PLM
LAKE & LAND MANAGEMENT CORP

BEAR LAKE

LAKE MANAGEMENT PLAN

2026

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Prepared for:
Bear Lake Lake Board (BLLB)

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Executive Summary

Bear Lake is a 455-acre inland lake located in Muskegon County, Michigan, within the Muskegon River watershed. The lake is an important recreational and ecological resource that supports boating, fishing, paddling, swimming, and wildlife habitat while serving as a valued natural feature for the surrounding community. As a developed urban lake receiving water from Bear Creek, Fenner's Ditch, groundwater, direct stormwater runoff, and precipitation, Bear Lake is strongly influenced by both watershed activities and in-lake ecological processes.

Long-term monitoring conducted between 2022 and 2025 indicates that Bear Lake continues to function as a eutrophic system characterized by elevated phosphorus concentrations, recurring algal blooms, reduced water clarity, and seasonal oxygen depletion within the deepest basin. Although water quality remains impaired, the monitoring data demonstrate encouraging progress toward reducing external phosphorus loading. Surface phosphorus concentrations have declined over the monitoring period, reflecting the benefits of previous watershed restoration efforts, particularly within the Bear Creek sub watershed. At the same time, continued monitoring has identified Fenner's Ditch and several urban stormwater outfalls as localized nutrient sources that represent the highest priorities for future watershed management.

The monitoring program also demonstrates that internal phosphorus loading has become an increasingly important factor influencing water quality. Temporary summer stratification within the deep basin results in periods of low dissolved oxygen that promote the release of phosphorus from bottom sediments, providing an additional nutrient source capable of sustaining algal productivity. While reductions in external nutrient loading have been documented, improvements in chlorophyll-*a* concentrations and water transparency have been more gradual, indicating that the lake's biological response continues to be moderated by internal nutrient cycling, seasonal weather conditions, and other ecological processes.

Recognizing that lake restoration is a long-term process, the plan establishes performance indicators, a comprehensive monitoring program, and a five-year adaptive management roadmap to guide future management decisions. Continued evaluation of phosphorus concentrations, algal productivity, water clarity, dissolved oxygen dynamics, and watershed nutrient inputs will allow restoration activities to be refined over time while ensuring that management efforts remain focused on the processes most limiting water quality.

Collectively, the findings presented in this plan indicate that Bear Lake is transitioning from a system dominated by widespread watershed nutrient inputs toward one in which localized external sources and internal phosphorus recycling have become the principal management challenges. Building upon the progress already achieved through watershed restoration while addressing these remaining nutrient sources provides the greatest opportunity for improving water quality, protecting aquatic habitat, and enhancing the recreational and ecological value of Bear Lake for future generations.

Four-Year Condition Summary

Annual surface total phosphorus averaged 37.6 µg/L over the four-year period, remaining above the 30 µg/L management target in every year. Surface phosphorus declined by approximately 14% from 2022 to 2025, but increased after the 2023 low. Chlorophyll-a averaged 28.0 µg/L—nearly three times the desirable benchmark—and water clarity remained close to 1 meter. Bottom-water phosphorus was consistently higher than surface phosphorus, with an exceptionally large vertical difference in 2023, supporting the need for targeted evaluation of internal phosphorus loading.

Indicator	2022	2025	Four-year mean	Interpretation
Surface TP (µg/L)	45.8	39.2	37.6	Above 30 µg/L target
Bottom TP (µg/L)	51.2	47.8	59.5	Elevated; strong 2023 deep-water spike
Chlorophyll-a (µg/L)	31.9	26.9	28.0	Persistently eutrophic
Secchi depth (m)	1.12	0.96	1.00	Stable to slightly lower clarity
Bottom DO (mg/L)	6.8	7.16	7.22	Annual means mask short-term deep hypoxia

Primary Management Direction

- Complete a lake-wide sediment phosphorus assessment and develop a phosphorus inventory before selecting or scaling future in-lake mitigation.
- Continue monthly growing-season monitoring, with expanded dissolved oxygen profiling and continuous logging at the deep basin.
- Move Fenner's Ditch from investigation toward a prioritized restoration strategy supported by loading estimates and before-and-after monitoring.
- Rank stormwater outfalls by nutrient and bacteria loading and implement source controls where the greatest benefit is expected.
- Continue selective invasive plant management while protecting native plant diversity, fish habitat, and shoreline function.
- Use a five-year adaptive framework in which monitoring results determine the timing, scale, and location of future restoration actions.

1. Purpose, Scope, and Management Philosophy

Purpose

The purpose of this Lake Management Plan is to provide a comprehensive, science-based framework for the long-term management and restoration of Bear Lake. The plan integrates current lake conditions, synthesizes water quality, biological, and watershed monitoring data collected between 2022 and 2025, evaluates the factors influencing lake function, and identifies priority management actions to improve and protect water quality. The plan also establishes an adaptive management framework that guides restoration activities, monitoring efforts, and management decisions through 2031, ensuring that future actions remain responsive to new scientific information and measurable environmental outcomes.

Integrated and Adaptive Management

Effective management of Bear Lake requires an integrated approach that recognizes the interaction between watershed processes and in-lake ecological function. External nutrient loading from tributaries, stormwater runoff, and surrounding land use influences water quality, while internal nutrient cycling and sediment phosphorus release affect biological productivity within the lake. Consequently, successful restoration depends on implementing complementary watershed and in-lake management strategies rather than relying on a single restoration technique.

The management framework presented in this plan integrates watershed nutrient reduction, targeted in-lake restoration, aquatic vegetation management, and long-term monitoring into a coordinated adaptive management program. Monitoring data are used to evaluate management effectiveness, quantify environmental response, and identify emerging resource concerns. This iterative process allows management priorities to be adjusted as new information becomes available, ensuring that restoration efforts remain scientifically supported, environmentally effective, and focused on achieving measurable improvements in water quality and ecosystem function.

1. Monitor	2. Evaluate	3. Prioritize	4. Implement	5. Measure	6. Adjust
Collect lake and watershed data	Interpret trends and sources	Select highest-value actions	Complete targeted work	Compare outcomes to objectives	Refine the program

2. Bear Lake Setting and Uses

Bear Lake is a developed inland lake located in Muskegon County, Michigan, within the Muskegon River watershed. The lake receives inflow from Bear Creek, Fenner's Ditch, direct stormwater runoff, groundwater, and precipitation before discharging downstream toward Muskegon Lake. The watershed is characterized by a mixture of residential, commercial, industrial, transportation, and remaining natural areas, resulting in multiple pathways for water, nutrients, sediments, and other pollutants to enter the lake. As a result, lake conditions respond rapidly to precipitation, watershed runoff, seasonal biological productivity, and short-term thermal stratification.

