Lake Hastings Watershed Implementation Plan

Appendix F to the Upper Big Blue District-Wide Water Quality Management Plan

September 2024

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Lake Hastings

Watershed Implementation Plan

Project Partners:

Prepared as an Appendix to the
Upper Big Blue NRD District-Wide WQMP

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Prepared for: Upper Big Blue Natural Resources District

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This water quality management plan was prepared to guide the project partners in improving water quality and aquatic resources within Lake Hastings and its watershed. The plan may also serve as a basis for seeking financial support for those projects. It has been written with guidance published in EPA's "Handbook for Developing Watershed Plans to Restore and Protect Our Waters," updated March 2008, including EPA's Nine-Elements of a Successful Watershed Plan. The planning process utilized a Community Based Approach.

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1. INTRODUCTION

Lake Hastings and its associated watershed were identified as a target area for project implementation within the existing *Upper Big Blue Natural Resources District (UBBNRD) District Wide Water Quality Management Plan (WQMP).* Lake Hastings is located in HUC 102702030302 within the City of Hastings and falls within both the Upper Big Blue NRD (UBBNRD) and the Little Blue NRD (LBNRD) (Figure 2). The drainage area for the lake includes 5,394 acres, or approximately 22% of the Headwaters West Fork Big Blue River HUC 12. The lake was constructed in 1959 by the Nebraska Department of Roads and Irrigation (now the Nebraska Department of Transportation) and is currently owned by the City of Hastings. The original purpose of the lake was recreation and flood control. Lake Hastings itself has a surface area of 68 acres, with a sediment basin at the inlet of the lake with a surface area of 8 acres (Figure 1). Surrounding the sediment basin and upstream portion of the lake is a public park (city owned) that is used extensively by the public for recreation. Beneficial uses assigned to Lake Hastings by the Nebraska Department of Environment and Energy (NDEE) include Aquatic Life, Agricultural Water Supplies, and Aesthetics (NDEE, 2021).

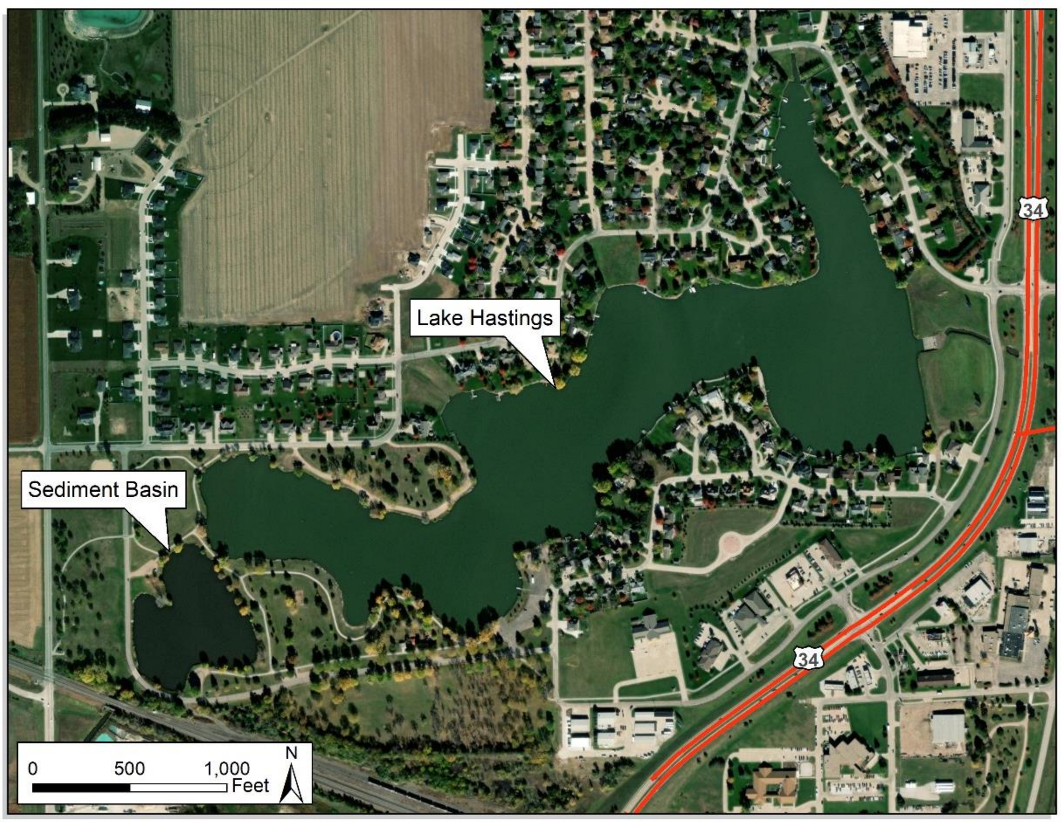


Figure 1: Aerial Map of Lake Hastings

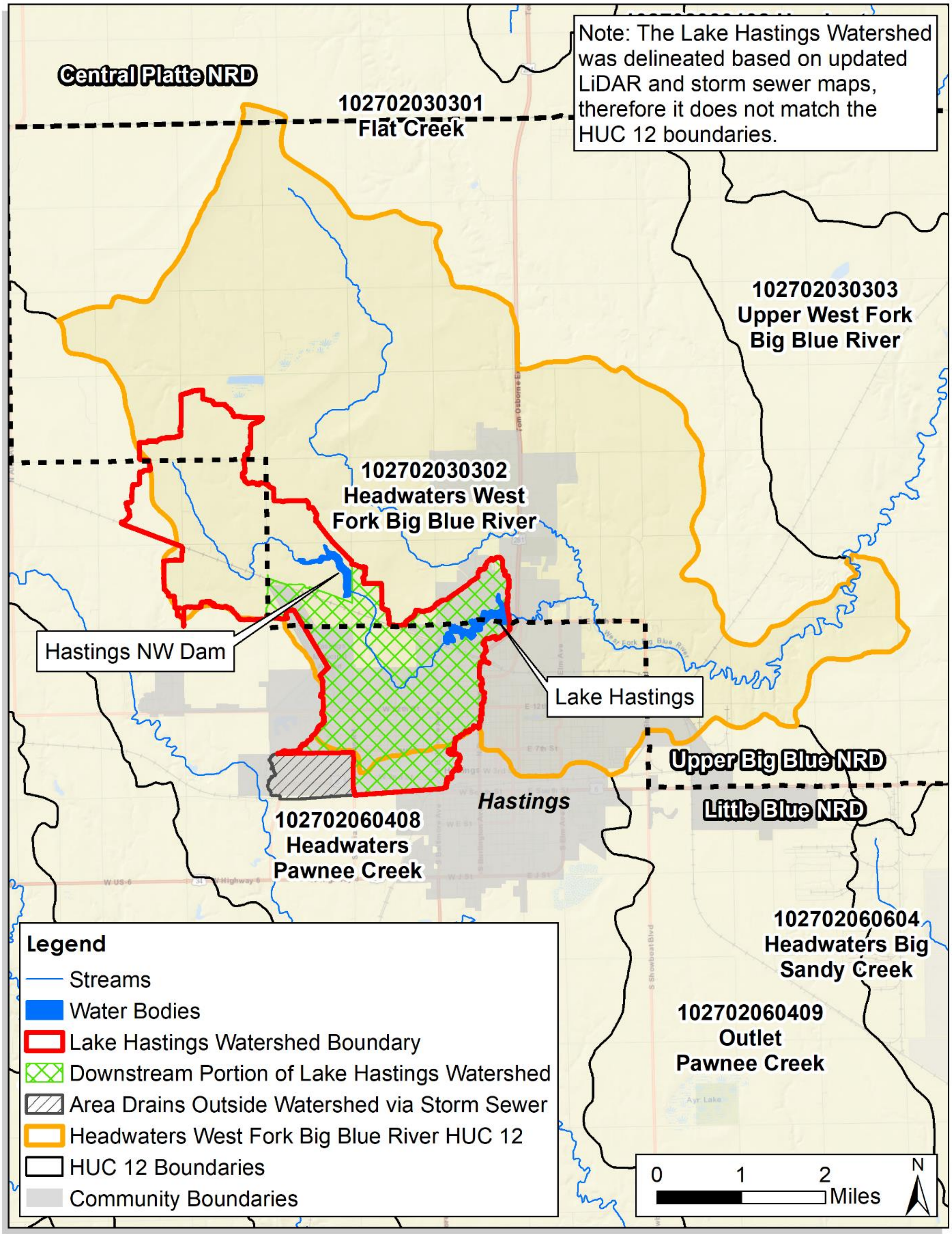


Figure 2: Location of Lake Hastings Watershed

1.1 PUBLIC INVOLVEMENT

Public and stakeholder feedback has been incorporated into this plan, resulting in a community guided vision for Lake Hastings, and a publicly supported implementation strategy. The following opportunities for public involve have been held:

- **April 6, 2023** - A public meeting was held to begin educating the community on problems facing Lake Hastings and begin gathering feedback on possible solutions. Following that meeting, the Lake Hastings Citizens Committee was formed to continue these discussions. The committee consisted primarily of residents who lived around the lake.
- **Throughout 2023** – The Lake Hastings Citizens Committee met three times.
- **November 29, 2023** – A stakeholder meeting was held with recreational users of Lake Hastings, residents from near the lake, producers from throughout the watershed, and project sponsors. At the meeting, initial results of the watershed evaluation were presented along with solutions that were likely to be prioritized. Following discussion, a facilitated visioning session was held to gather feedback on desired lake amenities and to allow stakeholders to sketch out their visions for Lake Hastings (Figure 3).
- **February 13, 2024** – A public open house style meeting was held to inform the public about the Lake Hastings Water Quality Management Plan and solicit their feedback. Information that was presented at the meeting included current conditions of the lake, the planning process, and proposed improvements to the lake and watershed.

Detailed meeting summaries, sign-in sheets, and other materials can be found in Attachment 1.

Figure 3: Stakeholder Meeting November 29, 2023

1.2 WATER QUALITY AND IMPAIRMENTS

The Aquatic Life beneficial use for Lake Hastings is currently impaired due to a fish consumption advisory (in place due to the presence of PCBs and mercury in fish tissue) and due to chlorophyll *a* (resulting from total nitrogen and total phosphorus). The fish consumption advisory has been in place since 2006, while nutrients and chlorophyll *a* were first added to the list of impairments in 2014The 2018 Integrated Report clarified that the impairment was due to chlorophyll *a* as a result of total nitrogen and total phosphorus levels. The Aesthetics beneficial use has been impaired due to sediment since 2010 (NDEE, 2021).

The City of Hastings conducted water quality sampling at Lake Hastings in 2022 to support the development of this plan (Table 1). Historical water quality data was available from NDEE sampling done in 2009 – 2012. In the most recent sampling, from 2022, total nitrogen exceeded the Nebraska water quality standard of 1,000 ug/L in all 12 samples. Total phosphorus also exceeded the Nebraska water quality standard of 50 ug/L in all 10 samples. Chlorophyll *a* data was not available in 2022, but it is believed that high lake turbidity caused by suspended sediment is currently limiting light penetration and resulting in lower algae production, despite high nutrient levels. There were fewer data available for turbidity in 2022, but the median value was observed to be higher than the Minnesota water quality standard for a warm water fishery, 25 NTU (MPCA, 2008), which is used for reference as Nebraska does not define a numeric value for turbidity.

Table 1: Lake Hastings Existing Water Quality

Parameter	Data Source	Data Period	Number of Samples	Median Value	Water Quality Standard (ug/L)
Total Nitrogen (ug/L)	NDEE	2009-2012	20	1,684	1,000
	City of Hastings	2022	12	1,877	
Total Phosphorus (ug/L)	NDEE	2009-2012	20	181	50
	City of Hastings	2022	10	113	
Chlorophyll *a* (mg/m^3)	NDEE	2009-2012	20	35	10
Turbidity (NTU)	City of Hastings	2022	4	59	25* (note this value is for reference only, and is not a Nebraska water quality standard)

**Turbidity reference value is based on Minnesota water quality standards, as Nebraska does not define a numeric value for turbidity.*

An important factor influencing the water quality of Lake Hastings is the presence of a major point source in the watershed, the North Denver Power Station. The power station is located south of Lake Hastings outside of the watershed and discharges non-contact cooling water pumped from a groundwater well on site directly to Lake Hastings. Since the power station operates on a back-up basis, water flow is not constant but is still estimated to be about 157 acre-feet per year, or about 20% of the total flows the lake receives in an average year. In a dry year like 2022, the power station discharge could account for over 50% of flows to the lake. Due to high nitrate levels in groundwater in the area, this discharge is a significant source of nitrogen loading in the lake.

