Indian Creek Reservoir Phosphorus TMDL Implementation Status Staff Report

California Regional Water Quality Control Board

Lahontan Region

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Executive Summary

Indian Creek Reservoir is located in Alpine County and was constructed to store treated wastewater exported from South Lake Tahoe for later use in pasture irrigation, and to serve as a recreational fishery. The reservoir was placed on the list of impaired water bodies required under Section 303(d) of the federal Clean Water Act, due to eutrophication. Development of Total Maximum Daily Loads (TMDLs), and TMDL implementation plans, is required for Section 303(d) listed water bodies under federal and California state regulations.

The Indian Creek Reservoir TMDL, approved by the U.S. Environmental Protection Agency in 2003, identifies load allocations for total phosphorus which, when implemented, are expected to result in the attainment of applicable water quality objectives and the protection of beneficial uses. The beneficial uses of concern in Indian Creek Reservoir are aquatic habitat and recreation uses. This report summarizes what implementation measures have taken place since the TMDL was approved, assesses whether the criteria established have been met, and provides recommendations on next steps and future implementation measures.

A review of the monitoring data from Indian Creek Reservoir indicates that targets for water quality objectives set in the TMDL have not yet been met. Issues persist with eutrophication such as harmful algal blooms. While there have been some measures to mitigate internal phosphorus loading, equipment failures and the 2021 Tamarack Fire may have hampered these efforts. Given that water quality objectives have not been met and the beneficial uses in Indian Creek Reservoir are not being fully attained, alternative measures to continue to address internal loading of phosphorus should be investigated and external sources of phosphorus should be more proactively mitigated.

1. Overview

1.1 Purpose

The purpose of this Implementation Status Staff Report is to assess the progress of the Indian Creek Reservoir Total Maximum Daily Load (TMDL), which had a target attainment date of 2024 of achieving the long-term total phosphorus and other water quality objective targets related to the protection of beneficial uses in Indian Creek Reservoir. This Status Report will provide an update on the implementation measures taken to achieve the TMDL targets and the status of Indian Creek Reservoir's water quality. This Status Report concludes with recommendations based on these findings.

1.2 Background

Indian Creek Reservoir (ICR) was constructed on an ephemeral tributary of Indian Creek, which itself is tributary to the East Fork Carson River in Nevada (Fig. 1 and 2). It receives flows from both Indian Creek and the West Fork Carson River through diversions into the Upper Dressler Ditch which then discharges into the reservoir. Water from ICR is released back into Indian Creek via Diamond Valley Ditch, and ultimately flows into Mud Lake in Nevada, providing irrigation water for several ranching operations. ICR is relatively shallow with a maximum pool size of 3,100 acre-feet and reaches a maximum depth of 50 feet near its main dam. The reservoir was originally designed to store tertiary-treated domestic wastewater effluent exported by the South Tahoe Public Utility District (STPUD) from the Lake Tahoe Basin, for later use in pasture irrigation. ICR was also designed to serve as a recreational trout fishery to support commercial and sportfishing, as well as water contact and non-contact water recreation. Export of all wastewater from the Lake Tahoe watershed has been required since the 1960s to protect the unique ecological and recreational values of Lake Tahoe; see Section 5.2 of the Water Quality Control Plan for the Lahontan Region. Treatment of wastewater effluent involved processes for nutrient removal including the addition of lime to remove phosphorus. However, some nutrients remained in the effluent such that during the period of wastewater disposal into ICR (1969-1989), it is estimated that roughly 52,000 pounds of phosphorus were added into the reservoir (California Regional Water Quality Control Board Lahontan Region 2001).

The reservoir became eutrophic due to the high levels of nutrients, and experienced problems starting in the 1970s including heavy growths of aquatic weeds, summer depletion of dissolved oxygen, fish kills from high levels of unionized ammonia, and taste and odor problems related to blue-green algae. ICR was identified as a Section 303(d) impaired water body in the mid-1980s (California State Water Resources Control Board 1988). In 1989, STPUD ceased disposal of wastewater to ICR, and began a long-term program of maintaining reservoir levels with freshwater diversions from Indian Creek and the West Fork Carson River (Fig. 2). Harvey Place Reservoir subsequently became the new reservoir for the domestic wastewater effluent.

Although concentrations of some wastewater constituents declined with freshwater inputs, phosphorus concentrations in the water column remained high and the reservoir continued to exhibit symptoms of eutrophication including low transparency, summer depletion of dissolved oxygen in deeper waters, and blooms of blue-green algae. A TMDL was developed by Regional Water Board staff in the early 2000s to address eutrophication in ICR due to persistent high concentrations of phosphorus. This report, which assesses data from 2003-2024, provides a summary of the status of ICR and progress towards implementing the TMDL. A draft of this report was circulated for review and comment to stakeholders in the watershed which included South Tahoe Public Utility District, Bureau of Land Management, and Alpine County staff.