Bear Lake provides important ecological, recreational, and aesthetic benefits to the surrounding community. The lake supports boating, fishing, swimming, paddling, and wildlife observation, while also providing habitat for warmwater fisheries, waterfowl, amphibians, aquatic invertebrates, and diverse native aquatic plant communities. Native aquatic vegetation, shoreline wetlands, and submerged habitat contribute to ecosystem function by stabilizing sediments, cycling nutrients, supporting aquatic food webs, and improving habitat complexity. Accordingly, management activities should seek to improve water quality while maintaining the ecological integrity and habitat diversity that support these resources.

Long-term monitoring indicates that water quality is influenced by several interacting stressors associated with both watershed processes and in-lake nutrient cycling. External nutrient and sediment loading from tributaries, stormwater runoff, and developed portions of the watershed continue to contribute phosphorus and suspended solids to the lake. In addition, phosphorus that has accumulated within depositional sediments over several decades is seasonally released under low dissolved oxygen conditions, providing an internal source of nutrients that sustains algal productivity during the growing season. These nutrient sources contribute to recurring cyanobacterial blooms, elevated chlorophyll-*a* concentrations, and reduced water transparency. Additional management challenges include invasive aquatic plant species that can reduce native plant diversity and interfere with recreational use, as well as localized stormwater discharges that have been identified as potential sources of bacteria and other urban pollutants.

Collectively, these factors demonstrate that the condition of Bear Lake is controlled by the interaction of watershed-derived nutrient inputs, internal phosphorus cycling, biological productivity, and land-use influences. Consequently, long-term improvement will require an integrated management strategy that addresses both external and internal nutrient sources while protecting the ecological functions that make Bear Lake a valuable natural resource.

3. Current Lake Condition

3.1 Water Quality

Water quality monitoring conducted between 2022 and 2025 indicates that Bear Lake continues to exhibit characteristics consistent with a eutrophic lake. Elevated nutrient concentrations, high biological productivity, and reduced water transparency remain the primary indicators of the lake's trophic condition. Although monitoring demonstrates encouraging reductions in watershed-derived phosphorus loading, overall lake response has been more gradual than anticipated, reflecting the influence of multiple interacting physical, chemical, and biological processes.

Surface total phosphorus concentrations continue to exceed the Bear Lake Total Maximum Daily Load (TMDL) target during much of the growing season, providing sufficient nutrient availability to support seasonal algal production. Chlorophyll-*a* concentrations remain elevated throughout spring, summer, and fall, indicating that algal biomass continues to limit water quality and recreational aesthetics. Correspondingly, Secchi disk transparency has remained relatively stable over the monitoring period, averaging approximately one meter, which is characteristic of eutrophic systems where algal biomass is the primary factor controlling water clarity.

Although Bear Lake is relatively shallow and frequently mixed by wind, temporary thermal stratification consistently develops within the deepest basin during periods of prolonged warm weather. These short-lived stratification events reduce dissolved oxygen concentrations near the sediment-water interface, creating conditions favorable for the release of phosphorus from bottom sediments. The resulting internal phosphorus loading supplements external nutrient inputs and contributes to continued algal productivity during late summer and early fall.

3.2 Aquatic Vegetation and Habitat

Aquatic vegetation surveys indicate that Bear Lake supports a diverse and ecologically important native plant community that contributes significantly to overall lake health. Native aquatic plants provide critical ecosystem services, including sediment stabilization, nutrient uptake, shoreline protection, habitat for fish and aquatic invertebrates, and spawning and nursery areas for numerous aquatic species. Maintaining these functions is essential to preserving the ecological integrity of the lake while supporting recreational uses.

Annual vegetation management has successfully maintained invasive aquatic plant populations at levels that minimize interference with boating, fishing, and other recreational activities while preserving the overall diversity of native vegetation. Eurasian watermilfoil and Curly-leaf pondweed remain manageable under the current management program, while Starry stonewort continues to be present within the lake and warrants continued surveillance because of its capacity for rapid expansion and dense colony formation.

The native plant community, including pondweeds (*Potamogeton* spp.), water lilies (*Nymphaea* spp.), coontail (*Ceratophyllum demersum*), Chara, and other beneficial species, continues to provide valuable habitat for fish, amphibians, waterfowl, and aquatic macroinvertebrates. Consequently, aquatic vegetation management should remain selective and targeted, emphasizing the preservation of native communities while controlling invasive species where they impair recreational use or threaten ecological function.

3.3 Tributaries and Stormwater

Recent watershed investigations have substantially improved the understanding of nutrient transport pathways and external loading sources within the Bear Lake watershed. Monitoring conducted between 2022 and 2025 demonstrates that tributaries and stormwater infrastructure contribute differently to the lake's nutrient budget, allowing restoration efforts to become increasingly focused on the most influential sources.

Bear Creek generally contributes lower-phosphorus water to the lake and reflects the measurable benefits of upstream watershed restoration projects, including the restoration of former agricultural and wetland areas. These findings indicate that previous investments in watershed restoration have reduced nutrient loading from portions of the watershed and have established an important foundation for continued water quality improvement.

In contrast, Fenner's Ditch remains one of the most significant localized sources of phosphorus entering Bear Lake. Elevated phosphorus concentrations have been consistently documented during both routine monitoring and storm events, indicating that the ditch continues to transport nutrient-rich runoff to the lake. Sediment investigations further suggest that ditch sediments contain biologically available phosphorus capable of being remobilized during periods of increased flow, thereby extending phosphorus delivery beyond individual runoff events.

Stormwater investigations initiated in 2025 further identified direct urban runoff pathways that contribute nutrients, suspended solids, and microbial contaminants to the lake. Sampling documented elevated *Escherichia coli* (*E. coli*) concentrations at multiple stormwater outfalls, with several locations exceeding recreational water quality criteria. These findings indicate the potential influence of illicit connections, failing sanitary infrastructure, wildlife, or other localized contamination sources and warrant additional source tracking in coordination with municipal stormwater managers.

3.4 Overall Condition

The comprehensive monitoring program completed between 2022 and 2025 demonstrates that Bear Lake is undergoing a measurable transition in response to long-term watershed restoration and integrated lake management. Previous restoration efforts have successfully reduced phosphorus loading from portions of the watershed, particularly within the Bear Creek sub watershed, and these improvements are beginning to be reflected in lake water quality. However, the ecological response has progressed more slowly than reductions in external nutrient loading, reflecting the continued influence of internal phosphorus cycling and localized nutrient sources.