In the long-term, the Hastings Utilities Aquifer Storage and Restoration Project, which utilizes pumping of high-nitrate groundwater and re-injection of low-nitrate groundwater to improve nitrate levels in city drinking water wells, may have a beneficial impact on nitrate levels in the non-contact cooling water. However, due to slow time of travel within aquifers, this project is not anticipated to have an immediate effect on nitrate levels within water discharged from the North Denver Power Station. Thus, potential future changes in groundwater nitrate levels were not incorporated into water quality modeling.

1.3 FISHERIES EXISTING CONDITION

Lake Hastings has long been a popular location for fishing and boating. However, recent sampling by the Nebraska Game and Parks Commission (NGPC) has confirmed local fears in a declining fishery. Fish sampling was completed in 2022 and found nine (9) species present in the lake: black bullhead, bluegill, channel catfish, common carp, gizzard shad, green sunfish, largemouth bass, red shiner, and white crappie. A copy of this report (Engel, 2022) is provided in Attachment 2. The following notable observations were also provided:

- Only 2 largemouth bass were sampled, and the population was considered to be poor. Bass declines could be caused by undesirable water quality and/or competition for food resources by other species such as gizzard shad, bluegills, or green sunfish.
- No bluegills were sampled that were preferred harvestable length (8 inches or better). The bluegill population was considered marginal.
- Only a limited sample of catfish were able to be sampled, however, it was determined that the population is likely doing well, and that some natural recruitment is occurring.
- There was only one crappie sampled of preferred harvestable size (10 inches or larger) but most were 6 to 8-inches. Crappie population may be suffering from over competition of resources.
- Common carp, gizzard shad, and green sunfish were all sampled. Common carp and gizzard shad are not considered very beneficial for small lakes.
    - The feeding behavior of carp stirs up sediment within a waterbody. Suspended sediment reduces ultraviolet light penetration needed for aquatic plant growth. Aquatic plants help oxygenate the lake and also provide habitat for aquatic insects and fish. Increased turbidity also inhibits sight feeding species like largemouth bass and crappie.
    - Shad can quickly over-populate, competing directly with bluegills and changing nutrient cycles.
    - Green sunfish often hybridize with bluegill and can take over small lakes, stunting both populations.

1.4 EXISTING LAND USE AND BMPS

The presence of Hastings NW Dam within the watershed and just upstream of Lake Hastings presents a unique condition that must be considered in the watershed modeling and analysis. Based on local stakeholder input, Hastings NW Dam only discharges during high flow events. Inspection of aerial imagery just below Hastings NW Dam over many years also reveals the lack of perennial streamflow below the dam due to the absence of a defined bed and bank; instead, there is only evidence of ephemeral stream paths that appear to be farmed through in most years. Because of these factors, the modeled watershed for Lake Hastings will only include the land use and acreage of the area below Hastings NW Dam and will not incorporate the contribution of any area above Hastings NW Dam, although there is likely still a small contribution from this area, particularly during high flow events. The congruence of modeling calibrated to land use with modeling calibrated to in-lake concentrations of pollutants, as discussed later on, suggests that this decision is representative of true (average annual) conditions. Unless otherwise noted, land use and associated values in this plan refer to the portion of the watershed downstream of Hastings NW Dam.

Land use within the watershed is mostly split between cropland and the City of Hastings, designated as urban use (Figure 4). Table 2 displays the breakdown of land use designations by acres and percentage of the total watershed area. This same data was also used in the watershed-level water quality model, Pollutant Load Estimation Tool (PLET), which is discussed more later.

Table 2: Downstream of Hastings NW Dam Watershed Land Use Values Used for PLET

Land Use	Acres	Percentage
Urban	1,848	63%
Cropland (primarily corn and soybeans)	899	31%
Pasture	75	3%
Forest	6	<1%
Non-Permitted AFOs	0	0%
Other (water, wetlands)*	95	3%
Total	**2,922**	**100%**

**Assumed to not contribute to pollutant loading in modeling*
Note: due to rounding, individual values may not add exactly to totals.

Based on a windshield survey competed by LBNRD in spring 2023, about 21% of cropland in the watershed has adopted no-till practice, with the remaining cropland distributed between strip-till (50%) and conventional tillage (29%). Cover crop adoption in the watershed is much less, with only about 2% of cropland observed to have cover crops. It is also important to note that much of the stream reach within the watershed lacks defined bed and banks, although a short stretch of the stream just upstream of the lake appears to be perennial in nature (Figure 6). The stream reach in the watershed consists of ephemeral headwaters streams, including the South Branch of the West Fork Big Blue River, which feeds into Lake Hastings.

Known existing urban BMPs include no-mow zones at inlets to Lake Hastings (Figure 7) and a rain sensor and smart sprinkler controller rebate for households looking to manage their yard irrigation more efficiently. Few other urban BMPs are known to exist. As Hastings is an MS4 community, it should be noted that any implementation strategies discussed later in the plan are not intended to include any requirements outlined in the City of Hastings' MS4 permit. This plan and proposed strategies for improving the water quality of Lake Hastings are intended to be supplemental to, or above and beyond, any required actions.

