SECTION 22 PLANNING ASSISTANCE TO STATES AND TRIBES PHASE I

LAKE OSAKIS SEDIMENT ANALYSIS
AND COMPREHENSIVE PLAN

June 2026
Final Report

US Army Corps of Engineers®
St. Paul District

ACRONYMS

Aquatic Invasive Species	**AIS**	National Environmental Policy Act	**NEPA**
Best Management Practices	**BMP**	Osakis Lake Association	**OLA**
Department of Environment, Great Lakes, and Energy	**EGLE**	Sauk River Watershed District	**SRWD**
Environmental Quality Incentives Program	**EQIP**	Section 22 Planning Assistance to States and Tribes	**PAS**
Houston Engineering, Inc.	**HEI**	State Revolving Fund	**SRF**
HSPF Scenario Application Management	**HSPF-SAM**	Subsurface Sewage Treatment Systems	**SSTS**
Hydrologic Engineering Center	**HEC**	U.S. Army Corps of Engineers	**USACE**
Hydrologic Engineering Center - River Analysis System	**HEC-RAS**	U.S. Geological Survey	**USGS**
Hydrologic Simulation Program FORTRAN	**HSPF**	USACE, St. Paul District	**District**
Judicial Ditch #2	**JD2**	Watershed Management Plan	**WMP**

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LAKE OSAKIS PLANNING ASSISTANCE TO STATES
TODD COUNTY, MINNESOTA

1. Introduction

1.1. Authority and Project Selection

The Lake Osakis Planning Assistance to States (PAS) Study is authorized by Section 22 of the Rivers and Harbors Act of 1974 (Pub. L. 93-251), as amended, codified at 33 U.S.C. § 426i. Section 22 empowers the Secretary of the Army, acting through the Chief of Engineers, to furnish technical and planning assistance to State, territorial, and local governments on water resources and related land resource projects. Section 22 authority was subsequently amended and expanded by the Water Resources Development Acts of 1986 (Pub. L. 99-662) and 1990 (Pub. L. 101-640) to include floodplain management, environmental protection planning, and nonstructural alternatives. Under this authority, the U.S. Army Corps of Engineers (USACE) may:

- Provide detailed engineering and environmental analyses
- Develop plans, studies, and designs
- Evaluate structural and nonstructural measures

This study will be conducted in accordance with applicable USACE planning regulations and guidance.

1.1.1. Sponsor Participants and Coordination

U.S. Army Corps of Engineers, St. Paul District (The District). The District is responsible for Project management and coordination with the Sponsor, Project partners, and other affected agencies. The District will submit the comprehensive plan report to the Sponsor along with any additional materials produced under the PAS agreement. The Project will be funded with the non-Federal sponsor providing 50% of the costs for developing the Plan. The costs of developing the Plan are projected to be $480,000 with the Federal and non-Federal shares each being $240,000. It is the District’s understanding that the Sponsor plans to coordinate with local and state partners to pursue all of the construction and enhancement measures of the comprehensive plan.

Sponsor. The Sponsor for this project was the Sauk River Watershed District (SRWD). Participants in the planning Project included project team citizen representation along with members of the drainage authority board, local and state agencies, and St. Paul USACE District staff. The Osakis Lake Association is also a key participant in the project and provided resources used in the analysis.

1.2. Study Purpose and Scope

The District proposes to create a comprehensive plan to rehabilitate and enhance the Project area through construction or implementation of measures that would maintain, enhance, and restore Lake Osakis and its watershed. A primary focus of the plan is the improvement of recreational use, aquatic habitat, and management of invasive species (AIS). Target concerns include water control level, watershed health, and water quality restoration.

The purpose of this PAS Comprehensive Plan is to document the development of the plan elements and explain how they would impact the study area. The Comprehensive plan meets USACE planning guidance and satisfies National Environmental Policy Act (NEPA) requirements. USACE developed this report with the SRWD serving as the non-Federal Project Sponsor. This report provides planning and engineering details of the Comprehensive Plan to allow for the Sponsor to proceed to subsequent project implementation.

The purpose of the report is to summarize the multidisciplinary efforts of USACE and SRWD that led to the Comprehensive plan. USACE organized the report to follow a general problem-solving format:

- Review existing conditions and anticipated future conditions;
- Identify Project goals and objectives;
- Formulate potential measures to address the objectives;
- Identify a reasonable combination of measures that create the comprehensive plan;

Supporting documentation is provided in the appendices of this report.

1.3. Study Area.

1.3.1. Lake Osakis

Lake Osakis is located in central Minnesota in the Upper Mississippi River Basin along the border of Todd and Douglas Counties. Lake Osakis is part of the Sauk River Watershed. The watershed also includes Faille and Smith Lake, located upstream of Osakis which is the headwaters of the watershed. Lake Osakis was placed on the 2004 State of Minnesota's 303(d) list of impaired waters. This list includes waters that fail to meet water quality standards and uphold that water body's designated use. The listings are based on intensive water quality monitoring of major lakes and streams in Minnesota's watersheds. Lake Osakis' primary recreation activities supported by the lake include boating and fishing. Water quality degradation of these lakes has impacted the recreational activities. Faille and Smith Lake are located upstream of Lake Osakis, thus, the water quality and ecological condition of these lakes have a profound impact on the Sauk River and other downstream resources. Lake Osakis is a large, deep lake with a very long residence time (approximately 5 years). About half of the lake is shallow enough to support submerged aquatic vegetation.

There is an outlet in the project area that serves as the outflow point from Lake Osakis. This outlet helps maintain the lake's water level, water quality, and overall health. Currently, work is proceeding on installing a rock arch rapids structure at the outlet of Lake Osakis, designed to minimize water fluctuations. A grant from the State of Minnesota has been awarded for the project and is proceeding through the permitting and bidding stage.

1.3.2. Judicial Ditch #2

Located west of Lake Osakis is Judicial Ditch #2, also known as JD2 or Crooked Lake Ditch. JD2 drains approximately 26,700 acres and accounts for a large portion (around 30%) of the lake's total watershed. Situated just west of Lake Osakis, the Judicial Ditch #2 sediment retention ponds were constructed between 2002 and 2004. They are owned and operated by the SRWD.

JD2 is a legal drainage system that drains a large portion of the historic Crooked Lake area and outlets into Lake Osakis. Crooked Lake was a 2200-acre shallow basin that once supported a diverse aquatic community. This basin was drained in the early 1900s to be converted to agricultural production, which is effectively the function of JD2. The land that drains to JD2 accounts for about 30 percent of Lake Osakis' watershed, carrying sediment and nutrients from the ditch and contributing landscape to the lake.

2. Purpose and Need Statement

This section describes the “purpose and need for the proposed agency action” for purposes of NEPA (40 C.F.R. § 1501.5(c)(2)(i)). This section also describes the development of Project objectives, including the identification of problems and opportunities, consideration of the measures and identification of the measures in the comprehensive plan. For planning purposes, the period of analysis was established as 50 years starting in 2027. The period of analysis is the period of time that an alternative would have significant beneficial effects.

2.1. Problems

USACE’s planning process starts with identifying problems and associated opportunities within the scope of the study area and study authority. From the list of problems and opportunities, and in collaboration with agency partners, USACE drafts specific objectives for the Project. The following section identifies the major problems affecting the study area. Most of the following problems manifest themselves through sediment accumulation, pathogens, and nutrient accumulation within Lake Osakis and its watershed.

Septic System Compliance. Uncontrolled release of untreated wastewater into ground and surface water. This leads to contamination with harmful pathogens, creating significant public health risks and degrading water quality.

Farming practices and fertilizers. Eutrophication of the lake, resulting in toxic algal blooms, oxygen depletion (creating "dead zones"), and harm to aquatic life, wildlife, and humans.

Private entity construction practices. Increased flow of pollutants and sediment into the lake through construction on property surrounding or near Lake Osakis, causing decreased water clarity and shoreline erosion.

Peat bog. Peat bogs are a vital wetland that stores large amounts of carbon. Peatland vegetation reflects the relationships among plants, topography, climate, and water. The Osakis study area is part of Minnesota’s peatlands with peat bogs being the most prominent peat landform. Peat bog degradation is primarily driven by human activities, predominantly farming practices and construction methods.

Walleye reproduction. A combination of concerns have impacted the reproduction of walleye within Lake Osakis. Increased phosphorus, algal blooms, and warming water cause a decline in the walleye population and a corresponding shift in the fish community.

Ravine erosion. Rainfall and surface erosion can lead to large amounts of sediment to be transported into the lake. This clouds the water, smothers aquatic plans, and damages certain fish habitats.

Expanded Drainage Area. In the early 1900’s, the establishment of JD2 greatly expanded the landscape contributing nutrients, sediment, and water to Lake Osakis. This drainage area expansion, alongside extreme weather patterns and modern land management, has contributed to an expansion of observed problems in Lake Osakis.

2.2. Objectives

Based on the identified problems affecting the Project’s natural resources and considering the management goals of the non-Federal sponsor, the Project goal is to maintain, enhance, and restore Lake Osakis and its watershed. The period of analysis was established as 50 years starting in 2027. Throughout the study area and over the 50-period of analysis, the objectives identified to meet the goal over the period of analysis are to:

- Maintain lake elevation and water storage levels to support the ecological health of the shoreline, wetlands, and aquatic habitats
- Protect, enhance, and restore water quality to sustain native aquatic life, support healthy ecosystem functions, and ensure suitability for recreational activities
- Protect, enhance, and restore the natural function of the inlet to maintain hydrologic connectivity
- Prevent the introduction of new invasive species, and control or eradicate existing populations to protect the integrity and diversity of native aquatic and terrestrial communities
- Protect, enhance, and restore diverse, resilient, and self-sustaining native aquatic communities, including fish, invertebrates, and other fauna

2.3. Constraints

The following constraints and considerations were included in measure formulation:

- Minnesota 103E Drainage law – Established the process for funding and maintaining public drainage systems
- Funding of Comprehensive Plan implementation
- Capacity of resources (monetary, personnel, local participation, etc.)
- Public waters – state-managed lakes and wetlands
- Landowner buy-in
- Public perception of the Comprehensive plan

2.4. Opportunities

Within the study area, there are opportunities for additional beneficial outcomes beyond addressing the aforementioned problems. Opportunities tend to focus on desirable future conditions, where something can be made better. The following opportunities were identified for this study:

- Minnesota 103E Drainage law as a means for addressing issues in public drainage systems through construction, repairs, or improvements.
- Development of future alternatives to the sedimentation ponds
- Pencil reed/Hard-stem Bulrush (Schoenoplectus acutus) re-establishment within Lake Osakis
- Redetermination of benefits and costs

The Osakis Lake Association is also working on additional feasibility studies to address some of the problems in the area. This information can be utilized in the comprehensive plan's development. There is an ongoing feasibility study to address septic tanks around Lake Osakis.

3. Existing Conditions and Future Without Project Conditions

In order to create measures and a comprehensive plan to address the concerns in the area, a more complete understanding of the existing conditions of Lake Osakis are needed to recognize the extent and breadth of the issues. The next sections detail data gathered along with discussion and recommendations based on that information.

3.1. Sediment Accumulation

Understanding how and why sediment gets deposited into the lake is crucial in building effective measures to reduce the rate of sedimentation. Sedimentation rates at two sites within Lake Osakis were calculated for the Osakis Lake Association (OLA) by a member of the Saint Croix

Watershed Research Station. Sediment cores were collected and analyzed for sediment age using radioisotope dating via lead-210, and sediment geochemistry via loss-on-ignition to determine the age and composition of each sample throughout the last few centuries. The study determined that Lake Osakis has experienced a long-term increase in sedimentation rate throughout the lake.

Two sites were sampled in Lake Osakis, one that was selected to represent the deepest section of the lake and the other within Miller Bay, a relatively shallow area near the JD2 inlet (Figure 1). The Central site showed a gradual increase in sedimentation since pre-1900. Post 1970, sediments were increasingly composed of carbonates and organic matter, indicating in-lake productivity. The Miller Bay site showed a faster sedimentation increase than the Central site, especially post-1975. Sediments were increasingly inorganic and not scientifically understood to be a result of eroded peat. This suggests watershed erosion may be the primary driving factor for increased sedimentation in that area.

Figure 1. Lake Osakis Sample Points

Using data from the sedimentation study, linear interpolation was used to estimate annual sediment accumulation between 1996 and 2025 (Table 2).[1] The timeline was subset to align with modeling data available from Hydrological Simulation Program-Fortran (HSPF) outputs for the area. The measured values from the study are bolded in Table 2, whereas the interpolated values are not bold.