Current conditions indicate that Bear Lake remains a eutrophic system characterized by elevated phosphorus concentrations, high algal biomass, reduced water transparency, and seasonal oxygen depletion within the deepest basin. These conditions continue to limit recreational aesthetics and contribute to the periodic release of phosphorus from bottom sediments during summer stratification. Consequently, the factors controlling lake water quality have shifted from broad watershed-wide nutrient loading toward a combination of localized external sources and internal nutrient recycling.

Overall, the monitoring record suggests that Bear Lake is best characterized as stable with measurable improvements in watershed conditions and a gradual positive trajectory toward improved water quality. Continued progress will depend on maintaining watershed restoration gains while implementing targeted management strategies that address remaining phosphorus sources, including Fenner's Ditch, urban stormwater runoff, and internal phosphorus loading.

4. Data Analytics: 2022–2025

The following analysis uses the annual summary values compiled from the 2022–2025 Grand Valley - Annis Water Resource Institute's (AWRI) reports. Because most values are seasonal or annual means rather than individual observations, the analytics are intended to describe direction, magnitude, variability, and management relevance.

4.1 Total Phosphorus

Surface total phosphorus decreased from 45.8 µg/L in 2022 to 39.2 µg/L in 2025, a 14.4% reduction. However, the four-year mean was 37.6 µg/L, and all annual means were at or above the 30 µg/L target. The lowest annual surface mean occurred in 2023 (30.25 µg/L), followed by increases in 2024 and 2025. This pattern suggests progress relative to 2022, but not a sustained decline.

Bottom-water phosphorus averaged 59.5 µg/L and exceeded surface phosphorus every year. The 2023 bottom-water mean of 90.6 µg/L was nearly three times the surface mean. This is the strongest annual indication of deep-water phosphorus accumulation in the four-year record.

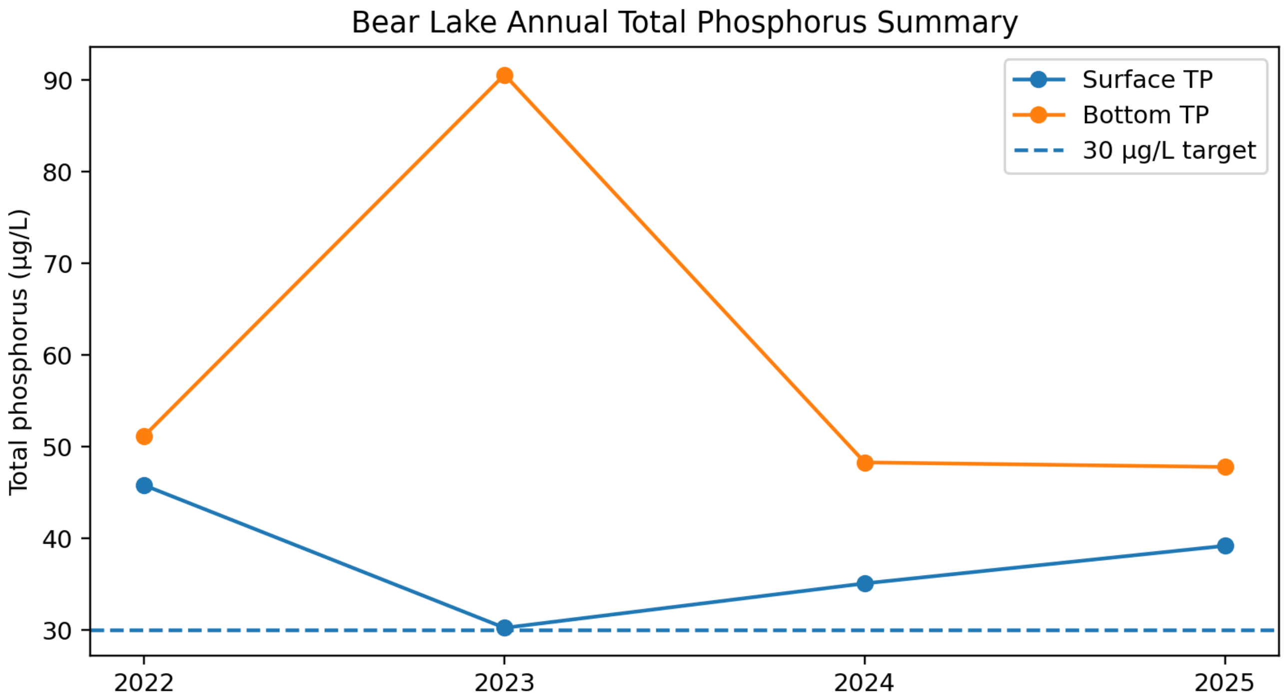

Figure 4-1. Annual surface and bottom total phosphorus compared with the 30 µg/L surface-water target.