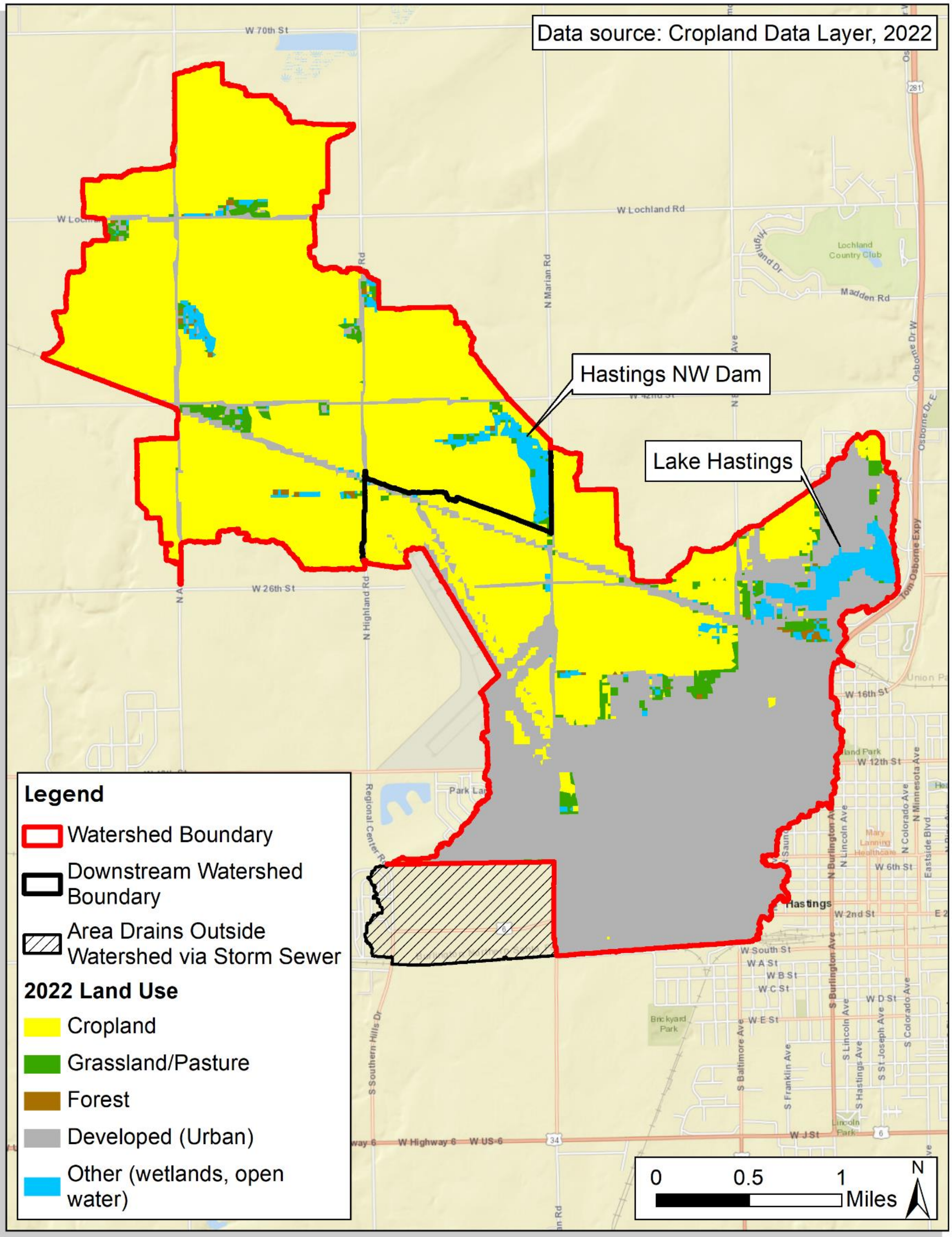


Figure 4: 2022 Land Use by PLET Category

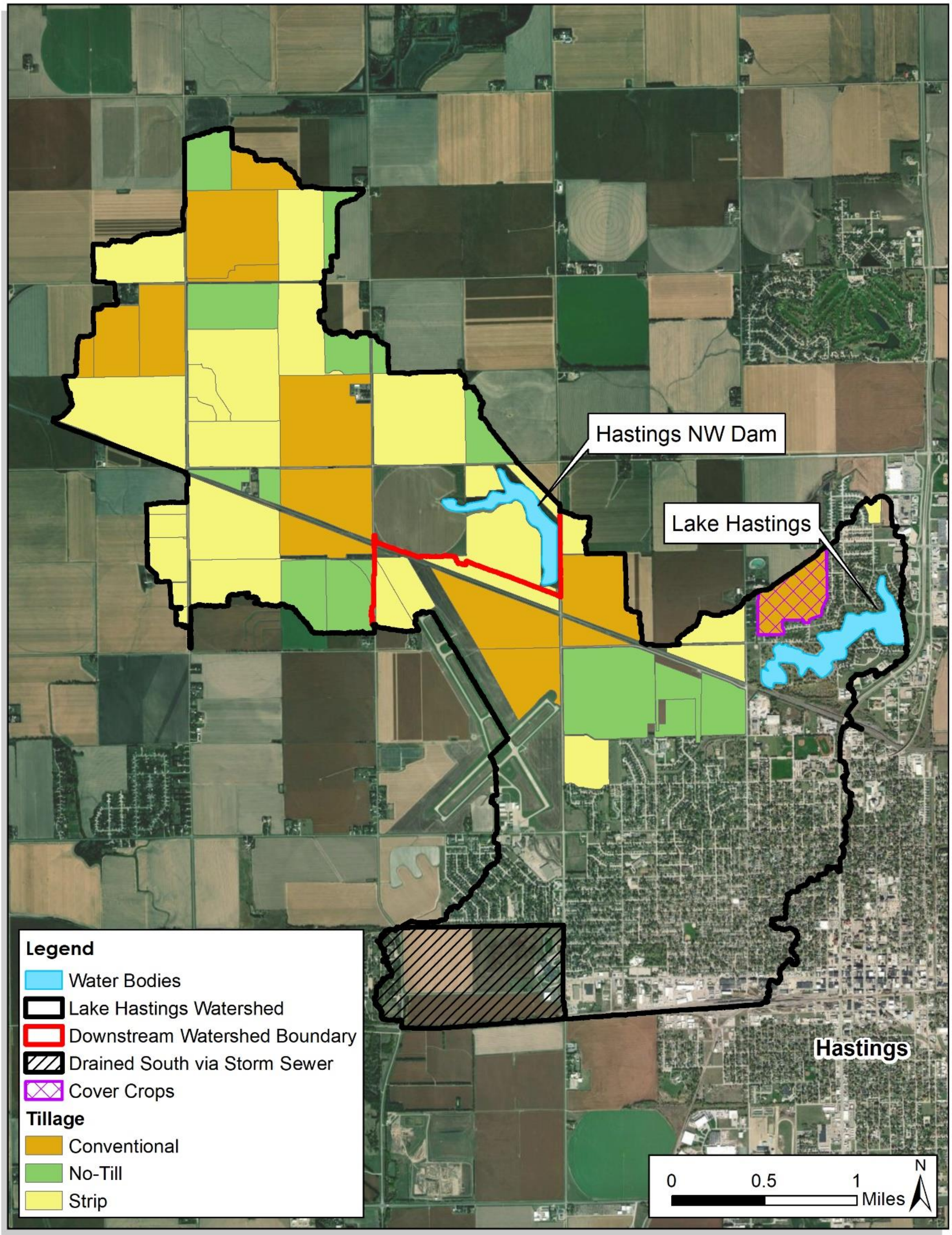


Figure 5: Existing Agricultural BMPs in the Watershed

Figure 6: Example of Stream Banks Just Upstream of Lake Hastings

Figure 7: No-Mow Zone at Inlet to Lake Hastings

1.5 SEDIMENTATION AND LAKE VOLUME LOSSES

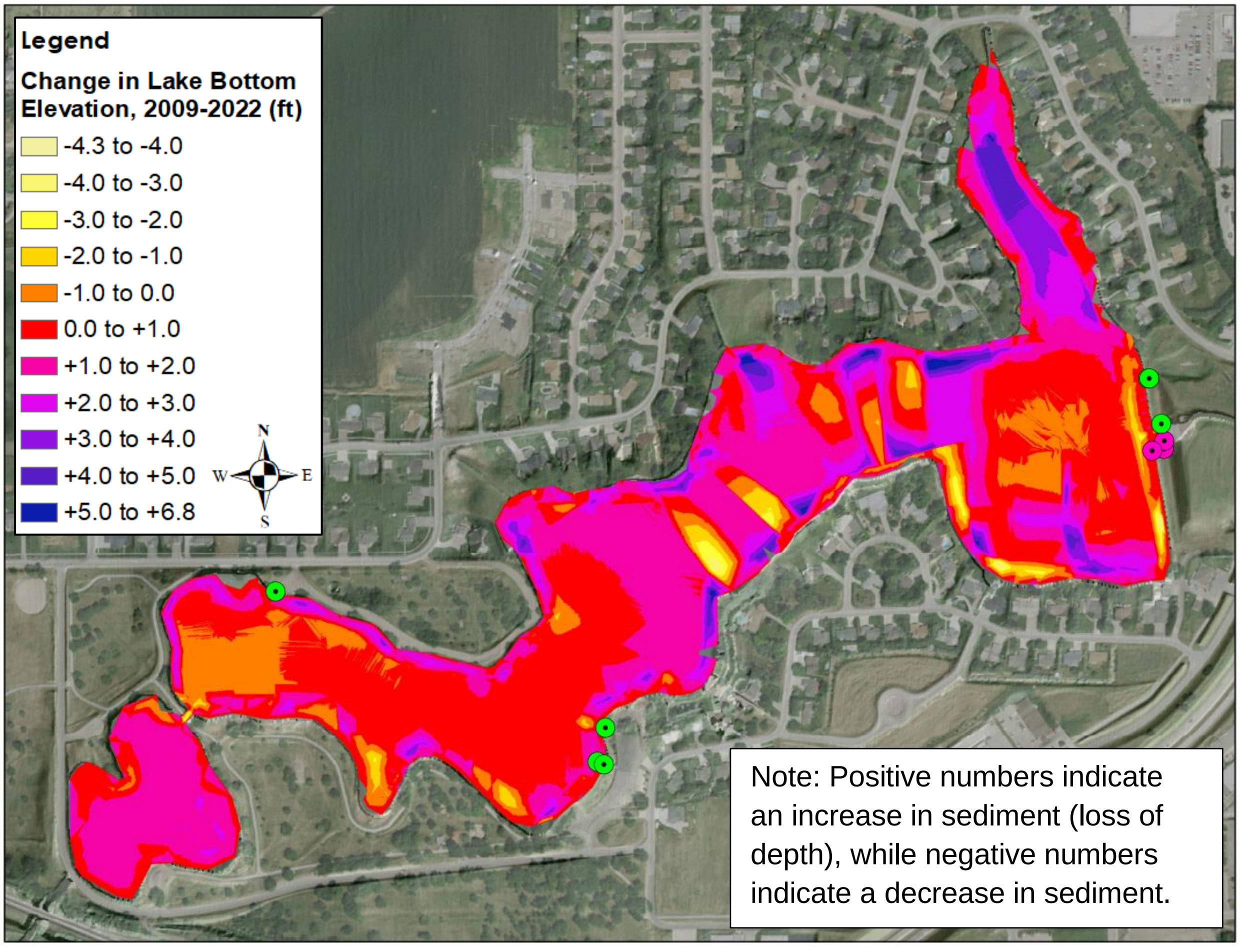
Lake Hastings was originally constructed with a volume of 276 acre-feet, as noted in both the original engineering as-built plans and the NeDNR dam database. In 1970, after significant sediment accumulation, the lake was dredged and excavated to an estimated volume of 525 acre-feet, based on records from the City of Hastings. Due to this expansion, the 1970 area and volume are considered the initial conditions of Lake Hastings, for the purposes of this plan.

Ten years later, in 1980, Hastings NW Dam was installed upstream of Lake Hastings and is believed to be capturing a substantial portion of the sediment that otherwise would have ended up in Lake Hastings. Two recent bathymetric surveys, one in 2009 conducted by EA Engineering and Science, and one in 2022 conducted by NRCS, help show that although Lake Hastings has lost over 20% of its conservation pool volume, the current-day rate of sedimentation is less than during the 1960s. In 2009, the lake volume (including the sediment basin) was 421 acre-feet, and in 2022, the volume was 404 acre-feet.

The total conservation pool volume lost due to sedimentation from 1970 to 2022 is 23%, while the annual volume loss based on comparing the 2009 and 2022 bathymetric surveys is only 0.3% each year (Table 3). Based on this disparity and the existence of Hastings NW Dam just upstream of the lake, it is probable sedimentation rates were higher prior to the construction of the NW Dam in 1980. Figure 8 shows the change in reservoir bottom elevation within Lake Hastings from 2009 to 2022. Across the lake, increases in sedimentation (or loss in lake depth) range from 1 foot to over 6 feet. Some isolated areas did exhibit a small gain in lake depth. The main body of the reservoir generally exhibits 2 feet or less of deposited sediment with the sediment basin showing the same general losses. A map showing “current” lake depths (created with 2022 bathymetric data) can be found in Attachment 2.

Table 3: Lake Volume Losses

Volume Loss Parameter	Percentage
Total Volume Loss (1970-2022)	23%
Average Annual Volume Loss (2009-2022)	0.3%



Note: Map data created by NRCS and provided courtesy of the City of Hastings

Figure 8: Change in Lake Bottom Elevation Due to Sedimentation from 2009 – 2022

2. WATER QUALITY MODELING METHODOLOGY

Two water quality models were used to predict pollutants loads within the watershed and the lake itself. The EPA Pollutant Load Estimation Tool (PLET) was used to estimate nitrogen, phosphorus, and sediment loads from the watershed. The equations from Canfield and Bachmann (1981) and Bachmann (1980) were used to model phosphorus and nitrogen concentrations and loads in the lake. PLET loads are used here to represent average annual conditions, while in-lake modeling has been calibrated to 2022 sampled conditions and is used to determine necessary loading reductions. Additional information on modeling methodology is provided in Attachment 3.

2.1 POLLUTANT LOAD ESTIMATION TOOL (PLET)

The Pollutant Load Estimation Tool (PLET) was used to estimate watershed loading of phosphorus, nitrogen, and sediment. PLET is hosted online by EPA and replaces the Spreadsheet Tool for Estimating Pollutant Loads (STEPL). PLET was also used to quantify load reductions in the BMP scenario discussed later on. More information about PLET can be found on the EPA website here: https://www.epa.gov/nps/plet. Some variables within the PLET model were left as default values, where appropriate. However, several others (discussed below) were updated to better represent the watershed:

- **Land use** values (Table 1) were obtained from the USDA-NASS Cropland Data Layer for 2022 and generalized into six categories for modeling purposes.
    - Cropland was considered areas designated as corn, sorghum, soybeans, popcorn, barley, winter wheat, oats, alfalfa, and triticale.
    - Urban included developed/open space, developed/low intensity, developed/med intensity, and developed/high intensity. Urban land use distribution was based on parcel analysis done by the City of Hastings.
    - Pasture included other hay/non alfalfa, barren, and grassland/pasture
    - Forest included deciduous forest, mixed forest, and shrubland
    - Non-permitted animal feeding operations (AFOs) were identified by aerial analysis and review of NDEE records. No non-permitted AFOs were identified in the watershed below Hastings NW Dam.
    - Wetlands and open water were not considered as part of the total land use within the model.
- **Manure application** was based on local stakeholder input and assumed to be equivalent to one typical application of manure (based on agronomic rates) to half of the cropland in the watershed. The PLET manure application tool was utilized to determine the overall manure application rate to all cropland, which was calculated to be equivalent to one month of application to all cropland. Agricultural animal counts within PLET, while minimal, were based on stakeholder input.
- **Unregistered Onsite Wastewater Treatment Systems (OWTS).** NDEE records of registered OWTS systems were reviewed. Registration requirements did not exist for OWTSs installed prior to 2001; therefore, the precise number of septic systems is not possible to determine. To estimate the number of OWTSs, a review of aerial imagery was compared to the NDEE registered facilities database, with the assumption that homesteads outside of Hastings likely each had their own OWTS. Zero unregistered OWTS were identified.
- In the **Universal Soil Loss Equation**, default values were updated based on local knowledge from stakeholder input, including existing levels of conservation practices.
- **Irrigated acres** were obtained in a shapefile from LBNRD and updated to reflect center pivot irrigation as seen in aerial imagery. Eight annual applications of one inch each were assumed for irrigated land.

- **Streambank erosion** was estimated by measuring the length of the stream reach in ArcGIS (Figure 9)and applying an erosion category of "moderate" based on field observations and stakeholder input. No gullies were noted within the watershed.

Figure 9: Perennial Stream Reach Within Watershed

2.2 LAKE MODELING

The confidence in results of any model depends on the quantity and quality of data that is required for model inputs. While the quality of data used for this project is not in question, the amount of nutrient data available for modeling was limited to five years. Both nitrogen and phosphorus concentrations in lakes can exhibit extensive seasonal and annual variation. The monitoring section of this plan addresses data needs that will increase confidence in future modeling results.

The artificial lakes model from Canfield and Bachmann (1981) was used for modeling the in-lake phosphorus concentrations. The equation is below:

$$TP = \frac{L}{z\,(\sigma + \rho)}$$

where

$\sigma = 0.114\,(L/z)^{0.589}$ (yr^{-1}), and σ denotes the sedimentation coefficient

TP = total phosphorus concentration (mg/m^3)

L=annual phosphorus loading per unit of lake surface area (mg/m^2*yr)

z=mean lake depth (m)

ρ=hydraulic flushing rate (yr^{-1})

The Canfield and Bachmann equation is a modified form of the 1969 Vollenweider model. The update is in the formula for the variable σ, with unique versions for natural and artificial lakes. As Lake Hastings is an artificial lake, that version is shown above. The total annual load to the lake can be calculated by multiplying L by the surface area of the lake.

Multiple iterations of this model were evaluated to understand lake and watershed dynamics and to attempt to calibrate the model. Ultimately, the median of all available water quality sampling data (2009-2012 & 2022) was used to calibrate the existing conditions model. Both the net and gross annual phosphorus load to the lake were calculated based on the median measured phosphorus concentration in 2009-2012 and 2022. According to Cunha and others (2014), about 61% of the total pollutant load can be assumed to remain in the lake. Therefore, the total annual load to the lake was considered the net annual load and the gross annual load was calculated assuming that the net annual load was 61% of the gross annual load. When the model was calibrated to the PLET output load for comparison, the output load was considered a gross annual load, since it represents the total load entering the lake. The difference between gross and net annual load is mostly noted here to ensure that comparisons between model calibrations are comparing the appropriate loads to each other. In this plan, reported loading will be gross loading unless otherwise noted.

The equation used for modeling in-lake nitrogen concentrations, from Bachmann (1980), is almost identical to the equation used for phosphorus modeling, except that the sedimentation coefficient (σ) is replaced with an attenuation coefficient (α) to represent nitrogen cycling. Bachmann (1980) does not give a way to calculate the attenuation coefficient, as it is derived within the study itself, so for the purposes of this report the mean artificial lake attenuation coefficient (8.7) within the study was used for modeling Lake Hastings.

The following inputs to the Canfield Bachmann model were used (Table 4):

- **Lake surface area** was an average of lake surface area recorded in the 2009 and 2022 bathymetric surveys and does not include the sediment basin area. Since the model is calibrated to water quality sampling data from 2009-2012 and 2022, bathymetric data from both 2009 and 2022 was used to approximate actual conditions for the entire data set.
- **Mean lake depth** was derived from an average of the lake volumes reported in the 2009 and 2022 bathymetric surveys.

- **Hydraulic flushing rate** was calculated as the inverse of the retention time. Retention time was calculated by assuming the annual runoff in the watershed was equal to the total outflow volume of the lake. Annual runoff volume was estimated using data from the Daily Erosion Project (Gelder et al., 2018). To obtain the 2022 flow rate, used for the sampling-calibrated modeling, the average annual runoff from 2009-2012 and 2022 (0.6 inches) was multiplied by the area in the watershed and added to the annual power plant discharge. Then, the lake volume was divided by the flow rate to obtain the average 2009-2012 and 2022 detention time. The detention time was determined to be 1.3 years (approximately 16 months), which correlates with a hydraulic flushing rate of 0.8 times per year.