Estimation of sedimentation rates, as well as the amount of unconsolidated sediment accumulated, correlate well with data Houston Engineering, Inc. (HEI) collected in 2024 during a bathymetric survey and collection of sediment cores. In Figure 2, there are four areas that were called out as high accumulation areas due to having a thicker layer of unconsolidated sediment. In an effort to extrapolate Heathcote's work, the sedimentation rate from the Miller's Bay site was applied to these areas. The Central lake site's sedimentation rate was then applied to the low accumulation areas (i.e., the remainder of the lake).

Results from the sedimentation rate study were reported as total dry mass accumulation rate (DMAR, g/m^2/year) and inorganic DMAR (InorgDMAR, g/m^2/year). The total mass of accumulated sediment includes inorganic matter (e.g., sand, silt, clay from watershed erosion), organic matter (e.g., decayed plant and algal material), and carbonates (e.g., calcium carbonate from in-lake precipitation or watershed weathering). InorgDMAR only includes inorganic material (e.g., sand, silt, and clay from watershed erosion). DMAR gives a full picture of how much sediment is accumulating while inorgDMAR helps identify sources of sedimentation. High inorgDMAR indicates a high likelihood of landscape erosion, whereas high organic or carbonate DMAR indicated likely in-lake biological activity.

[1] Data for 2024 and 2025 was extrapolated from the Heathcote study data.

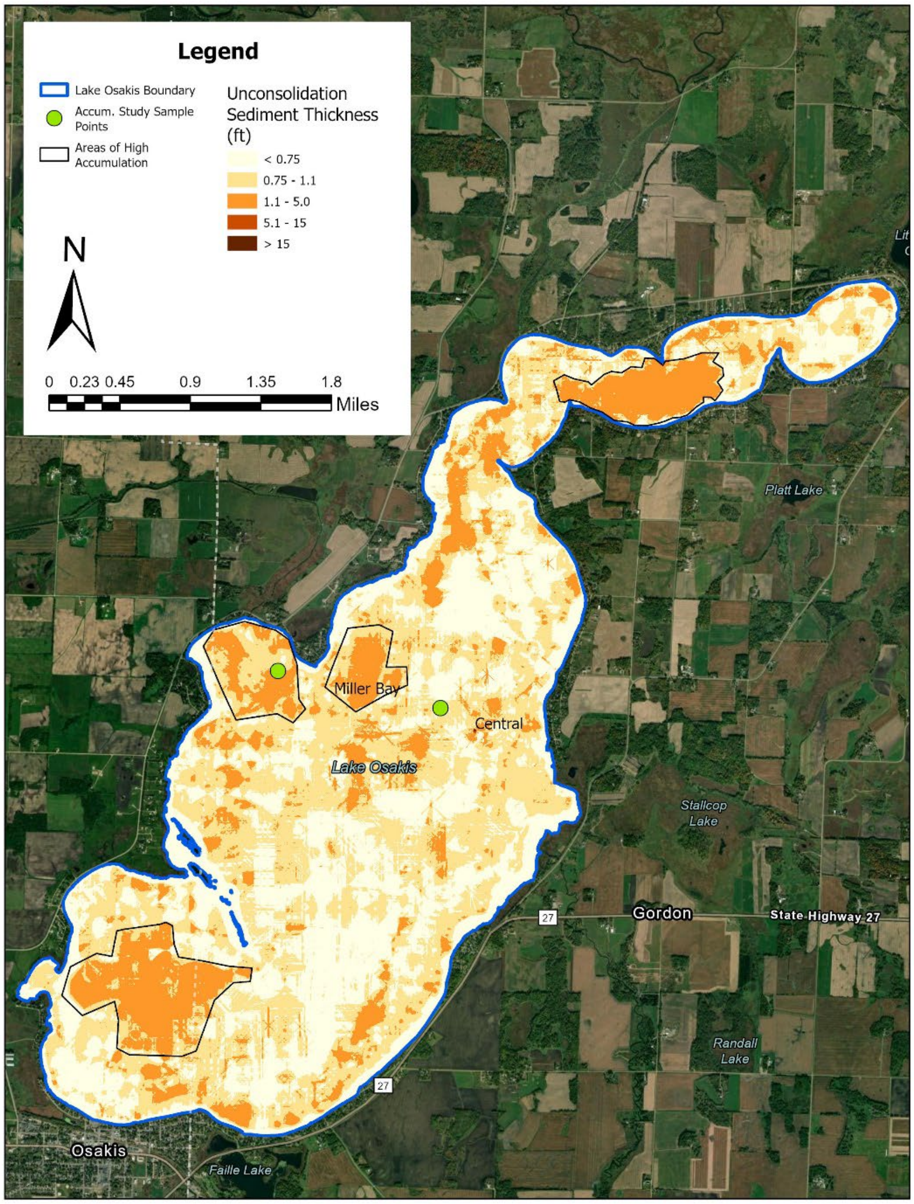


Figure 2. Lake Osakis Sediment Thickness Map

3.2. Hydrologic Simulation Program FORTRAN (HSPF)

The accumulation of sediment within Lake Osakis was calculated using the information gathered from the soil cores and sediment age data was compared against output from the HSPF surface water quality model for the watershed to determine if the data from the model aligned with the real world measured data. For this comparison, the inorganic DMAR from the sediment accumulation study was compared against the HSPF sediment loading for an equivalent comparison, as HSPF does not include organic material or carbonate precipitation in its overall sediment calculations.

The HSPF model outputs annual loading estimates to Lake Osakis from the three major tributaries, direct drainage from the surrounding landscape, suspended sediment within the lake, and it also quantifies the mass of sediment leaving the lake. With this information, an annual mass balance was calculated to estimate the total mass of sediment being deposited within the lake for the 20 simulated years within the HSPF model output (1996-2015). Although the two calculations produce results that are typically within the same order of magnitude, Table 4 shows that there are differences between the two methods of calculating annual sediment accumulation.

Although there are differences in the estimated magnitude of deposition, both methods do show a gradual increase in sedimentation rate during the 20 years of overlapping data (Figure 3).

3.3. Limitations

Each calculation method is not without its limitations. Lake Osakis is a large lake, spanning nearly eight miles from one side of the lake to the other. There are multiple distinct sections within the lake that may have had very different accumulation rates of sediment throughout the past 125+ years. The sediment accumulation study that used radiometric dating to determine the age of sediment at different layers of the lakebed had only two sampling locations within the lake. The different accumulation rates measured at those two sampling locations were applied across the entire lake with the assumption that accumulation rates throughout the entire lake would be similar to one of those accumulation rates. This may not be the case.

The HSPF model also has potential limitations for estimating sediment deposition within Lake Osakis. Because the drainage area to Lake Osakis is also the very headwaters region for the entire Sauk River Watershed, and subsequently the Sauk River Watershed HSPF model, calibration of model data within the drainage area to the lake can be challenging. Although HSPF does have robust functionality for in-lake process calculations, the Sauk River Watershed HSPF model was not set up to explicitly estimate in-lake dynamics. Therefore, even with calibration and validation of the model at the outlet of the lake, determining the effect that the lake is having on inputs from the surrounding landscape and tributaries is difficult, leading to greater uncertainty of the quantity of sediment entering the lake.

HSPF is also not able to account for large, localized and unpredictable erosions events. For instance, large gully formation during an intense rainfall event. This, in combination with a lack of estimation of direct lakeshore erosion may also lead to the model misrepresenting the total load of sediment being deposited in the lake.

3.4. Discussion and Recommendations

No matter the sedimentation calculation method, thousands of tons of inorganic sediment are being deposited within Lake Osakis each year through various delivery pathways. Normal sedimentation rates for lakes within central Minnesota are expected to be between 1-2 mm of sediment accumulation per year[2]. Based on the median (dry) bulk density of sediments within Lake Osakis (0.205 g/cm^3), that would equate to approximately 8,786 tons of total sediment accumulation within Lake Osakis annually under natural conditions. Current estimates of total DMAR are nearly 18,000 tons per year for the lake (Table 3).

Excess sediment deposition can have numerous detrimental effects on the lake including loss of aquatic habitat and spawning areas for fish, increased plant and algal growth due to the sediment-associated nutrients (e.g. phosphorus), and decreased lake depth in areas of high accumulation, to name a few.

[2] Edlund, M.B. and Ramstack, J.M. 2009. Historical Water Quality and Biological Change in Northcentral Minnesota Lakes. Final report submitted to the Minnesota Pollution Control Agency from the St. Croix Watershed Research Station, Marine on St. Croix, Minnesota, 55047. 84 pp.

Management and conservation practices targeted at reducing sediment from reaching Lake Osakis can have multiple benefits and could be considered as one method for improving water quality and recreational opportunities within the lake. Based on the HSPF data, in combination with the sedimentation estimates presented, the majority of the excess sediment load to the lake is fairly equally split between direct drainage surface runoff and sediment from Judicial Ditch 2 (Crooked Lake drainage). Addressing these sources could be achieved through a suite of targeted conservation and management practices. In-field and edge-of-field best management practices such as cover crops, reduced tillage, water and sediment control basins, and grassed waterways, to name a few, can reduce erosion of surface sediments, thus decreasing the amount of sediment entering Lake Osakis from direct surface runoff. Near stream or instream conservation practices such as wetlands can trap sediment from the contributing drainage area to a portion of the lake (e.g. Judicial Ditch 2). Measures such as these can greatly reduce the mass of sediment reaching Lake Osakis from contributing tributaries.

It is worth noting that a substantial portion of the sediment accumulation within Lake Osakis was connected to production within the lake. To address this, activities that manage or remove sources of this sediment accumulation such as invasive vegetation management and focused dredging would likely benefit the overall health and function of Lake Osakis. However, these efforts may show limited benefits if the sediment from the surrounding watershed is not also addressed.

As climate patterns fluctuate and rainfall events change in frequency and intensity, the current sedimentation rates within Lake Osakis may continue to change and may keep increasing through time if left unchecked. Adopting practices that factor in climate resiliency (e.g. water storage practices like wetland) may provide a significant benefit to the Lake Osakis area and serve multiple beneficial water quality and habitat improvement roles.

4. Measures

4.1. Measure Development

During a community stakeholder meeting conducted as part of this PAS project, several measures were identified that could aid in making progress towards the goals and objectives for this plan. Each of these measures were combined into a series of alternatives that collectively make up the community supported range of actions that are being evaluated for improving Lake Osakis as part of this comprehensive planning effort. During that same community stakeholder meeting, attendees also weighed in on the alternative combinations. Table 1 below provides a list of the measures identified and the series of alternatives developed from those measures.

Table 1. Measures and Alternatives Developed

Objective Focus	Measure	Alternatives				
		Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
Lake Elevation/Water Storage	Shoreline Stabilization	N	Y	Y	Y	Y
	Outlet Modification	Y	Y	Y	Y	Y
	Wetlands restoration*	Y	Y	Y	Y	Y
	Focused dredging	N	N	N	N	Y
Water Quality Improvement	Septic compliance/monitoring	N	Y	Y	Y	Y
	In-Lake Treatment**	N	N	Y	Y	Y
	Sed Ponds (Stabilization, Expansion) **	N	N	Y	Y	Y
	Future State	N	N	N	N	Y
	Feasibility Study	N	Y	Y	Y	Y
	Channel Stabilization**	Y	Y	Y	Y	Y
Aquatic Life and Invasive Species Control	Invasive Species Management (DNR/County weed treatment)	N	N	N	Y	Y
	Fisheries Habitat enhancement	N	N	N	N	Y
	Pencil Reed/Hard-stem Bulrush (Schoenoplectus acutus) Restoration	N	N	N	N	Y
Public	Public engagement	Y	Y	Y	Y	Y
	Ag/Capital engagement	Y	Y	Y	Y	Y
	Ag Incentivization*	N	Y	Y	Y	Y
	Lake Ownership Education	N	N	Y	Y	Y
*Additional information or modeling needed						
** Dependent on another measure						

The remainder of this section will describe the process used for assessing each of the potential measures individually, as well as the likely progress that would be made towards the goals and objectives of this plan. Subsequently, the section titled “Alternative Evaluation and Comparison” assesses how the various alternatives (i.e., combinations of measures) will make progress towards the goals and objectives of this plan.

4.2. Lake Elevation/Water Storage Measures

Measures identified in this section have the primary purpose of making improvements towards the lake elevation and water storage objective for this comprehensive plan. Each measure may also have additional benefits that would support other goals and objectives associated with this plan.

