Lac Courte Oreilles, Sawyer County Phosphorus Site-specific Criteria Analysis*

WDNR Technical Support Document (2022) For Rule Board Order WY-21-20

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* This rulemaking and analysis follow a previous rulemaking on this topic from 2019. This Technical Support Document is an update to two previous technical documents:

- *2018 Lac Courte Oreilles, Sawyer County: Phosphorus Site-specific Criteria Analysis, WDNR Technical Support Document*
- *2019 Addendum* (to the above 2018 document)

These technical documents can be found for reference on WDNR's website at https://dnr.wisconsin.gov/topic/SurfaceWater/RuleUpdates.html, or by going to WDNR's home page and searching for "Lac Courte Oreilles site-specific criteria".

Wisconsin Department of Natural Resources

101 S. Webster St.
Madison, WI 53703

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Executive Summary

This Technical Support Document has been prepared in support of a site-specific phosphorus criterion of 10 µg/L total phosphorus (TP) for Lac Courte Oreilles (LCO), in Sawyer County. In response to a rulemaking petition filed by the Courte Oreilles Lakes Association and the Lac Courte Oreilles Band of the Lake Superior Chippewa Indians, the Wisconsin Department of Natural Resources (WDNR) re-assessed the reasonably available scientific data and analyses for LCO.

Lac Courte Oreilles has a coldwater aquatic life designated use, based on the presence of two coldwater fish species, cisco and whitefish. Of these, whitefish are the more sensitive species. WDNR developed a model based on over thirty years of extensive data from LCO to predict how whitefish (*Coregonus clupeaformis*) habitat would respond to reduced phosphorus concentrations in the lake. This model was developed for LCO as part of a 2018 rulemaking effort and was supplemented with additional lake data from the most recent years, through 2021.

Additionally, WDNR ran a more generalized EPA hypoxia model for lakes with coldwater fish, but determined that the WDNR model was more accurate and robust for analysis of LCO conditions.

The updated WDNR model results were very similar to those from the prior technical analyses and continue to support 10 µg/L as an appropriate criterion to improve whitefish and cisco habitat and thus help to support the designated use of LCO for fish and aquatic life. Because of the extensive work documented in WDNR's 2018 Technical Support Document and 2019 Addendum, as well as LimnoTech's 2016 analysis, those documents are frequently referenced here. This document focuses on presenting updated results and new analysis.

The main findings of this analysis are as follows:

- The statewide TP criterion of 15 µg/L is not sufficient to protect the coldwater community in LCO. Due to site-specific characteristics of LCO, a lower criterion is necessary.
- WDNR's updated analysis confirms that a TP criterion of 10 µg/L is appropriate and necessary to increase whitefish survival during the most stressful seasonal warm periods. Further, the proposed criterion is not more stringent than reasonably necessary for attaining that protection, as concentrations above this point would not provide sufficient coldwater fish habitat.
- There are multiple factors impacting the fishery in LCO. Phosphorus is a controllable factor, while some of the other factors such as temperature and sediment characteristics may not be controllable and are outside the WDNR's regulatory authority.
    - When setting a criterion for one of the contributing factors (phosphorus), it should be set at a level that reasonably addresses that factor's role in attaining the desired habitat quality.
    - While addressing phosphorus alone is not likely to provide optimal habitat for all coldwater species, a site-specific criteria for phosphorus can be set at a level that will contribute to improving the coldwater habitat.
    - Phosphorus has continued to increase in the most recent water samples, continuing the upward trend previously observed. Although individual years have exceeded the statewide phosphorus criterion of 15 µg/L, none of the basins are yet listed as impaired using the WDNR's standard 5-year assessment approach. However, all are currently exceeding 10 µg/L.
- WDNR updated its 2019 model with the newest data to recommend an appropriate TP criterion.
    - Because of site-specific conditions, the amount of oxythermal habitat (simultaneously suitable dissolved oxygen and temperature) WDNR would normally try to maintain for whitefish (as detailed in

the state's proposed oxythermal criteria) may not be attainable in this particular lake. However, habitat can be improved to a degree necessary for enabling whitefish survival.

    - The proposed phosphorus criterion will preserve some suitable oxythermal habitat for whitefish, the most sensitive coldwater species, with a dissolved oxygen (DO) concentration of at least 3 mg/L and temperature of not more than 18.9°C for 4 out of 5 years.

- In addition to updating its LCO-specific model with the newest data to recommend a TP criterion, WDNR also explored a new hypoxia model from the U.S. Environmental Protection Agency (EPA). After examining both approaches, WDNR concluded that the WDNR model provides a more accurate representation of conditions in LCO than EPA's more generalized model.
- It is WDNR's obligation under the Clean Water Act to set an appropriate criterion to protect the lake's designated uses (in this case, a coldwater fish and aquatic life use), regardless of whether the state can require implementation actions.
    - Because all phosphorus sources in the watershed are currently nonpoint, there would be no regulatory requirements or economic impacts as a result of the proposed site-specific phosphorus criterion.
    - Setting a site-specific criterion provides a benchmark for voluntary efforts to reduce phosphorus. It also increases the potential for local entities to secure grant funding from WDNR or other sources to address the issues and improve the condition of the lake.
    - Any future point source dischargers in the watershed would have permit limits based on the more protective criterion.

1. Background: Lac Courte Oreilles

Lac Courte Oreilles is a deep lowland drainage lake in Sawyer County near Hayward, WI. The lake straddles state land and Tribal lands of the Lac Courte Oreilles Band of the Lake Superior Chippewa (the Tribe). The lake has three major basins, West, Central, and East (the deepest); several small bays along the shoreline of the major basins; and a large bay called Musky Bay that is somewhat restricted from the rest of the lake (Figure 1). The lake is listed as a state Outstanding Resource Water.

Because of the presence of two coldwater fish species, cisco and whitefish, the lake is classified by WDNR as a two-story fishery lake. Cisco are a resident, reproducing population that are present in each of the three main basins. Whitefish are thought to be a transient species in LCO, that migrate in from Whitefish Lake upstream of LCO. While not thought to be a resident, reproducing population, they are a valuable part of the LCO coldwater community. Only the deepest basin, the East, has conditions that can support whitefish during the warmer parts of the summer, as whitefish require colder water temperatures than cisco. Bays on two-story fishery lakes are too shallow to support coldwater fish year-round, and thus are not assessed against the water quality criteria for the two-story fishery portion of the lake.

LCO is one of only thirteen inland lakes in the state with the known presence of whitefish; ten of these lakes support both cisco and whitefish similar to LCO. Lakes with cisco as the only coldwater species are more common. Two of the other cisco-whitefish lakes are Whitefish and Grindstone Lakes, both of which are adjacent to LCO. These two coldwater fish species not only comprise an important fishery of their own, but also serve as prey for larger predator species in LCO, including walleye, musky, and northern pike. According to a white paper studying predator-prey relationships within LCO and other two-story fishery lakes in the region and state, "Within the Upper Chippewa watershed cisco lakes are rare but they do produce large predators, at 3-5 times the relative frequency of non-cisco lakes" (Pratt, 2015). The paper points out that reduction of appropriate habitat for these coldwater fish due to warming

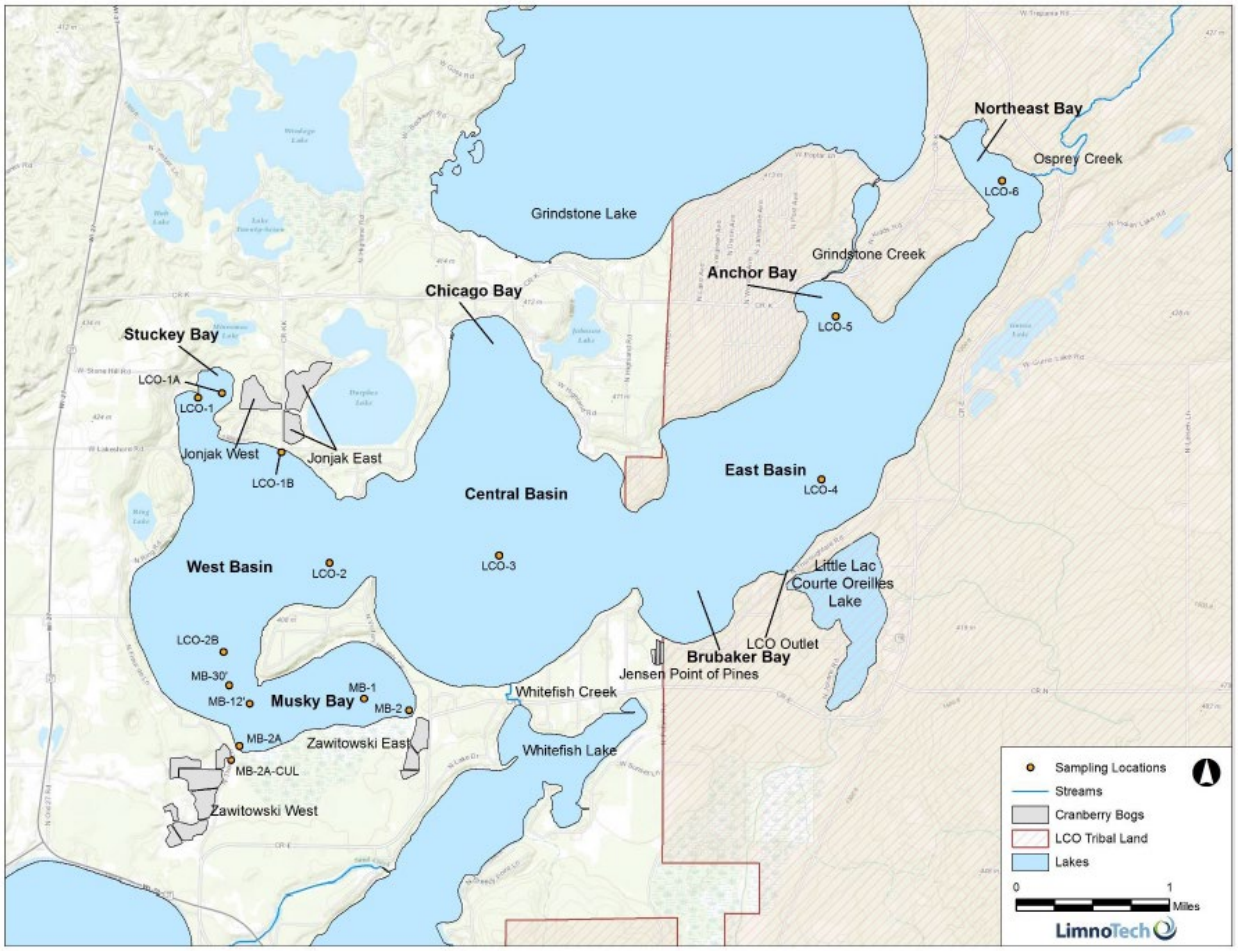
and eutrophication relegates them to compressed areas with minimal refugia in which to hide from predators. This can lead to predator species decimating these prey populations, which in turn would affect the population of predator species in the long run. For all of these reasons, it is important to safeguard both the cisco and whitefish populations of LCO into the future, particularly given the increasing stressor of warming temperature.