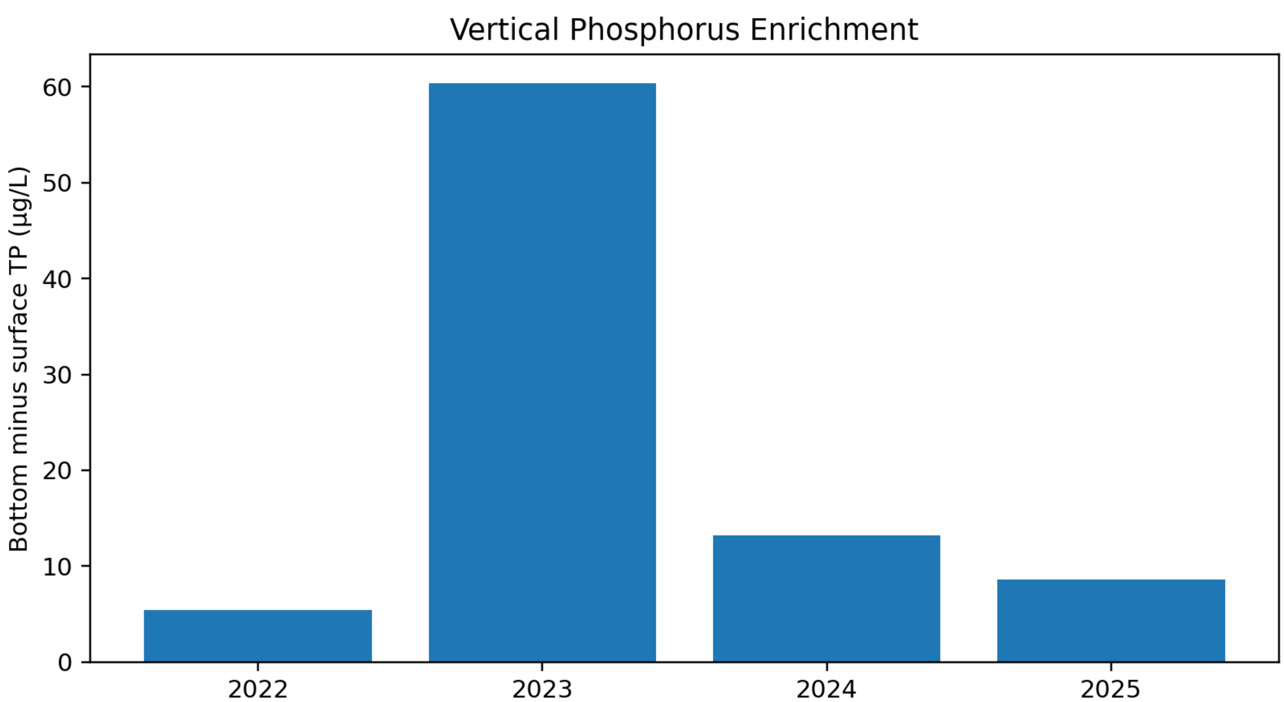

Figure 4-2. Annual vertical phosphorus enrichment, calculated as bottom TP minus surface TP.

4.2 Algal Biomass and Water Clarity

Surface chlorophyll-a averaged 28.0 µg/L and exceeded the 10 µg/L benchmark by 129% to 219% each year. Chlorophyll-a declined by 15.7% from 2022 to 2025 but remained firmly within eutrophic conditions. The four annual values track surface phosphorus reasonably well (Pearson r ≈ 0.78), although the dataset is too short for formal inference.

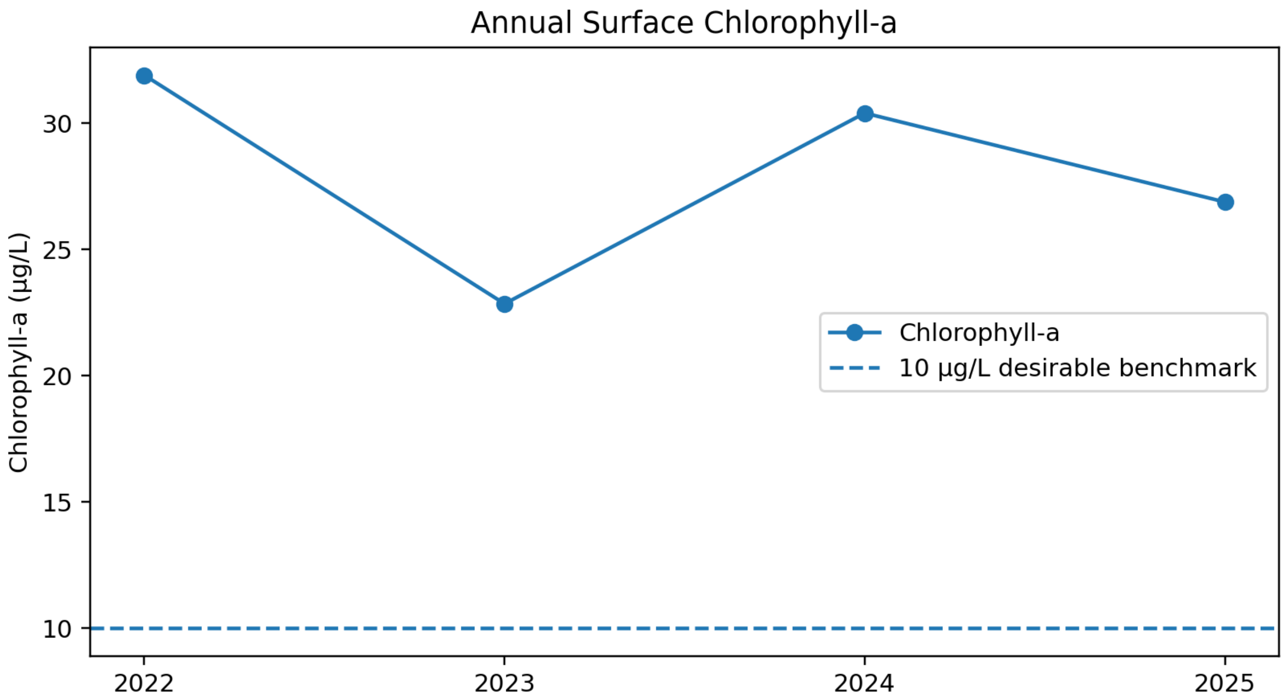

Figure 4-3. Annual surface chlorophyll-a compared with the 10 µg/L desirable benchmark.

Water clarity, as measured by Secchi depth, provides an integrated indicator of lake condition by reflecting the combined effects of algal biomass, suspended sediments, dissolved organic matter, and light penetration through the water column. Because Bear Lake is a eutrophic system, Secchi transparency is influenced primarily by phytoplankton abundance, although weather conditions, wind-induced sediment resuspension, and seasonal nutrient cycling also contribute to year-to-year variability.

Between 2022 and 2025, annual mean Secchi depth averaged 1.00 meters, indicating relatively poor water transparency consistent with eutrophic lake conditions. Annual average transparency declined from 1.12 meters in 2022 to 0.96 meters in 2025, representing an overall reduction of approximately 14.3 percent over the four-year monitoring period. Despite this gradual decline, year-to-year variability remained relatively modest, suggesting that water clarity has remained generally stable within a narrow range rather than exhibiting substantial interannual fluctuations.