4.2.1. Shoreline Stabilization

Shoreline stabilization would include nature-based stabilization techniques that establish a buffer to reduce erosion and enhance shoreline habitats. The long-term goal is to prioritize locations along the lakeshore for restoration and/or stabilization efforts and to quantify the likely improvements to water quality conditions of Lake Osakis. The following describes how the shoreline of Lake Osakis was assessed to rank specific parcels for shoreline stabilization measures.

Landowner parcels surrounding the lake were analyzed using GIS data to determine the average percent slope and probable soil erodibility within each parcel. Slope was categorized into groups of low (<2%, yellow), medium (2%-6%, orange), or high (>6%, red) based on thresholds found in the Minnesota Stormwater Manual for classifying landscape runoff coefficients (See Figure 3).

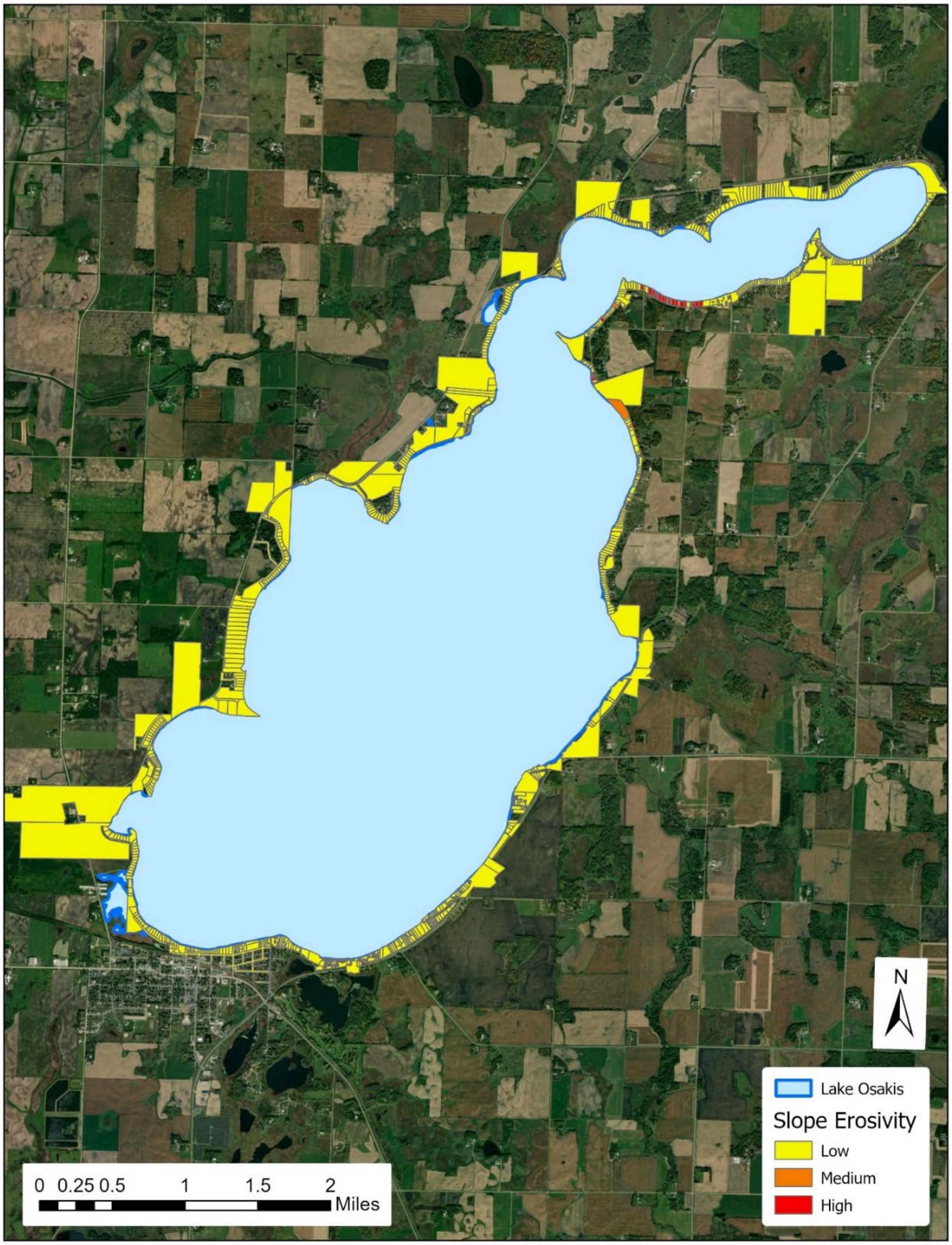


Figure 3. Lake Osakis Parcel Slope Erosivity

Revised Universal Soil Loss Equation (RUSLE) soil erodibility (k) data was used to determine the expected erosion potential of the soil within each parcel. Similarly to slope, soil erodibility for each parcel was categorized into groups of low (<0.15, yellow), medium (0.15-0.24, orange), or high (<0.24, red) based on thresholds defined by the Technical Guide to RUSLE and NRCS-USDA State Office of Michigan. Low values are indicators of low erosion probability while high values are indicators of high erosion probability (See Figure 4).

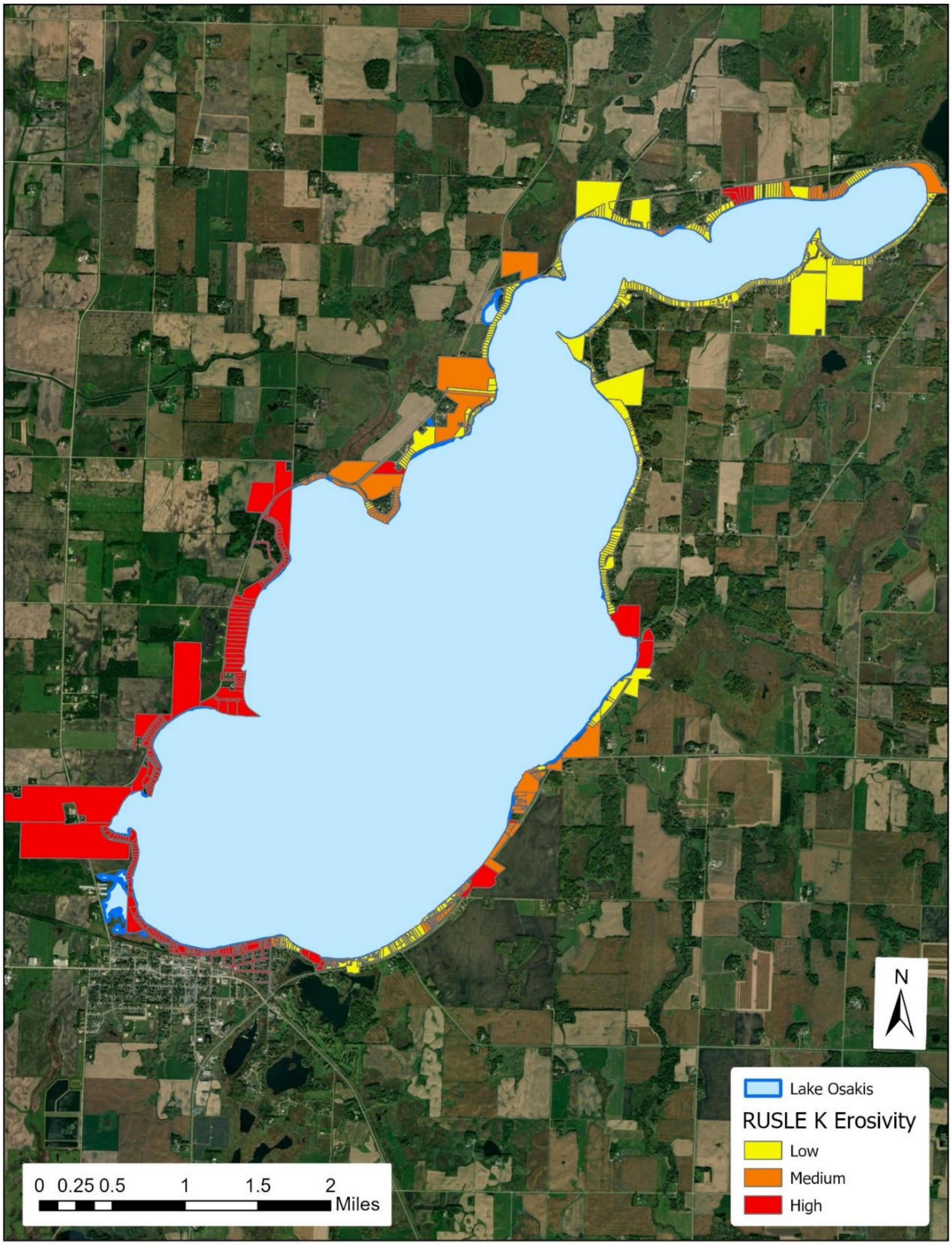


Figure 4. Lake Osakis Parcel RUSLE K Erosivity

All parcels around the lake were then analyzed for potential wind/wave erosion using the NRCS-USDA "Guidance for design and layout of vegetated wave protection for earthen embankments and shorelines (Technical Release 56)".

Effective lake fetch was determined along the shoreline of Lake Osakis after reviewing the prevailing wind patterns in the area (Figure 5). Two primary wind directions were prevalent throughout the year. Stronger winds out of the SSE typically occur during the warmer months of the year while winds from the NW are more common during the colder months of the year. Effective fetch was calculated at each parcel for both prevailing wind directions, northwest and south-southeast (Table 2).

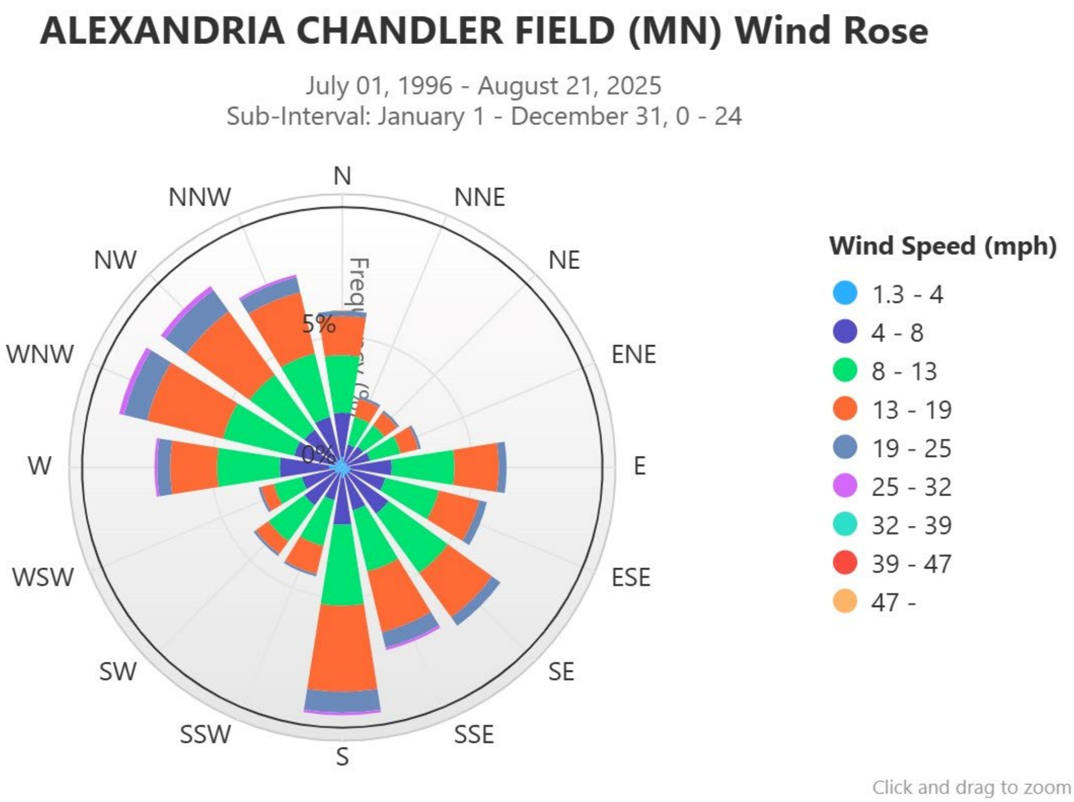


Figure 5. Alexandria Chandler Field Wind Rose

Table 2. Alexandria Average Wind Speed

Compass Directions	N	NNE	NE	ENE	E	ESE	SE	SSE
Average Wind Speed (mph)	10	10	9.5	10.1	10.4	10.6	10.6	11.8
Sum of Wind Speed (±22.5 degrees)	31.4	29.5	29.6	30	31.1	31.6	33	34.3
Compass Directions	S	SSW	SW	WSW	W	WNW	NW	NNW
Average Wind Speed (mph)	11.9	10.2	8.9	8.7	10.8	12.5	12.6	11.4
Sum of Wind Speed (±22.5 degrees)	33.9	31	27.8	28.4	32	35.9	36.5	34

Following guidance from USDA Technical Release 56, the effective fetch distance was calculated, taking into account not only the direct fetch but also the energy transferred from the wind to the water from all directions within a 90-degree arc. Combined results, from both wind directions are presented in Figure 6.

