Vermont (2018). *Implementation Procedure for the 2018 Aquatic Life Water Quality Criteria .*