Lac Courte Oreilles has a long record of sampling by WDNR staff, Tribal staff, and the Courte Oreilles Lake Association (COLA). There is strong local interest and a history of active participation in managing the lake and watershed to protect the fishery, manage invasive species, and support recreational uses.

The 30-year data record on LCO shows that the amount of habitat available for whitefish is significantly depleted during the warm summer months. This is due to both a depletion of oxygen in lower depths of the lake and warming temperatures in the upper portion of the lake. A reduction of phosphorus concentrations is predicted to increase the amount of oxygen, thereby improving whitefish habitat in most years enough to allow their survival during the more stressful warm periods. This will improve available habitat for cisco as well.

LCO has been listed as impaired for low dissolved oxygen (DO) impacting the coldwater aquatic life designated use since 2018. Although the phosphorus concentrations have not yet exceeded the statewide phosphorus criterion for two-story fishery lakes of 15 µg/L, the most recent data show increasing trends and imminent exceedance of this criterion in each basin. Further, even with TP levels below 15 µg/L, whitefish habitat has been shown to be insufficient and fish kills have occasionally occurred. Therefore, a TP criterion lower than 15 µg/L is necessary to enable survival of whitefish and a more resilient coldwater community in this lake.

Figure 1. Lac Courte Oreilles map showing tributaries, major basins and bays, sampling stations, Lac Courte Oreilles Band of Lake Superior Chippewa Tribal land, and cranberry bog locations. Source: LimnoTech, 2016.



2. Basis for site-specific criteria

2.1. Regulatory authority

A site-specific criterion is established for an individual waterbody or segment when the statewide criterion is either over- or under-protective to support the designated uses of the waterbody due to site-specific characteristics. The authority for adopting any water quality criteria is established in Wis. Stat. s. 281.15:

> **(1)** The department shall promulgate rules setting standards of water quality to be applicable to the waters of the state, recognizing that different standards may be required for different waters or portions thereof. Water quality standards shall consist of the designated uses of the waters or portions thereof and the water quality criteria for those waters based upon the designated use. Water quality standards shall protect the public interest, which include the protection of the public health and welfare and the present and prospective future use of such waters for public and private water systems, propagation of fish and aquatic life and wildlife, domestic and recreational purposes and agricultural, commercial, industrial and other legitimate uses. In all cases where the potential uses of water are in conflict, water quality standards shall be interpreted to protect the general public interest.

The statute further states:

> **(2)** In adopting or revising any water quality criteria for the waters of the state or any designated portion thereof, the department shall[…]:
>
> **(b)** Consider information reasonably available to the department on the likely social, economic, energy usage and environmental costs associated with attaining the criteria and provide a description of the economic and social considerations used in the establishment of the criteria.
>
> **(c)** Establish criteria which are no more stringent than reasonably necessary to assure attainment of the designated use for the water bodies in question.
>
> **(d)** Employ reasonable statistical techniques, where appropriate, in interpreting the relevant water quality data.
>
> **(e)** Develop a technical support document which identifies the scientific data utilized, the margin of safety applied and any facts and interpretations of those data applied in deriving the water quality criteria, including the persistence, degradability and nature and effects of each substance on the designated uses, and which provides a summary of the information considered under this section.

WDNR has addressed these statutory factors when determining whether a site-specific criterion should be proposed for LCO, as explained throughout this document and summarized in Section 8.

Wisconsin Administrative Code also specifically allows for the development of phosphorus site-specific criteria under Wis. Adm. Code s. NR 102.06(7):

> **NR 102.06 Phosphorus.** (7) SITE-SPECIFIC CRITERIA. A criterion contained within this section may be modified by rule for a specific surface water segment or waterbody. A site-specific criterion may be adopted in place of the generally applicable criteria in this section where site-specific data and analysis using scientifically defensible methods and sound scientific rationale demonstrate a different criterion is protective of the designated use of the specific surface water segment or waterbody.

In accordance with the administrative code, WDNR is to use its technical expertise to determine if the statewide phosphorus criterion should be modified to protect the designated uses. The code authorizes WDNR to establish a site-specific criterion if scientific data supports the decision.

2.2. Applicable designated use and water quality criteria

WDNR regulations in ch. NR 102, Wis. Adm. Code, establish designated uses. The designated use pertinent to this rulemaking is Lac Courte Oreilles' fish and aquatic life designated use. Lac Courte Oreilles has a designated fish and aquatic life use of "Cold water community" ("coldwater"). Section NR 102.04(3)(a) states: "This subcategory includes surface waters capable of supporting a community of cold water fish and other aquatic life, or serving as a spawning area for cold water fish species." Lac Courte Oreilles supports cisco and whitefish, two coldwater species. Cisco are a resident, reproducing population, while whitefish are a transient population that migrates into LCO from nearby Whitefish Lake, just a quarter mile upstream. Existing code language in s. NR 102.06(2)(i) defines a "stratified two-story fishery lake" as "a stratified lake which has supported a cold water fishery in its lower depths within the last 50 years." Lac Courte Oreilles falls within that definition. A stratified two-story fishery lake is one type of coldwater community.

A statewide total phosphorus criterion of 15 µg/L applies to all two-story fishery lakes in the state. Development of the state's 2010 phosphorus criteria is described in WDNR's 2010 Technical Support Document for that rule (insert citation & ref). In the section on development of the two-story fishery lake criterion of 15 µg/L, the document states:

> "The proposed criterion of 15 µg/L is based on the mean concentration of reference lakes plus one standard deviation. Reference lakes were selected based on a minimum of human impact, and the phosphorus concentrations were derived through interpretation of sediment cores. In all cases, the bottom of the core was used to present pre-settlement conditions."

In this approach, it does not appear that whitefish were specifically accounted for. The coldwater fishes in Wisconsin's inland lakes include cisco, whitefish, lake trout, other trout species that are more commonly thought of as stream trout but may also use lake habitat (brook, brown, or rainbow trout), and the invasive rainbow smelt. The large majority of Wisconsin's two-story fishery lakes have only cisco and/or "stream" trout species—the hardier of the coldwater species. Only 13 lakes have whitefish and 5 have lake trout, the two most sensitive species, requiring colder temperatures. Therefore, the group of reference lakes used in the 2010 analysis was unlikely to have included many whitefish or lake trout lakes, and may not be fully protective of those species. While 15 µg/L may be protective of some lakes with whitefish or lake trout, others may require a site-specific criterion to provide a similar level of protection as was intended by the statewide criterion. In fact, the 2010 phosphorus technical support document states that:

> "The Department recognizes that the concentration of 15 µg/L is higher than the 10 µg/L associated with classic oligotrophic lakes and the 12 µg/L promulgated by the Minnesota Pollution Control Agency [for lake trout lakes]. Also, the concentration would seem to result in a concentration too high to support a lake trout fishery as depicted on Figure 3 below [not shown here]. Given the apparent conflict and the relatively small number of these lakes, 2-story lakes may be candidates for site-specific criteria development."

In determining whether a more stringent criterion is needed to support a designated use, WDNR considered factors such as the following: whether the designated use is protected by the statewide phosphorous criterion; whether there is a clear link between the phosphorous concentrations and the protection of these designated uses; and whether scientific evidence demonstrates that a more stringent phosphorous criterion is necessary to protect the designated uses. The intent of a site-specific criterion is to provide a similar level of protection of a waterbody's uses as was intended by the statewide criterion. WDNR also considered that the final criterion must not be more stringent than reasonably necessary for protection of the designated uses.