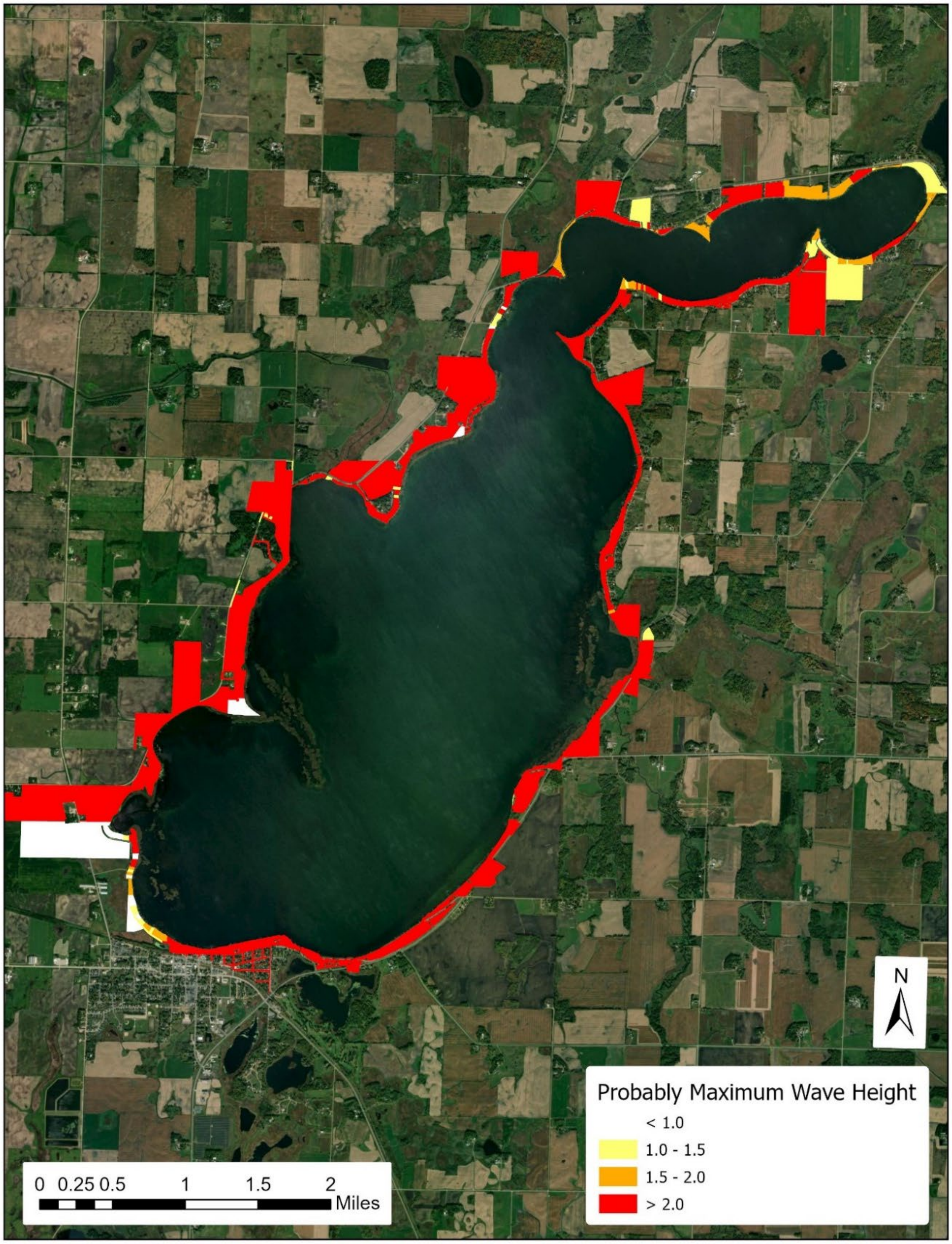


Figure 6. Lake Osakis Maximum Wave Height

The complete analysis of fetch and resulting wave energy led to a range of probable maximum wave heights for each parcel, accounting for both prevailing wind directions. Each parcel was classified into wave energy levels based on maximum wave height reaching shore, shown in *Table 3*. Wave energy classification thresholds were defined based on methods for analyzing wave height probability from the Michigan Department of Environment, Great Lakes, and Energy (EGLE) - Inland Lake Shoreline Energy Assessment Tool (https://storymaps.arcgis.com/stories/f96ed53ac0744ad8ad500d8be3cf39c5). These wave height thresholds can be used for both storm-generated wave height and boating activity. However, for this analysis only natural wind-driven waves were considered, and near shore bathymetry and the presence or absence of aquatic vegetation were ignored.

A typical distribution of significant wave heights for Lake Osakis was created (see *Figure* 7), assuming the maximum wave classification accounting for both possible prevailing wind directions. Each parcel was classified into energy levels based on maximum wave height thresholds shown in Table 3.

Table 3. Wave Height Parcel Classification

Wave Height (H_s)	Classification	Number of Sites
<1 ft	Low	19
1-1.5 ft	Moderately Low	55
1.5-2 ft	Moderately High	95
>2ft	High	767

Categorizing all parcels along the lake, 19 sites have a maximum wave height energy classification of “low” under both prevailing wind conditions, 55 sites are classified as “moderately low” energy under at least one of the prevailing wind conditions, 95 sites are classified as “moderately high” energy under at least one of the prevailing wind conditions, and 767 sites are classified as “high” energy under at least one of the prevailing wind conditions.

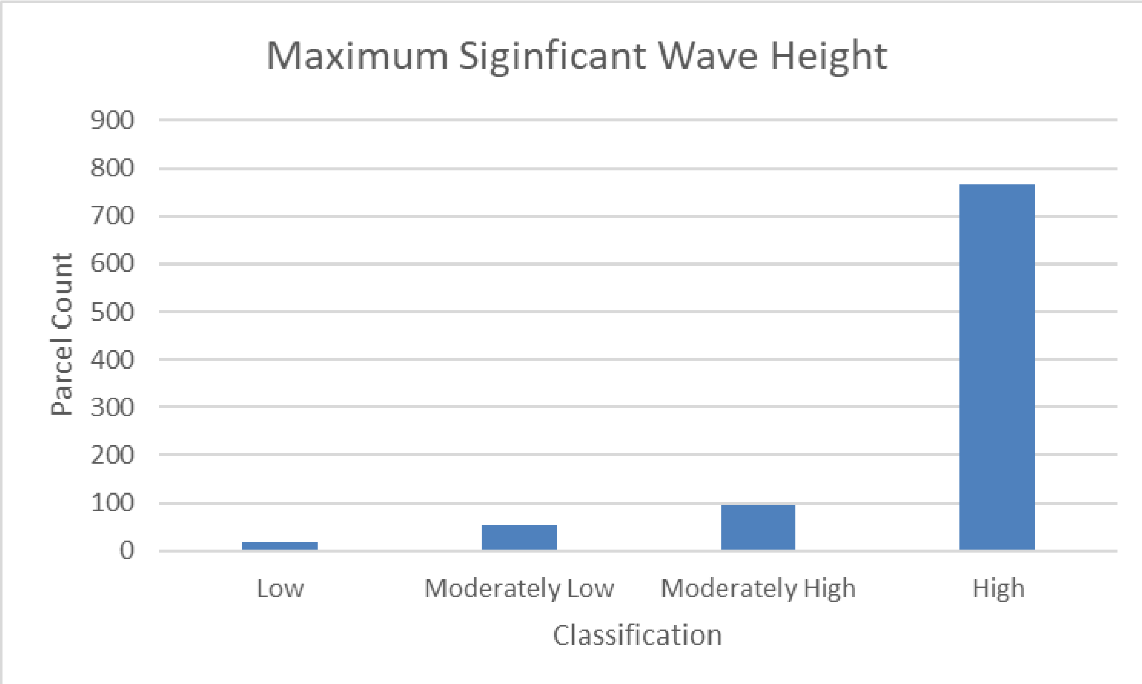


Figure 7. Parcel Maximum Significant Wave Height

Future site visits would need to be completed to determine if there is a correlation between visible erosion and the factors considered here (slope, soil erodibility, and maximum wave height). If a correlation is determined, sites could then be prioritized for best management practices (BMPs) to be installed along the shoreline to reduce or prevent further or future erosion. Depending on the BMPs used for shoreline stability, not only could water quality be improved throughout the lake with reduced sediment and nutrients entering the water, but wildlife habitat could also be improved/restored. It is also important to note that the current assessment approach for this measure does not recognize areas that already have shoreline protection implemented. The extent of current shoreline protection around the lake should also be considered if future efforts seek to implement shoreline protection.

4.2.2. Outlet Modification

Outlet modification involves processes to replace, repair, or modify the lake outlet(s) to help manage water levels and protect the habitats within the Study Area. Community members identified that frequent large swings in lake elevations are impacting the reactional use of Lake Osakis and may be creating issues for shoreland stability as well. The Osakis Lake Association (OLA) led a feasibility study and preliminary design report for exploring modifications to the outlet of Lake Osakis as a measure for improving lake elevation stability and water storage within Osakis. A State grant has been awarded to the JD #2 Drainage Authority for the project and is proceeding through the permitting and bidding stage.

Appendix A provides the engineer’s report for this effort. The engineer’s report recommends a rock arch rapids structure with a modified outlet that:

1. Maintains the outlet elevation consistent with the ordinary high water level
2. Provide benefits for modulating high and low elevations in the lake
3. Provides drastically decreased operation and maintenance

4. Restores longitudinal aquatic life migration between Lake Osakis and the Sauk River

The Lake Osakis CE-QUAL-W2 model was used to compare the performance of the proposed outlet modification against the existing structure. The results of this analysis demonstrate the benefits of the new design in stabilizing lake elevations.

Figure 6 illustrates the hydraulic rating curve for both the existing and proposed spillway, showing the relationship between water surface elevation and discharge capacity. The proposed spillway is designed to be more efficient, allowing a significantly higher volume of water to be discharged as lake levels rise. The hydraulic performance of the spillway was defined using a generalized power law equation derived from the engineering design and rating curve analysis. This equation provides a precise fit for the structure's discharge characteristics and takes the general form:

$$Q = A1SP * (WSE - ESP)^{B1SP}$$

Where:

Q: Discharge (flow rate)

A1SP: An empirical discharge coefficient

WSE: Current Water Surface Elevation

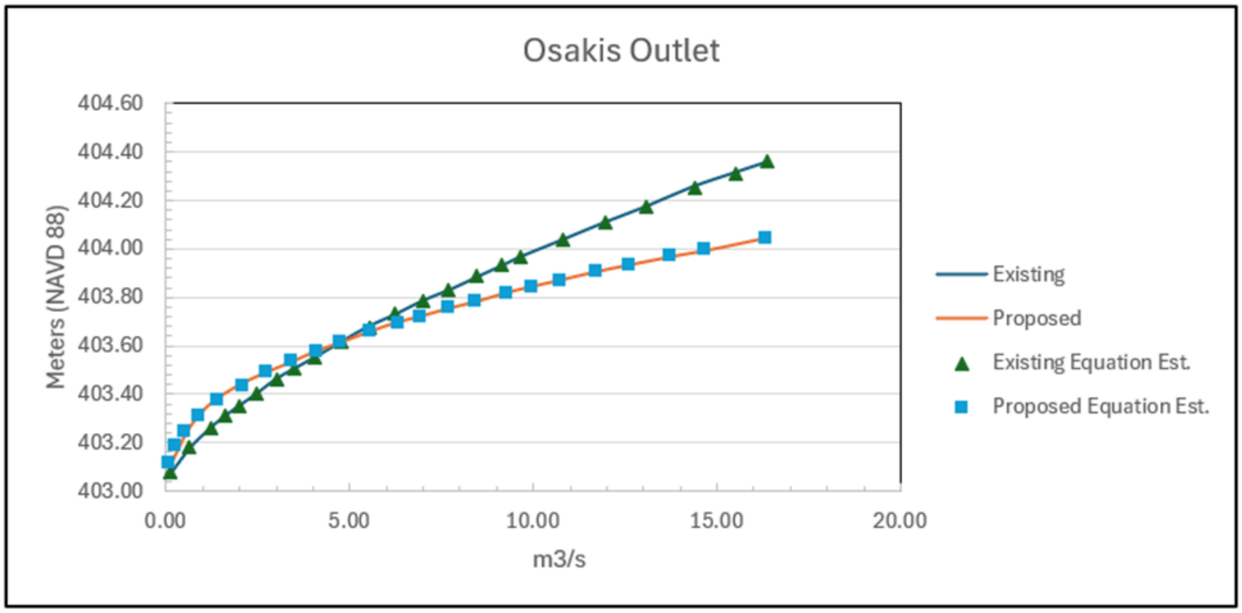
ESP: Elevation of the Spillway crest

B1SP: An empirical discharge exponent

The specific A1SP and B1SP coefficients derived from the hydraulic analysis (shown in Figure 8) were used to accurately represent the existing and proposed outlets' behavior within the CE-QUAL-W2 model. For Lake Osakis specifically, the resulting equation for the proposed rock arch rapids spillways is:

$$Q = 15.9497 * (WSE - 403.0353)^{2.2421}$$

This equation indicates a greater capacity to pass water during high-flow events compared to the existing spillway's capacity.