Table 4: Input Values to In-Lake Modeling of Existing Conditions

Input	Value
Lake surface area	67 acres
Mean lake depth	5.8 feet (1.8 meters)
Hydraulic flushing rate (2009-2012 & 2022)	0.8 times per year

3. POLLUTANT SOURCES AND LOADS (CURRENT CONDITIONS)

For the purposes of this plan, point sources of pollution such as NDEE regulated facilities were considered to be meeting permitting conditions and not contributing beyond the pollutant limits set by permits. There is a major point source within the Lake Hastings watershed that contributes to the lake’s nutrient load: the North Denver Power Station. This source was considered in terms of overall load and modeling but will not be addressed as part of load reductions to meet water quality standards. Similarly, OWTS registered with NDEE are assumed to be within the bounds of their permitting requirements.

Additionally, permitted AFOs (typically medium and large operations) are assumed to be meeting their regulatory requirements. These facilities are designed to contain any runoff that is generated by storm events that are less than or equal to a 25-year, 24-hour rainfall event. However, non-permitted AFOs (typically small facilities) do not have regulatory requirements imposed on them and are thus considered for pollutant loading and management recommendations.

3.1 PHOSPHORUS

The total phosphorus load is modeled to be 2,671 lb/yr. The load is split evenly between urban land (48%) and cropland (46%), with all other sources contributing less than 5% of the total load. Without reliable water quality data to calibrate the model, or lake bottom sediment-phosphorus sampling to calculate sediment release rates, it was not possible to calculate internal loading. However, based on available data, the internal load is likely to be relatively minor compared to the external load. Table 5 shows the breakdown of phosphorus loads by source and the acres that each source takes up in the watershed. As additional water quality data is collected at Lake Hastings, this model could be updated.

Table 5: Phosphorus Sources and Average Annual Loads to Lake Hastings

Source	Acres	Annual Phosphorus Load (lb/yr)	Percentage of Total Load
External Nonpoint Loads[1]			
Urban	1,847	1,270	48%
Cropland	899	1,231	46%
Streambanks	N/A	69	3%
Pastureland	75	38	1%
Forest	6	1	<1%
OWTS	N/A	0	0%
Non-Permitted AFOs	N/A	0	0%
External Point Loads[2]			
Power Plant	N/A	63	2%
Total Load		**2,671**	**100%**

[1]*Source: PLET Water Quality Modeling*

[2]*Source: Derived from sampling data, provided by City of Hastings*

Note: the acres listed may not add up precisely to the total area of the watershed due to rounding throughout the modeling process.

3.2 NITROGEN

The total nitrogen load is modeled to be 17,427 lb/yr. About half of the nitrogen load (46%) in the watershed is from urban nonpoint sources, with the remaining loading mainly coming from cropland (30%), followed by discharge from the North Denver Station power plant (22%). Table 6 shows the breakdown of nitrogen loads the acres that each source takes up in the watershed.

Table 6: Nitrogen Sources and Average Annual Loads to Lake Hastings

Source	Acres	Annual Nitrogen Load (lb/yr)	Percentage of Total Load
External Nonpoint Loads[1]			
Urban	1,847	7,940	46%
Cropland	899	5,159	30%
Pastureland	75	358	2%
Streambanks	N/A	178	1%
Forest	6	1	<1%
OWTS	N/A	0	0%
Non-Permitted AFOS	N/A	0	0%
External Point Loads[2]			
Power Plant	N/A	3,791	22%
Total Load		**17,427**	**100%**

[1]*Source: PLET Water Quality Modeling*

[2]*Source: Derived from sampling data, provided by City of Hastings*

Note: the acres listed may not add up precisely to the total area of the watershed due to rounding throughout the modeling process.

3.3 SEDIMENT

The total sediment load was modeled to be 742 tons/yr. The majority of sediment loading originates from cropland (60%), followed by urban runoff (23%) and streambanks (15%). Table 7 shows the load breakdown by source for sediment and the acres that each source comprises.

Table 7: Sediment Sources and Average Annual Loads to Lake Hastings

Source	Acres	Annual Sediment Load (tons/yr)	Percentage of Total Load
External Loads			
Cropland	899	445	60%
Urban	1,847	174	23%
Streambanks	N/A	111	15%
Pastureland	75	12	2%
Forest	6	<1	<1%
OWTS	N/A	0	0%
Non-Permitted AFOs	N/A	0	0%
Total Load		**742**	**100%**

Source: PLET Water Quality Modeling

Note: the acres listed may not add up precisely to the total area of the watershed due to rounding throughout the modeling process.

Buildup of sediment on the lake bottom can result in lake volume loss, impacts to recreational uses, harm to aquatic habitat and fisheries, and reduced water quality. Sedimentation can also be a driver of phosphorus loads, as phosphorus adsorbs to (attaches to) sediment. Therefore, decreasing sediment loads or sediment suspension can help curb phosphorus concentrations. Suspended sediment within the lake column also plays an important part in lake dynamics. By blocking sunlight penetration into the water column, suspended sediment can suppress algal growth even in cases of high nutrients. Conversely, if suspended sediment levels decrease without an accompanying decrease in nutrient levels in a eutrophic lake, algal growth is likely to skyrocket.

This deeper understanding of the sediment-nutrient-chlorophyll dynamics of Lake Hastings highlights the need for a comprehensive approach to both nutrient and sediment practices identified within the implementation section of this plan. With relatively high existing TSS levels (Table 1), consideration of these dynamics and continued monitoring of TSS will be important when addressing nutrient and chlorophyll *a* concentrations.

3.4 MODEL CONGRUENCE

General modeling calibration/validation targets or tolerances have been identified for watershed hydrology and water quality parameters by Duda et al. (2012). These values attempt to provide some general guidance, in terms of the percent mean errors or differences between simulated and observed values, so model users can gauge what level of agreement or accuracy (i.e., very good, good, fair) may be expected from the modeling application (Duda et. al, 2012).

The phosphorus and nitrogen loads generated by PLET for the watershed are highly congruent (in agreement) with the expected loads based on in-lake modeling. Table 8 provides the estimated loads from each method for phosphorus and nitrogen, and the percent difference between them. In accordance with Duda et. al (2012), a percent difference between simulated and recorded values for nutrients of less than 15% correlates to "very good" model calibration.

For this comparison, the PLET model represents simulated conditions, and in-lake modeling represents recorded values, as it is based on in-lake sampling. The percent difference between modeled phosphorus levels is 2.0% and the percent difference between modeled nitrogen levels is 5.2%, suggesting very good model congruence for both pollutants and providing confidence in the results.

Table 8: PLET and In-Lake Modeling Congruence

Pollutant	PLET Load (lb/yr)	Lake Modeling Load (lb/yr)	Model Congruence (Percent difference between models)
Phosphorus	2,671	2,719	1.8%
Nitrogen	17,427	16,506	5.4%

For planning purposes, the loading estimates from the in-lake modeling will be used to represent current conditions and to set load reduction targets. These models allow for calculation of in-lake pollutant concentrations using either a known or projected load as an input. Additionally, the in-lake modeling can estimate a projected load based on known pollutant concentrations. Changes to the projected load will be calculated based on the application of BMPs to the PLET model.

4. REQUIRED POLLUTANT LOAD REDUCTIONS

Pollutant load reduction requirements are set at levels to address two water quality impairments identified for Lake Hastings. The Aquatic Life beneficial use for Lake Hastings is currently impaired due to chlorophyll *a* (total nitrogen, total phosphorus), and the Aesthetics beneficial use is impaired due to sediment (NDEE, 2020). Both of these impairments are addressed as part of this plan. The Aquatic Life beneficial use is also impaired due to a fish consumption advisory; however, this will not be addressed as part of this plan because the source of many of these compounds is atmospheric and not confined to watershed boundaries.

4.1 SEDIMENT REDUCTION GOALS

To address the impairment to Aesthetics due to sediment, the existing annual sediment load should be reduced. Currently, the total volume loss since the lake was renovated in 1970 is estimated to be about 23%, and the annual volume loss is estimated to be 0.3% per year. The annual volume loss is directly connected to the annual sediment load, which was modeled in PLET to be 742 tons/year. The goals for sediment are to: (1) increase reservoir conservation pool volume via removal of accumulated sediment and (2) reduce average annual sediment loads to the reservoir.

4.2 NUTRIENT LOADING CAPACITY

In order to reduce chlorophyll *a* levels, nitrogen and phosphorus loads need to be reduced. Therefore, required pollutant load reductions are expressed as reductions to phosphorus and nitrogen. However, increasing the nutrient loading capacity of Lake Hastings will also help to meet water quality standards. This is noted here because increasing the loading capacity allows less strenuous (higher) pollutant load reduction targets. Therefore, an increase in lake volume, due to removal of accumulated sediment has been accounted for in the pollutant load reduction goals. Additional details on sediment removal are discussed alongside other planned BMPs in Section 6.2.

The total phosphorus and nitrogen loading capacities for Lake Hastings were determined using in-lake modeling, discussed previously. Lake volume and surface area used to model current conditions are the average of the two most recent bathymetric surveys in 2009 and 2022. To model future lake conditions, as a result of sediment removal, the following input values were used:

- **Lake surface area** used to model conditions before sediment removal was the same as used for existing conditions (an average of the 2009 and 2022 bathymetric survey area). Lake surface area used to model conditions after sediment removal was from the 2022 bathymetric survey.
- **Mean lake depth** used to model conditions before sediment removal was the same as used for existing conditions. Mean lake depth used to model conditions after sediment removal was calculated by dividing the 2022 surface area by the increased lake volume. The lake volume is anticipated to increase from the 2022 volume due to the removal of 44 acre-feet of accumulated sediment.
- **Hydraulic flushing rate** was calculated as described in section 0 but used average annual runoff from 2007-2022 (2.6 inches) to better represent average future conditions in the watershed. Before and after sediment removal conditions used the same respective volumes as were used to calculate mean lake depth, as described above.

Table 9: Input Values to In-Lake Modeling of Future Conditions

Input	Value (Before Sediment Removal*)	Value (After Sediment Removal)
Lake surface area	67 acres	68 acres
Mean lake depth	5.8 feet (1.8 meters)	6.3 feet (1.9 meters)
Hydraulic flushing rate (2007-2022)	2.0 times per year	1.9 times per year

**Represents current lake conditions*

4.3 NUTRIENT (CHLOROPHYLL *A*) REDUCTION GOALS

The current phosphorus concentration of 166 ug/L will need to be reduced by 70% to meet the water quality standard of 50 ug/L (Table 10). According to the model, the current load of 2,719 lb/yr would need to be reduced to 433 lb to achieve an in-lake concentration of 50 ug/L. This equates to a required reduction of 84%. With the removal of accumulated sediment, the phosphorus load capacity of Lake Hastings would be increased to 448 lb/yr, which would also equate to a required reduction of 84%.

The current nitrogen concentration of 1,705 ug/L will need to be reduced by 41% to meet the water quality standard of 1,000 ug/L (Table 11). The current load of 16,506 lb/yr would need to be reduced to 11,898 lb/yr to achieve an in-lake concentration of 1000 ug/L under current in-lake conditions. This equates to a 28% required reduction. With the removal of sediment, the nitrogen load capacity of the lake would be increased to 12,713 lb/yr, requiring a lower required nitrogen load reduction of 23%.

Table 10: Phosphorus Reduction Goals for Lake Hastings

Total Phosphorus	Current Level	Water Quality Goal	Reduction Needed	
In-Lake Concentration	166 ug/L	50 ug/L	116 ug/L	70%
Pollutant Load	2,719 lb/yr	448 lb/yr	2,272 lb/yr	84%

Source: In-Lake Water Quality Modeling

Table 11: Nitrogen Reduction Goals for Lake Hastings

Total Nitrogen	Current Level	Water Quality Goal	Reduction Needed	
In-Lake Concentration	1,705 ug/L	1,000 ug/L	705 ug/L	41%
Pollutant Load	16,506 lb/year	12,713 lb/year	3,793 lb/year	23%

Source: In-Lake Water Quality Modeling

5. IMPLEMENTATION STRATEGY

The implementation strategy for the Lake Hastings target area includes multiple practices that target pollutant sources through the ACT approach (Avoid, Control, Trap), also known as a "treatment train." All nonpoint pollutant sources are addressed. The identification of management practices and best suited locations were identified through stakeholder input, analysis of aerial imagery, and the Agricultural Conservation Planning Framework (ACPF) Tool. For a detailed description of BMPs, refer to the PLET BMP descriptions (Tetra Tech, Inc., 2022).