In this technical support document, WDNR has analyzed whether the site-specific characteristics of LCO warrant establishment of a lower site-specific TP criterion for the lake to protect its two-story fishery, primarily its most sensitive species, whitefish. The WDNR has concluded that a site-specific criterion would be appropriate in this case, as demonstrated in the remainder of this document.

2.3. Site-specific characteristics of LCO

This report enumerates several site-specific characteristics of LCO that make a site-specific criterion appropriate and necessary. In summary:

- The rate of oxygen depletion in LCO has been shown to be an outlier when compared to other lakes. The temperature and dissolved oxygen profiles are unusual, likely due to the factors mentioned above, leading to a narrower band of oxythermal habitat than expected based on the lake's depth and its phosphorus and chlorophyll *a* concentrations. Based on these historical concentrations alone and the morphometry of the lake, one would expect better dissolved oxygen levels in LCO, but instead there are high rates of oxygen depletion (Section 5).
- The presence of whitefish within the coldwater community is, in itself, rare in Wisconsin lakes. Whitefish are a more thermally-sensitive species than cisco. Only thirteen lakes in the state—out of more than 15,000 lakes—have a known whitefish presence, and in several of these lakes the whitefish may be transient, as in LCO, which emphasizes the rarity of this species. Although reproducing populations are not thought to populate LCO, protection of mature fish that use the lake for habitat is important given the rarity of the species. The adult fish that frequent LCO may survive to reproduce within nearby Whitefish Lake. As discussed in the previous section, the statewide phosphorus criterion may not be protective of all two-story fishery lakes that contain whitefish, which are likely good candidates for site-specific criteria.
- LCO is experiencing multiple stressors. While this includes nutrient inputs, there are also serious effects from other less-controllable factors such as warming water temperatures that reduce coldwater habitat, and unusual sediment characteristics that increase the rate of oxygen depletion, further restricting habitat (Section 4).

Because there are multiple factors at play in this lake, and only one of these factors—phosphorus levels—is likely controllable, it is necessary to curb phosphorus inputs to the extent possible in order to mitigate the effects of the other factors and preserve this rare coldwater fishery into the future.

3. Water quality trends in LCO

3.1. Phosphorus

WDNR supplemented earlier data reported in 2018 and 2019 with total phosphorus data from the LCO Tribe and COLA to complete the dataset up to 2021.

Using the WDNR's phosphorus assessment methods in its 2022 Wisconsin Consolidated Assessment and Listing Methodology Guidance (WisCALM) (WDNR, 2021), WDNR compared the most recent five years of data from LCO to the statewide total phosphorus criteria for two-story fishery lakes. None of the three main basins "clearly exceeds" the phosphorus criterion of 15 µg/L and are therefore not yet listed as impaired, despite the upward trend (Table 1). A waterbody would be listed as impaired for phosphorus if it "clearly exceeds" its criterion, which is determined if the entire two-sided 80% confidence interval around the mean exceeds the criterion. A waterbody "clearly attains" the criterion if the entire confidence interval is below the criterion. A result of "may attain," as for the West Basin, means that the mean is below the criterion but the confidence interval straddles the criterion.

Table 1. Total phosphorus (TP) assessment data for Lac Courte Oreilles, 2017-2021.

				Total Phosphorus (µg/L)		
WBIC	WATERS ID	Station Name	Natural Community	TP Criterion (Aqu. Life)	Mean (80% confidence interval)	Aqu. Life Status
2390800	15368	West Basin (LCO-2)	TWO-STORY	15	14.70 (13.86-15.59)	May Attain
2390800	15368	Center Basin (LCO-3)	TWO-STORY	15	13.44 (12.64-14.29)	Clearly Attains
2390800	15368	East Basin (LCO-4)	TWO-STORY	15	13.22 (12.48-14.00)	Clearly Attains

To analyze trends over time, annual average total phosphorus (TP) concentrations were calculated from samples taken at < 2 m deep between June 1 and September 15. Several outlier TP values were removed for the trend analysis. Outliers were identified as > 3 standard deviations from the mean log(TP) for the station or >15 µg/L change in TP in 7 days or less. Outliers were not removed from the assessment calculations in Table 1. TP samples reported as below the detection limit were estimated as LOD/$\sqrt{2}$, which equals 5 µg/L for the TP method. Annual averages were calculated separately for each main basin station. First, daily mean TP was calculated if there were multiple samples on a single day. Then the assessment period was divided into three equal length periods (June 1 to July 6, July 7 to August 11, August 12 to September 15), and the mean TP was calculated for each of these periods. Annual means were calculated from these period means. Years with no samples in one or more periods were excluded from the trend analysis. Simple linear regressions between TP and year were used to estimate the rate of change in TP over time.

In the East Basin, which has the longest data record, this provided a total data period from 1988 to 2021. Figure 2 shows an increasing phosphorus trend over this time period, with 2021 exceeding the statewide phosphorus criterion of 15 µg/L. In the West and Center Basins, the data record is from 1996 to 2021, but frequent sampling begins in 2001. Phosphorus has also been increasing over time in these two basins, with the most recent years exceeding the statewide phosphorus criterion of 15 µg/L (Figure 3). The lowest TP observed in the lake on record was 6.3 µg/L (1995, East Basin).

Figure 2. Trends in mean total phosphorus in the East Basin of Lac Courte Oreilles from 1988 to 2021.

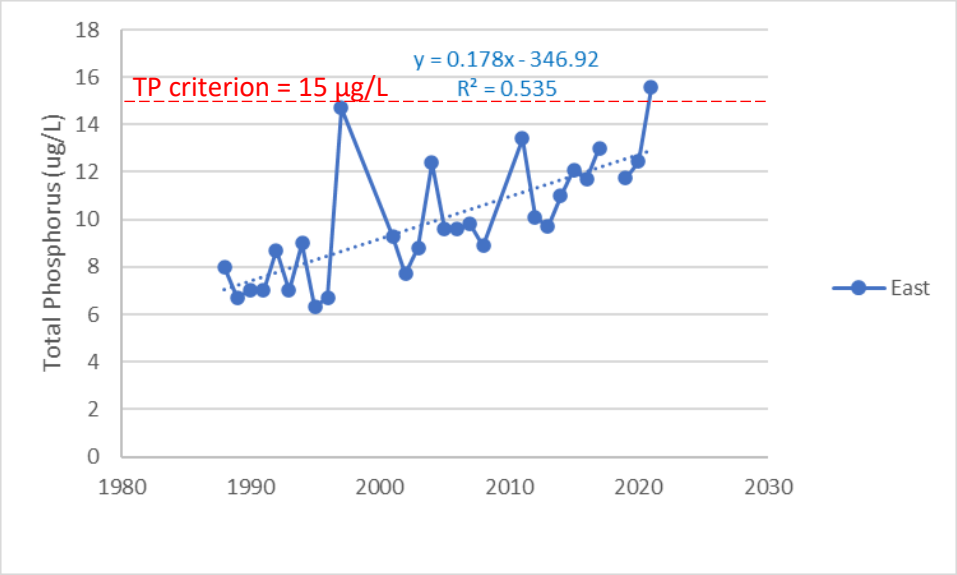
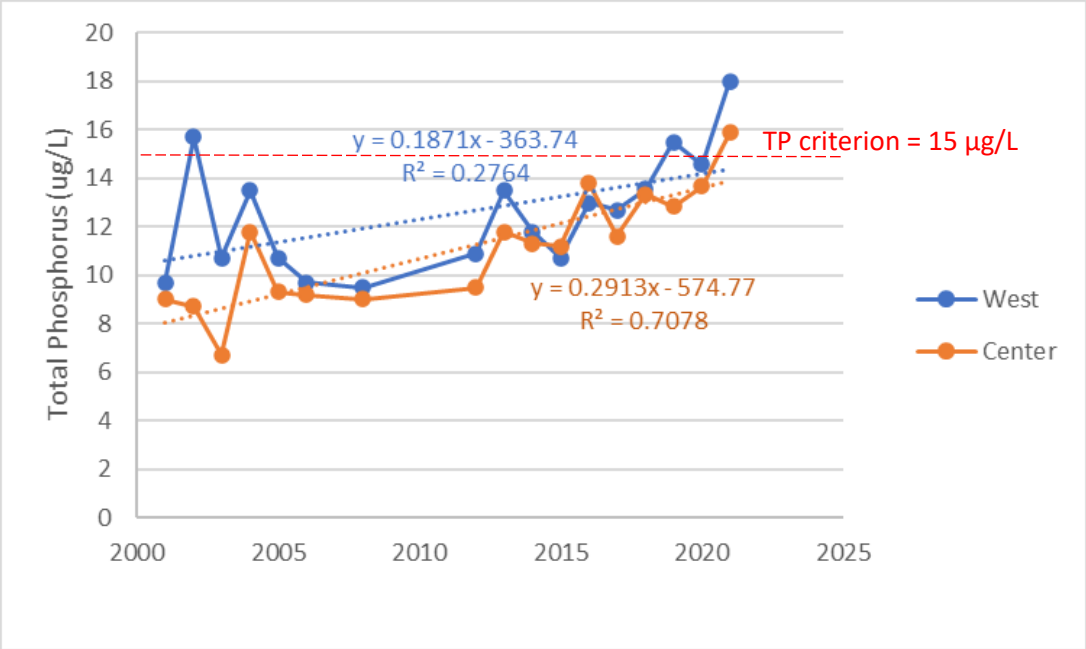


Figure 3. Trends in mean total phosphorus in the West and Center Basins of Lac Courte Oreilles from 2001 to 2021.