Existing Spillway		Proposed Spillway	
ESP	403.0211	ESP	403.0335
A1SP	10.5114	A1SP	15.9497
B1SP	1.5165	B1SP	2.2421

Q=10.5114(WSE-403.0211)^1.5165	Q=15.9497(WSE-403.0353)^2.2421
RMSE =0.061 CMS	RMSE =0.088 CMS
R^2= .99984	R^2= .99968

Figure 8. Osakis Proposed and Existing Spillway Rating Curves and CE-QUAL-W2 Spillway Coefficients

Figure 9 shows the long-term effect of this improved design on water levels from 1996 to 2015. The analysis reveals that the proposed outlet successfully modulates lake elevations, reducing the extreme highs and lows experienced with the current structure.

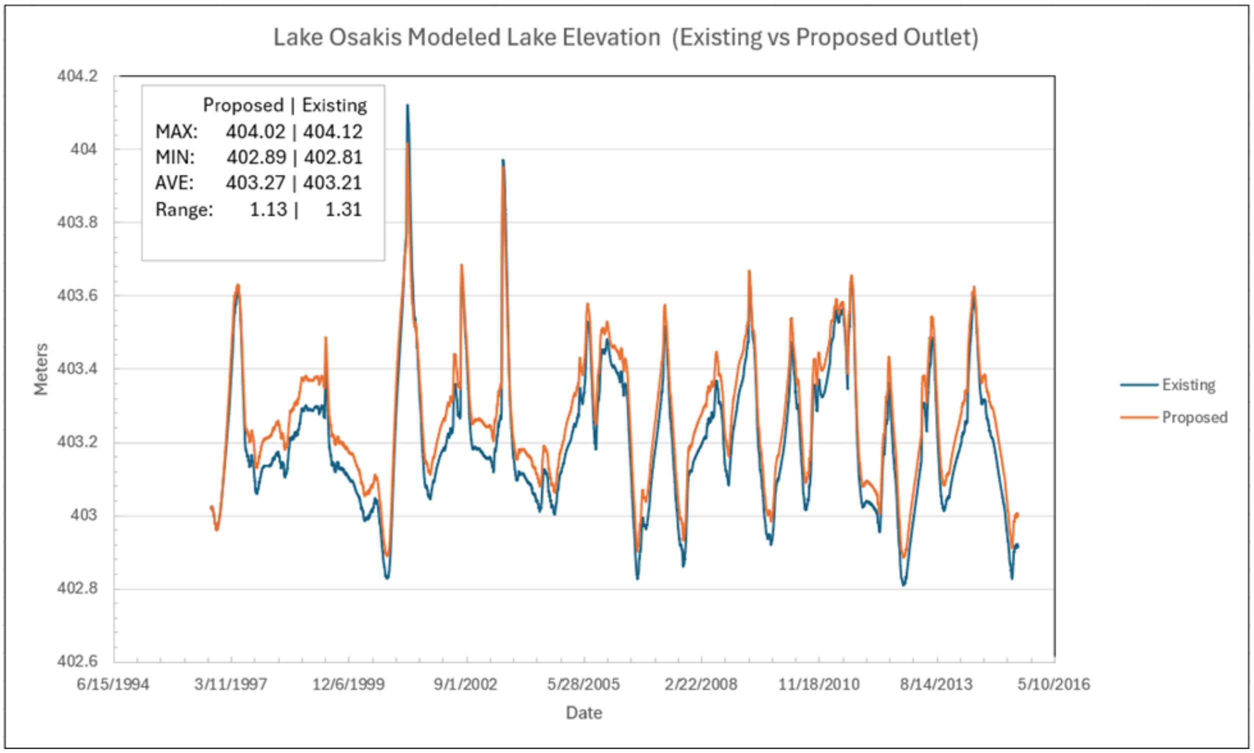


Figure 9. Lake Osakis Modeled Lake Elevations

Key findings from the modeling include:

1. Reduced Fluctuation: The overall range of lake level fluctuation is reduced from 1.31 meters with the existing outlet to 1.13 meters with the proposed design.
2. Lower Peak Elevations: The maximum modeled lake elevation is lowered from 404.12 meters to 404.02 meters.
3. Higher Low Elevations: The minimum modeled lake elevation is raised from 402.81 meters to 402.89 meters.

These modeling results confirm that the proposed rock arch rapids structure would effectively reduce the frequent large swings in lake elevations, addressing the primary concerns raised by the Osakis Lake Association and community members. The design provides a more stable and predictable water level, which will benefit both recreational use and shoreland stability.

4.2.3. Wetlands Restoration

Wetland restoration, as a method, is focused on re-establishing the natural hydrology of an area using native vegetation and water storage potential within the wetland. This method should improve the ability to store and filter water within the Lake Osakis Watershed.

As mentioned earlier, much of the drainage area to the west of Lake Osakis was once part of the Crooked Lake drainage basin and did largely drain to the North into the Long Prairie River. However, a drainage ditch was constructed which drained Crooked Lake and redirected the flow of water into Lake Osakis. Creating or restoring wetlands throughout the former Crooked Lake basin and elsewhere in the Lake Osakis Watershed has the potential to store and treat water on the landscape before it enters Lake Osakis and potentially replicate some of the ecological functions provided by the historic Crooked Lake. Wetland restorations should reduce sediment and nutrients delivered to Lake Osakis as well as provide additional water storage and increased habitat.

A GIS-based terrain analysis was conducted to find natural depressions in the landscape where water could be stored and where historic wetlands could be restored. The resulting potential water storage and wetland locations were screened and prioritized using a number of criteria including; potential storage volume, drainage area, and expected runoff volume delivered to the storage location (10yr, 24hr storm event).

Once a short list of prioritized storage locations was created, a brief engineer's review was conducted to eliminate likely unsuitable locations based on the potential constructability of the practice. Appendix A contains details for each specific water storage and/or wetland area including storage volume, expected annual sediment and phosphorus reduction, and anticipated costs.

Wetland restoration was simulated using the HSPF Scenario Application Management (HSPF-SAM) program. HSPF-SAM allows users to simulate various conservation practices, agricultural BMPs, and land use changes. For the wetlands restoration measure, surface runoff from 4,407.4 acres of cropland mainly in the JD2/Crooked Lake drainage area was modeled as being treated by newly restored wetland BMPs in HSPF-SAM, representing the drainage areas of 21 sites selected for potential wetland restoration. This represents 14.3% of all cropland (2.9% of all land) draining to Lake Osakis.

Water quality improvements for the storage locations were estimated using HSPF-SAM outputs and cross referenced against data from the Minnesota Pollution Control Agency's BMP Effects Estimator Tool (BEET). Unit load reduction estimates were pulled from the existing HSPF data and are presented in Table 4. With that, expected sediment and nutrient load reductions, specifically phosphorus reductions, were also used to rank and prioritize each storage location. Collectively, all locations could store 469 acre-feet of water, reduce annual sediment loading to Lake Osakis by 1,386 tons per year, and reduce phosphorus loads to the lake by approximately 506 lbs. per year. Installation costs [Environmental Quality Incentives Program (EQIP) cost-share] range from $21,480 to $1,388,597, for a total of $3,507,725 if all 21 possible locations are constructed/restored.

Table 4. Annual Sediment Load

	Sediment (tons/ac/yr)	Total Phosphorus (lbs/ac/yr)	Total Nitrogen (lbs/ac/yr)
Annual load reduction	0.028	0.217	5.253

These proposed wetlands would serve to store and treat additional water on the landscape, in many instances in locations that were part of the former Crooked Lake or associated drainage area. However, much of this land, and other areas surrounding Lake Osakis are used for agricultural purposes. Landowner willingness and implementation cost are two great hurdles that will need to be overcome if these possible storage locations are to be constructed.

4.2.4. Focused Dredging

This section describes an effort to estimate the potential volume, mass, and cost of sediment and phosphorus removal from Lake Osakis through focused dredging. The purpose of this was to analyze the possible benefits of dredging, evaluate how dredging could improve environmental and recreational conditions of Lake Osakis, and provide a rough cost estimate for dredging activities. A dredging measure would involve the excavation of material from within the Study Area to maintain water levels and remove sediment from the Lake.

In 2024, bathymetric survey data, lakebed sediment core samples, and water quality samples were collected. Bathymetry and sub-surface profile data were collected using a BSS+ multi-frequency sonar sediment profiling system. Lakebed sediment samples were collected using a sediment Vibracore-D System. Survey grid spacing for the bathymetric survey was set to 200 m for shallow zones of the lake and the northern arm, and to 400 m for the deep central portion of the lake. The sub-bottom profiler defined the top and bottom of the unconsolidated sediment (i.e. dredgeable material). Sediment core samples were collected with Vibracore-D to verify and calibrate the sonar returns from the BSS+ System. Additional soil core samples were collected using a simple gravity sampler for analysis of sediment phosphorus concentration. Data gathered from field work was then analyzed in ArcGIS Pro to determine unconsolidated sediment thickness, mass, and total phosphorus mass.

Using sediment thickness and sediment phosphorus concentration, a system for ranking the areas for dredging suitability was created. Measured sediment thickness and sediment phosphorus concentration were separately split into five equal quantile groups and reassigned a value of 1-5. The lowest values were placed into a group and given the value of one, values in the second quantile were given a value of two, and so on through to the highest values which were placed into a group and given a value of five. The reclassified sediment thickness and sediment phosphorus concentration values were summed to create a single dredging suitability ranking. Higher sediment thickness and higher sediment phosphorus concentration values led to higher dredging suitability values (See Figure 10). The highest numbered areas were then determined to be the highest valued areas to dredge. Note that water depth is not a significant factor when dredging.