To provide an accurate load reduction estimate from practice implementation, the water quality modeling process also followed a "treatment train" approach (illustrated in Figure 10) which is comprised of six levels of treatment. Pollutant load reductions begin with the implementation of education and outreach, and runoff is progressively treated (pollutants removed) until it reaches a receiving waterbody (i.e., Lake Hastings). This figure is meant for illustrative purposes only, as the exact approach to treatment varies based on pollutant sources, type, and location.

The implementation strategy presented in this plan should be used as a guide and may be subject to revision as new information becomes available. In all cases, only willing landowners will be included in this voluntary implementation strategy.

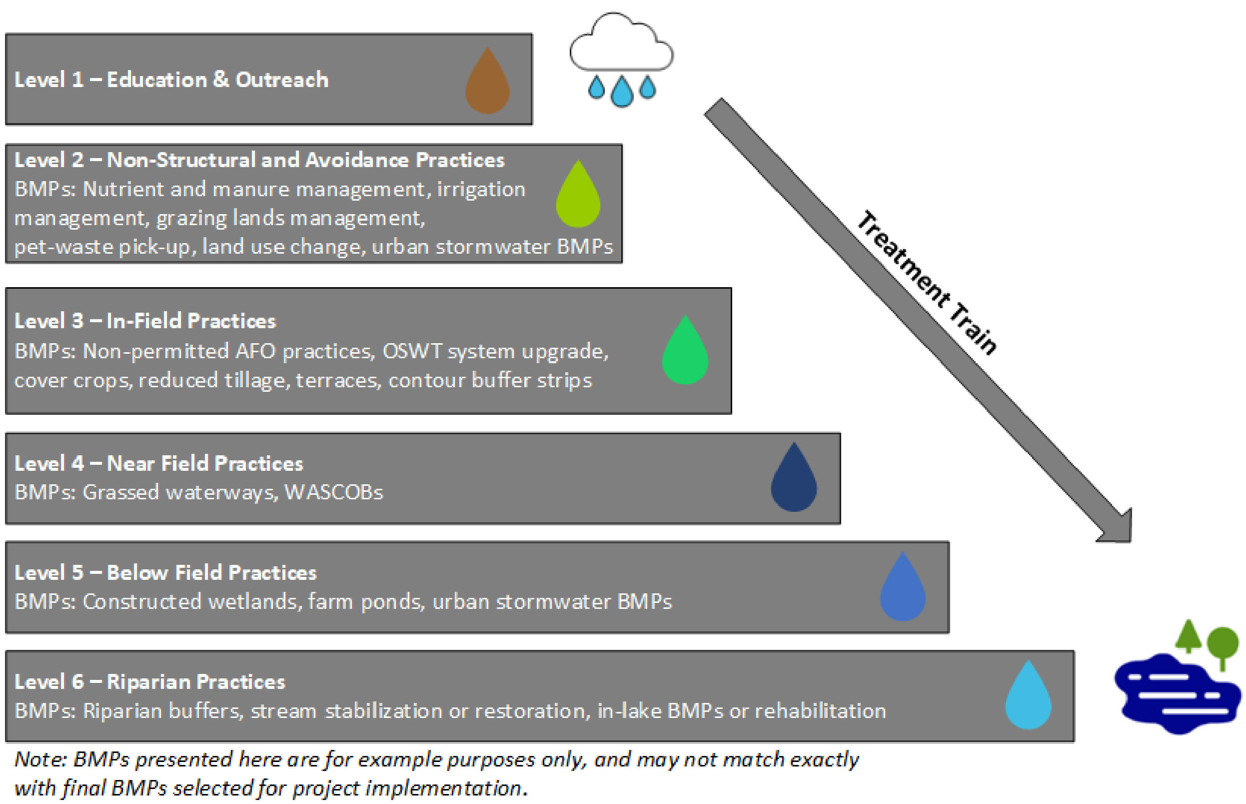


Figure 10: Implementation of Priority BMPs through a "Treatment Train" Approach

6. BMP TARGETING

6.1 DRAINAGE AREA TREATMENT

BMPs for the Lake Hastings watershed area are focused on reducing nutrient loads. By implementing these practices throughout the target area, the effectiveness of downstream projects and BMPs will be increased. Cropland is targeted for the largest number of practices (Table 12), but all nonpoint pollutant sources are addressed by at least one BMP practice. Figure 11 provides an overview of locations where BMPs could potentially be placed based on ACPF analysis. Note that some fields may have multiple BMPs. It is important to note that ACPF only sites BMPs within agricultural land, and no equivalent tool was available for siting urban BMPs. Additional siting of urban stormwater BMPs will be completed during the implementation of this plan through outreach and education efforts.

The locations identified in these maps provide a starting point for discussion with willing landowners and are not all necessary to meeting water quality goals. Rather, different combinations of the practices identified will likely provide similar outcomes, and costs and landowner preferences are principal factors to take into consideration when implementing BMPs.

The following BMP implementation scenario was evaluated by applying BMPs to the PLET model. This scenario represents the best-case scenario and may be difficult to fully achieve. However, it will be a helpful place to start plan implementation, and even incremental increases in BMP adoption will have a beneficial impact on the water quality of the watershed.

6.1.1 CROPLAND

The modeled BMP scenario involved the following measures across all cropland:

- Cover crops
- Nutrient (including manure) management
- No-till
- Grassed waterways

6.1.2 URBAN

Due to the highly urban nature of a portion of the watershed, urban BMPs will be as important as agricultural BMPs. All urban land was modeled to be treated by an urban BMP suite that could include a range of practices, including, but not limited to:

- Pet waste signage and outreach
- Porous pavement
- Bioswales
- Rain garden
- Low or No-phosphorus fertilizer

6.1.3 STREAMS

Streambank stabilization along the perennial stream reach with an effectiveness of 90%. A detailed assessment of that portion of the stream is recommended for design purposes.

6.1.4 OTHER BMPS

Not all BMPs were capable of being modeled, however, there are several others that stakeholders identified, and which may be effective. There may also be location specific factors that influence adoption or effectiveness of certain BMPs. Therefore, the following BMPs should also be considered during implementation:

- WASCOBs
- Contour buffer strips
- Nutrient removal wetlands
- Farm ponds
- Irrigation management BMPs (as described in Chapter 7, *UBBNRD District Wide WQMP*)
- BMPs for grazing lands or non-permitted AFOs (as described in Chapter 7, *UBBNRD District Wide WQMP*)

Table 12: Priority BMPs and Targeted Pollutant Sources for Lake Hastings

BMP	Pollutant Sources and Primary Area Treated*						
	Entire Watershed	Cropland	Urban	Pastureland	Non-Permitted AFOs	OWTS	Gully/Stream bank
Education & Outreach	2,828						
Irrigation Water Management Practice Suite		360					
Nutrient Management		899					
No-Till		899					
Cover Crops		899					
Grassed Waterways/Riparian Buffers		899		75			
Grazing Management				75			
Urban Stormwater Practice Suite			1,847				
Stream Restoration / Stabilization (miles)	**						0.6

Source: PLET Water Quality Modeling
**Area treated is in acres, unless otherwise noted*
***Stream restoration and stabilization also provide treatment to all upstream sources*

Based on the PLET model, BMP adoption achieved a watershed nitrogen load reduction of 42%, meeting the goal of 15%. It also would result in a phosphorus load reduction of 64%, which would not meet the goal of 83%, and a sediment load reduction of 86%.

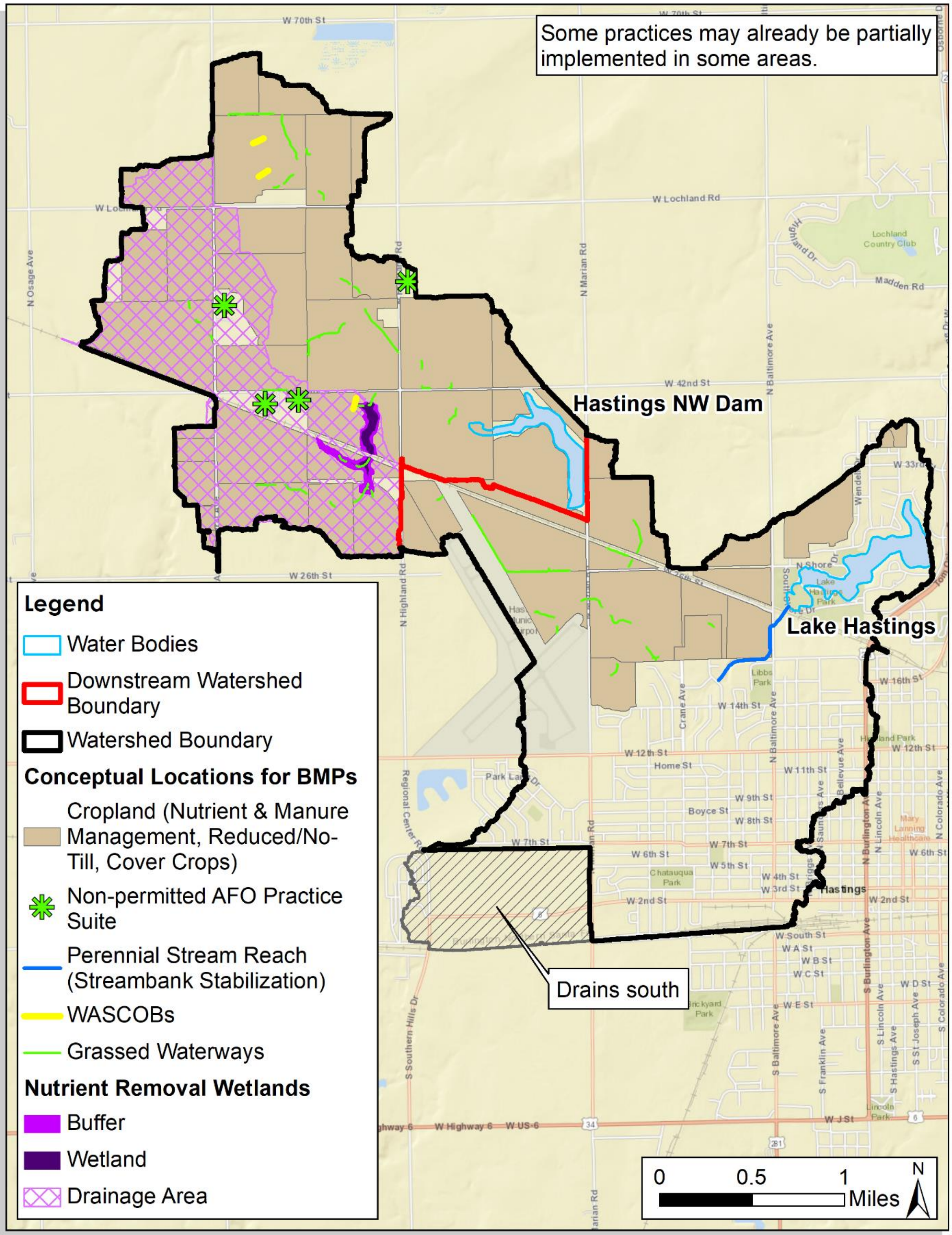


Figure 11: Conceptual Locations of Soil Health and Facility Management BMPs

6.2 IN-LAKE TREATMENT

The proposed BMP implementation strategy for the drainage area above Lake Hastings watershed will achieve the nitrogen load reduction target, however, it falls short of the phosphorus reduction target. Therefore, additional in-lake management practices are needed. Additionally, these practices will address the impairment to aesthetics caused by sedimentation.

Conceptual locations for each practice have been identified, however, it is recommended that all in-lake management practices be finalized through the development of final engineering designs and updated cost opinions. A conceptual map of these practices is located in Figure 12 and a larger format version is provided in Attachment 2. A detailed engineering design project will be needed to fully design, permit, and construct the in-lake practices. The following recommendations are based on all currently available data concerning Lake Hastings but may require alterations as more data becomes available. These recommendations incorporate stakeholder priorities and suggestions from the November 2023 visioning session.

Sediment Storage Basin – Renovation of the existing sediment storage basin at the inlet of the lake is recommended to improve capture of nutrients and sediment, as well as other pollutants, before they reach the lake. The existing basin is no longer functional, as it is at capacity for sediment storage. Restoring and enhancing physical features of the basin will increase pollutant removal performance thus ensuring its benefits are realized in the long term. The following items have been identified:

- The addition of a rock riprap weir at the inlet to the lake would increase retention of sediment and nutrients within the basin.
- Riprap breakwaters and flow check structures are also proposed within the basin to slow flow and provide maintenance access from the shoreline to the sediment basin.
- Removing approximately 28,446 cubic yards (17.6 acre-feet) of sediment from this area would increase depth approximately 4 feet and significantly increase capacity for sediment retention and protection of the main lake. This material would be utilized in the construction of the breakwaters with the remaining spoiled at an upland location. Removing sediment from the sediment basin would significantly increase the useful life of the basin, especially when paired with implementation of watershed BMPs.