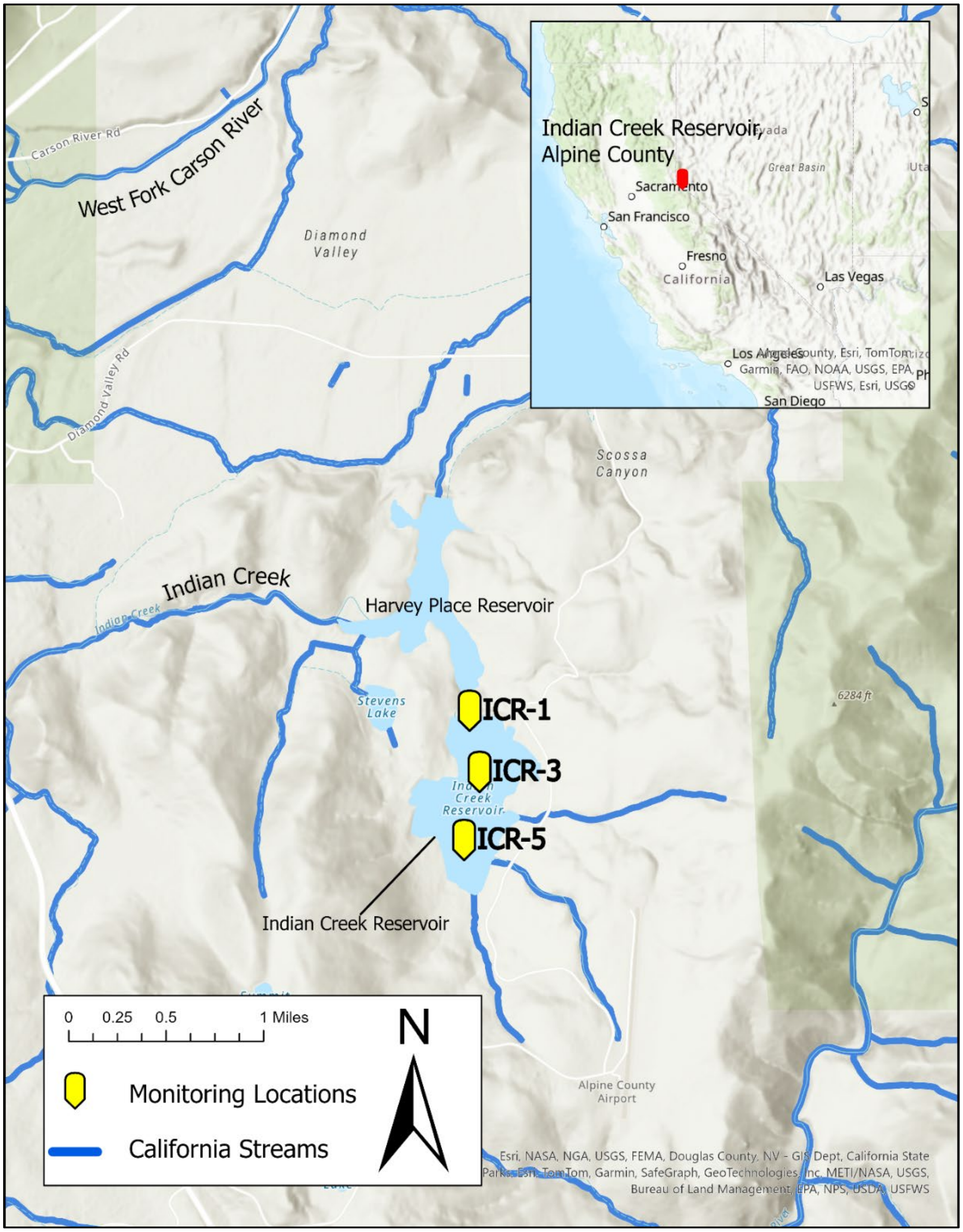

Fig. 1 Site map of Indian Creek Reservoir and other waterbodies including Indian Creek, West Fork Carson River, and Harvey Place Reservoir in Alpine County, CA. Monitoring locations on Indian Creek Reservoir are demarcated.

Fig. 2 Outflow of Indian Creek into Upper Dressler Ditch, the main inflow into Indian Creek Reservoir.

1.3 TMDL Summary

Purpose: The ICR TMDL focuses on control of total phosphorus loading, since a literature review indicated that phosphorus is the primary nutrient currently contributing to eutrophication. The TMDL is designed to protect beneficial uses; the literature shows that reduction of external and internal phosphorus loading should reduce biological productivity and lead to protection and enhancement of beneficial uses, and attainment of water quality objectives for eutrophication-related parameters other than phosphorus including dissolved oxygen, chlorophyll-*a*, and water clarity (Secchi depth).

TMDL Dates of Approval: July 24, 2002 (Lahontan Regional Board), July 1, 2003 (USEPA).

Target*:* An annual mean concentration in the water column of 0.02 mg/L total phosphorus, which the literature indicated will promote mesotrophic, rather than eutrophic conditions and thus protect beneficial uses (cold freshwater habitat [COLD], water contact recreation [REC-1], non-contact water recreation [REC-2], and commercial and sport fishing [COMM]). The numeric total phosphorus target for the TMDL is expressed as an annual mean, rather than a mean of monthly means (Table 1).

Loading Capacity*:* The maximum amount of phosphorus that can be present in the water column if a concentration of 0.02 mg/L total phosphorus is to be maintained is 82 lb/yr. The load allocations for surface runoff and tributary inflow are set as a 10-year rolling averages to account for seasonal and annual variations in runoff, tributary flows, and phosphorus concentrations (Table 2).

Schedule for Attainment: Interim target expected to be met in 2013; Long term target expected to be met in 2024.

Implementation and Monitoring*:* The ICR TMDL Staff Report identifies an implementation and monitoring program to provide a reasonable assurance of implementation. Within this plan, Regional Board staff are expected to conduct comprehensive reviews of monitoring data, and assess progress toward implementation and attainment of targets at five year intervals. The ICR TMDL identifies STPUD as responsible for maintaining ICR along with part of the diversion and conveyance facilities which provide inflow to ICR. STPUD also monitors tributary inflow and water quality in ICR. Other landowners and land managers in the watershed including STPUD, the U.S. Bureau of Land Management, and Alpine County are responsible for control of external sources of loading to ICR. The implementation program does not specify the means of compliance with the TMDL but rather establishes a process for identification and implementation of controls for external and internal sources of phosphorus loading to Indian Creek Reservoir. Implementation is to be done in coordination with the Lahontan Regional Board's ongoing watershed management planning and nonpoint source control efforts.

Table 1. Numeric Targets and Indicators for Indian Creek Reservoir TMDL.

Indicator	**Target Value**
Total P concentration	(Interim*) No greater than 0.04 mg/L, annual mean (Long term[1]) No greater than 0.02 mg/L, annual mean
Dissolved oxygen concentration	(Interim) 30-day mean 6.5 mg/L; 7 day mean minimum 5.0 mg/L; 1 day minimum 4.0 mg/L (Long term) Shall not be depressed by more than 10 percent, below 80 percent saturation, or below 7.0 mg/L at any time, whichever is more restrictive
Secchi depth	Summer mean no less than 2 meters
Chlorophyll a	Summer mean no greater than 10 µg/L
Carlson Trophic Status Index	Composite index no greater than 45 units

*Interim targets were expected to be attained by 2013.; [1]Long term targets were expected to be attained by 2024.

Table 2. Estimated Existing Phosphorus Loads to ICR and TMDL Load Allocations for ICR from External and Internal Sources.