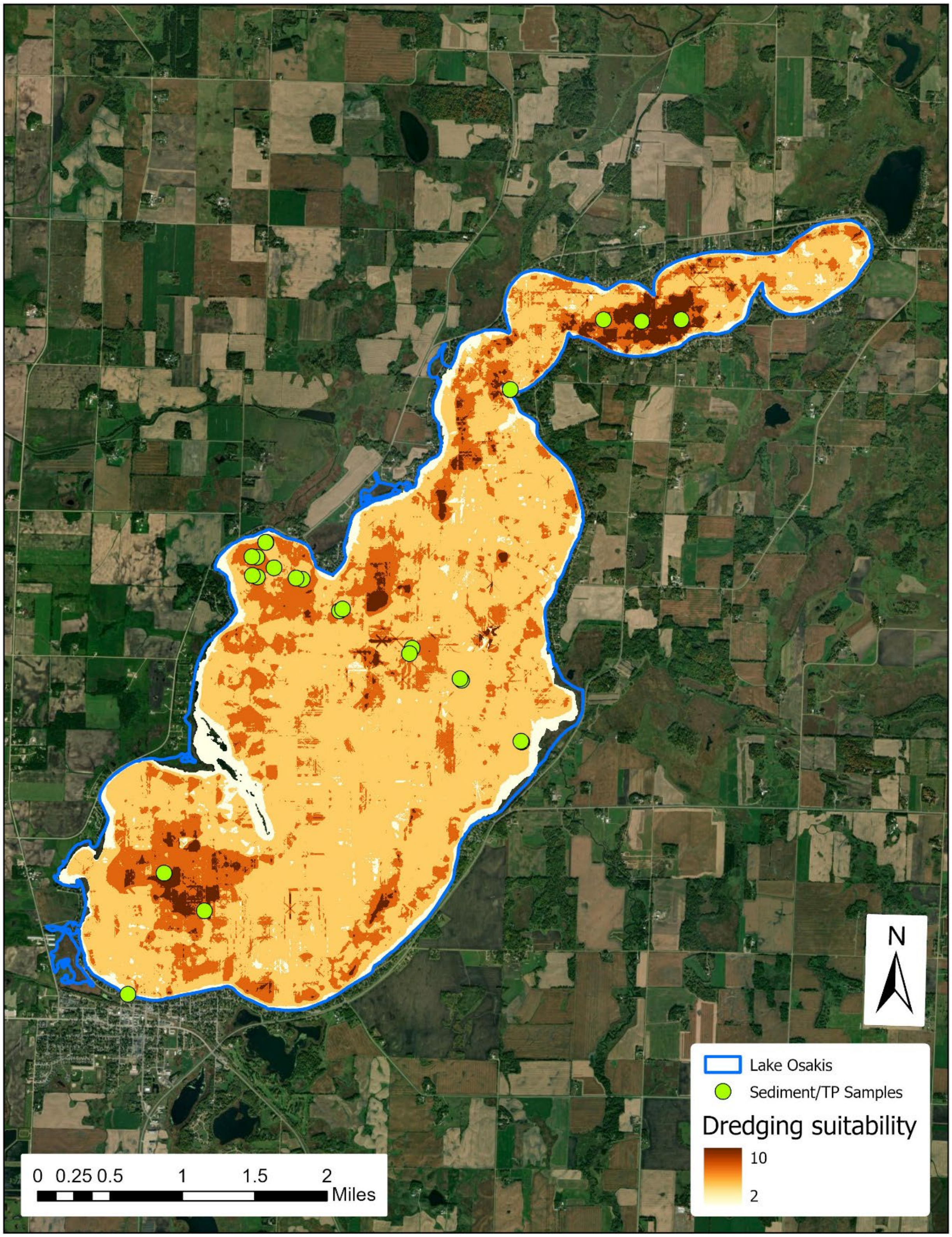


Figure 10. Osakis Dredging Suitability

Four locations were determined to be high priority areas for considering dredging (Figure 11) as an alternative method to improve water quality in Lake Osakis. The volume of dredged material was calculated using the proposed dredging area and the measured unconsolidated sediment thickness data collected from the bathymetric survey. Based on the volume and mass of sediment to be dredged and the concentration of phosphorus in the sediment, the mass of associated total phosphorus was estimated to provide an idea of the amount of phosphorus which could be removed from the lake system. Finally, a rough cost estimate from dredging was determined.

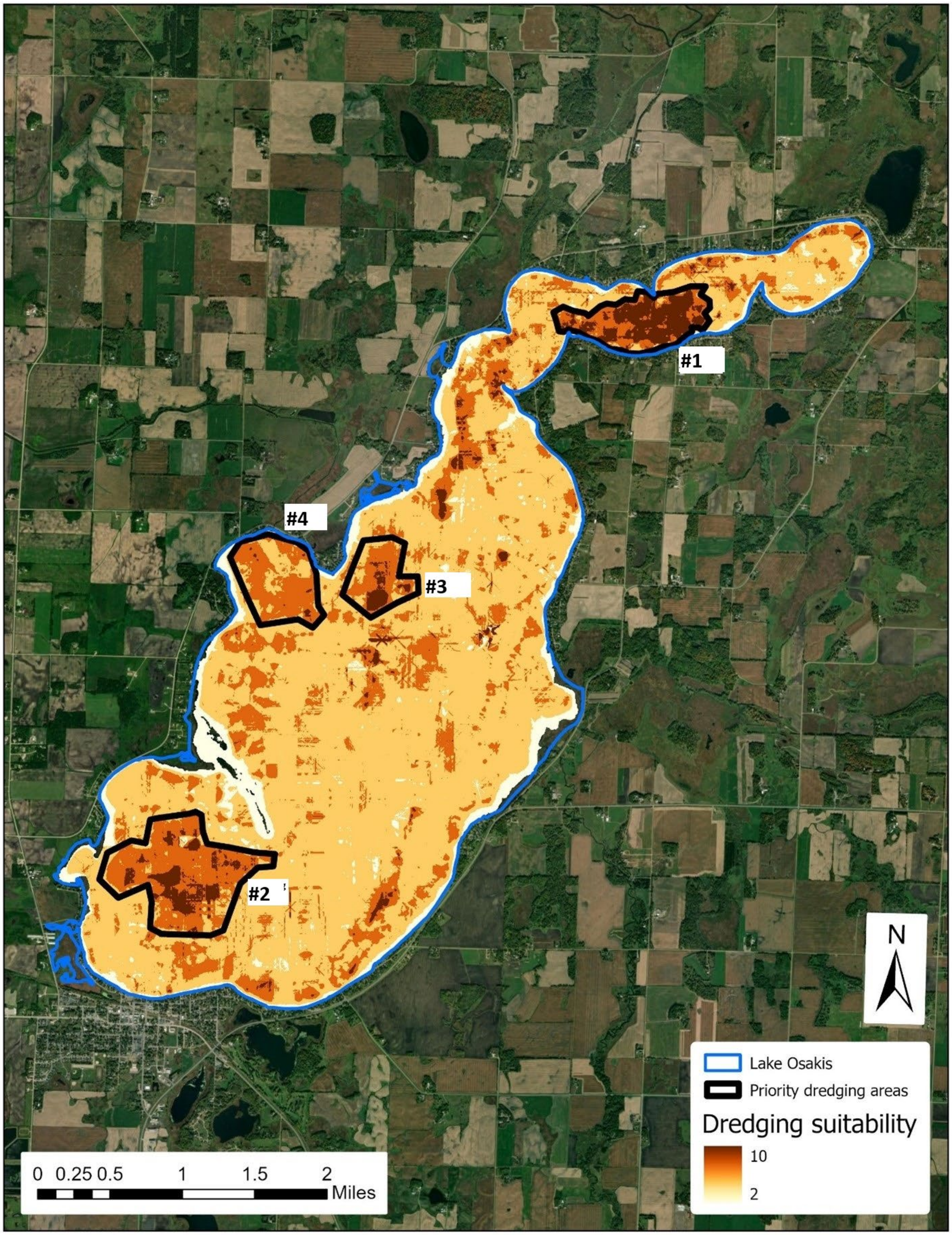


Figure 11. Osakis Dredging Suitability - Priority Areas

Some assumptions were made to generate these preliminary cost estimates (*Table 5*). A dredging pump distance of 4 miles was assumed. Dredging cost at the assumed 4-mile pumping distance would likely start somewhere between $15-$16 per cubic yard. Each additional mile would raise the cost by approximately $2.50 per cubic yard. The mobilization of equipment and pipe/equipment was assumed to be approximately $1.3 million. Each additional or reduced mile of pumping could change the mobilization cost by +/- $160,000.

As seen in the table below the cost to dredge material from portions of Lake Osakis would be anywhere from $5.0 million to $13.4 million per site. This is assuming that only one site is chosen. The mobilization cost ($1.3 million) would only be charged once if more than one site was to be dredged via a single mobilization. Site 3 seems to the most cost-effective at $46.44/lb of total phosphorus removed.

Table 5. Dredging Cost Estimates

Dredging Area	Volume of dredged material (yards^3)	Cost of pump distance of 4 miles	Cost of dredging material	Total Cost	Total Mass of TP removed (lbs.)	Cost Effective ness (cost per lbs. of TP)
1	511,317	$1,300,000	$8,181,065	$9,481,065	33,026	$287.08
2	758,166	$1,300,000	$12,130,652	$13,430,652	133,947	$100.27
3	232,711	$1,300,000	$3,723,378	$5,023,378	108,160	$46.44
4	328,441	$1,300,000	$5,255,051	$6,555,051	122,673	$53.44

By using a lake dredge to remove nutrient-rich sediments, water quality could improve significantly. These improvements would likely contribute to reductions in algae blooms and associated toxins, increased dissolved oxygen levels, and decreased turbidity. Removal of sediment can also help with restoring aquatic habitats, creating deeper areas that provide refuge for fish during seasonal temperature changes, removing debris that suffocates fish eggs and encouraging growth of native plant species. This type of alternative also increases water storage and enhances recreational and aesthetic value of the lake.

While dredging has many benefits, there are also some limitations to consider. The alternative is extremely expensive and involves intensive permitting. There is also a large item to consider when dredging: where all the sediment will go once it’s removed. This can add significantly to the cost depending on location and if the land needs to be purchased.

KEY TAKEAWAY: If the sediment and phosphorus being delivered to the lake from the surrounding watershed are not also addressed, materials will most likely be redeposited within the dredged locations.

4.3. Water Quality Improvement Measures

4.3.1. Septic Compliance/Monitoring

Septic systems have the ability to impact the groundwater and surface water resources within the watershed. In order to avoid environmental consequences, septic compliance and monitoring is a necessary measure. Out of 916 land parcels around Lake Osakis, 704 parcels are in Todd County, and 212 parcels are in Douglas County. Information on septic system compliance for these parcels was requested from Douglas and Todd County staff. County staff were able to provide compliance data for 511 of 916 parcels around Lake Osakis. Out of the 511 parcels that have septic system compliance information available, 199 have been updated since 2008, when significant updates were made to the Minnesota State Rules on septic system compliance. Across both counties, most septic systems were older than 2008 (Figures 12 and 13), with a higher percentage having been updated recently in Douglas County. In Figure 12 and 13, Yes means that the system has been updated since 2008. No means that the parcel has not been inspected or updated since 2008. No data means that there was not information available on the parcel relative to septic system.

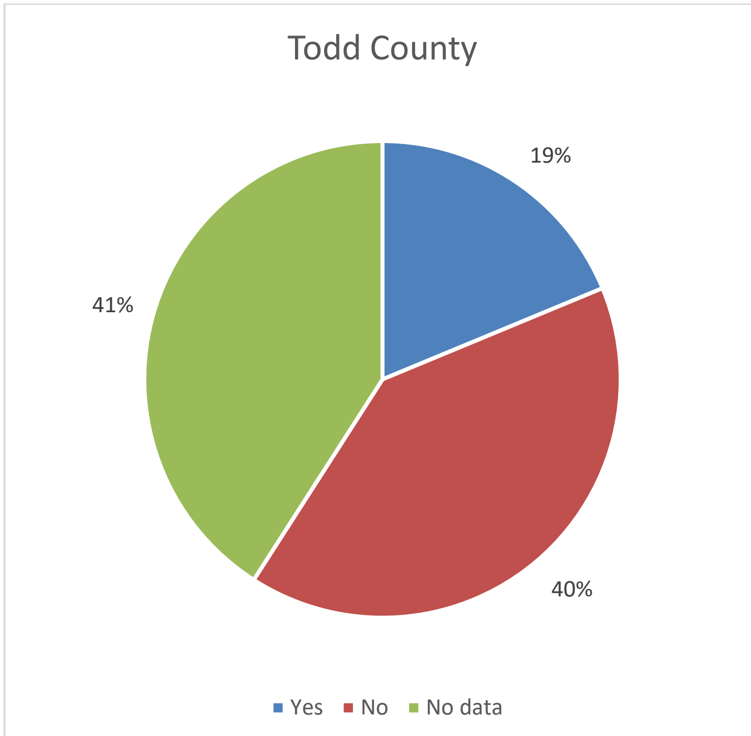


Figure 12. Todd County Septic Systems identifying if the septic system has been updated since 2008.