The restored sediment basin has the capability to reduce pollutant loads to the lake by 61%, according to Cunha et al. (2014). However, to ensure this treatment efficiency is maintained long term, additional measures (discussed below) have also been identified.

Lake Sediment Removal – Sediment removal in targeted hot spots is recommended to address the aesthetics impairment due to sedimentation. Excluding the sediment basin, a total of 44 acre-feet of sediment is proposed to be removed, which would increase the volume of the lake from 385 acre-feet to 428 acre-feet. This increased volume would specifically be beneficial for increasing the loading nutrient loading capacity of the lake. However, several other important benefits can also be realized if sediment removal is targeted:

- Improve and restore boat access
- Fishable area from the shore (including fishing piers)
- Decreased suspension of lake bottom sediment and nutrients with deeper water that is less impacted by wave action, will further improve water quality
- Aquatic and fish habitat could be improved by increasing depth and bottom diversity,

During the final design process, a full grading plan would be developed to focus sediment removal to strategic areas within the lake. This design process will be done in partnership with Nebraska Game and Parks Commission (NGPC) staff with the goal of achieving NGPC's recommended lake depths, which would further improve aquatic habitat and the fishery. These general guidelines consist of the following (Blaser, 2012):

- At least 25% of the basin is 12 feet deep, or greater
- 50% of the basin is at least 8 feet deep
- No more than 25% of the basin should be 5 feet, or less

There are several options for sediment removal methods. For the purposes of cost estimates and schedule development, this plan assumes dry mechanical dredging (drawdown and excavation) will be used, as it offers several benefits: reduced spoils area, less sediment suspension issues, and improved access to construct other in-lake practices. The final design process would further clarify these details.

Lake Hastings dam has a 36" drawdown pipe that is anticipated to be the primary method of lowering lake levels. Drawing the lake all the way down could take approximately 1 month, however sediment removal could potentially start right away in the upstream portions of the lake. Additional dewatering efforts, such as excavating trenches to help direct water drainage and dry out sediment, may further improve this process. Time to complete sediment removal and build aquatic habitat and other improvements could take 6-12 months, depending on a number of factors including access through the lake bottom and how much it is able to dry out. Once completed, refilling the lake could take 6-12 months, however, this time could be significantly reduced if timely rainfall events occur.

If funding allows, further sediment removal would increase all these benefits. An additional 69 acre-feet of sediment could be removed to bring the lake back to the 1970 excavated volume (525 ac-ft) and would cost an additional $2,000,000 (approximately) beyond the cost estimate provided in this plan. If needed, water quality modeling could be updated to reflect these proposed changes during the final design phase.

Of special note, during the design phase the city will need to work with DNR to update the discrepancies in storage volumes found between the original as-builts, bathymetry data, DNR records, and final design drawings. This will also include ensuring a correct water right for storage (among other potential permits) is obtained.

Fish Management – Target depth for fish management should be at least 8 ft. for 50% of the reservoir and depths of 12 ft. or greater for 25% of the reservoir to prevent summer and winter fish kills. If the lake is drawn down for sediment removal a fish renovation should be conducted followed by stocking of game fish species. NGPC recommends that the lake be restocked with:

- Bluegill
- Largemouth Bass
- Black Crappie
- Channel Catfish

Aquatic Vegetation Management: Sediment and carp removal will likely lead to a decrease in turbidity followed by a sharp increase in aquatic vegetation. Aquatic vegetation will likely need to be managed, at least at the swimming beach. Future plans for Lake Hastings should include a vegetation management plan.

Wetland Creation – Creation of a wetland just upstream of Lake Hastings is proposed to allow additional sediment and nutrients to settle out before inflow reaches the sediment basin, extending the life of the sediment basin. The wetland would be approximately 7 acres and would receive runoff from both urban and agricultural portions of the watershed, although it would not be able to capture runoff from residential areas directly adjacent to the lake. Wetland creation would also provide habitat for wildlife and opportunities for education and outreach for citizens and the nearby schools.

Shoreline Protection and Stabilization – Shoreline stabilization and protection from erosion is proposed in targeted areas along the shore of Lake Hastings. This would consist of replacing existing broken concrete with rock rip rap, or placing new rock rip rap where no protection exists. Stabilizing areas prone to erosion would help reduce the sediment load to Lake Hastings, improve the aquatic habitat along the shoreline, and improve the safety of the shore to lake users.

No Wake Zone – A no wake zone is proposed in the portion of the lake nearer to the dam, as shown in Figure 12. The no wake zone would help prevent disturbance and resuspension of lake bottom sediment and nutrients and reduce wave action that can erode shorelines.

Drainage Channel Rehabilitation – Rehabilitation and stabilization of an existing small drainage channel into the lake is proposed to prevent nutrients and sediment from reaching the lake.

Outreach and Education - By pairing recreation improvements with both in-lake and drainage area water quality improvements, landowners and community members will have a better understanding of the importance of adopting BMPs and may have additional buy-in to participate in BMP adoption. Additionally, these recreation facilities could be completed at the same time as water quality improvements to take advantage of drawn down water levels and contractor efficiencies. Stakeholders also identified the following recreation improvements:

- Swimming beach
- Boat ramp and dock replacement
- Fishing piers
- Aquatic habitat (brush piles, rock shoals, deepwater, etc.)

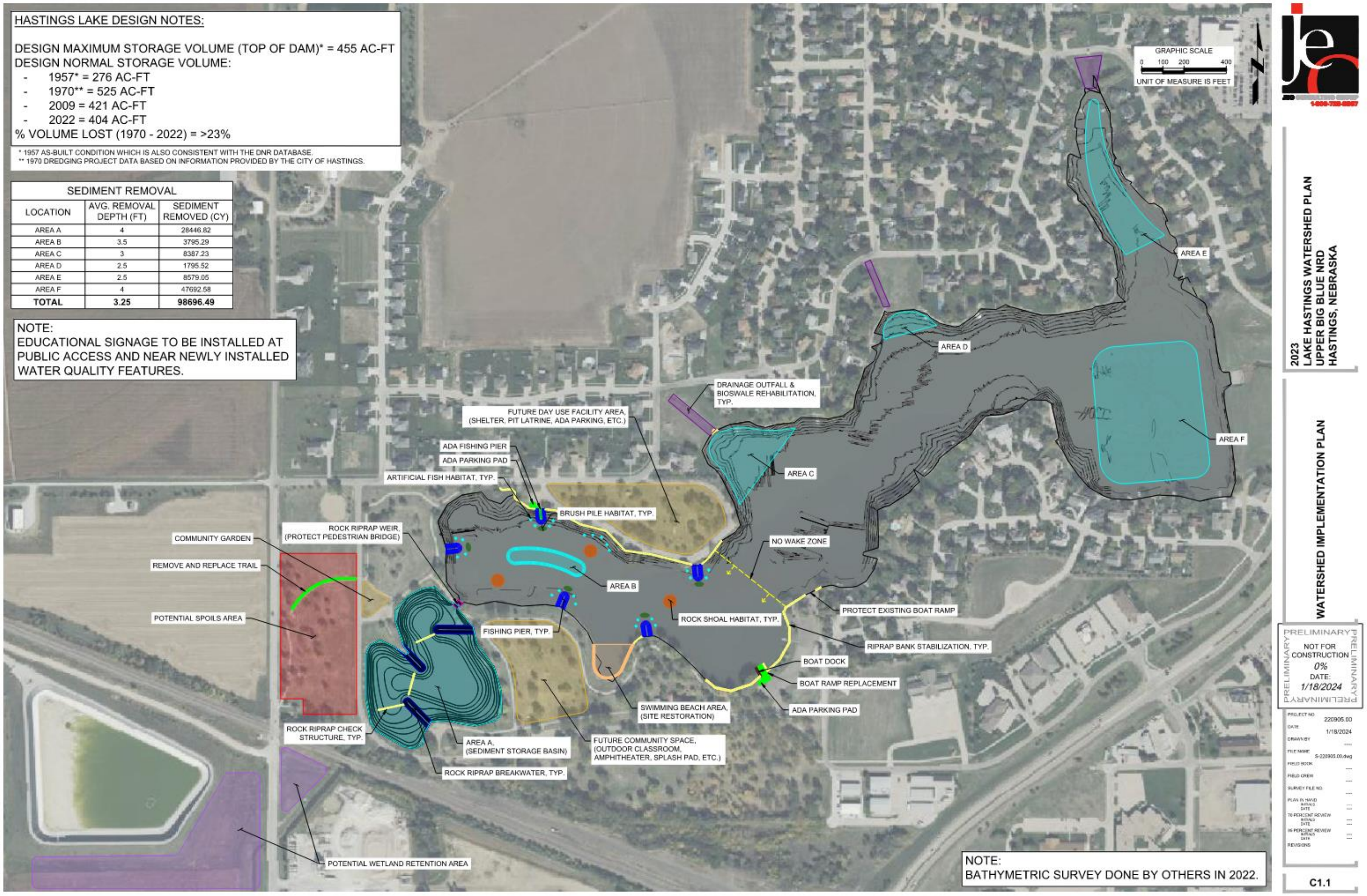


Figure 12: Conceptual Drawing of Proposed In-Lake BMPs

7. FOCUS AREAS

Focus areas within the watershed provide a starting point for targeted BMP implementation. With the small size and urban-rural land use of the Lake Hastings watershed, the following focus areas were identified (Figure 13):

- Agricultural land below Hastings NW Dam (1,057 acres or 19% of watershed)
- Lakeside neighborhood (387 acres or 7% of watershed)
- Remaining urban land (1,494 acres or 28% of watershed)
- Remaining agricultural land (2,490 acres or 46% of watershed)

By organizing the watershed into these areas, it can be easier to identify locations to implement BMPs and target various outreach and education strategies. Agricultural land below Hastings NW Dam and the lakeside community around Lake Hastings should be seen as the highest priority for implementation, due to proximity, pollutant availability, and stakeholder engagement. Urban BMPs beyond the lakeside community will also be crucial to meeting water quality goals.

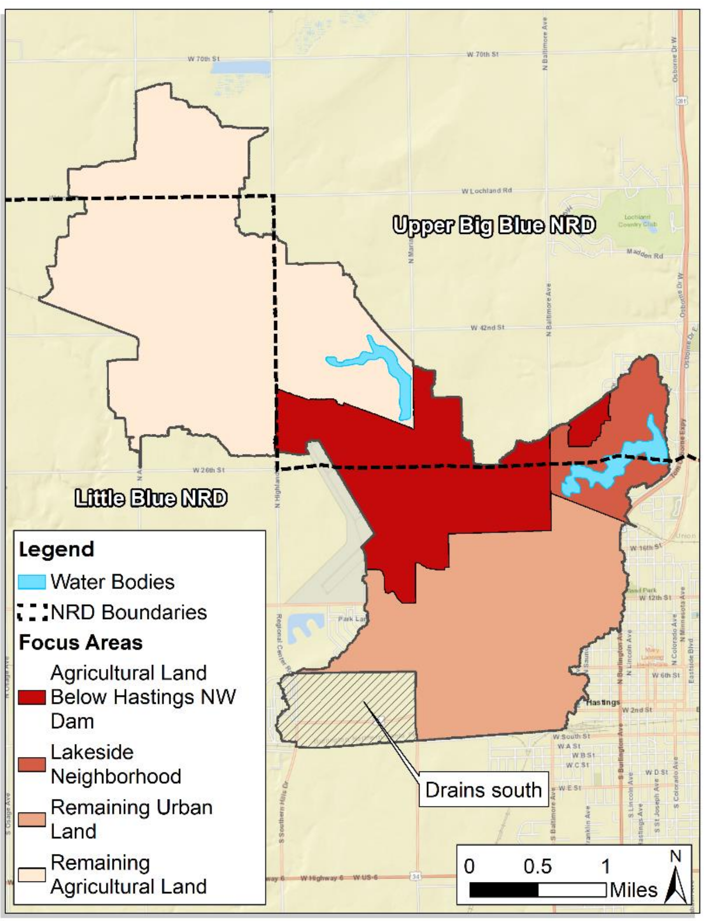


Figure 13: Focus Areas in the Lake Hastings Watershed

8. GATEWAY BMPS

The adoption of priority BMPs across the watershed is important to help meet water quality standards. However, purely focusing on this "means" to achieve this "end" may lead to failure in widespread adoption of priority BMPs.

Conservation is not everyone's top priority, and oftentimes landowners and producers are not initially eager to participate in new water quality projects or sign up for unfamiliar BMPs. This is especially true if the practices cost them time or money, are confusing, or do not meet the immediate need of their farm. The same can be said for homeowners and urban stormwater BMPs. One strategy for overcoming this hurdle is to ensure that "gateway" BMPs are offered.