Source	Estimated Existing phosphorus loads (lb/yr) and % of total to ICR	Load Allocations for ICR (lb/yr) to satisfy TMDL
EXTERNAL SOURCES		
Precipitation	3	3
Direct surface runoff	68	17
Tributary inflow	43	32
A. Total External Load (lbs/yr)	114 [24%]	52 [53%]
INTERNAL SOURCES		
Total anoxic load (by literature formula from Welche and Cooke, 1999, for 120-day stratification period)	204	
Total oxic load (by subtraction)	150	
B. Total Internal Load (lb/yr)	354 [76%]	46 [47%]
C. Loss in Reservoir outflow	137	18
Total Load (A+B)	468	98
NET WATER COLUMN LOAD (A+B-C)	331	80

2. Progress Analysis

2.1 Implementation Evaluation

Implementation of the TMDL is the responsibility of STPUD (for control of internal phosphorus loading) and of the U.S. Bureau of Land Management, Alpine County, STPUD, and other landowners and land managers in the watershed (for control of external sources). The implementation program includes the formation of a stakeholder group for ongoing discussion of TMDL issues, identification of sites in the watershed that need Best Management Practices (BMPs), and implementation of BMPs on rangelands in the surrounding area following procedures in the *California Rangeland Water Quality Management Plan*.

As part of the implementation measures to address internal loading, a Clean Water Act section 319 grant was awarded to STPUD in 2006 to install a hypolimnetic oxygenation system (HOS), and by 2008 the system was in place. The HOS was upgraded in 2013, which tripled the existing air receiver volume and resulted in increased oxygen production. The system is operated during late spring and summer. However, in 2017 the system began to experience operational problems. Mechanical issues have persisted since then, resulting in the HOS being non-operational in 2024 and 2025. STPUD staff informed the Water Board in early 2025 that replacement parts are needed in order to fix the HOS, which would require a major upgrade to the electrical service that is required to run the system. These improvements entail significant upfront costs, as well as a major increase in the ongoing costs for electrical services. STPUD does not currently plan to continue operating the HOS.

An alternative project identified by STPUD is the implementation of a chemical treatment method (i.e., flocculants) in ICR. This treatment could potentially reduce the amount of phosphorus being released from sediments. STPUD is currently investigating the effectiveness of several different chemical treatment methods including aluminum-based coagulants and a lanthanum-based sorbent. An additional project proposed by STPUD is the installation of flow gauges on the reservoir’s inflow and outflow, which would lead to a better understanding of residence time in the reservoir.

Efforts identified in the ICR TMDL to address external loading have not been pursued. Regulatory actions to ensure implementation of BMPs to control external sources have also not been considered yet. A group of Water Board staff and several stakeholders was formed in 2003 and met once for a field tour in March 2004 to visit and identify sites where external loading could be addressed. There are no records that indicate any further follow-up between this group and Water Board staff. Erosion control efforts in response to Tamarack Fire damage are described in section 2.4 Challenges and Considerations

2.2 Monitoring Measures

Water quality samples for each of three sites (ICR-01, ICR-03, ICR-05) and at multiple depths are collected monthly in ICR. Physical parameters (dissolved oxygen, chlorophyll-a, Secchi depth) are measured at the same frequency and at the same sites (Fig. 1).

During its operation, the HOS was monitored 2-3 times per week. Parameters that were recorded included run time, air pressures, air dryer temperature, oxygen pressures, oxygen flow, pump amps, and building temperature.

In 2019 STPUD began conducting regular monitoring for harmful algal blooms (HABs), which includes sampling for cyanobacteria species and cyanotoxin concentrations. STPUD posts advisory signs in accordance with State guidelines established for recreational waters for the protection of public health. Depending on the levels of cyanotoxins detected during monitoring, different signage is utilized to alert recreational water users about potential health risks. “Caution” signs are the lowest level advisory, “Warning” signs indicate increased cyanotoxins, and “Danger” signs indicate the highest-level advisory when microcystin exceeds 20 μg/L, the threshold identified by the California Office of Environmental Health Hazard and Assessment.

2.3 Monitoring Results

Summary of 2015 Status Report: Between 1989 and late 1998, sampling was only done at the near-surface in ICR, and the results did not allow conclusions about depth profiles of temperature, dissolved oxygen (DO), or nutrients. Starting in late 1998 there has been monthly depth profile sampling at several locations in ICR, including Secchi depth transparency (collection started in 2000) and measurements of DO, temperature and pH at various depths. The TMDL addressing phosphorus in ICR was adopted by the Lahontan Regional Board in July 2002. Shortly after its adoption STPUD began monitoring phosphorus and chlorophyll-a concentrations monthly at three different sites in ICR (Fig. 1). In 2015, the available data were reviewed and the implementation status report (Lahontan Regional Water Quality Control Board 2015) indicated that all interim targets for water quality parameters were being met, and that internal loading was being sufficiently addressed.

Summary of 2003-2024 Data: Monitoring data from between 2003 and 2024 were available for analysis. Overall, long-term numeric targets are not being met (Table 3). Symptoms of eutrophication persist in ICR, with frequent HABs occurring during the summer and fall. Danger advisories for cyanotoxin presence were issued in 2022 and 2023.

The primary TMDL target for mean annual total phosphorus has not been attained and the interim goal for total phosphorus is only occasionally being met (Fig 3). Phosphorus concentrations are significantly greater in the summer (Tukey’s HSD $p<0.01$), and fall ($p<0.01$), when HABs are more prevalent, compared to spring. Phosphorus concentration is also significantly higher in the hypolimnion (the colder, bottom layer of a stratified lake) compared to the epilimnion (the warmer, top layer of a stratified lake; $p<0.01$).