3.2. Chlorophyll *a*

WDNR supplemented earlier data with chlorophyll *a* data from the LCO Tribe and COLA to complete the dataset up to 2021. This resulted in data records for East, West, and Center basins from 2000 to 2021.

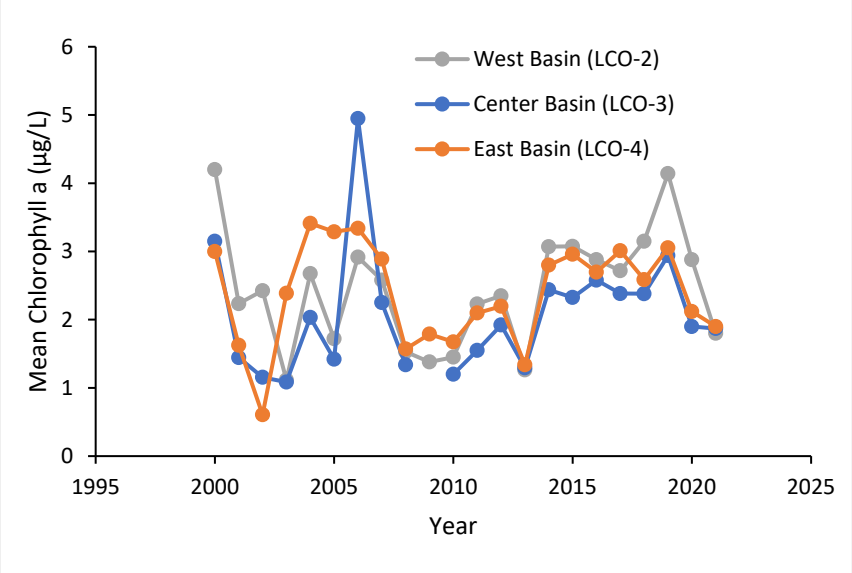
LCO's chlorophyll *a* levels are very low. Chlorophyll *a* is used to assess for attainment of the aquatic life use following WisCALM protocols (WDNR, 2021). The chlorophyll *a* target to protect the aquatic life use for two-story fishery lakes is 10 µg/L chl *a*. Chlorophyll *a* assessments for aquatic life are conducted similarly to those for TP. Each of LCO's three basins "clearly attains" its chlorophyll *a* target of 10 µg/L for aquatic life protection (Table 2).

Table 2. Chlorophyll *a* assessment data for Lac Courte Oreilles' aquatic life use of two-story fishery lake, 2017-2021.

				Chlorophyll *a* (µg/L)		
WBIC	WATERS ID	Station Name	Natural Community	Chl *a* Thresh. (Aqu. Life)	Mean (80% confidence interval)	Aquatic Life Status
2390800	15368	West Basin (LCO-2)	TWO-STORY	10	2.95 (2.63-3.31)	Clearly Attains
2390800	15368	Center Basin (LCO-3)	TWO-STORY	10	2.20 (1.94-2.49)	Clearly Attains
2390800	15368	East Basin (LCO-4)	TWO-STORY	10	2.38 (2.13-2.66)	Clearly Attains

To analyze trends over time, annual average chlorophyll *a* concentrations were calculated from samples taken at < 2 m deep between July 1 and September 15. Annual averages were calculated separately for each station on the lake. Chlorophyll *a* concentrations in LCO have remained well below the threshold of 10 µg/L, with each basin having a 5-year average of between 2 and 3 µg/L (Table 2, Figure 4). Low chlorophyll *a* concentrations in Lac Courte Oreilles are not surprising given that phosphorus concentrations are also below 15 µg/L. In most lakes, the increase in chlorophyll *a* per unit increase in TP begins after TP reaches 15-20 µg/L. Chlorophyll *a* did not change significantly over time at any of the three stations according to simple linear regressions predicting chlorophyll *a* based on year for each station.

Figure 4. Trends in mean chlorophyll *a* in the West, Center, and East Basins of Lac Courte Oreilles from 2000 to 2021.



3.3. Aquatic plants

An aquatic plant survey was conducted in LCO in 2010, which is documented in the 2018 Technical Support Document. Aquatic plant thresholds for northern drainage lakes were applied for both the general condition assessment (attained if tolerant species ≤73%) and the phosphorus response assessment (attained if phosphorus-sensitive species are >51%).

The results of the plant survey showed that the whole-lake plant community is healthy. The plant community attains the general condition threshold used to assess for response to a range of disturbances, with tolerant species present at 27% of sampling points. It also attains the threshold that would indicate a response specific to phosphorus, with phosphorus-sensitive species present at 87% of sampling points. Therefore, TP does not need to be reduced from current concentrations in the main basins to protect the aquatic plant community. The survey is described in more detail in WDNR's 2018 Technical Support Document (WDNR, 2018).

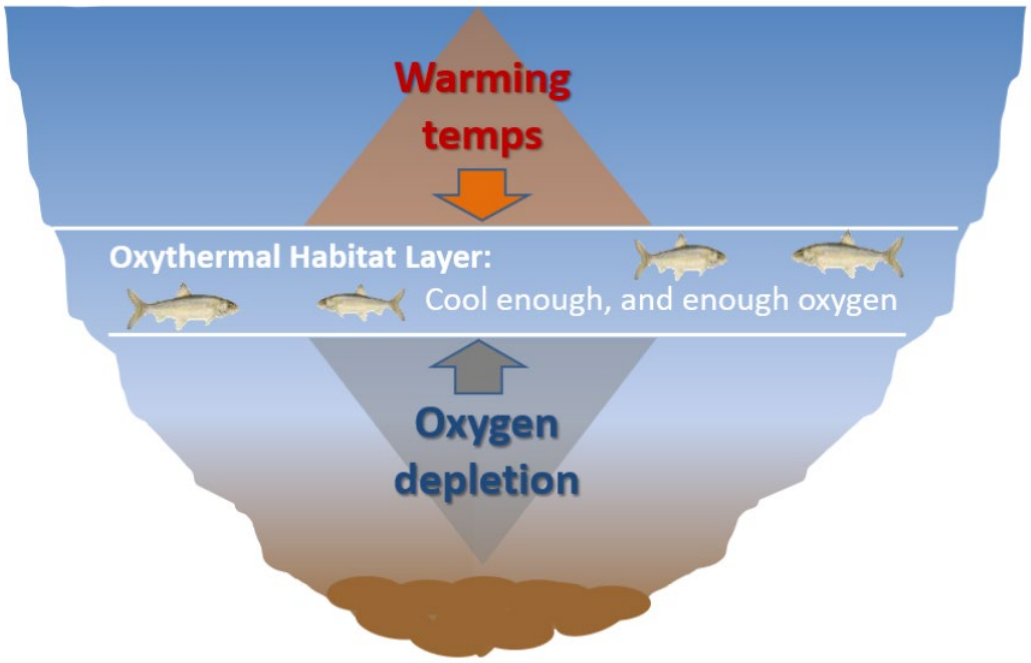
4. Two-story fishery lakes and oxythermal habitat

4.1. Oxythermal habitat

Existing code language in s. NR 102.06(2)(i) defines a "stratified two-story fishery lake" as "a stratified lake which has supported a cold water fishery in its lower depths within the last 50 years." Coldwater fishes, such as cisco and whitefish in Lac Courte Oreilles, need a band of water that has both cold enough temperatures and high enough oxygen for them to survive. At the beginning of the summer, the hypolimnion (deepwater layer) and thermocline (transitional middle layer) usually have both; but by the end of the summer the dissolved oxygen (DO) is sometimes greatly depleted, squeezing the fish upward into a very narrow layer in the thermocline in which they can survive (Figure 5). During long, hot summers this layer may disappear altogether, causing a fish kill. Therefore, a measure that combines both DO and temperature is most appropriate for assessing support of the two-story fishery habitat. The layer of suitable habitat that serves as a refuge for fish in the warm parts of the summer is called the "oxythermal layer" or "oxythermal habitat". It can be defined using several variables, including the target dissolved oxygen concentration, which is typically between 3 and 6 mg/L, the maximum appropriate temperature, which varies by species, and the desired depth or thickness of the oxythermal layer. More information is contained in Section 5 describing the oxythermal layer targets that were set for Lac Courte Oreilles in this analysis.

To measure a lake's available volume of oxythermal habitat, vertical temperature and DO profiles are taken in the deepest part of the lake while the lake is stratified. For Lac Courte Oreilles, these profiles were assessed from the deep point at each of the three major basins. Multiple profiles are typically needed to account for variability, both during the summer season and across years. The profiles are plotted as temperature vs depth and DO vs depth. The vertical extent of the depth profile at which the DO is above its target and the temperature is at or below its specified threshold is determined. The thickness of the layer of suitable habitat is termed "oxythermal layer thickness", or OLT. The use of vertical profiles to determine the amount of available oxythermal habitat is illustrated in Section 5, Figure 7.