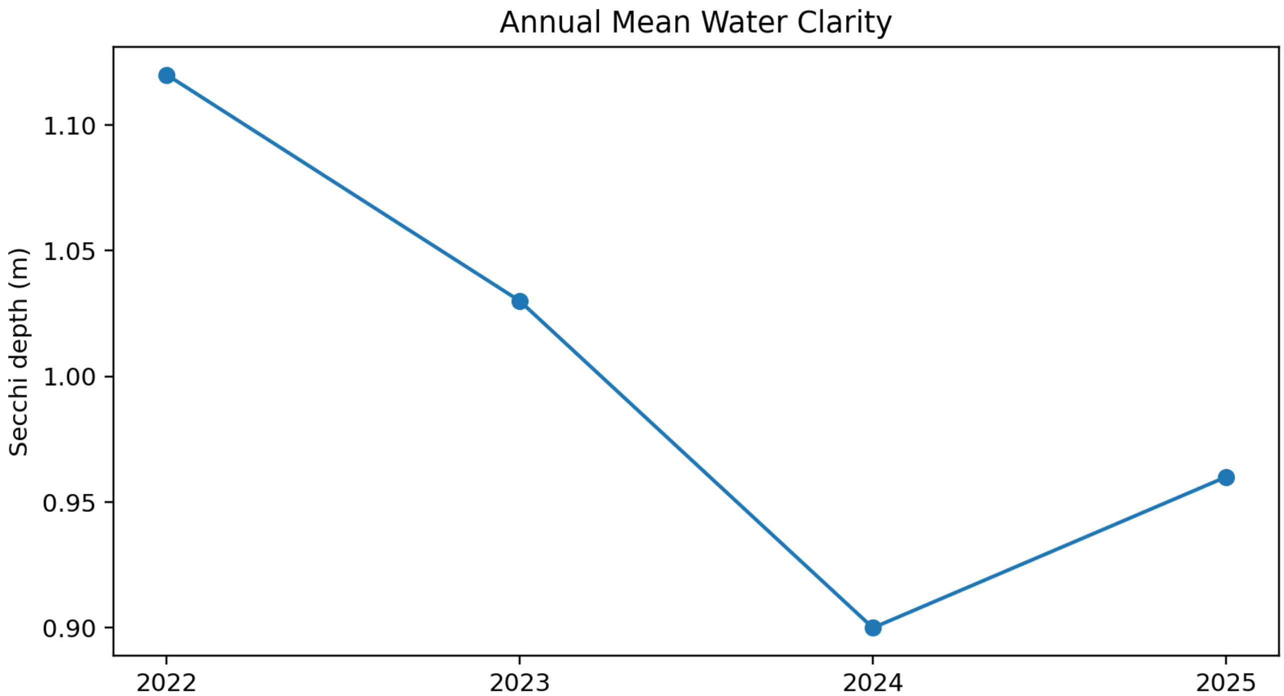

Figure 4-4. Annual mean Secchi transparency.

4.3 Dissolved Oxygen and Internal Loading

Dissolved oxygen (DO) is one of the most informative indicators of lake function because it directly influences aquatic habitat, nutrient cycling, and sediment chemistry. Monitoring conducted between 2022 and 2025 demonstrates that dissolved oxygen conditions within Bear Lake exhibit a consistent seasonal pattern. During spring, the water column is generally well mixed, resulting in adequate oxygen concentrations throughout the lake. As water temperatures increase during summer, however, temporary thermal stratification develops within the deepest basin. Although Bear Lake is relatively shallow and experiences frequent wind-induced mixing, these short-lived periods of stratification are sufficient to isolate bottom waters from atmospheric oxygen replenishment, allowing dissolved oxygen concentrations near the sediment-water interface to decline rapidly.

Annual mean bottom dissolved oxygen concentrations ranged from approximately 6.8 to 8.0 mg/L over the four-year monitoring period. While these annual averages suggest generally suitable oxygen conditions, they mask brief but ecologically significant periods of hypoxia that occur during the summer months. For example, monitoring completed in 2024 documented a minimum bottom dissolved oxygen concentration of approximately 0.1 mg/L at the deep basin monitoring site (Site 1), indicating nearly anoxic conditions. These low-oxygen events are not adequately represented by seasonal or annual averages but are critical because they initiate chemical changes at the sediment-water interface that promote the release of phosphorus from bottom sediments.

Under oxygenated conditions, much of the phosphorus contained within lake sediments remains bound to iron and other mineral compounds. As dissolved oxygen concentrations decline, these chemical bonds become unstable, allowing phosphorus to be released into the overlying water where it again becomes biologically available. This process, commonly referred to as internal phosphorus loading, supplements external nutrient inputs and provides an additional source of phosphorus capable of sustaining algal growth during late summer and early fall. Consequently, even as watershed restoration efforts reduce external phosphorus loading, internally recycled phosphorus may continue to support nuisance algal production and delay measurable improvements in water quality.

The dissolved oxygen record indicates that internal phosphorus loading is likely concentrated within the deepest depositional areas of Bear Lake rather than occurring uniformly throughout the lake. This observation is consistent with the vertical phosphorus gradients observed during water quality monitoring. The data suggest that the lake is transitioning from a system primarily influenced by watershed-derived nutrient inputs toward one in which internal nutrient recycling exerts an increasingly important influence on seasonal water quality.