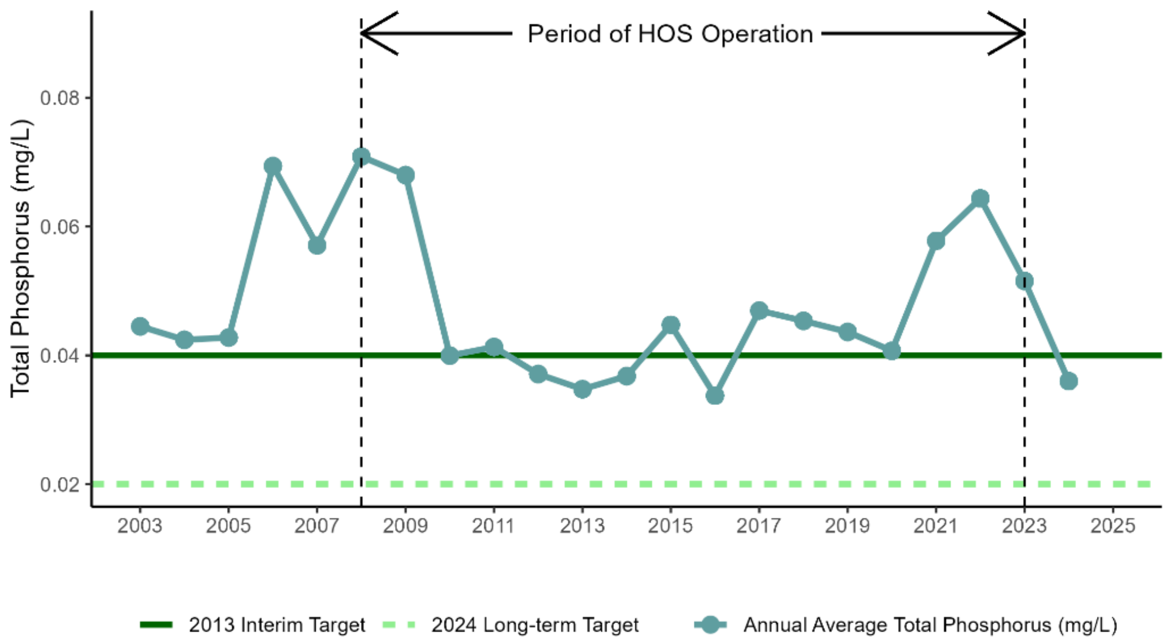

Fig. 3 Annual average of total phosphorus in ICR compared to the long-term (dashed light green line) and short term (solid dark green line) TMDL targets for total phosphorus.

Table 3. Summary of monitoring results and TMDL compliance.

Indicator	Target Value	Evaluation Schedule	Compliance
Total phosphorus concentration	(Interim[1]) No greater than 0.04 mg/L, annual mean (Long term[2]) No greater than 0.02 mg/L, annual mean	Annual mean of samples collected from all depths from all sites over the reporting period.	**No**, the long-term objective is not being met. The interim objective was met five out of 17 years during the reporting period.
Dissolved oxygen	(Interim[1]) 30-day mean 6.5 mg/L; 7-day mean minimum 5.0 mg/L; 1 day minimum 4.0 mg/L (Long term[2]) Shall not be depressed by more than 10 percent, below 80 percent saturation, or below 7.0 mg/L at any time, whichever is more restrictive	Mean of samples collected from all depths at each site measured monthly over the reporting period.	**No**, the long-term objective is not being met. DO is more regularly meeting the interim objectives and only fell below the interim objectives 68 times in total.
Secchi depth	Summer mean no less than 2 meters	Mean for all readings collected over the reporting period.	**Partially**, the objective was consistently met between 2010-2017. SD did not meet the objective in 2023.
Chlorophyll-*a*	Summer mean no greater than 10 µg/L	Mean for all samples collected over the reporting period	**Partially**, Chl-*a* was trending downward until 2015 when a large spike occurred. Since then, Chl-*a* had been trending lower but then spiked again in 2023.
Trophic State Index	(Secchi depth) TSI no greater than 45 units	Mean of all TSI (SD) derived from SD readings (in meters) collected from all sites over the reporting period.	**Partially**, the objective was met in 2012, 2013, and 2016.
Trophic State Index	(Chlorophyll-a) TSI no greater than 45 units	Mean of all TSI (Chl-a) derived from Chl-a concentrations (in ug/l) collected from all sites over the reporting period.	**No**, TSI was below the target in 2013, but has since exceeded 45 units each year.
Trophic State Index	(total phosphorus) TSI no greater than 45 units	Mean of all TSI (TP) derived from TP concentrations (in ug/l) collected from all sites over the reporting period.	**No**, TSI was below the target in 2013, but has since exceeded 45 units each year.

[1] Interim targets were expected to be attained by 2013; [2] Long term targets were expected to be attained by 2024

There is a slightly weak, but negative correlation between dissolved oxygen and total phosphorus concentrations in the hypolimnion during the period of stratification (linear regression R^2=0.27, p<0.00). In the years immediately following implementation of the HOS, DO concentration steadily increased on average throughout the reservoir. In 2015, average DO concentration started to decline and has maintained a downward trend since.

Similarly, Secchi depth improved to levels that met the objective of 2m after implementation of the hypolimnetic oxygenation system. However, around 2016 Secchi depth was reduced to levels that didn't meet the objective, and clarity has remained relatively low since (Fig. 4). Following this trend, chlorophyll-*a* appeared to be trending lower between 2008 and 2015 but peaked in 2015. Chlorophyll-*a* returned to levels that met the TMDL target in subsequent years but reached another peak in 2023 (Fig. 5). In 2023, ICR also experience a "Danger" level HAB advisory. Chlorophyll-*a* is correlated with total phosphorus in the near-surface of ICR (linear regression R^2=0.26, p<0.00; Fig. 6)