Figure 5. In late summer, cisco and whitefish can live only within the layer of water with cold enough temperatures and high enough oxygen. The upper layer of the lake has enough oxygen, but is too warm. The lower layer is cool enough, but has low oxygen.



Coldwater fish kills

According to the WDNR fisheries management files and fish kill database, summer fish kills of coldwater species were documented in Lac Courte Oreilles in 2015 and 2016. These fish kills were summer kills of cisco and whitefish in the main basins. The cause of the kills appears to be due to the reduction of oxythermal layer thickness. The cisco and whitefish were forced into the cooler hypolimnion to regulate their body temperatures, however, the hypolimnion did not have sufficient oxygen for survival.

4.2. Factors influencing LCO's oxythermal layer

WDNR's 2018 Technical Support document details five factors influencing oxygen depletion in LCO, outlined below. While the first two of these factors (factors 1 and 2) would likely improve with reductions in phosphorus, the others (factors 3 to 5) are unrelated to phosphorus and likely uncontrollable. There is a full description of each of the following factors in the 2018 report.

Although each of these factors is at play in LCO, this analysis focuses solely on the role that changes in phosphorus levels can play in attaining sufficient oxythermal habitat. In cases such as this, where multiple factors are contributing to a problem, a criterion for one of the contributing factors (in this case, phosphorus) should be set at a level that reasonably addresses that factor's role in the waterbody's condition, recognizing that addressing a single factor alone may not result in optimal habitat for all coldwater species present.

Factors 1 and 2 may be improved with reductions of phosphorus concentrations:

1) **Decomposition of organic matter in the water column.** Oxygen is depleted when algae suspended within the water column decomposes. Reducing phosphorus is likely to reduce chlorophyll *a* concentrations to some degree. If chlorophyll *a* is reduced, it should result in less oxygen depletion and a wider oxythermal layer, which would be more protective for whitefish and cisco. Concentrations of chlorophyll *a* in the water column are low, so this process may not be a large contributor to oxygen depletion. However, it is possible that a small reduction in the concentration could result in a meaningful improvement.

2) **Aerobic decomposition of sediment organic matter *from algal production*** (as opposed to land-based inputs in number 3)**.** Sediment organic matter is a combination of algae produced in the lake and organic matter from the land, such as leaf litter or wetland plants. Although both of these sources are present, it is yet unknown what proportion of LCO's sediment organic matter is from each source. If the sediment organic matter is mostly ***from algal production*** in the lake, then reducing phosphorus concentrations would improve oxygen levels over time, which could contribute to more oxythermal habitat for whitefish and cisco.

Factors 3 to 5 are unrelated to ambient phosphorus concentrations and would not be affected by reductions in in-lake phosphorus concentrations:

3) **Aerobic decomposition of sediment organic matter *from land-based inputs.*** As described under factor 2, sediment organic matter is comprised of both algae produced in the lake and organic matter from the land, such as leaf litter or wetland plants. If sediment organic matter mostly comes ***from land-based inputs***, management options for reducing external inputs should be examined. Reducing phosphorus concentrations in the ambient lake water would not be effective.

4) **Oxidation of reduced substances in the sediment.** A portion of LCO's oxygen depletion is caused by the oxidation of reduced substances, such as methane, ammonium, nitrite, manganese, iron, or sulfide. Further study is needed to quantify how much these processes contribute to oxygen depletion, though a comparison to other lakes

indicates that it may be higher in LCO than in other lakes. Limited data found high concentrations of iron in the hypolimnion of the West Basin with an increase over the summer season, providing evidence that oxidation of at least one reduced substance is occurring in Lac Courte Oreilles. Reducing phosphorus will not affect oxidation of reduced substances.

5) **Warming surface water temperatures.** Historically, LCO's epilimnion (upper layer of lake water) was often cold enough to provide suitable habitat for coldwater fish even in late summer, but since 1975 epilimnetic and surface water temperatures have increased by 2.5 and 2.7ºC, respectively. If the warming trends continue, future warming will further exacerbate thermal stress for cisco and whitefish. Reducing phosphorus will not reduce water temperature.

The number of different factors that could impact the amount of oxythermal habitat in LCO are many, some of which are confounding and poorly understood (see 2018 Technical Support Document for a more complete analysis). However, for this rulemaking effort, WDNR chose to focus on the net effect of phosphorus concentrations on oxythermal habitat. There are several reasons to focus on phosphorus: its effects are well understood and more easily modeled, there is long-term phosphorus data available for LCO, there are state phosphorus criteria, and phosphorus is more controllable than the other factors. However, it is important to recognize that while phosphorus reduction can address some of these impacts and improve whitefish survival during stressful periods, the other factors influencing the lake mean that phosphorus reductions alone may not result in oxythermal habitat that fully supports whitefish.

WDNR's phosphorus analysis is described in the following sections and further information is available in WDNR's 2019 Addendum to the Technical Support Document. A significant correlation was found between phosphorus and oxygen depletion. This relationship is useful for estimating how much oxythermal habitat could be gained by reducing in-lake phosphorus concentrations. The next section describes the methods for translating a phosphorus reduction scenario into an estimated gain in oxythermal habitat.

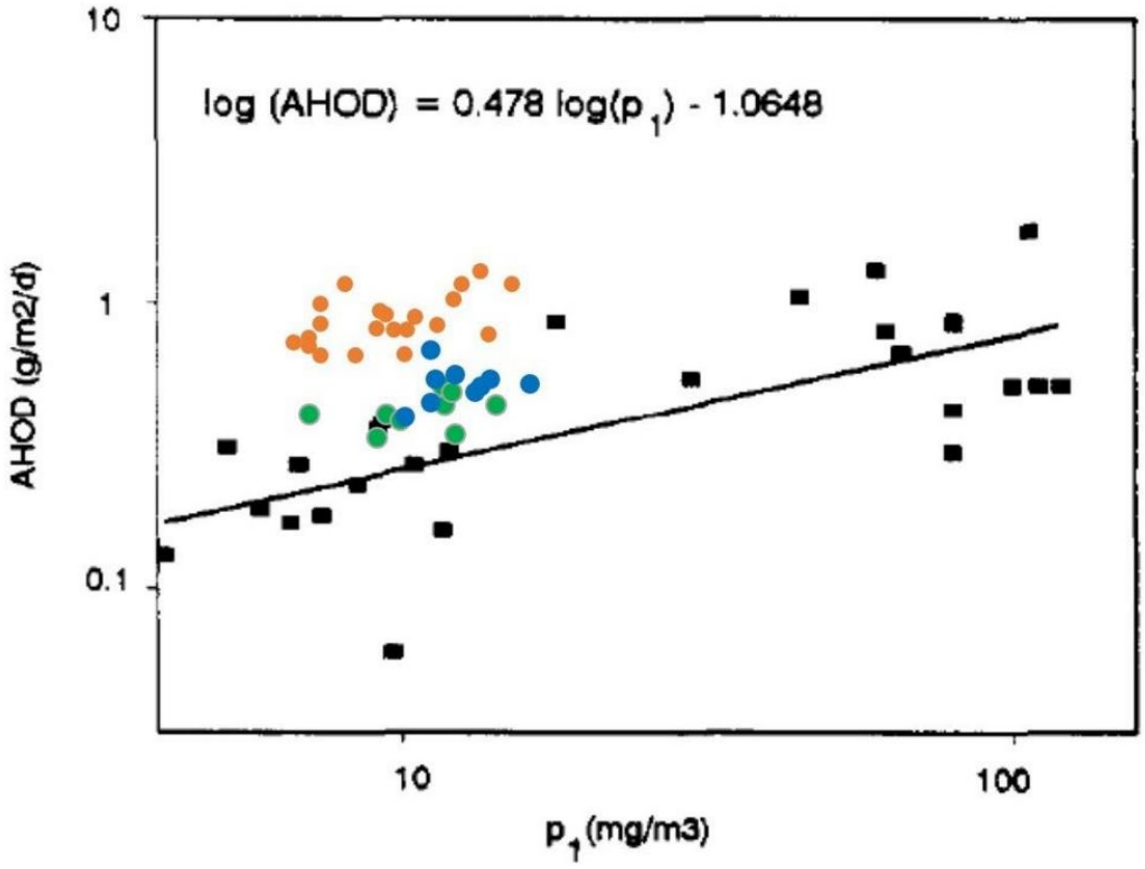
5. Oxygen depletion analysis

5.1. Background and comparison to other lakes

In a deep, stratified lake like LCO, oxygen in the deepwater layer of the lake (hypolimnion) declines at the same rate throughout the warm summer months (in scientific literature this rate is typically referred to as hypolimnetic oxygen demand, or HOD). WDNR found that the rate of oxygen depletion in LCO varies from year to year, and that increases in annual phosphorus concentrations are associated with increases in the rate of oxygen depletion (in a manner similar to how oxygen depletion varies in relation to phosphorus concentrations *across* lakes as in Chapra and Canale, 1991). Given this relationship, it is likely that oxygen depletion will slow if in-lake phosphorus concentrations can be reduced.