Utilizing gateway BMPs helps to start the dialogue and sets reluctant BMP adopters on a path of enhanced conservation. Essentially, by helping a farmer implement a BMP that is important or familiar to them (even when it is not a priority BMP, as identified in this plan) an opportunity is created to establish a relationship and build trust with that farmer. A gateway practice can show how conservation can actually solve on-farm problems or demonstrate that barriers to adoption can be overcome.

Gateway BMPs can be combined with priority BMPs in a 'buy one, get one' scenario where adoption of a priority practice can result in the full cost of a different BMP preferred by the landowner being covered. Ultimately, this type of incentivization can lead to increased interest in conservation adoption of priority BMPs. Thus, non-priority BMPs can be the "gateway" to getting priority BMPs implemented.

9. MEETING WATER QUALITY STANDARDS

Implementing a comprehensive strategy for Lake Hastings that includes management practices both throughout the watershed and within the lake will result in the lake meeting water quality standards for nitrogen and phosphorus. It is assumed that if lake nutrient concentrations meet the water quality standards, chlorophyll *a* will also meet the standard. It is also anticipated that the combination of watershed-level practices and in-lake management will result in decreased sedimentation within acceptable limits. Therefore, targeting sediment and nutrients is the focus of this plan.

9.1 NUTRIENTS

On their own, drainage area BMPs will reduce the phosphorus load by 64%. In-lake BMPs will reduce the phosphorus load by an additional 61%, yielding a cumulative phosphorus reduction of 86%. If the phosphorus load reduction goal is achieved, the in-lake phosphorus concentration is expected to be 45.4 ug/L, which falls below the standard of 50 ug/L (Table 13).

Drainage area BMPs will result in a 42% reduction in total nitrogen loads. In-lake measures will reduce the nitrogen load by an additional 61%, resulting in a cumulative nitrogen load reduction of 77%. If the load reduction goal is achieved, the in-lake nitrogen concentration is expected to be 294.3 ug/L, which is well below the water quality standard of 1,000 ug/L (Table 13).

Table 13: Estimated Pollutant Load Reductions for Lake Hastings

Pollutant Load Reductions	Nitrogen (lb/yr)	Phosphorus (lb/yr)	Sediment (tons/yr)
Beginning Load	16,506	2,719	742
Load reduction from drainage area BMPs	6,911	1,729	641
Load reduction from in-lake BMPs	5,853	604	61
Final pollutant load	3,742	386	39
Total Reduction	12,764	2,333	703
Total Reduction (%)	77%	86%	95%
Reduction Goal (%)	23%	84%	N/A
Will Meet Pollutant Reduction Goal?	Yes	Yes	N/A

Source: PLET and In-Lake Water Quality Modeling

By surpassing the goals set for reduction of nitrogen and phosphorus, there is room for BMP adoption and efficacy to operate within real-world constraints. There is a margin of safety with the approach outlined in this plan that provides enhanced confidence for success

9.2 CHLOROPHYLL *A*

Based on the nutrient reductions achieved by watershed and in-lake BMPs, chlorophyll *a* is predicted to fall below the water quality standard (Table 14). Algal growth is directly linked to high nutrient concentrations. Therefore, by reducing the nutrient concentrations within Lake Hastings, it is expected that chlorophyll *a* will also be addressed.

Table 14: Estimated Pollutant Concentration Reductions for Lake Hastings

Water Quality Element	Nitrogen (ug/L)	Phosphorus (ug/L)	Chlorophyll *a* (ug/L)
Existing Concentration (2009-2022)	1,705	166	35[1]
Concentration After BMPs	294.3	45.4	Not modeled
Water Quality Standard	1000	50	10
Will Meet Water Quality Standard?	**Yes**	**Yes**	**Yes***

[1]*2009-2012 median value*

**As described in narrative, it is anticipated that chlorophyll* a *will meet the water quality standard.*

9.3 SEDIMENT

While no numeric reduction goal was established for sediment, load reductions associated with management measures were estimated. Drainage area BMPs account for an 86% reduction to sediment loads to Lake Hastings, while in-lake measures account for an additional 61% reduction, yielding a cumulative sediment load reduction of 95% (Table 13). By reducing the sediment load by 95%, annual volume loss would be reduced approximately from 0.3% to 0.02%. (Table 15). Proposed sediment removal would remove 44 acre-feet of sediment from the main body of the lake, resulting in a new volume of 428 acre-feet. This would get the lake closer to the 1970 renovated lake volume of 525 acre-feet. By reducing both the total volume loss and the annual volume loss, Lake Hastings would fall well below the water quality standard for Aesthetics.

Table 15: Estimated Volume Loss Changes for Lake Hastings

Volume Change	Bathymetric Value
Total Volume Loss	
Beginning Volume (acre-feet)	385
Volume Increase (acre-feet)	44
Volume After Sediment Removal	428
Annual Volume Loss	
Beginning Annual Volume Loss	0.3%
Sediment Loading Reduction	95%
Annual Volume Loss After BMP implementation	0.02%

10. MONITORING

10.1 OVERVIEW

Although nutrient reduction benefits of implementing external and internal management practices have been estimated and provide a path to meeting water quality standards, cumulative benefits of implementing a comprehensive plan are difficult to accurately project. Thus, a sound monitoring and data collection network will be critical to adaptively manage Lake Hastings.

The City of Hastings will follow standard operating procedures to develop sound, defensible monitoring strategies and networks; responsibly manage data; and disseminate information to decision makers and other stakeholders. Coordination with NDEE and other agencies through existing monitoring programs may assist in meeting these monitoring goals. Steps will be taken to ensure collection of scientifically valid data, which may include the development of Quality Assurance Project Plans (QAPPs) for state review, when required.

Specific monitoring goals and objectives have been identified to ensure data is used for its intended purposes. Targeted parameters, monitoring sites, and monitoring frequency have been defined to meet each objective. NDEE guidance (Archer and others, 2020; NDEE, 2022) has been reviewed to ensure the following goals are also consistent with standard methods and requirements in Nebraska. In addition to funding, other considerations should also be accounted for when prioritizing monitoring efforts, including confidence in current assessments, short term data/information needs, and available staff.

Monitoring Goal 1: Evaluate the water quality condition of Lake Hastings for beneficial use support and to validate and refine water quality models

- Monitoring parameters:
    - Field measurements: water clarity (Secchi depth), top to bottom profiles (0.5 m increments) for water temperature, dissolved oxygen, pH, conductivity, and turbidity
    - Chemical (grab) sampling: Total phosphorus, dissolved orthophosphorus, kjeldahl nitrogen, nitrate-nitrite nitrogen, total suspended solids (TSS), chlorophyll *a*, turbidity (could also be completed through in-field measurement)
- Monitoring site: NDEE site LLB3HASTNG01 (deep water site)
- Monitoring frequency: Every two weeks from May – September, with at least 10 samples taking during this period

Monitoring Goal 2: Estimate pollutant loads and source contributions to Lake Hastings

- Monitoring parameters:
    - Field measurements: water temperature, dissolved oxygen (DO), pH, conductivity, turbidity, stream flow/discharge
    - Chemical (grab) sampling: Total phosphorus, kjeldahl nitrogen, nitrate-nitrite nitrogen, total suspended solids (TSS), chloride, ammonia, turbidity (could also be completed through in-field measurement)
- Monitoring site: Primary inflow
- Monitoring frequency: Every two weeks from May - September, with at least 10 samples taken during this period
- Power plant will continue to be monitored per existing NPDES requirements.

Monitoring Goal 3: Gather bathymetric and sediment data to improve water quality modeling and BMP designs

- Conduct bathymetric survey as needed for pre-construction or 10 years after most recent bathymetric survey.
- Conduct lake bottom sediment-phosphorus sampling to better characterize internal phosphorus loads originating from lake bottom sediments.
- As needed, conduct spatial assessment of soft sediment using ground penetrating radar or manual sediment depth measurements.
- Conduct bathymetric survey or as-built topographic survey following the completion of any sediment removal or BMP installation project.

10.2 COORDINATION WITH NDEE

Due to Clean Water Act requirements, NDEE must regularly assess all navigable waters in the state. They accomplish this assessment via a six-year basin rotation, where each major watershed in the state receives focused water quality testing once every six years. The Big Blue River Basin, which contains the Lake Hastings Watershed, will be a focus of the rotation next in 2024 (Figure 14). The City of Hastings and other project partners will work with NDEE to coordinate monitoring and implementation efforts within the watershed with awareness of the rotation cycle.

To be considered in beneficial use assessments, water quality data must be received by NDEE from agencies by November 1 of the year prior to the April 1 Integrated Report submittal. It is recommended that coordination with NDEE be completed well in advance of this date to allow ample time for a review of the data and an opportunity to correct any errors or supply supplemental information that may be needed.

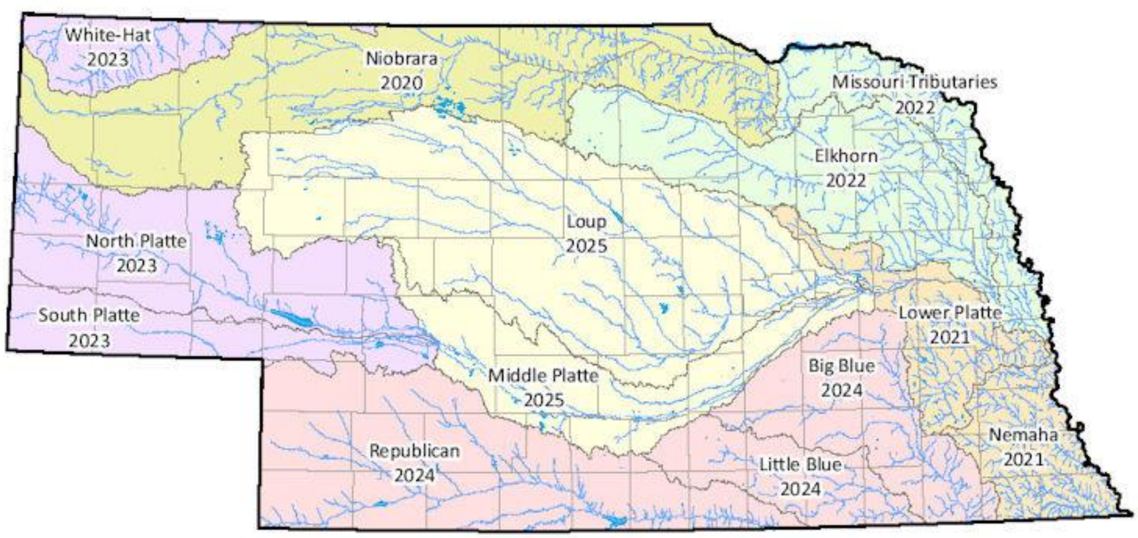


Image Source: NDEE, 2023

Figure 14: NDEE Annual Basin Monitoring Rotation

11. EDUCATION AND OUTREACH

Chapter 6 of the *UBBNRD District Wide WQMP* provides a broad programmatic approach that will be utilized to complete education and outreach activities. To supplement that information, the following specific actions and information has been identified for the Lake Hastings watershed:

- Identified Target Audiences
    - Recreational users of Lake Hastings
    - Residents directly adjacent to Lake Hastings
    - Producers, landowners, residents, and other property owners within focus areas
    - Rural homeowners on private wells and septic systems
    - Lake Hastings Citizen Committee
- Methods and Materials
    - Utilize parcel ownership information, along with the detailed BMP location information created with the ACPF Tool or through the watershed assessment, to contact specific landowners about BMPs applicable to their properties
    - A postcard mass mailing followed up by phone calls will help start initial implementation efforts and/or increase attendance at public meetings
    - Utilize the existing knowledge and awareness around Lake Hastings to build a message around improving watershed conditions.
    - Develop signage to be used at project demonstration sites, key watershed entrances or landmarks, and other highly visible areas.
    - Post flyers, and advertise on local message boards in Co-Ops, gas stations, etc.
    - Hold targeted coffee shop meeting, tailgate sessions, and other informal/casual informational exchanges to build relationships and to learn more about the constraints and hurdles to BMP adoption
    - Partner with local Co-Ops or agricultural consultants to demonstrate BMPs, hold field days, and to distribute information
    - Piggyback on existing events held by UNL Extension, Master Gardener Program, local Co-Ops, and others – Training and demonstration field days, information booths, recognition picnics, etc.
    - Outdoor recreation clinic (kayaking, frisbee golf, etc.) in Lake Hastings Park.
- Evaluation Process
    - Surveys will be used to monitor and evaluate the effectivness of outreach strategies and materials.
    - Event attendees will receive questionnaires about their awareness and attitudes of water quality issues, existing levels of BMP adoption, and barriers to adoption.
    - Similar surveys will also be conducted at the watershed level at the beginning of the project to help establish a baseline understanding.