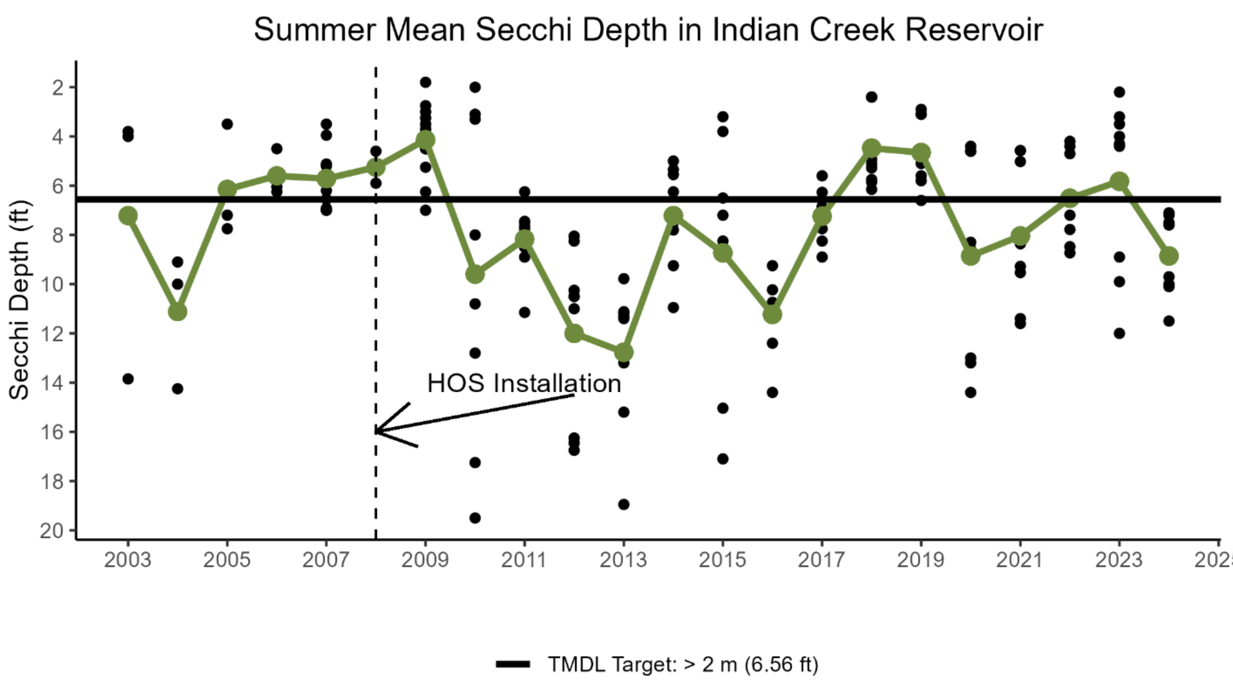

Fig. 4 Summer means of Secchi depth in ICR compared to the corresponding TMDL target.

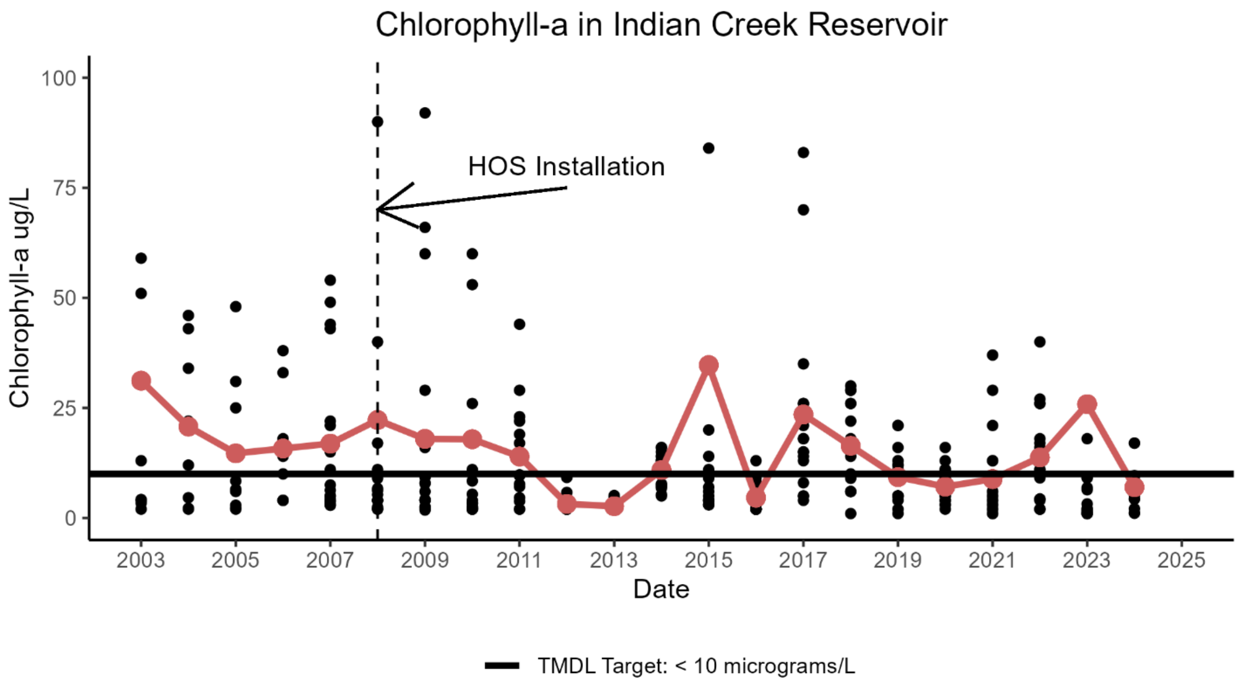

Fig. 5 Mean of summer chlorophyll-a values in ICR compared to the corresponding TMDL target. Not included in plot are outlier chlorophyll-a measurements of 200 and 240 µg/L at ICR1 and ICR3 respectively on July 14, 2015.

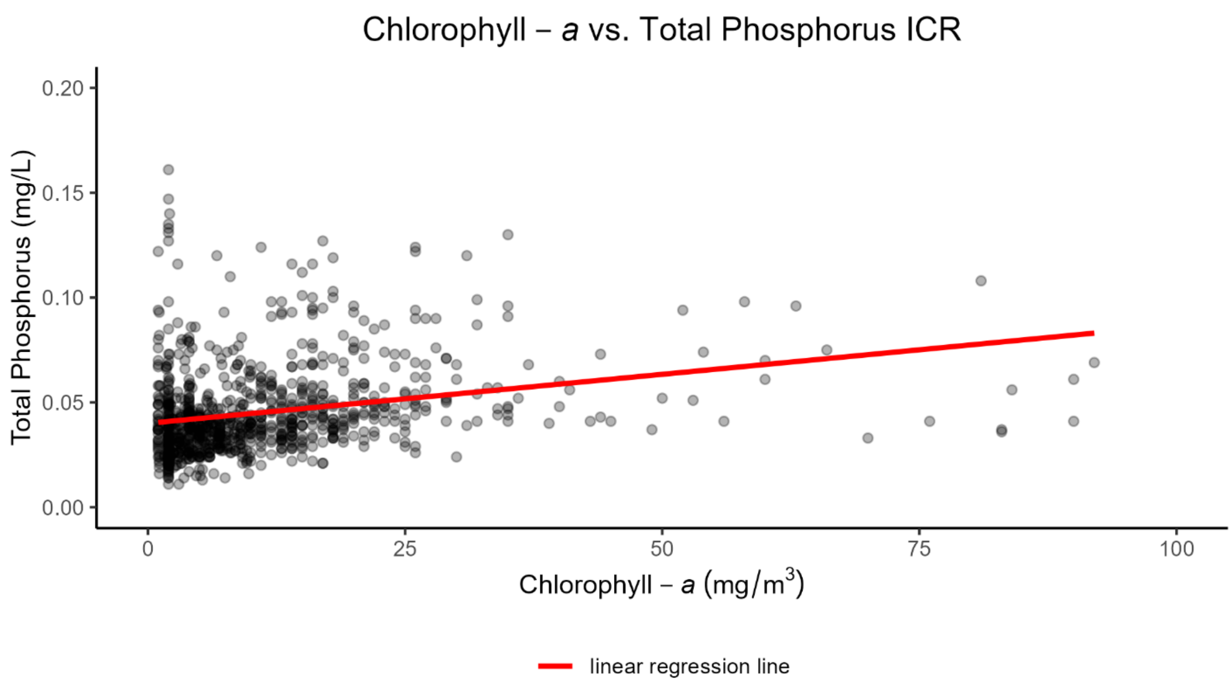

Fig. 6 Visualizing the correlation between total phosphorus and chlorophyll-*a* in the epilimnion of ICR with linear correlation (R^2=0.26).