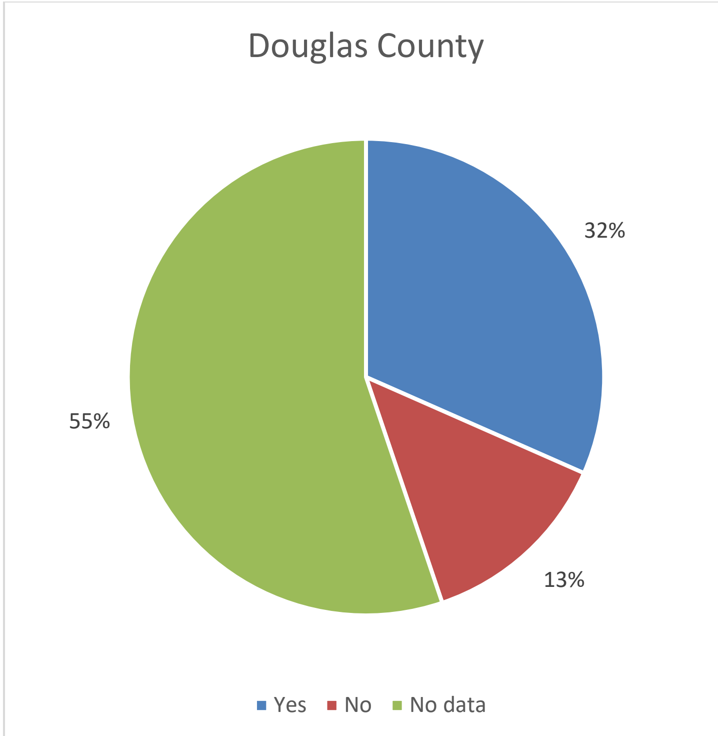


Figure 13. Douglas County Septic Systems identifying if the septic system has been updated since 2008.

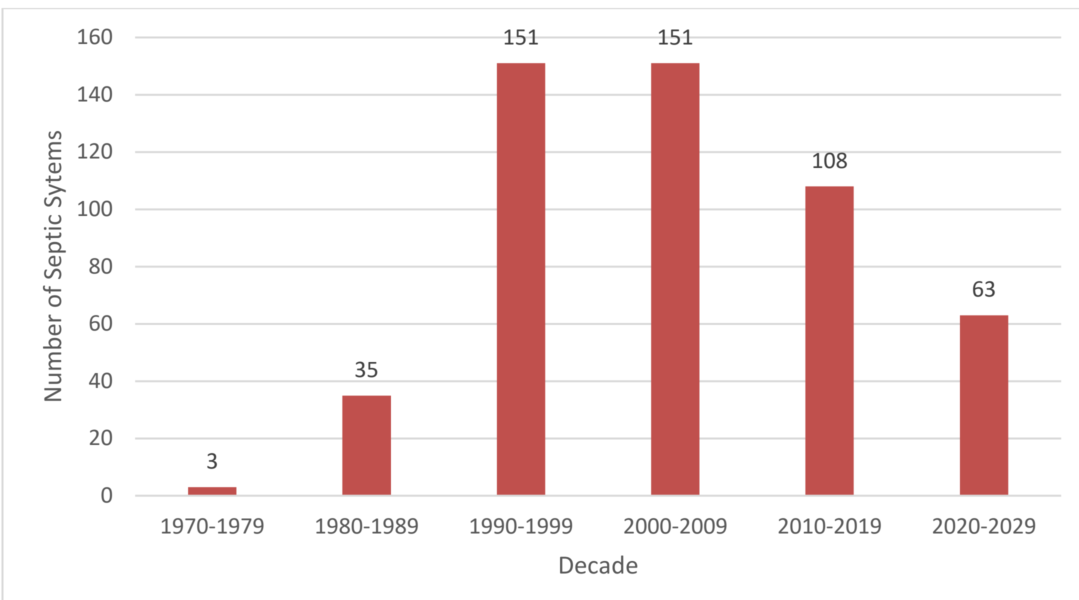


Figure 14. Septic System Age by Decade

Todd County also provided data on last known complaints on septic systems. Septic data was available for 416 of the 704 parcels around Lake Osakis in Todd County. Out of those 416 parcels, 301 parcels have a system with a complaint after the system's most recent known update (*Figure* 14).

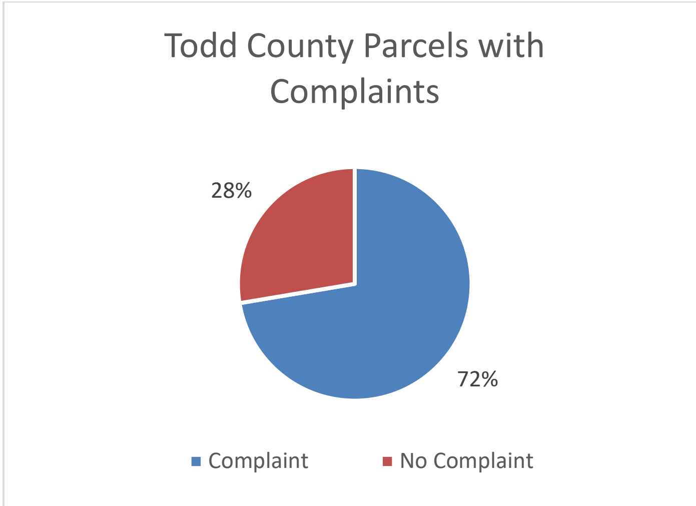


Figure 15. Todd County Septic Complaints

While this project does not make direct ties between the age of a septic system and the risk of contaminants to Lake Osakis, the data provided by the counties does suggest that many parcels around Lake Osakis have older septic systems which may not currently follow Minnesota State Rules on septic system compliance. As a result, it does seem likely that Lake Osakis could benefit from a strategic approach to modernizing septic treatment around the lake.

During the development of this plan, the OLA completed a scoping study for options to improve sanitary sewer around Lake Osakis. The scoping study presented pros and cons, as well as suitability criteria and relative cost for; 1) waste management approaches (e.g., individual, regional, or centralized), 2) types of collection systems, 3) treatment methods, and 4) governance structure/operating entity. The scoping study will likely be used by local decision makers to guide a more detailed engineering feasibility study to evaluate viable alternatives for future improvements.

In order to understand the potential nutrient reduction benefits from improved sanitary sewer around Lake Osakis, the modeled subsurface sewage treatment systems (SSTS) loading in the HSPF model was reviewed. It was assumed that an improved sanitary sewer system around Lake Osakis would remove up to 90% of the SSTS nutrient load delivery, as has been documented in other regional lakes [see Otter Tail Lake Case Study of Individual and Clustered (Decentralized) Wastewater Management Program…; accessed January 30, 2026]. Based upon the modeled methodology and this assumption, improved sanitary sewage treatment could reduce nutrient loading to Lake Osakis by an average of 254 lbs/year of phosphorus and 5,230 lbs/year of nitrogen.

In the HSPF model, SSTS systems are modeled to contribute 100 gallons of water, 5.4 lbs of nitrogen, and 0.26 lbs of phosphorus per person per day to the environment. To find the total annual load from SSTS, the per person loading rate was applied to the number of "equivalent persons" contributing to SSTS systems around Lake Osakis. An "equivalent person" is considered a single individual using an SSTS for the whole year. The total number of equivalent persons was then estimated by multiplying the number of parcels around the lake (916 parcels) by the average persons per household (2.5 and 2.3 people per household for Todd County and Douglas County, respectively). The total number of people was then adjusted to account for the number of seasonal houses (70%). It is assumed seasonal housing is used for 25% of the year. In total, the equivalent persons on Lake Osakis is estimated to be 1,075 people who collectively contribute 60 acre-feet of water, 5,811 lbs or nitrogen, and 283 lbs of phosphorus per year to Lake Osakis.

4.3.2. In-Lake Treatment

In-lake treatment encompasses a variety of methods aimed at improving water quality directly within Lake Osakis. These techniques are designed to control invasive species, reduce nutrient concentrations, and enhance the overall health of the aquatic ecosystem. The main in-lake treatments considered include hypolimnetic withdrawal/circulation, aeration, invasive plant management, alum treatment, carp population control, and biological augmentation.

4.3.2.1. Hypolimnetic Withdrawal or Circulation

Hypolimnetic withdrawal or circulation is a technique used to improve the water quality of lakes by removing or circulating water from the bottom layer, or hypolimnion, of the lake. This method is particularly effective in stratified lakes, where the water column is divided into distinct layers with different temperatures and oxygen levels.

In a stratified lake, the hypolimnion is typically cooler and has lower oxygen levels compared to the upper layers. Over time, this bottom layer can accumulate nutrients such as phosphorus and nitrogen, which can lead to problems like algal blooms and decreased water quality. Hypolimnetic withdrawal or circulation relies upon structures that can either remove water from the hypolimnion or circulate water within the lake. This method can be particularly beneficial in lakes that are subject to high nutrient inputs from external sources, such as agricultural runoff or wastewater discharge.

4.3.2.2. Aeration

Aeration is a method to improve water quality in lakes and ponds. Aeration systems may improve water quality by moving oxygen to deeper water. The release of nutrients from lake sediment can be slowed with increased aeration and therefore help decrease algal growth. While this method is not a permanent solution, it can potentially help temporarily. Other methods focused more on watershed health than spot aeration.

4.3.2.3. Invasive Plant Management and Harvesting

Invasive aquatic plants are non-native plants that can potentially create recreational nuisances in lakes and reduce native plant diversity. In some instances, when invasive plants become too abundant, they can cause economic or environmental harm. Once an invasive species is established in a waterbody, eradication is an unrealistic goal. Plant management is complex, and reductions in invasive plants often require long-term and resource-intensive efforts. Discussing management proposal(s) with a local Invasive Species Specialist is recommended as a first step.

Mechanical harvesting is an effective and environmentally friendly management strategy used for removing nuisance aquatic plants from waterbodies. Through harvesting, plant-choked waters can be cleared, or channels can be cut through areas of dense vegetation, enhancing recreational use and increasing water flow. Harvesting may also be an option for the removal of large filamentous algae blooms, which provides relief to existing algae issues with the added benefit of removing the biomass and reducing the overall nutrient load.

4.3.2.4. Aluminum Sulfate Treatment

Aluminum sulfate, also called alum, is a nontoxic compound commonly used in drinking water treatment. In lakes, it can be applied using specialized equipment that disperses the alum evenly across the water surface. When added to the water, alum removes phosphates from the water column through precipitation, forming a heavier than water particulate known as floc. This floc then settles to the lake bottom to create a barrier which prevents further phosphorus release to the water column from lakebed sediments.

4.3.2.5. Carp Population Control and Biomanipulation

The premise behind biomanipulation is the manipulation of biotic components of a lake as opposed to conventional nutrient management. The goal of water quality improvement is achieved through the manipulation of higher-level consumers of a lake. Controlling carp populations in lakes is a critical ecological strategy aimed at restoring water quality and aquatic habitat. Carp—especially Common Carp (Cyprinus carpio)—are highly invasive and disruptive due to their feeding behavior, which uproots vegetation and stirs up sediment, leading to turbid water and phosphorus release.

Biomanipulation is typically used in lakes that are small, shallow, and are in closed systems. Biomanipulation tends to work well in shallow lakes since organisms are not spatially separated by depth. Lakes that are candidates for biomanipulation should also be closed systems because connections between a lake and other waterbodies will inhibit the ability to control fauna like carp within the target lake.

4.3.2.6. Biological Augmentation

Biological augmentation involves introducing beneficial microbes and enzymes to enhance natural biodegradation of organic matter and nutrients. When paired with nanobubble or side-stream oxygenation technologies, microbial activity can be increased by improving oxygen availability in critical zones like the sediment-water interface.

4.3.3. Channel stabilization

Channel stabilization is a measure that could be applied to any connection or inlet into Lake Osakis. Channel stabilization can help reduce sediment erosion and improve water quality throughout the watershed. Channels and streambanks are typically reinforced to prevent erosion and channel degradation over time.

Channel stabilization as a BMP is not available to be modeled in HSPF-SAM and is difficult to simulate properly in HSPF. Therefore, reductions in sediment transport due to channel stabilization were not simulated in HSPF. Instead, we post processed the HSPF data to identify the sediment traveling through JD2.

Based on the assessment of the Channel Stabilization measure, a 53.2% reduction of suspended sediment could be achieved by stabilizing the unstable or degrading portions of JD2. It is important to note that the estimate does not imply that all of this reduction in sediment would come from a reduction in channel erosion, as the sediment traveling through the JD2 drainage system is a mixture of overland and near channel sources. Additional information on the channel stabilization measure can be found in Appendix A.

4.4. Public Involvement Measures

This section describes the measures developed that pertain to the general public and their engagement with the lake and the overall watershed.

4.4.1. Public Engagement

Public engagement within the watershed and public education about the watershed and the conservation efforts occurring within the watershed has the potential to provide ecological improvements and boost recreational use. Standard elements of a public engagement plan can include targeted outreach and educational campaigns that inform users and residents about their connection to the watershed. For example, describing how daily activities (i.e. lawn care, recreational boating, etc.) can impact water quality. This type of engagement and education could be implemented via newsletters, flyers, and social media posts. Additional engagement could be accomplished through hands-on activities that give residents the ability to directly impact the Study Area. Outside of education, engaging with the public could be improved through the establishment of feedback channels such as through surveys or public meetings.