Plan and project sponsors will utilize these target audiences and outreach methods when building project level communication and outreach plans, typically as part of a Project Implementation Plan (PIP). The PIP will identify the specific and tailored actions for each target audience.

12. SCHEDULE

A timeframe for implementing general actions is provided in Table 16. Actions are subject to approval by the City of Hastings, or other project sponsors, and may change as the plan is implemented. Phase I activities will include the initiation of drainage area BMPs and in-lake BMPs. Phase II will begin upon the five-year revision of this plan and will include any implementation that was not completed during Phase I. A summary of progress achieved during Phase I will be included in the plan revision.

Table 16: Schedule for Implementation within the Lake Hastings Watershed

Activity	Phase I																				Phase II
	2024				2025				2026				2027				2028				2029-2033
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
NDEE and EPA acceptance of the plan		X																			
Monitoring (ongoing)		X	X			X	X			X	X			X	X			X	X		
Apply for funding		X	X														X	X			
Annual stakeholder community meeting			X				X				X				X				X		
I&E to ag producers				X	X			X	X			X	X			X	X				
I&E to urban homeowners						X	X			X	X			X	X			X	X		
Drainage area BMP implementation				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
In-Lake BMP Engineering													X	X	X	X	X	X	X	X	
Streambank Stabilization Assessment														X	X						
Urban BMPs Assessment					X	X	X	X													
Project evaluation																				X	
Final reporting																				X	
Stream Stabilization Implementation																					X
In-Lake BMP Implementation																					X
Update WQMP																					X
Continue BMP implementation as needed																					X

**The assigned NDEE basin rotation monitoring year for the Big Blue River Basin is 2024*

13. MILESTONES

Major milestones that pertain to monitoring, planning, and management practice implementation are provided in Table 17. These milestones will be used to gauge progress towards meeting the desired project schedule. As the implementation of this plan is initiated, milestones will be adjusted accordingly for changes to the schedule.

Table 17: Milestones for Implementation Inside the Lake Hastings Watershed

Activity	Phase I (Percent Complete Milestones)																				Phase II
	2024*				2025				2026				2027				2028				2029-2033
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
Finalize QAPP		100			100																
Assess data and evaluate progress (annually)				20				40				60				80				100	
Project report(s)		100		100		100		100		100		100		100		100		100		100	
Phase 1 PIP		50	100																		
Additional funding: Phase 1		50	100																		
In-Lake BMPs Final Engineering															30		60	90	100		
Phase 2 PIP																		50	100		
Additional funding: Phase 2																		50	100		
Identify additional BMP needs																	25	50	75	100	
Prepare final report(s)																	25	50	75	100	
Work one-on-one with producers and homeowners		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	100	
Drainage Area BMPs							30						60							100	

**The assigned NDEE basin rotation monitoring year for the Big Blue River Basin is 2024*

14. EVALUATION

EVALUATION MEASURES

The purpose of establishing evaluation criteria is to ensure implementation progresses as planned, to identify adjustments in the plan when necessary, and to learn from both successes and failures. In doing so, evaluation criteria have been established to assess all aspects of implementing this plan. Evaluation criteria are the tangible products from implementation and help to demonstrate progress towards project goals.

The City of Hastings will be responsible for monitoring, evaluating, and reporting on progress. The city will work with project partners to track evaluation metrics. Many nonpoint source projects do not result in immediate and measurable changes in water quality. Therefore, other evaluation metrics will assist with measuring progress. The following metrics will be used to document and evaluate progress:

- Biannual reports
- Engineering plans (30%, 60%, 90% and final drafts)
- Water quality monitoring data
- BMP implementation records
- I&E metrics such as number of meeting/events held, attendees, changes in knowledge or attitudes, and other feedback from the public
- Pictures and articles from media outlets
- Funding received and spent
- Changes in land use

As progress is tracked, the city will evaluate these records against the milestones identified in the plan. Should it be realized that implementation is falling short of milestones, the NRD will consider assembling stakeholders to review or update strategies.

Progress will be reported biannually (twice) and at 5-year increments, as shown in the schedule and milestones. Within each progress report, the city will provide insight (both quantitative and qualitative) on each of the following key questions:

- Which techniques and approaches worked... or did not work?
- What were the major obstacles or barrier to adoption?
- Did the project solve the problem that it was designed to address?
- What lessons were learned that can be applied to future projects?
- Which on-the-ground techniques (or BMPs) were most accepted by landowners?

If necessary, data can also be incorporated back into water quality modeling. During the 5-year evaluation, the watershed plan will be updated with new data and lessons learned to improve the implementation approach. Stakeholders will have an opportunity to provide input prior to starting the next increment.

WATER QUALITY MILESTONES

The UBNRD, in conjunction with NDEE and other partners, have identified monitoring goals, parameters, sites, and frequency. This data will be used to evaluate progress against water quality milestones, with the end goal of achieving water quality standards. For the purpose of these milestones, Total Phosphorus was selected as the monitoring parameter to help gage progress. This is because phosphorus is the key limiting nutrient and driver of other water quality conditions within the lake. Table 18, lays out the anticipated milestones, with the final water quality goals anticipated to being achieved in 2030, in accordance with the overall schedule and milestones. It should be noted that these reductions are just estimates and are subject to revision as the plan is implemented and actual results are monitored. It is also possible that measurable water quality changes within the lake may not be observable until after all in-lake BMPS are implemented, due to variability in annual rainfall, the timing or location of specific BMPs being installed, and other factors that influence relative effectivness of any BMP.

Table 18: Water Quality Milestones

Year	Estimated Median Total Phosphorus in Lake Hastings	Comments
2023	166 ug/L	Baseline/current conditions
2024	162 ug/L	
2025	150 ug/L	
2026	131 ug/L	
2027	111 ug/L	
2028	84 ug/L	
2029	78 ug/L	
2030	45 ug/L	Completion of in-lake BMPs & Achievement of water quality standards

15. TECHNICAL AND FINANCIAL RESOURCES

15.1 COST ESTIMATE

The preliminary opinion of total cost of implementing this plan is provided in Table 19. These costs are approximate numbers only and were identified based on the requirements to meet water quality standards. When possible, BMP costs were determined from the United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS) Environmental Quality Incentives Program (EQIP) practice payment schedule (USDA, 2019). Costs estimated for in-lake measures were based on average unit prices from a wide range of past project costs and should only be used for general planning purposes. These costs are subject to change based on scoping requirements, final designs, inflation, bidding climate at the time of construction, and project size and complexity.

Table 19: Implementation Costs for the Lake Hastings Watershed

Practice	Units	Existing Level	New Units	Unit Cost	Total Cost
Education/Outreach (Including Signage)	Year	N/A	5	$10,000	$50,000
Nutrient Management	Acre	N/A	899	$75	$67,432
Cover Crops	Acre	67	832	$44	$36,601
Grassed Waterways	Acre	N/A	4	$5,277	$21,741
No-Till	Acre	261	638	$30	$19,143
Urban Stormwater Practice Suite	Year	N/A	5	$10,000	$50,000
Subtotal (Drainage Area Treatment)					**$244,917**
Stream Restoration/Stabilization	Foot	N/A	3,356	$167	$560,452
Subtotal (In-Stream Work)					**$560,452**
Construction***	Each	N/A	*	*	$4,389,540
Engineering	Each	N/A	*	*	$921,803
Subtotal (In-Lake Work)					**$5,311,343**
Updates to Watershed Plan	Each	N/A	1	$75,000	$75,000
Additional Monitoring	Year	N/A	5	$10,000	$50,000
Streambank and Urban BMPs Assessment	Each	N/A	**	**	$25,000
Subtotal (Planning/Monitoring)					**$150,000**
Total					**$6,266,712**

**In-Lake practice quantities and costs may change, subject to detailed engineering.*

***Costs of streambank and urban BMP assessments may change subject to detailed scoping.*

**** Additional sediment removal could occur if funding allows. An additional $2,000,000 (approximately) would be required to return the lake back to its 1970 volume of 525 acre-feet.*

15.2 FUNDING PARTNERS AND TECHNICAL ASSISTANCE PROVIDERS

The following partners are anticipated to provide assistance for the implementation of this plan. A brief description of each of their capabilities and funding resources is provided, however no assistance is guaranteed until a project contract has been approved. Additional partners may be identified as a project moves forward and the city will be actively looking for those opportunities.

- **City of Hastings:** The city will take ultimate responsibility for championing the implementation of this plan. The city will lead and coordinate efforts among the other agencies. It will provide funding, education, and/or support at various levels and be the first point of contact for potential partners. It will lead the effort to pursue grant applications for implementation.
- **Little Blue and Upper Big Blue NRDs:** Due to the urban/rural nature of the watershed, the city will coordinate closely with both NRDs. It is anticipated that the NRDs will take a leading role with landowners and BMPs located within the agricultural areas of the watershed.
- **NDEE:** Through the Section 319 program, NDEE will provide both technical and financial assistance. Staff will continue to provide insight to ensure a successful project. Grant funding is also anticipated once a PIP is approved. This funding is anticipated to be used to assist with implementation of BMPs, finalize engineering, conduct education and outreach, and to execute studies or collect data. Additionally, support and services related to water quality sampling are planned to begin in 2024.
- **Nebraska Extension:** Extension staff will be involved in education and outreach efforts. Extension brings the latest research from the University of Nebraska regarding agricultural BMPs and has established relationships and a positive reputation with producers. Additionally, Extension also runs the Master Gardener program in Nebraska.
- **NRCS:** Funding from existing NRCS programs such as EQIP will be used for implementation of BMPs and will be leveraged against other funding sources. Staff will be available to provide technical assistance on BMPs. Additional support may be provided through the State or National Water Quality Initiative.
- **Nebraska Environmental Trust (NET):** The NET is a grant source that can be used to assist in education and outreach activities, BMP implementation, and design services. Eligible projects include those that result in a net environmental gain to land, air, water, and/or wildlife. Applications are competitive and typically due annually in September.
- **Nebraska Game and Parks Commission (NGPC):** NGPC can provide technical support and advice on aquatic habitat, fisheries, anger access, and recreational improvements. Additionally, funding through the aquatic habitat program, angler access, or other administered grants may be available.
- **Producers and Property Owners:** Area stakeholders, which includes property owners, farmers, and urban homeowners, will be key to putting projects on the ground by understanding the long-term benefits to water quality. They may also provide support through in-kind efforts or cash matching of various BMPs.

16. SUMMARY AND NEXT STEPS

Within this plan is an abundance of technical information and many recommendations for improving the Lake Hastings Watershed. This page attempts to boil this information down to something more manageable and actionable. The following steps should begin to be pursued right away:

1. **Continue with and expand water quality sampling in the lake – through coordination with NDEE - as outlined in Section 10.** A robust data set is important to provide a better understanding of lake dynamics, ensure water quality modeling and associated implementation strategies are appropriate, and evaluate the outcome of future implementation projects.
2. **Apply to NDEE for a Nonpoint Source Water Quality Grant (Section 319)** to fund initial BMP implementation, education/outreach efforts, complete assessments for stream stabilization and urban BMPs, and to finalize engineering designs for lake restoration. During the final design phase, value engineering and coordination with potential funding sources should be conducted to maximize the amount of sediment that can be strategically removed from the lake.
3. **Coordinate with UNL Extension** to begin an education and outreach campaign that will support BMP adoption. Section 0 should be used as a starting point.
4. **Begin targeting the following areas to implement priority BMPS.** These “focus areas” should be prioritized for initial outreach, encouragement for BMP adoption, and potentially enhanced cost-share.
    a. Cropland between Hastings NW Dam and Lake Hastings:
        i. No-till or strip till
        ii. Cover crops
        iii. Grassed waterways or stream restoration
        iv. Nutrient management
    b. Lake Hastings residents:
        i. Fertilizer management (no/low phosphorus fertilizer)
        ii. Pet waste signage and outreach
        iii. Rain garden
5. **Install signage around the watershed, near Lake Hastings, and at BMP demonstration sites** to begin to raise awareness and provide educational opportunities.
6. **Complete an Urban BMP Assessment** to support citing and prioritizing urban stormwater BMPs throughout the watershed.
7. **Utilize “gateway BMPs”** as a way to initially engage farmers that are reluctant to adopt priority BMPs right away, as discussed in Section 8.
8. **Develop a local sinking fund to help pay for in-lake renovations,** which will take place during Phase 2 of this plan. These funds would be matched against funds from other project partners or grant sources. This consists of sediment removal, sediment basin rehabilitation, aquatic habitat, and other in-lake practices identified in Section 6.2 **This should be closely coordinated with NGPC.**

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