Additionally, eutrophication still appears to be an issue according to the Carlson Trophic State Index (TSI). The TSI, calculated using three parameters (Secchi depth, chlorophyll-*a*, and total phosphorus), indicates eutrophic conditions in ICR for all years except for 2012, 2013, and 2016 (Fig. 7). There doesn't seem to be a downward trend in the TSI values, and values remain near 2008 levels. There was also a noticeable increase in the TSI values around 2015 and 2023 which follows the decreased clarity and increased chlorophyll-*a* levels in ICR around these times.

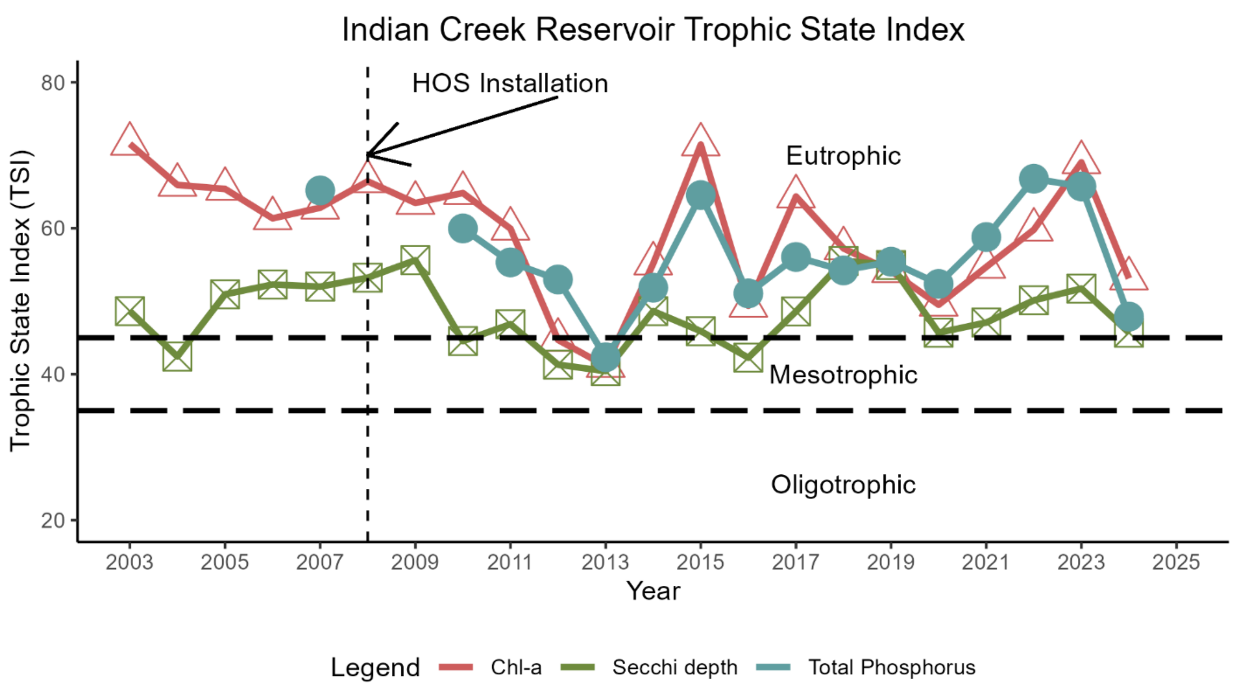

Fig. 7 Carlson Trophic State Index values. Values above 45 TSI units indicate eutrophic conditions.

2.4 Challenges and Considerations

In 2021, the Tamarack fire burned over 68,000 acres in Alpine County including the land surrounding ICR (Fig. 8). A Tamarack Post Fire Monitoring plan was developed and implemented by Surface Water Ambient Monitoring Program staff to look at the impacts of the fire to water quality. Monthly and storm event monitoring occurred to gather data including total phosphorus, total suspended solids, turbidity, pH, and dissolved oxygen at several locations. Results from this monitoring effort showed highly increased levels of sediment delivery and total phosphorus in the surrounding watersheds in the aftermath of the fire in 2021, followed by a fairly quick recovery. As a result, the Tamarack Fire may have hindered progress being made in

ICR and could be a contributing factor to the increase in total phosphorus beginning around that time.

To address these fire-related impacts, the U.S. Bureau of Land Management, the majority landowner in the ICR watershed, has taken the following restoration measures: aerial seeding (5,751 acres); contour tree felling (50 acres); noxious weed surveys and treatment (550 acres); planting of trees including Jeffrey pine, sugar pine, incense cedar, giant sequoia and ponderosa pine (28,800 trees over 500 acres); sagebrush planting (80,000 seedlings over 350 acres); hazard tree removal (323 acres); and fence repair (2 miles). These activities will serve to reduce encroachment of noxious weeds and lessen erosion resulting from unstable slopes by accelerating habitat recovery. Even though these restoration efforts were not carried out as part of the TMDL implementation strategy, they do address external loading to ICR and could alleviate the impacts resulting from the Tamarack Fire.

Fig. 8 Burned trees in the Indian Creek watershed adjacent to Upper Dressler ditch (April 29th, 2025).

3. Conclusions and Recommendations

3.1 Summary

- Water quality in ICR does not meet all TMDL targets.
- In recent years and occasionally throughout the TMDL evaluation period, Secchi depth and chlorophyll-*a* met their TMDL targets.
- Fire-related impacts are likely hindering water quality improvements in ICR, emphasizing the need to better understand and address external loading of phosphorus.
- STPUD no longer has the means to operate the HOS.
- Alternative implementation measures to mitigate internal loading should be considered, and opportunities to address external phosphorus loading to ICR should be identified along with a plan and schedule for implementation.

