Water Quality Improvement Plan for

Hannen Lake

Benton, Iowa

Total Maximum Daily Load
for pH and algae

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Watershed Improvement Section
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General Report Summary

What is the purpose of this report?

This report serves two major purposes. First, this report satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for all impaired 303(d) waterbodies. Second, this report should serve as a resource for locally-driven water quality improvements to Hannen Lake in an effort to improve the water body and successfully restore the lake.

What's wrong with Hannen Lake?

For the 2010 reporting cycle, the Class A1 (primary contact recreation) uses for Hannen Lake are assessed (monitored) as "not supported" based on results from the ISU statewide survey of lakes and the SHL ambient lake monitoring program. Using the median values from these surveys from 2004 through 2008 (approximately 26 samples), Carlson's (1977) trophic state indices for Secchi depth, chlorophyll-a, and total phosphorus were 65, 70, and 73 respectively for Hannen Lake. According to Carlson (1977) the Secchi depth and chlorophyll-a values place Hannen Lake in between the eutrophic and hypereutrophic categories while the total phosphorus value places Hannen Lake in the hypereutrophic category. These values suggest high levels of chlorophyll-a and suspended algae in the water, moderately poor water transparency, and high levels of phosphorus in the water column.   Sources of data for this assessment include (1) results of the statewide survey of Iowa lakes conducted from 2004 through 2007 by Iowa State University (ISU), (2) results of the statewide ambient lake monitoring program conducted from 2005 through 2008 by State Hygienic Laboratory (SHL), and (3) information from the IDNR Fisheries Bureau.

The levels of inorganic suspended solids at this lake were relatively low and do not suggest potential problems related to non-algal turbidity. The median level of inorganic suspended solids in Hannen Lake (2.7 mg/L) was the 44th lowest median of the 132 lakes sampled by the ISU and UHL programs.

Data from the 2004-2008 ISU and UHL surveys suggest a moderately large population of cyanobacteria exists at Hannen Lake, which contributes to the aesthetically objectionable conditions due to algal turbidity at this lake. These data show that cyanobacteria comprised 74% of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (22.8 mg/L) was the 43rd highest of the 132 lakes sampled.

The Class B(LW) (aquatic life) uses are assessed (monitored) as "partially supported" based on results from the ISU and UHL lake surveys. The dissolved oxygen data show 1 violation of the Class B(LW) criterion in 26 samples (4%). Based on IDNR's assessment methodology, these violations are not significantly greater than percent of the samples and therefore do not suggest impairment of the Class B(LW) uses. The pH data, however, show 10 violations of the Class A1,B(LW) criterion for pH in 26 samples (38%). Based on IDNR's assessment methodology these violations are significantly greater than 10 percent of the samples and therefore suggest impairment of the Class A1,B(LW) uses at Hannen Lake. These pH violations, however, likely reflect the excessive primary productivity at Hannen Lake and do not reflect the input of pollutants into this lake.

What is causing the problem?

Hannen Lake suffers from multiple impairments (algal growth and pH) which can be tied to excessive nutrient levels, specifically phosphorus. Water entering the lake is mostly runoff. Sediment enters the lake via surface water runoff. Phosphorus attached to this sediment is the main source of the phosphorus in the lake. Hannen Lake has a small overflow weir but this is ineffective for removing the phosphorus so it continually recycles between sediment and biomass. Over time, excess phosphorus has built up within the lake, which, in turn, supports exceedingly high amounts of biomass. Additionally, in an attempt to remove sediment the lake was dredged in 2004, but the spoils were used to build a small island that attracts geese in the northern portion of the lake. Geese feces are an additional source of phosphorus. The life cycles of the biomass, mostly composed of blue-green algae, are what lead to the additional impairments of nuisance algal growth and pH. This report will address the impairments of algal growth and pH for both Primary contact and Aquatic Life uses.

What can be done to improve Hannen Lake?

To improve Hannen Lake water quality, a physical mechanism allowing phosphorus to be removed from the lake must be instated. This would require dredging the lake and removing the dredged material off site away from the lake. Additionally, geese must be discouraged from roosting on the lake. Land practices reducing sediment loss and phosphorus reduction within the watershed would also benefit the lake.

Who is responsible for a cleaner Hannen Lake?