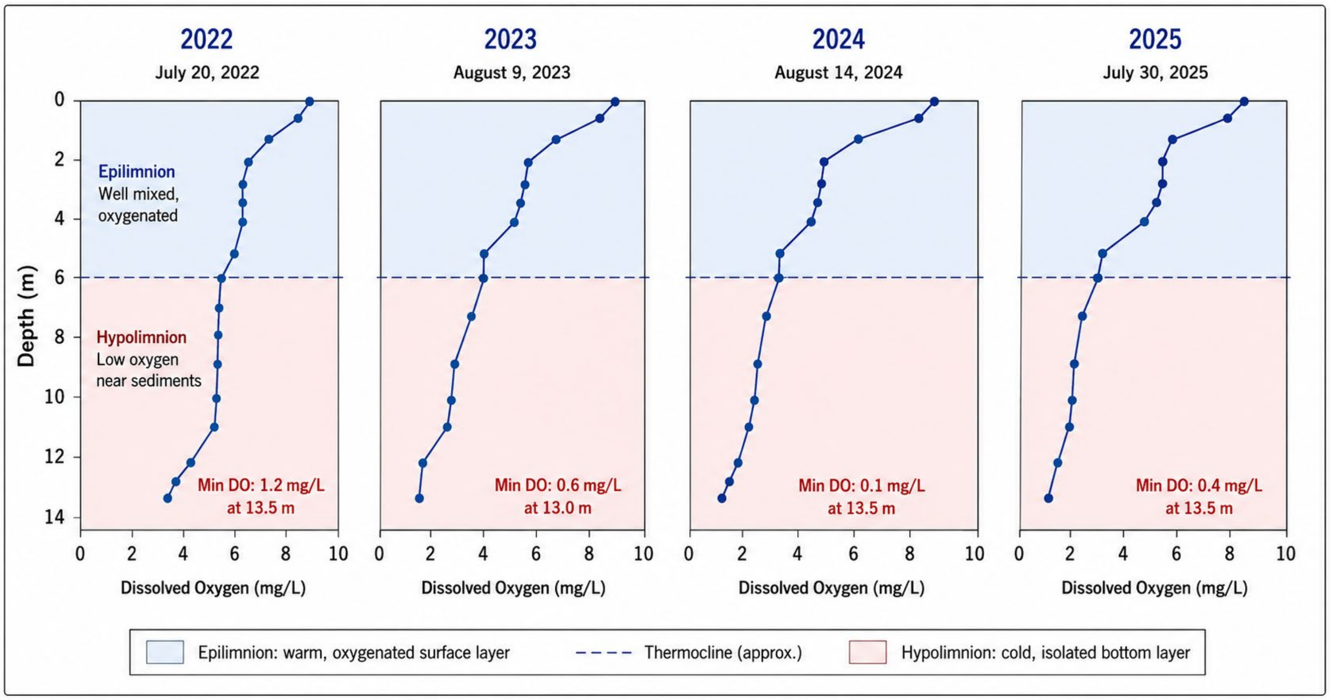

Figure 4-5. Annual summer dissolved oxygen depth profiles.

4.4 Four-Year Metrics and Management Meaning

Collectively, these indicators demonstrate that while measurable progress has been achieved in reducing phosphorus concentrations, the lake continues to exhibit characteristics of a eutrophic system, reflecting the slower biological and ecological response to reductions in nutrient loading.

Surface total phosphorus declined by approximately 14% between 2022 and 2025, representing encouraging progress toward reducing external nutrient inputs. However, concentrations remain above the established water quality target, indicating that continued watershed nutrient reduction and management of internal phosphorus loading will be necessary to achieve long-term restoration objectives.

Bottom water phosphorus concentrations exhibited a smaller overall decline and substantially greater year-to-year variability than surface concentrations. This variability reflects the influence of seasonal stratification, dissolved oxygen depletion, and internal phosphorus release from lake sediments. These observations reinforce the importance of continued sediment characterization and evaluation of internal phosphorus loading as a significant contributor to the lake's nutrient budget.

Chlorophyll-*a* concentrations declined by nearly 16% during the monitoring period, suggesting modest reductions in algal biomass. Despite this improvement, average chlorophyll-*a* concentration remains nearly three times greater than commonly accepted benchmarks for mesotrophic conditions, indicating that algal productivity continues to be a primary factor limiting water quality and recreational use. Because chlorophyll-*a* represents the biological response to nutrient availability, it should remain a primary performance indicator for evaluating restoration success.

Water transparency remained relatively stable throughout the monitoring period despite reductions in phosphorus concentrations. This finding indicates that improvements in water clarity may not occur immediately in response to reduced nutrient concentrations and can continue to be influenced by multiple interacting factors, including algal biomass, internal nutrient recycling, weather conditions, and sediment resuspension. Continued long-term monitoring will be important to evaluate whether ongoing reductions in nutrient concentrations result in measurable and sustained improvements in water transparency over time.

Annual mean bottom dissolved oxygen concentrations remained within generally acceptable ranges and exhibited relatively little year-to-year variation. However, annual averages obscure the occurrence of short-duration hypoxic events documented within the deep basin during summer stratification. These episodic low-oxygen conditions are critical because they promote internal phosphorus release from bottom sediments and are not adequately represented by seasonal averages. Consequently, future monitoring should continue to emphasize depth-profile measurements and, where practical, continuous dissolved oxygen logging to better characterize the timing, duration, and severity of hypoxic events.

Overall, the monitoring results indicate that Bear Lake is responding positively to watershed restoration efforts but remains in a transitional stage of recovery. Continued reductions in external phosphorus loading, combined with management strategies targeting internal phosphorus recycling, are expected to produce gradual improvements in algal biomass, water clarity, and overall ecological condition over time.

Metric	4-year mean	2022→2025	Variability	Benchmark status	Management meaning
Surface TP	37.6 μg/L	−14.4%	Moderate	Above target	Continue external and internal P reduction
Bottom TP	59.5 μg/L	−6.6%	High	No formal target	Prioritize sediment assessment
Chlorophyll-a	28.0 μg/L	−15.7%	Moderate	2.8× benchmark	Use as biological response indicator
Secchi depth	1.00 m	−14.3%	Low	Eutrophic range	Expect gradual response
Bottom DO	7.22 mg/L	+5.3%	Low annual	Means acceptable	Capture episodic hypoxia with loggers

5. Interpretation of Lake and Watershed Processes

The monitoring program completed between 2022 and 2025 demonstrates that Bear Lake is responding to long-term watershed restoration efforts; however, the factors controlling water quality have evolved as restoration has progressed. Reductions in external phosphorus loading from portions of the watershed, particularly within the Bear Creek sub watershed, indicate that previous restoration investments have been successful in reducing nutrient inputs. As a result, the remaining external phosphorus load is becoming increasingly concentrated within a limited number of sources, most notably Fenner's Ditch and selected urban stormwater outfalls. This shift suggests that future watershed management should transition from broad, watershed-wide restoration efforts toward targeted projects capable of producing measurable phosphorus load reductions from these remaining high-priority sources.

Although reductions in external loading represent an important restoration milestone, multiple lines of evidence indicate that internal phosphorus loading has become an increasingly important influence on summer water quality. Temporary thermal stratification within the deepest basin, episodic dissolved oxygen depletion near the sediment-water interface, elevated bottom-water phosphorus concentrations, and sediment incubation studies all indicate that phosphorus stored within lake sediments is periodically recycled back into the water column during the growing season. This internal nutrient source likely contributes to sustaining algal productivity after external inputs have declined. While these observations clearly demonstrate that internal loading is occurring, the magnitude, spatial distribution, and chemical composition of sediment phosphorus have not yet been fractionated at a resolution sufficient to support the design of a comprehensive lake-wide phosphorus mitigation program. Additional sediment fractionation and internal loading assessments therefore remain a high management priority.

The biological response of Bear Lake has progressed more gradually than the observed reductions in phosphorus loading. Although surface phosphorus concentrations have declined, improvements in chlorophyll-*a* concentrations and water transparency have been comparatively modest. This response is consistent with expectations for eutrophic lakes, where internal nutrient recycling, seasonal weather conditions, hydraulic residence time, sediment resuspension, and food-web dynamics can continue to influence algal production despite reductions in watershed nutrient inputs. Consequently, measurable improvements in overall ecological condition may require several years to become evident following reductions in nutrient loading.