3.2 Conclusions

Conditions in ICR do not appear to be improving significantly and targets set in the ICR TMDL are not being achieved. It is likely that external factors including conditions exacerbated by climate change – drought, episodic high precipitation events, and wildfires are contributing sediment and nutrient loads that influence eutrophication in the reservoir (Brooks et al. 2016, Moss et al. 2011). Internal implementation measures such as the HOS, while helpful, are likely not sufficient to address the phosphorus loading issue. Additionally, since the HOS is no longer operating, water quality improvements, if any, associated with the historic operation of the HOS, will not occur.

The weak correlation observed between DO and total phosphorus doesn't support the viability of a HOS to significantly reduce internal phosphorus loading. Water quality monitoring data further indicate that implementation of the HOS alone is not enough to prevent eutrophication in ICR. In other similar types of waterbodies, HOSs have had mixed results with some seeing minor improvements in water quality parameters while others see little to no improvements (Liboriussen et al. 2009, Mehner et al. 2008, Seelos et al. 2021). Additionally, shallow reservoirs like ICR may have a greater oxygen demand compared to deeper lakes resulting in an oxygen demand that is unable to be met by the current oxygenation system (Pereira & Mulligan 2023, Liboriussen et al. 2009).

Additional implementation measures to address internal loading identified in the Staff Report for the TMDL included dredging, hypolimnetic withdrawal, maximization of freshwater flows, and harvesting of periphyton to remove nutrients. While some of these measures may be effective, they are either cost prohibitive, administratively infeasible, or would not lead to long term improvements to water quality (Pereira & Mulligan 2023).

Results from other parameters including chlorophyll-*a*, Secchi depth, and the Carlson Trophic State Index (TSI) also indicate that the current implementation measures are not sufficient to address eutrophication in ICR. There are no clear trends over time to demonstrate a decline in chlorophyll-*a* concentration or improvements to Secchi depth and the TSI. Furthermore, the clear relationships between total phosphorus concentration and these parameters indicate that without addressing the limiting nutrient in ICR (total phosphorus), there is very little likelihood of improving water clarity or reducing the incidence of HABs (Lahontan Water Board 2001, USEPA 1988).

The ICR TMDL estimates that external sources of phosphorus only contribute 24% of the total load to ICR. Nonetheless, external sources present a significant portion of the phosphorus entering the reservoir, contributing to eutrophication, and are not currently being addressed. Wildfire in particular has the potential to increase phosphorus loading into lakes via atmospheric deposition and runoff, leading to the increased occurrence of HABs (Olson et al. 2023, Paul et al. 2022). As such, fire-related impacts have been highlighted as an important consideration for TMDL planning and in restoration efforts (Paul et al. 2022).

3.3 Recommendations

These recommendations pertain primarily to actions Water Board staff should take to facilitate attainment of water quality standards in ICR. These recommendations also recognize the importance of addressing HABs in addition to meeting the specific water quality target values established in the TMDL.

The Water Board should work with STPUD to permit the use of flocculants in ICR since their application would directly address HABs and public health concerns. Monitoring efforts associated with this implementation measure should be leveraged for future TMDL status assessments and other potential TMDL updates. This proposed project, as well as the installation of flow gauges on ICR’s inflow and outflow, are likely more feasible next steps for addressing water quality impairments. Given the relatively low cost of chemical treatment, the current investigation being carried out by STPUD, and the positive outcomes seen in similar waterbodies where comparable treatments have been applied, this option seems promising (Cavalcante et al. 2022, Cruz et al. 2024, Haggard et al. 2005, Pereira & Mulligan 2023). Installation of flow gauges would also help determine a more accurate residence time for ICR and help clarify the sources of pollutant loading to the reservoir. Further exploration of the monitoring data collected by STPUD, combined with increased understanding of the residence time in ICR, will allow for more accurate phosphorus loading calculations and should be pursued as part of the next phase of the TMDL implementation. The feasibility and potential for positive impacts from phosphorus control projects should be further considered and discussed between Water Board staff and stakeholders. Additionally, the monitoring and reporting plan should be reassessed and discussed between the Water Board and STPUD to bridge the gap that exists between ICR TMDL water quality assessment needs and the goal of reducing HABs in the reservoir. The outcome of these discussions will allow for refinement of the list of potential projects and development of a stepwise approach to improve conditions in ICR.

Water Board staff should re-initiate collaboration with landowners in the watershed to investigate methods of reducing external loading including retention/detention ponds, streambank stabilization, hillslope stabilization, habitat restoration, and vegetated treatment systems. As part of this collaboration, Water Board TMDL and permitting staff should work with landowners to develop a proactive approach to address phosphorus loading from external sources. Proactive measures are needed now more than ever given that future wildfires and climate change impacts including warmer temperatures, decreased snowpack, and earlier snowmelt will likely lead to even higher in-lake productivity (Sadro et al. 2018a, 2018b).

Nevertheless, wildfires present an opportunity for agencies such as BLM to access federal funding sources for emergency stabilization and rehabilitation projects. It is important to take advantage of these funds to address the potentially devastating impacts of wildfires since other sources of federal funding can vary significantly from year to year.

The above recommendations allow for a flexible approach to TMDL implementation that will directly address public health concerns in ICR. Therefore, implementation measures should be reconsidered and reprioritized throughout the watershed to allow for the use of flocculants in ICR, reevaluate monitoring and reporting efforts, and engage with landowners to address external loading.

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Appendix

I. Harmful Algal Blooms

Cyanobacteria, also known as blue-green algae, are naturally occurring organisms found in waterbodies. Under certain conditions, cyanobacteria can undergo rapid growth and produce toxic compounds, forming harmful algal blooms (HABs). Conditions that favor HABs include increased nutrient inputs, low flows, stagnant water, and sustained high temperatures (SWAMP Freshwater and Estuarine Harmful Algal Bloom Program 2025a). California's Freshwater Harmful Algal Bloom program began developing in 2014 and started issuing advisories in 2016 (SWAMP Freshwater and Estuarine Harmful Algal Bloom Program 2025b). Advisories are issued based on visual observations and/or increasing levels of cyanotoxin presence from "Caution", "Warning", to "Danger" advisory levels.