In its 2018 LCO Technical Support Document, WDNR found that LCO's rate of oxygen depletion in the East Basin, the basin most suited to whitefish habitat, is greater than that of a group of lakes that were studied by Chapra and Canale (1991). Chapra and Canale found that a lake's phosphorus concentration is generally a good predictor of oxygen depletion. Figure 6 illustrates that relationship, showing how areal hypolimnetic oxygen demand (AHOD, a measure of oxygen depletion that is normalized by depth for the purpose of developing a model across lakes of varying depths) increases with increasing phosphorus concentrations. However, LCO's East Basin has annual AHOD values that are higher than would be predicted based on concurrent annual phosphorus concentrations. This site-specific characteristic of LCO—a higher than expected oxygen depletion rate—is likely tied to the multiple stressors outlined in Section 4 of this document. This is one reason that WDNR used a site-specific model for LCO to explore its phosphorus-oxygen relationships.

Figure 6. Areal Hypolimnetic Oxygen Demand (AHOD, a measure of oxygen depletion normalized by depth) of the East Basin (orange), Central Basin (green), and West Basin (blue) in Lac Courte Oreilles compared to the AHOD of 25 different lakes of varying phosphorus concentrations (p_1) (LCO samples are graphed on top of Figure 3 in Chapra and Canale 1991).



In 2019, WDNR developed a model to derive a phosphorus concentration that would result in attainment of an oxythermal habitat layer that supports whitefish and cisco in Lac Courte Oreilles. The model used the relationship between phosphorus and oxygen depletion to reconstruct oxygen profiles during late summer periods (when oxygen concentrations are at their lowest) for scenarios of in-lake phosphorus concentrations between 5 and 20 µg/L. Late-summer oxygen profiles were reconstructed each year between the years 2000 and 2018, and linked with temperature profiles that were collected at the same time, and from these profiles the amount of oxythermal habitat was calculated. Oxythermal habitat calculations were aggregated across all years to quantify how many years suitable habitat was available versus how many years it was not. From these results, WDNR analyzed whether there was a phosphorus concentration that would result in attaining oxythermal habitat for most years.

In 2022, at the start of the current rulemaking effort, WDNR updated its 2019 model with the most recent data from LCO for 2018-2021. The model was rerun, incorporating the new data. Because the newer data were similar to the existing data, the results remained largely the same, further corroborating the findings from 2019. The 2022 results are discussed here, but readers can refer to the 2018-19 documents for more detailed descriptions of model development if necessary.

5.2. Oxygen depletion model

A predictive model was built to quantify the relationship between phosphorus and oxygen depletion. Phosphorus samples have been collected from LCO every year since 1988. Dissolved oxygen has also been collected over the same time period; however, early dissolved oxygen profiles before the year 2000 often only had one day of data available during stratification season. A rate of oxygen depletion cannot be calculated from one day of data within a year, and therefore phosphorus and oxygen data were discarded prior to the year 2000. From the year 2000 forward, annual phosphorus concentrations were calculated by selecting only surface samples during summer months, calculating monthly averages, and then calculating an annual average across months. The rate of oxygen depletion was calculated in two steps. First, for each day a dissolved oxygen profile was collected, a hypolimnetic average oxygen concentration was calculated using measurements from the depth of the thermocline to the bottom of the lake. Second, a regression line was fitted to describe the relationship between time and average oxygen concentration. The slope of the regression represents the rate of oxygen depletion (i.e., HOD).

To describe the relationship between oxygen depletion and phosphorus concentration, a special type of linear model was used called linear mixed effects. A linear mixed effects model allows the incorporation of data from multiple sites to better understand the relationship between phosphorus and oxygen depletion. WDNR pooled data from all three main basins together within a mixed effects model that utilized the *lme4* library of the R Statistical Programming language (Bates, 2014; R Core Team, 2019). The model took the form of the following formula, using R *lme4* notation (Bates, 2014) where S is the monitoring station random effect:

Equation 1

$$\ln(AHOD_{10}) \sim \ln(TP) + (TP|S)$$

The above model relates the natural log of the areal HOD (g m^{-2} d^{-1}) below 10 meters of depth, to the natural log of annual average growing-season median surface TP, for each site-year combination, while varying the slope and intercept for each station S. The most likely coefficients for the east, central, and west basin are 0.29, 0.13, and 0.10 respectively. The East Basin has the most data and is most likely to provide suitable oxythermal habitat, and therefore model results were only used for that site.

5.3. Oxygen profile reconstruction

In 2016, a coalition of LCO stakeholders wrote a proposal for site-specific phosphorus criterion for LCO (LimnoTech, 2016). In this proposal, they provided a solution that predicts change in HOD given changes in in-lake TP concentrations, then adjusts the DO profile curve given the proportional change in HOD. To calculate HOD based on in-lake phosphorus concentrations, they used the following formula derived from Chapra and Canale (1991):

Equation 2

$$HOD_{future} = HOD_{present} * \left(TP_{future}/TP_{present}\right)^{\beta_1}$$

The coefficient β_1 represents the slope of the relationship between TP and HOD from the Chapre and Canale (1991) multi-lake study, which had a value of 0.478. For this new assessment WDNR instead used the LCO site-specific coefficient of 0.29 (see Oxygen Depletion Model Section) to replace the multi-lake coefficient in Equation 1. Then, the initial yearly oxygen profile in the springtime was reduced at the rate of HOD_{future} to reconstruct what summer minimum oxygen conditions would look like if TP concentrations were reduced (Figure 7). When the reconstructed oxygen profiles are paired with the temperature profiles measured at the same time, reconstructed oxythermal bands can be measured to test if their thicknesses of oxythermal habitat are suitable for supporting whitefish and cisco populations.

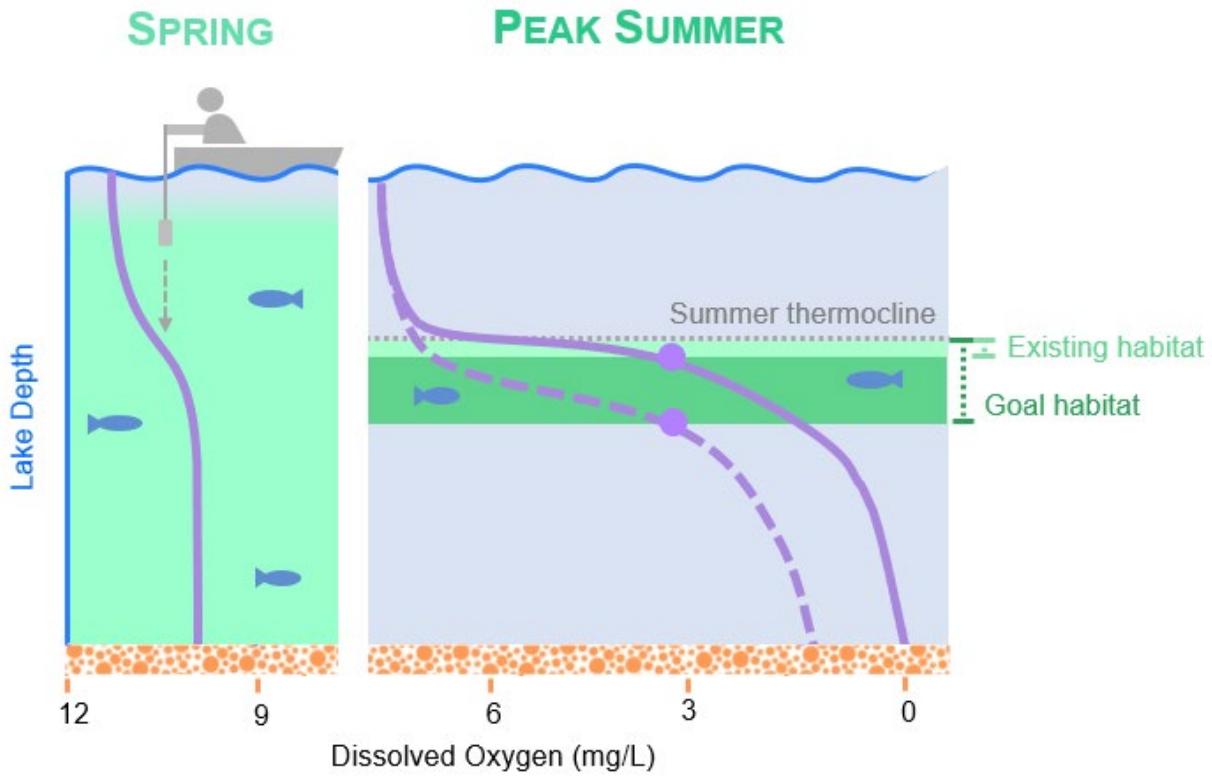
Figure 7. A conceptual diagram (not to scale) illustrating the process of reconstructing dissolved oxygen (DO) profiles from a simulated reduction of in-lake phosphorus concentration.

Temperature and DO are monitored at 1 meter increments with a probe, from the surface of the lake to the bottom. These measurements are used to construct a DO profile (purple lines) for each sampling date. The DO concentration is shown on the bottom axis with higher concentrations on the left; DO decreases from the lake's surface to the bottom for each profile.