Taken together, these findings indicate that Bear Lake has entered a transitional stage of restoration in which continued progress will depend on addressing the remaining localized external phosphorus sources while simultaneously evaluating and managing internal phosphorus cycling. Future restoration success should therefore be assessed using multiple long-term performance indicators rather than any single water quality metric. Trends in phosphorus concentrations, chlorophyll-*a*, water transparency, dissolved oxygen dynamics, and internal phosphorus loading should be evaluated collectively.

5.1 Historical Phosphorus Mitigation Treatments

Targeted phosphorus mitigation has been incorporated into Bear Lake management to address phosphorus accumulation within the deeper portions of the lake and nutrient inputs associated with Fenner’s Ditch. Beginning in 2023, Phoslock applications were directed toward these areas as part of an effort to reduce the availability of phosphorus capable of supporting nuisance algal production. Two Phoslock applications were completed in 2023, followed by three applications in 2024. Beginning in 2025, EutroSORB G replaced Phoslock as the phosphorus-binding material. Three applications were completed on June 3, July 15, and August 21, with approximately 515 pounds applied over 12 acres during each treatment, for a total of 1,545 pounds. Treatment continued to focus on the deeper portions of Bear Lake and Fenner's Ditch, where monitoring has identified both internal phosphorus accumulation and continued external phosphorus inputs.

Year	Product	Treatment Dates	Approx. Area per Application	Amount per Application	Seasonal Total
2023	Phoslock	June 14; August 28	12 acres	1,320 lbs.	2,640 lbs.
2024	Phoslock	May 30; June 27; August 22	12 acres	1,030 lbs.	3,090 lbs.
2025	EutroSORB G	June 3; July 15; August 21	12 acres	515 lbs.	1,545 lbs.
Total		**8 applications**			**7,275 lbs.**

6. Management Goals and Performance Indicators

The long-term goals of this Lake Management Plan are intended to provide measurable benchmarks for evaluating restoration progress and guiding adaptive management. Rather than focusing on a single water quality parameter, these goals address the physical, chemical, and biological processes that influence Bear Lake's ecological condition. The associated performance indicators establish quantifiable metrics that can be tracked through continued monitoring to assess the effectiveness of management actions and inform future lake management priorities and decision making.

Goal	Performance indicators
Reduce phosphorus availability	Move annual surface TP toward or below 30 µg/L; reduce deep-water TP enrichment; document lower SRP during low-oxygen periods.
Reduce algal productivity	Move growing-season chlorophyll-a toward 10 µg/L and reduce the frequency, duration, and severity of cyanobacteria blooms.
Improve transparency	Achieve a sustained upward trend in Secchi depth while accounting for weather and seasonal variability.
Protect habitat and native plants	Maintain native species richness and coverage while preventing expansion of invasive aquatic plants.
Reduce localized watershed inputs	Lower phosphorus and bacteria loads from Fenner's Ditch and priority stormwater outfalls.
Strengthen adaptive decision-making	Maintain consistent monitoring, annual review, and five-year plan updates tied to measurable outcomes.

7. Management Strategies and Priority Actions

Priority 1: Sediment Assessment and Phosphorus Mitigation Plan

- Collect sediment cores from deep basins, transitional areas, and depositional nearshore zones.
- Complete phosphorus fractionation and estimate the lake-wide inventory of releasable phosphorus.
- Map phosphorus hot spots and relate sediment chemistry to dissolved oxygen and deep-water TP.
- Evaluate the effectiveness, appropriate scale, and future application of phosphorus mitigation technologies following completion of the sediment phosphorus inventory and identification of treatment priorities.
- Develop a phased implementation plan with treatment objectives, cost ranges, and monitoring requirements.

Priority 2: Comprehensive Water Quality Monitoring

- Continue monthly growing-season monitoring of TP, SRP, chlorophyll-a, Secchi depth, nitrogen species, temperature, dissolved oxygen, cyanobacteria, and microcystin.
- Maintain consistent stations and depths to protect trend comparability.
- Install continuous temperature and dissolved oxygen loggers at the deep basin.
- Complete a formal five-year trend analysis after the 2030 season.

Priority 3: Fenner's Ditch Restoration

- Quantify baseflow and storm-event phosphorus loads.
- Identify high-accumulation sediment reaches and upstream erosion sources.
- Evaluate sediment removal, stabilization, riparian restoration, and phosphorus interception.
- Monitor before and after implementation to document load reduction.

Priority 4: Stormwater Management

- Continue wet-weather sampling and rank outfalls by flow, phosphorus, suspended solids, and bacteria.
- Investigate sources associated with repeated high E. coli measurements.
- Evaluate infiltration, filtration, bioretention, hydrodynamic separation, and other site-appropriate controls.
- Coordinate long-term improvements with local municipalities and transportation agencies.

Priority 5: Watershed Protection

- Protect restored wetlands and previous watershed investments.
- Promote natural shorelines, responsible fertilizer use, erosion control, and runoff reduction.
- Maintain tributary monitoring to identify emerging sources.

Priority 6: Aquatic Vegetation Management

- Conduct annual vegetation surveys and map invasive species distribution.
- Use selective treatments where nuisance or invasive growth interferes with access or ecological balance.

- Protect native plant beds and evaluate restoration opportunities where habitat is limited.
- Track Eurasian watermilfoil, Curly-leaf pondweed, and Starry stonewort over time.
- Manage nuisance native aquatic vegetation, including cattails and water lilies, where growth becomes excessive, interferes with recreational use or access, or otherwise warrants management

Priority 7: Waterfowl Management

- Monitor populations and seasonal use of Bear Lake by Canada geese, mute swans, and other waterfowl, particularly in areas where large numbers routinely congregate, feed, or nest. Use selective treatments where nuisance or invasive growth interferes with access or ecological balance.
- Identify shoreline areas that encourage concentrated waterfowl use, including maintained turf extending to the water's edge, public access areas, beaches, and other open shoreline environments.
- Promote shoreline practices that discourage excessive waterfowl congregation, including native shoreline vegetation, reduced mowing near the water, and vegetated buffers that create a physical separation between open lawn areas and the lake.
- Discourage intentional feeding of geese, swans, and other waterfowl, which can artificially concentrate bird populations, increase nutrient and bacterial inputs, and contribute to nuisance conditions.
- Evaluate appropriate population-management or deterrent strategies where excessive waterfowl populations are documented, in coordination with applicable state and federal wildlife regulations and agencies.