HAB monitoring began at ICR in 2019. "Danger"-level advisories for cyanotoxin presence were issued in 2022 and 2023. These conditions occurred in the years immediately following the Tamarack Fire (Fig. I.1). According to a 2023 annual report by South Tahoe Public Utility District, peak cyanobacteria concentrations occurred in July-August 2023. Of the cyanobacteria species present, *Microcystis* dominates ICR (Fig. I.2). HABs will likely continue to be a nuisance in the reservoir, and changes to weather patterns and temperature due to climate change could exacerbate the issue (Tewari 2022).

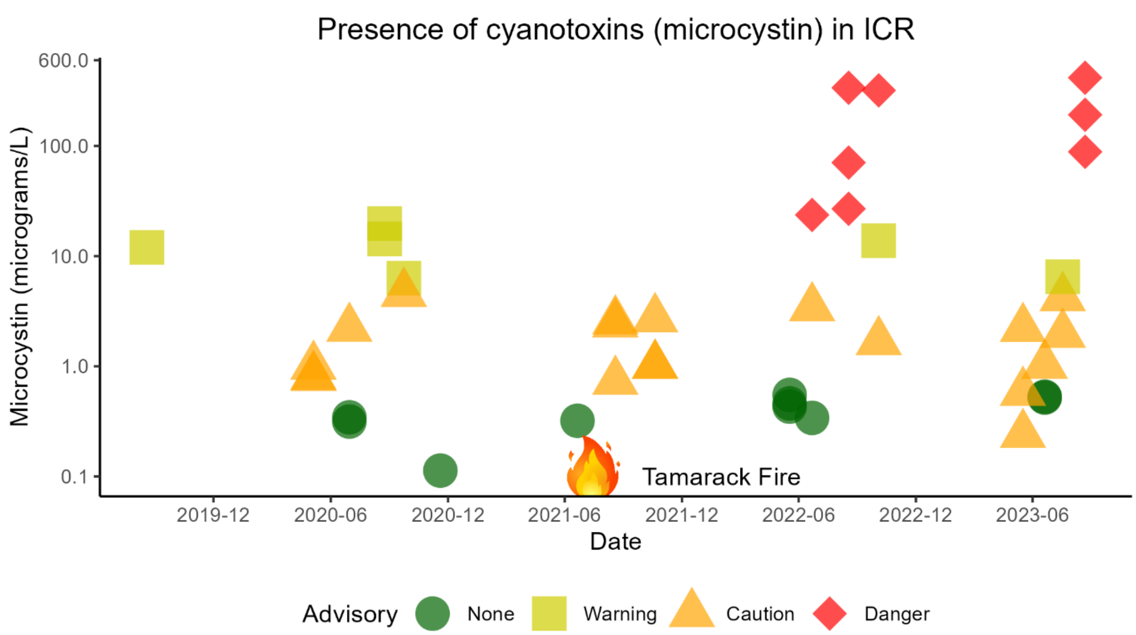

Fig. I.1. Scatter plot of the concentration of microcystin detected in ICR between 2019 and 2023. The y-axis is displayed using logarithmic scale (log_{10}). The date of the Tamarack Fire is represented by a fire icon on the date axis.

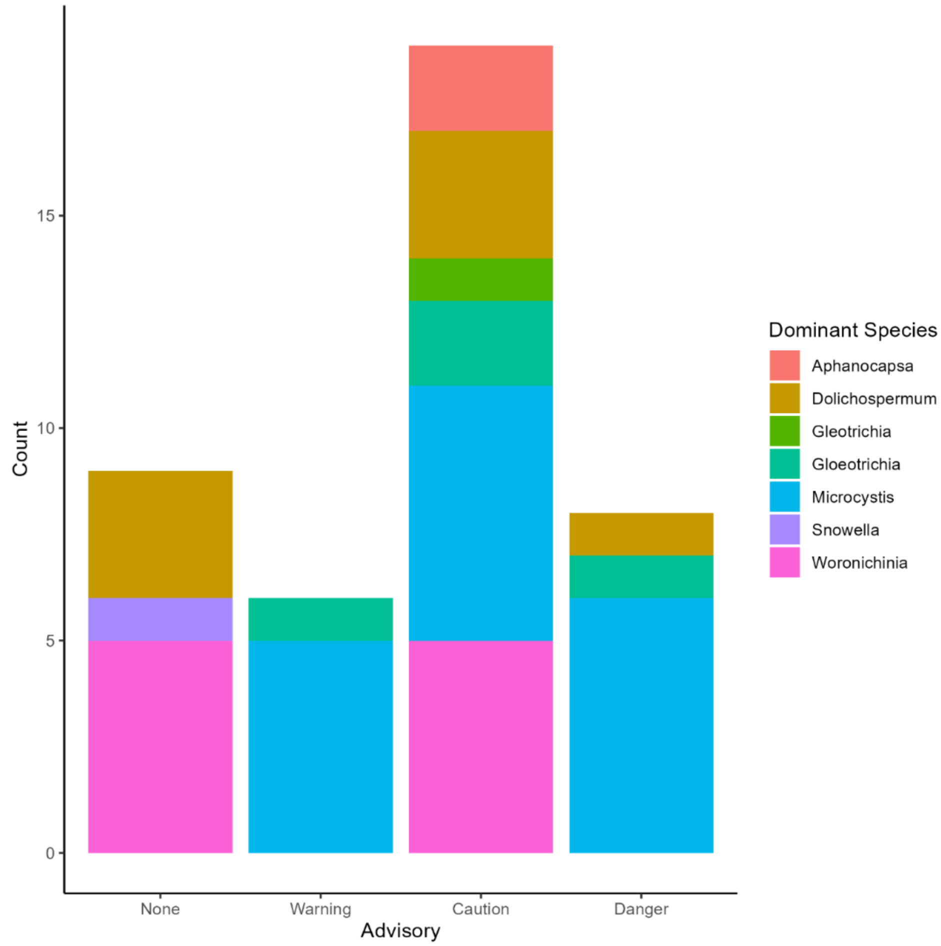

Fig. I.2. Bar chart showing the count and composition of cyanobacteria species identified based on the overall advisory level issued. *Microcystis* appears to be the dominant cyanobacteria species in ICR. During "Danger" advisories, *Microcystis* was by far the dominant species which makes microcystin the likely relevant cyanotoxin of concern in the reservoir. *Woronichinia* seems to be associated with lower-threat conditions that result in a "Caution" advisory or no advisory at all.

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