4.4.2. Agricultural Engagement/Incentivization

Engagement with the agricultural community near the Study Area plays a critical role in watershed improvements. Key components of engagement include producer-focused outreach and technical assistance that connect on-farm practices to their impact on Lake Osakis. Engagement opportunities could include demonstration projects and informational flyers that directly link common farming practices and their trickle-down influence. An incentive program is an additional method discussed. Implementing an agricultural incentive program would require a multi-step process including developing a foundation of established requirements, obtaining funding for the incentives, and gaining participant buy-in. This process would ideally use sustainable farming practices to help avoid excessive amounts of phosphorus or other chemicals from entering the watershed.

Similar to wetland restoration, the HSPF-SAM program was utilized to simulate the agricultural incentivization measure. Agricultural BMPs simulated in HSPF-SAM include:

- Alternative Tile Inlets
  - Treating 600 acres along JD 2
  - Treating 100 acres along CD 43/Boss Creek
- Controlled Tile Drainage
  - Treating 400 acres in JD 2
  - Treating 100 acres in CD 43/Boss Creek
- Wetland Restoration
  - Treating 100 acres in Crooked Lake Basin
- Tile Line Bioreactors
  - Treating 200 acres in JD 2
  - Treating 100 acres in CD 43/Boss Creek

In total, 1,600 acres of cropland in the drainage area of Lake Osakis were modeled for treatment with BMPs under the agricultural incentivization measure. This represents 5.2% of all cropland (1.1% of all land) draining to Lake Osakis. The outcomes of this assessment were provided as inputs to the CE-QUAL-W2 model as shown in **Appendix A**. Estimates of the water quality reductions in sediment and nutrients delivered to Lake Osakis for this measure in shown in Table 6.

Table 6. Load reductions resulting from the Agricultural Engagement/Incentivization as estimated through HSPF-SAM.

Sediment	TN	TP
21.4 tons/yr	2,171.9 lbs/yr	77.8 lbs/yr

4.5. Development of Array of Alternatives

Alternative plans are developed from different combinations of the various measures that would result in attaining the planning objectives. In general, a measure may stand alone as an alternative that can be implemented independently or in combination with other measures. A refined array based on the initial alternatives table (Table 1) was carried forward, as seen in Table 7.

The alternative plans for this study were developed through a multi-step process. The following outlines the steps that USACE, the District, and partners used in the development of the alternatives.

1. Identification of general locations and categories of improvements: During the measures development meeting, the team determined four general topic focus areas that most needed intervention. This included lake elevation/water storage, water quality improvement, aquatic life and invasive species control, and public perception. Due to the small scope of the project, the team decided to focus on those four focuses and not extend beyond.
2. Review of management goals: Several discussions occurred with the partners to determine the major objectives of the project for the watershed district.
3. Measure development: Various measures were proposed as potential solutions or components to address the concerns in the area. The team developed and discussed possible structural and non-structural measures. Based on the scope and scale of the project, the team brought forward the measures that could realistically be implemented.
4. Smallest alternative: The team identified the smallest alternative that would produce results that would meet the project objectives. The alternative includes the key measures that should be part of any action alternative.
5. Largest alternative: The team identified the largest possible alternative that would be feasible to implement in the area.

5. Alternative Evaluation and Comparison

The purpose of this overall project is to determine an array of measures that provide comprehensive support of project goals and objectives. This section documents the process used to determine the priority measures and the evaluation of the alternative variations. Costs of implementation were not used in the evaluation due to the scope and nature of the project. All evaluated alternatives were developed to achieve this outcome, but to varying degrees.

5.1. Comparison of Array of Alternatives

The array of alternatives was evaluated based on the quantitative results from the CE-QUAL-W2 model simulations. The modeling provides clear evidence to compare the effectiveness of each alternative in meeting the project's goals and objectives. Four alternatives were developed to simulate potential management options for Lake Osakis (Table 6). The four-action alternatives include five measures that can be implemented to improve water quality in Lake Osakis. They include outlet modification, wetland restoration, focused dredging, in-lake treatment, and agricultural incentivization.

No Action Alternative: This alternative provides no benefits and allows current water quality degradation and hydrologic instability to continue.

Alternative 1 (Watershed Controls): This alternative provides a strong foundational improvement, delivering the best results for water clarity and dissolved oxygen in the lake's main body. However, the model shows it is insufficient on its own to fully address the core problem of internal phosphorus recycling.

Alternative 2 (Ag Incentivization added): The model results indicate that this alternative is less effective than Alternative 1 alone, causing a modest but consistent degradation across multiple key water quality parameters.

Alternative 3 (Alum Treatment added): This alternative improves upon Alternative 2 by targeting internal nutrient processes. It provides measurable reductions in phosphorus and algae, but its overall benefit is less pronounced than the dredging scenario (Alternative 4).

Alternative 4 (Dredging added): This alternative provides the most significant water quality improvements among the pre-defined scenarios. By directly addressing internal loading through dredging, it achieves the largest reductions in total phosphorus and chlorophyll-a, directly targeting the drivers of nuisance algal blooms.

This analysis demonstrates a clear hierarchy of effectiveness, driven by the varying ability of each strategy to address the dominant issue of internal nutrient loading.

Table *6*. Management Measures for Alternatives

Measure	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**	**Baseline**
Outlet Modification	Y	Y	Y	Y	N
Wetlands restoration	Y	Y	Y	Y	N
Focused dredging	N	N	N	Y	N
In-Lake Treatment (Alum)	N	N	Y	Y	N
Ag Incentivization	N	Y	Y	Y	N

5.2. Modeling-Based Alternatives Analysis

To provide a quantitative basis for evaluating the proposed alternatives, the calibrated CE-QUAL-W2 model was used to simulate Lake Osakis' response to each management scenario. The analysis focused on the summer period (June-September) from 1996-2015, when water quality impacts are most pronounced. The following sections summarize the key findings.

5.2.1. Whole-Lake Response to Alternatives

When compared to the baseline condition, all action alternatives were predicted to improve summer water quality. However, the magnitude and character of the improvement differed significantly between the strategies, as summarized below in Table 7.

Table 7. Whole-Lake Summer Response Relative to Baseline (Mean Change)

Scenario	Dissolved Oxygen	Secchi Depth	Chlorophyll-a	Total Phosphorus	Phosphate	Total Suspended Solids	Turbidity
Alt 1	+0.300 mg/L	+0.172 m	-5.458 µg/L	-0.019 mg/L	-0.004 mg/L	-0.684 mg/L	-0.947 NTU

Alt 2	+0.264 mg/L	+0.153 m	-5.032 µg/L	-0.018 mg/L	-0.004 mg/L	-0.596 mg/L	-0.825 NTU
Alt 3	+0.279 mg/L	+0.162 m	-5.332 µg/L	-0.019 mg/L	-0.004 mg/L	-0.618 mg/L	-0.855 NTU
Alt 4	+0.292 mg/L	+0.170 m	-5.560 µg/L	-0.020 mg/L	-0.005 mg/L	-0.635 mg/L	-0.877 NTU

The results highlight a key distinction:

- Alternative 1 (Watershed Controls) produces the strongest improvement in physical habitat metrics, including water clarity (Secchi Depth) and low-end dissolved oxygen.
- Alternative 4 (In-Lake Dredging) produces the largest reduction in the drivers of eutrophication, including chlorophyll-a (algae) and total phosphorus.

5.3. Incremental Effects of Management Actions

To understand the specific impact of each management step, an incremental analysis was performed. This analysis revealed:

1. Watershed Framework (Alt 1 vs. Baseline): Provided a broad and consistent improvement across nearly all parameters.
2. Agricultural Incentivization (Alt 2 vs. Alt 1): Introduced a modest but consistent degradation, indicating this measure, as modeled, partially offset the gains from the watershed framework.
3. In-Lake Treatments (Alt 3 & 4 vs. Alt 2): Both alum and dredging recovered the degradation from Alt 2 and provided additional benefits, with dredging (Alt 4) showing the strongest positive effect on reducing phosphorus and algae.

5.4. Spatially-Explicit Response (Epilimnion, Hypolimnion, and Miller Bay[3])

The model confirmed that the different alternatives impact distinct areas of the lake differently:

- Watershed controls (Alt 1) provided the greatest benefit to the epilimnion (surface waters), improving the optical environment.
- In-lake treatments (Alt 3 and 4) had the most significant impact on the hypolimnion (bottom waters), directly targeting the source of internal phosphorus loading that fuels late-summer algal blooms.

JD2 (Miller Bay), being directly influenced by the JD2 tributary, showed a more localized and amplified response to all management actions.

This detailed spatial analysis confirms that a comprehensive management strategy must address both external loading to benefit the surface waters and internal loading to improve the health of the deep waters.

[3] Miller Bay is referenced as Branch 2 in the CE-QUAL-W2 modeling.

6. Comprehensive Plan

A comprehensive plan represents a suite of actionable measures designed to fully address the challenges identified within a watershed. The following section describes the final comprehensive plan developed for the Lake Osakis study area.

Based on the quantitative results of the CE-QUAL-W2 modeling and detailed analysis, Alternative 4 was identified as the recommended Comprehensive Plan. This selection is based on its superior ability to meet the project's goals and objectives. The modeling conclusively shows that Alternative 4, which includes outlet modification, wetland restoration, focused dredging and agricultural incentivization, provides the most robust and significant improvements to water quality by addressing both external loads and the critical internal phosphorus cycling that drives eutrophication in Lake Osakis.

The Comprehensive Plan is meant to be implementable with each measure as a possible stand-alone project. While the comprehensive plan is identified as Alternative 4, the approving authority has control on implementation timing, location, and construction. USACE is not involved in the construction of the project. The responsibility to implement the comprehensive plan is up to the Sauk River Watershed District and other approving agencies.

Based on input at the measures development meeting and the determination of the Sauk River Watershed District, Alternative 4 was determined to be the strategy for the Comprehensive Plan. Alternative 4 was chosen based on the alternative's ability to meet the objectives and project goals. The following section describes the components of the Comprehensive Plan.

6.1. Description of Comprehensive Plan

6.1.1. Outlet Modification

Engineering changes to outlet structures to improve water-level control, reduce erosion, and enhance hydraulic stability through measures such as adjustable controls or culvert reconfiguration. Exact outlet sites and structural details will be determined by the Watershed District.

6.1.2. Wetland Restoration

Establish or improve native hydrology and vegetation to improve nutrient uptake, habitat, and flood attenuation through regrading, invasive species removal, and native planting. Exact restoration locations and extents will be determined by the Watershed District.

6.1.3. Focused Dredging

Selective removal of accumulated sediments in targeted in-lake areas to restore lake depth and reduce internal phosphorus loading. Dredge footprints and disposal sites will be determined by the Watershed District.

6.1.4. In-Lake Treatment

Targeted chemical, biological, or physical treatments (for example, phosphorus-binding agents or aeration) to reduce internal nutrient cycling and improve water quality. Treatment types, dosing, and placement will be determined by the Watershed District. More detail on the alternative is provided in **Appendix A**.

6.1.5. Agricultural Incentivization

Voluntary programs and cost-share incentives to encourage practices such as cover crops, buffers, and nutrient management that reduce runoff and sediment from agricultural lands. Broader empirical evidence demonstrates that these practices are vital for long-term soil health, hydrologic resilience, and comprehensive sediment reduction across the watershed. Program scope, participant outreach, and adaptive monitoring of water quality impacts will be developed and administered by the Watershed District to ensure long-term watershed health goals are achieved.

7. Implementation

This section describes the implementation framework for the Comprehensive Plan and clarifies roles, authorities, and next steps. The current effort was completed under a Section 22 Planning Assistance to States agreement. USACE's role is limited to providing technical planning support and documentation. The Corps does not possess implementation authority for construction, permitting, funding, or long-term operation of the measures described in the plan.

Implementation responsibility rests with the Sauk River Watershed District and the other local, state, and federal approval authorities identified in the plan. Those entities retain authority over project timing, site selection, design refinements, procurement, permitting, funding decisions, and construction oversight. Successful implementation will require the Sauk River Watershed District and partners to complete their own regulatory reviews, secure necessary permits and funding, develop detailed engineering and construction documents, conduct public engagement, and establish operations, maintenance, and monitoring programs. This plan is intended to inform and support those processes by identifying recommended measures, anticipated benefits, and implementation considerations.