Priority 8: Community Stewardship

- Provide annual public updates using clear data visualizations.
- Develop shoreline and homeowner best-management-practice guidance.
- Encourage volunteer observations, photo documentation, and citizen monitoring where useful.

8. Monitoring Program

A comprehensive monitoring program is essential for evaluating lake conditions, measuring restoration progress, and supporting adaptive management. Continued collection of physical, chemical, and biological data provides the information needed to identify emerging water quality concerns, assess the effectiveness of management actions, and refine future restoration strategies. The monitoring program outlined below emphasizes consistency in sampling methods and locations to ensure that long-term trends can be accurately evaluated and management decisions remain grounded in sound scientific data.

8.1 Core Lake Monitoring

Component	Frequency	Locations	Purpose
Water chemistry	Monthly, April–October	Established lake stations; surface and bottom	Track nutrients and biological response
Temperature/DO profiles	Each sampling event; continuous at deep basin	Deep basin and representative secondary sites	Document stratification and hypoxia

Secchi depth	Each lake visit	All long-term stations	Track transparency
Cyanobacteria/microcystin	During routine sampling and visible blooms	Surface waters and affected areas	Protect recreation and quantify bloom response
Aquatic vegetation	At least annually	Lake-wide littoral zone	Track native diversity and invasive species
Sediment chemistry	Baseline, then as needed	Representative depositional zones	Quantify internal loading potential

8.2 Watershed Monitoring

- Monitor Bear Creek and Fenner's Ditch under baseflow and storm conditions.
- Measure flow whenever feasible so concentrations can be converted to loads.
- Continue priority stormwater outfall sampling during representative rainfall events.
- Use pre- and post-project monitoring for every major restoration action.

9. Bear Lake Best Management Practices

Topic	Recommended practice
Shorelines	Maintain or restore native shoreline vegetation, minimize hard armoring where feasible, stabilize eroding areas, and avoid removing beneficial aquatic plants solely for aesthetics.
Nutrients	Avoid phosphorus fertilizer unless soil testing demonstrates need; keep leaves, grass clippings, and pet waste out of streets, drains, and the lake.
Stormwater	Redirect roof and driveway runoff to vegetated areas, rain gardens, or infiltration systems; maintain catch basins and avoid illicit discharges.
Septic and wastewater	Inspect and maintain septic systems where applicable and address sanitary cross-connections or failing infrastructure.
Boating and recreation	Prevent aquatic invasive species transfer, minimize sediment disturbance in shallow areas, and report unusual blooms or plant growth.
Construction and erosion	Use erosion and sediment controls, stabilize exposed soil promptly, and protect drainage swales and wetlands.

10. Five-Year Adaptive Management Roadmap (2027–2031)

The Five-Year Adaptive Management Roadmap provides a phased framework for implementing the recommendations presented in this Lake Management Plan. The roadmap recognizes that lake restoration is an iterative process in which monitoring, evaluation, implementation, and reassessment occur concurrently. Each phase builds upon the results of previous efforts, allowing management strategies to be refined as new scientific information becomes available. This adaptive approach ensures that restoration investments remain focused on the highest-priority nutrient sources, measurable environmental improvements, and the long-term protection of Bear Lake's ecological health.

Year	Primary emphasis	Key actions
2027	Resolve priority uncertainties	Complete sediment study design and sampling; continue monitoring; quantify Fenner's Ditch and stormwater priorities.
2028	Design targeted restoration	Develop phosphorus mitigation plan; select Fenner's Ditch and stormwater projects; establish project-specific performance targets.
2029	Implement priority actions	Begin phased watershed or in-lake projects where design and permitting are complete; maintain full monitoring.
2030	Evaluate and optimize	Compare project outcomes with baseline; refining treatment scale, location, and monitoring intensity.
2031	Update the plan	Complete five-year trend analysis; document progress toward goals; prepare the next planning cycle.

11. Decision Framework and Measures of Success

Major restoration investments should proceed when monitoring identifies a defined source, the expected phosphorus reduction can be estimated, the proposed action is technically appropriate for site conditions, and post-project monitoring can verify performance.

1. Define the management problem and the measurable outcome.
2. Confirm the source, magnitude, and spatial extent using site-specific data.
3. Compare feasible alternatives, costs, permitting needs, longevity, and uncertainty.
4. Implement at a scale appropriate to the available evidence.
5. Measure the response and adjust subsequent phases.

11.1 Long-Term Success Indicators

- Sustained reductions in surface and bottom phosphorus.
- Reduced frequency and magnitude of deep-water SRP and TP accumulation.

- Lower chlorophyll-a and fewer nuisance cyanobacteria events.
- Gradual improvement in Secchi transparency.
- Healthy native aquatic plant diversity with invasive species maintained at manageable levels.
- Reduced phosphorus and bacteria loads from priority tributaries and stormwater outfalls.
- Continued use of monitoring to refine management investments.

12. Long-Term Vision

The long-term vision for Bear Lake is a resilient urban lake that supports recreation, native aquatic communities, and improved water quality while remaining protected from renewed nutrient loading. Success will not be defined by a single treatment or one favorable sampling year. It will be demonstrated by sustained trends, reduced uncertainty, protection of previous watershed investments, and a management program capable of adapting as the lake responds.

Appendix A. Annual Water Quality Summary

Year	Surface TP	Bottom TP	Surface chlorophyll-a	Secchi depth	Bottom DO
2022	45.80	51.20	31.90	1.12	6.80
2023	30.25	90.60	22.85	1.03	6.90
2024	35.10	48.30	30.40	0.90	8.00
2025	39.20	47.80	26.88	0.96	7.16

Units: phosphorus and chlorophyll-a = μg/L; Secchi depth = m; dissolved oxygen = mg/L.

Appendix B. Analytical Notes

- Percent change was calculated from the 2022 annual mean to the 2025 annual mean.
- Four-year means are arithmetic means of annual summary values.
- Vertical phosphorus enrichment equals annual bottom TP minus annual surface TP.
- Benchmark comparisons use 30 μg/L for surface total phosphorus and 10 μg/L for chlorophyll-a.
- Correlations based on four annual observations are descriptive only and should not be interpreted as statistically conclusive.
- Annual dissolved oxygen means can conceal short-duration hypoxia; depth-specific profiles and continuous loggers are more appropriate for internal-loading evaluation.

Appendix C. Source Documents

This consolidated plan was developed from Bear Lake Management Plans and the Bear Lake Water Quality Data 2022–2025 workbook, which compiles tabulated results from the 2022–2025 Grand Valley State University Annis Water Resources Institute reports.