- The left-most profile represents a typical existing DO profile in the spring season, before the lake stratifies and DO is nearly uniform from the surface to the lake bottom. Oxythermal habitat is available throughout the lake.
- The two profiles on the right represent late summer. The right-most profile represents a typical existing DO profile at the end of summer when most DO has been depleted. The dashed-line DO profile represents a hypothetical profile using $\boldsymbol{HOD}_{future}$ from Equation 2, representing late summer conditions under a reduced-phosphorus scenario. Reductions in phosphorus are predicted to improve DO levels, so more DO would be maintained even during late summer.

After the lake stratifies in the summer, temperatures are assumed to be cold enough for coldwater species from the thermocline down. The green bands represent the amount of suitable habitat where temperatures are cold enough and DO is above 3 mg/L. The green bands are bounded on the top edge by the thermocline and the bottom edge by the point where DO dips below 3 mg/L (purple dots).

- The light green band represents the amount of suitable oxythermal habitat under existing conditions.
- The dark green band represents the theoretical improvement in habitat volume if in-lake phosphorus concentrations were reduced. The dark green band shows that less oxygen depletion would occur over the spring and summer with lower in-lake phosphorus concentrations, leaving a wider band of suitable habitat.



5.4. Oxythermal habitat target

In a related rule package, WY-23-13, WDNR is proposing an oxythermal habitat criterion for two-story fishery lakes in revisions to ch. NR 102, Wis. Adm. Code. The proposed criterion requires a layer of water at least 1 meter in depth which attains both a DO concentration of 6 mg/L and the appropriate temperature range for the species that are expected to be present. For cisco, temperatures within this layer must be below 73°F, for whitefish below 66°F. Because whitefish are the more sensitive species in LCO, the temperature limit of 66°F is applied. Under this proposed criterion, if the oxythermal layer thickness is less than 1 meter at any point during the summer, that year is considered "not attaining" the threshold; if any two or more years sampled within the assessment period do not attain the threshold, the lake is considered not attaining the proposed criterion.

Because of site-specific conditions, the proposed statewide oxythermal criteria for whitefish may not be attainable in this lake. Although phosphorus concentrations less than the current criterion of 15 µg/L would improve oxythermal habitat, in years when the hypolimnion is warmer even the most extreme reductions in phosphorus may not result in an oxythermal layer of 1 m water thickness at 18.9°C and 6 mg/L DO. This is because phosphorus is only one of several factors at play in this lake, including the uncontrollable effects of rising temperature and reactions in the sediments that also influence oxygen depletion.

Nevertheless, achieving additional depth in the oxythermal layer – even if it is not 1 m of thickness—is expected to be feasible for LCO and will help to sustain whitefish through stressful periods and prevent fish kills. Specifically:

- *DO component:* LCO may not be able to achieve a DO of 6 mg/L at temperatures < 18.9°C at all times, but could achieve a DO of 3 mg/L at most times to sustain survival. A DO of 3 mg/L is a marginal state at which fish can survive, but are likely to experience non-lethal (sublethal) effects such as reduced metabolism, growth rate, or reproduction (Hrycik et al. 2016). Although DO of 3 mg/L for extended periods would be harmful, this criterion is meant to enable survival during the most stressful (hottest and least oxygenated) periods of the summer. This would mean short-term exposure to low DO, rather than long-term conditions that would not be viable.
- *Oxythermal layer thickness component:* According to the DNR model, LCO may not be able to achieve an oxythermal habitat depth of 1 meter at all times, but could achieve at least some (greater than zero) oxythermal habitat depth during most years to sustain survival.
- *Site-specific target:* Therefore, in this analysis the oxythermal habitat target is defined as preserving at least some depth of oxythermal habitat with DO >3 mg/L and temperature <18.9°C for 4 out of 5 years. The analysis focuses on setting a TP criterion that will attain this target to maintain the lake's coldwater designated use.

Table 3. Comparison of proposed LCO target to proposed statewide criterion.

Oxythermal target for whitefish	DO (mg/L)	Temp (°C)	Thickness of suitable habitat	# Years attaining
Proposed statewide criteria	6	18.9	At least 1 meter	4 out of 5
Proposed LCO target	3	18.9	> 0 meters	4 out of 5

Each of the oxythermal layer components shown in Table 3 (dissolved oxygen concentration, temperature, and thickness of the oxythermal layer) affects how often the lake attains its oxythermal target. Several scenarios from the model are shown in Figure 8 to evaluate the potential to attain different oxythermal targets with varying DO concentrations and layer thicknesses. Figure 8 shows that LCO may very seldom be able to maintain a DO of 6 mg/L (green lines) throughout the summer even if TP were reduced to the lowest levels historically observed (6.3 µg/L TP in 1995, East Basin). A DO target of 3 mg/L (blue lines) is attainable in more years, with the thickness of the oxythermal layer increasing as phosphorus is reduced. Below 11 µg/L TP, the WDNR model projects at least some available oxythermal habitat in 4 out of 5 years. Phosphorus concentrations above 11 µg/L are not projected to maintain suitable habitat in 4 out of 5 years. A proposed criterion of 10 µg/L TP allows a 1 µg/L margin of safety. Therefore, a criterion of

10 µg/L is not more stringent than reasonably necessary to enable whitefish survival. Phosphorus concentrations lower than 10 µg/L are desirable and if watershed reduction efforts achieve TP below 10 µg/L, habitat for coldwater fish will likely improve further.

Phosphorus concentrations ranging from 7 – 11 µg/L TP would provide better oxythermal habitat when hypolimnetic temperatures are warm (>18.9°C) than current phosphorus concentrations of ~12-15 µg/L provide. The improvements that a lower TP would achieve could prevent mortality most years, but may still result in sublethal effects during short timeframes when DO concentrations are at or below 3 mg/L.

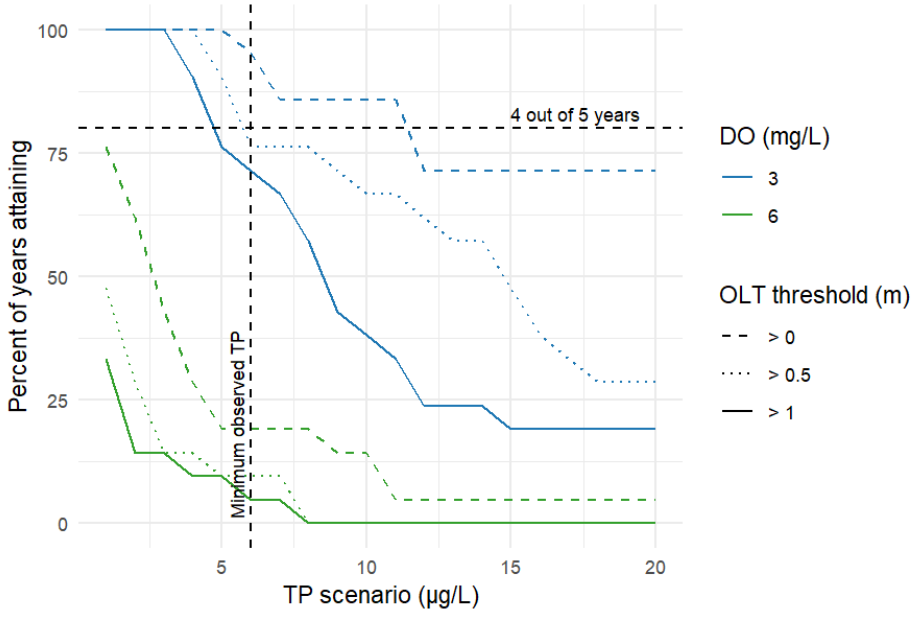
The proposed criterion (10 µg/L) also satisfies the expectation that the proposed criterion is statistically different from the existing statewide criterion (15 µg/L). Using the model in Equation 1, for a scenario in which TP concentrations equal 15 µg/L at the deep hole station in the East Basin, the expected oxygen depletion (i.e., AHOD, see Section 5.2) at that site would equal 0.97 (g m^{-2} d^{-1}). The attainment of TP concentrations equal to the proposed criterion of 10 µg/L would result in an estimated oxygen depletion of 0.86 (g m^{-2} d^{-1}). Using a bootstrapping resampling technique with 1000 repetitions, we derived an 80% confidence interval of AHOD for the proposed SSC ranging from 0.83 to 0.90 (g m^{-2} d^{-1}), which does not overlap the baseline AHOD of 0.97 (g m^{-2} d^{-1}).

Figure 8. Percent of years when oxythermal layer thickness would attain varying amounts of oxythermal habitat for whitefish (with temperatures <18.9°C), for a gradient of total phosphorus concentration between 1 and 20 µg/L.

Six different target scenarios are modeled to predict how many years would attain each target.

- Green lines represent three target scenarios targeting a dissolved oxygen (DO) of 6 mg/L. Blue lines represent three target scenarios targeting a DO of 3 mg/L.
- Temperature is held constant, with a target of attaining <18.9°C, the threshold for whitefish, LCO's most thermally-sensitive species.
- In both green and blue scenarios, solid lines represent attainment of the target over 1 meter or more of oxythermal layer thickness (OLT). Dotted lines show attainment of an OLT of .5m or greater, and dashed lines indicate attainment of at least some amount of OLT (greater than zero).

Modeling results shown in this graph indicate that a DO of 6 mg/L (green lines) is not projected to be attainable under any of the three OLT scenarios even with phosphorus reductions below 6 µg/L TP, which is the minimum recorded in LCO or in other relatively pristine Wisconsin lakes. The topmost blue dashed line indicates that a DO of 3 µg/L is projected to be attainable in 4 out of 5 years over at least some depth of habitat, though maintaining a full meter or half meter of habitat over the entire summer is unlikely in most years. As shown in the top line, reductions of phosphorus to 11 µg/L or less are predicted to allow some volume of habitat with a DO of 3 µg/L and cold enough temperatures throughout the summer in 4 out of 5 years.



6. EPA's national hypoxia and phosphorus models

Along with updating the 2019 LCO-specific model with the newest data to recommend a TP criterion, WDNR also explored using a new hypoxia model from the U.S. EPA as an additional approach for deriving a site-specific TP criterion to protect oxythermal habitat. After examining both approaches, WDNR concluded that WDNR's LCO-specific model provides a more accurate representation of conditions in LCO than EPA's more generalized model, as follows:

- WDNR's LCO-specific model:
    - uses only data collected in LCO
    - uses over 30 years of intensive data from this lake
    - can show annual patterns and variation in oxygen depletion in this specific lake going back many years.
- EPA's national hypoxia model:
    - is based on a wide variety of two-story fishery lakes across the nation
    - only uses a single summer sample from each lake
    - shows how oxygen depletion differs between lakes but not how it changes in a single lake over a season or multiple years.

The U.S. EPA developed recommended (but optional) nutrient criteria aimed at conserving oxythermal habitat for cold water fish in inland lakes (U.S. EPA, 2021a). Rather than recommending static criteria values for groups of lakes, the criteria development tools are provided as a series of models, including the two explored for LCO: EPA's Hypoxia Model and Total Phosphorus Model (available online at the links provided in the references, U.S. EPA, 2021b and c). These models are used in combination. First the hypoxia model was applied to LCO to derive a chlorophyll *a* target that is meant to prevent oxygen depletion. Then, the resulting chlorophyll *a* target was entered into the phosphorus model to determine a phosphorus concentration that would achieve the chlorophyll *a* target, thereby estimating a potential phosphorus criterion to protect against hypoxia.

After exploring the EPA Hypoxia Model in relation to LCO, WDNR determined that it has specific weaknesses in application to LCO:

- The first concern is that the chlorophyll *a* concentration on Lac Courte Oreilles is almost always below the chlorophyll targets returned by the model, but the lake still suffers from fish kills at times due to low oxygen concentrations.
- Second, the EPA Hypoxia model estimates the initial day of stratification in LCO occurs mid-April, which is too early. A thermal dynamics model fit specifically to Lac Courte Oreilles indicates that this date is at least 2 weeks early (Winslow et al. 2017), and existing temperature profiles from the deep hole in the East Basin show that Lac Courte Oreilles is usually still mixed in early to mid-May and stratified by mid- to late-June. The initial day of stratification is very important for determining the hypolimnetic oxygen demand (HOD) because it affects the estimates of initial water temperature, initial oxygen concentration, and total days of stratification. Inaccuracies in the modeled initial date of stratification greatly affect the resulting chlorophyll *a* target. When DNR adjusted the EPA Hypoxia model to better approximate a realistic stratification date, the model's resulting chlorophyll values (over 20 µg/L) were far higher than chlorophyll values ever observed in the lake, which are almost always below 4 µg/L.

Based on the findings above, WDNR determined that WDNR's LCO-specific modeling approach described earlier in this report provides the best approach for developing a site-specific phosphorus criterion for LCO.

7. Economic and social considerations

As required under Wis. Stats. 281.15(2)(b) and 227.137, WDNR prepared an Economic Impact Analysis, which is separate from this Technical Support Document. The economic and social considerations around establishing a site-specific criterion for LCO are summarized here.

The phosphorus sources within the LCO watershed are all nonpoint sources, such as forested or agricultural lands, cranberry operations, and shoreline residences. WDNR does not have the authority to require phosphorus reductions from nonpoint sources. Therefore, there are no regulatorily required reductions of phosphorus discharges and consequently no economic impacts to existing entities within the watershed. Any actions taken to achieve the goal of 10 µg/L TP will be voluntary on the part of local residents, businesses, or organizations. However, it is WDNR's obligation under the Clean Water Act to set an appropriate criterion to protect the resource, regardless of whether WDNR can currently require implementation actions.

Further, the new criterion is an important protective measure, since any future point source dischargers in the watershed would be required to comply with the new, more protective criterion. This is important because although LCO's current status as a state Outstanding Resource Water (ORW) provides some additional protections from new dischargers, these would be insufficient for LCO. Under WDNR's antidegradation policy for a new discharger to an ORW, "effluent limitations for substances in the new or increased portion of the discharge will be set equal to the background levels of these substances…" (ch. NR 207.03(3), Wis. Adm. Code). In LCO, WDNR's analysis clearly demonstrates that the current background levels of phosphorus are too high to be protective. If the lake's criterion remained at 15 µg/L, and the phosphorus concentrations within the lake remained at levels near or above that criterion, setting effluent limits at 15 µg/L or at the lake's background concentration would be too high to be protective of whitefish. Any new discharge based on the lower criterion of 10 µg/L TP would be more protective of the whitefish population.

Setting an appropriate criterion is also expected to provide benefits within the current setting of nonpoint sources. The LCO Tribe, the Courte Oreilles Lakes Association, and other local entities have been very proactive in seeking voluntary phosphorus reductions. However, as shown in Section 3, phosphorus concentrations continue to rise. This indicates that further action is needed. Setting the right goal as a state-promulgated criterion elevates the message that further action is necessary, and provides the scientific rationale to motivate increased voluntary efforts throughout the watershed.

Recognition of this issue also increases the potential for local entities to secure grant funding from WDNR or other sources. WDNR provides $2.3-3.3 million annually to local communities to address lake and watershed issues through its Surface Water Grants program. These grants can fund a wide variety of water quality and restoration activities, management plan implementation, land easements, and tools such as ordinance development. Being listed as impaired increases the points a lake can earn on these grant applications. Additionally, official recognition of the problem may increase scoring in other areas by demonstrating a greater level of need. These factors provide a better chance at securing grant funding, which is critical for enabling local communities to achieve improved conditions within their lake.

The local economy and heritage in Sawyer County are largely driven by the quality of its lakes and other natural resources. During the past several years, WDNR has received an outpouring of support from residents, businesses, and local governments requesting that WDNR enact a phosphorus criterion that will adequately protect whitefish and cisco in this lake, to preserve its integrity as one of a relatively small number of coldwater fishery lakes in the state.

8. Satisfaction of Statutory requirements

This analysis focuses on a scientific demonstration that a more stringent criterion is necessary to support LCO's aquatic life designated use as a coldwater, two-story fishery lake for cisco and whitefish. Specifically, a lower phosphorus criterion is necessary to enable the survival of whitefish, the more sensitive of the lake's two coldwater species.

After review and analysis, WDNR determined that 10 µg/L total phosphorus is a necessary and appropriate site-specific criterion, which is not more stringent than reasonably necessary. WDNR's analysis satisfies Wis. Stat. s. 281.15(2)(b) to (e), enumerated in Section 2 of this document, by doing the following:

(b) Providing a description of economic and social considerations and costs used in establishment of the criteria.

- WDNR prepared an Economic Impact Analysis document addressing these factors (overview provided in Section 7 of this document). The Economic Impact Analysis found that:
  - Establishing this criterion will not result in any regulatorily required actions or costs.
  - Establishing a scientifically-derived goal is important to the local and regional community in protecting a valued resource for residents and tourism, bolstering the potential for grant funds to address water quality issues, and motivating further voluntary actions.

(c) Establishing criteria that are no more stringent than reasonably necessary to assure attainment of the designated use.

- In cases such as this, where multiple factors are contributing to a problem, a criterion for one of the contributing factors (phosphorus) should be set at a level that reasonably addresses that factor's role in the waterbody's condition, recognizing that addressing a single factor alone may not result in optimal habitat for all coldwater species present.
- A criterion of 10 µg/L is expected to provide enough oxythermal habitat to enable survival of whitefish during periods of stressful, warm conditions in late summer.
- Phosphorus concentrations above 11 µg/L are not projected to maintain suitable habitat. A proposed criterion of 10 µg/L TP allows a 1 µg/L margin of safety. Therefore, a criterion of 10 µg/L is not more stringent than reasonably necessary to enable whitefish survival.

(d) Employing reasonable statistical techniques to interpret the relevant water quality data.

- Lac Courte Oreilles is data-rich, with decades of water quality data collected by the LCO Tribe, the lake association, and DNR biologists.
- The amount of available data enabled WDNR to specifically model the interactions between phosphorus, dissolved oxygen, and the oxythermal layer in LCO. These modeling and statistical techniques were applied to determine the appropriate phosphorus concentration for LCO.

(e) Developing a technical support document identifying the scientific data utilized, the margin of safety applied and any facts and interpretations of those data applied in deriving the water quality criteria.

- This Technical Support Document details the robust modeling and statistical techniques used to evaluate the long-term dataset to determine the appropriate phosphorus criterion. It explains the margin of safety applied and interpretation of the findings.

Based on all of the above findings, WDNR recommends promulgating a phosphorus criterion of 10 µg/L as a necessary measure toward maintaining the coldwater fish populations and overall quality of Lac Courte Oreille into the future.

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