Everyone who lives and works within the watershed or wishes to utilize a healthy Hannen Lake has an important role to play in improving and maintaining the lake. The future of Hannen Lake depends on citizens and landowners in the watershed adopting land use changes on a voluntary basis. The best chance for success in improving Hannen Lake lies with private citizens working with government agencies that can provide technical, and in some cases financial, support of local efforts to improve the lake and its watershed. Citizens interested in making a difference in Hannen Lake should contact their local soil and water conservation district or the Iowa DNR Watershed Improvement Section for information on how to get involved.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Hannen Lake, Benton County (S34,T82N,R11W, IA 02-IOW-01810-L_0)
Surface water classification and designated uses:	Class A1(Primary Contact Recreation) Class B(LW) (Aquatic Life) Class HH (Fish Consumption, Not impacted by impairment of TMDL)
Impaired beneficial uses:	Class A1, Class B(LW)
Identification of the pollutant and applicable water quality standards:	Excessive phosphorus has caused nuisance algal growth, and pH (2010 303(d)).
Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	The target load is 137.7 lbs/year of total phosphorus (TP) or a maximum daily load of 1.51 lbs.
Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:	Existing load is estimated to be 648.6 lbs per year and a 79 percent reduction is required.
Identification of pollution source categories:	Excessive phosphorous delivered from cropland and internal nutrient recycling.
Wasteload allocations for pollutants from point sources:	There are no point sources discharging into Hannen Lake, therefore the Wasteload Allocation is zero.
Load allocations for pollutants from nonpoint sources:	123.9 lbs year or 1.36 lbs per day TP.
A margin of safety:	13.8 lbs year or 0.15 lbs per day TP.
Consideration of seasonal variation:	Seasonal variation is accounted for in the calculation of the TMDL via a

	statistical analysis including a coefficient of variation.
Reasonable assurance that load allocations will be met:	Load allocations can be achieved voluntarily via watershed/water quality improvements implemented through voluntary public participation.
Allowance for reasonably foreseeable increases in pollutant loads:	Nearly all available land for intensive agriculture is currently under such use and human and livestock populations appear stable. Therefore no allowance for an increase in pollutant loads was given.
Implementation plan:	Although not required by the Clean Water Act, a general Implementation Plan is included in this report to assist managers in removing this lake from the 303(d) List.

1. Description and History of Waterbody

The Federal Clean Water Act requires all states to develop lists of impaired waterbodies that do not meet water quality standards (WQS) and support designated uses. This list of impaired waterbodies is referred to as the state's 303(d) list. In addition to developing the 303(d) list, a Total Maximum Daily Load (TMDL) must be developed for each impaired waterbody included on the list. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can tolerate without exceeding WQS and impairing the waterbody's designated uses. The TMDL calculation is represented by the following general equation:

$$TMDL = LC = \Sigma\ WLA + \Sigma\ LA + MOS$$

Where:
TMDL = total maximum daily load
LC = loading capacity
Σ WLA = sum of wasteload allocations (point sources)
Σ LA = sum of load allocations (nonpoint sources)
MOS = margin of safety (to account for uncertainty)

For the 2010 reporting cycle, the Class A1 (primary contact recreation) uses for Hannen Lake are assessed (monitored) as "not supported" based on results from the ISU statewide survey of lakes and the SHL ambient lake monitoring program. Using the median values from these surveys from 2004 through 2008 (approximately 26 samples), Carlson's (1977) Trophic State Indices for Secchi depth, chlorophyll-a, and total phosphorus were 65, 70, and 73 respectively for Hannen Lake. According to Carlson, these Secchi depth, chlorophyll-a, and total phosphorus values all place Hannen Lake in between the eutrophic and hypereutrophic categories. These values suggest high levels of chlorophyll-a and suspended algae in the water, moderately poor water transparency, and high levels of phosphorus in the water column.

The levels of inorganic suspended solids at this lake were relatively low and do not suggest potential problems related to non-algal turbidity. The median level of inorganic suspended solids in Hannen Lake (2.7 mg/L) was the 44th lowest median of the 132 lakes sampled by the ISU and SHL programs. This means of the 132 lake 88 had higher median levels of inorganic suspended solids making this lake better than average in respect to inorganic suspended solids.

Data from the 2004-2008 ISU and UHL surveys suggest a moderately large population of cyanobacteria exists at Hannen Lake, which contributed to the impairment for algal turbidity. These data show that cyanobacteria comprised 74 percent of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (22.8 mg/L) was the 43rd highest of the 132 lakes sampled. This means of the 132 lakes 89 lakes had lower median cyanobacteria wet mass concentrations making this lake worse than average.

This WQIP will be most useful as a resource to coordinate and target efforts to improve water quality. Public involvement is of the utmost importance in restoring the water quality in Hannen Lake, which is a reflection of the surrounding land and land management practices. Since local landowners, tenants, and businesses have the most influence in deciding how this land is used, they also have the most influence in improving the water quality of Hannen Lake. Government action alone cannot restore Hannen Lake. A successful restoration effort will require citizen action and involvement, with this document serving as a tool for guiding how to best proceed.

2. Description and History of Hannen Lake

Hannen Lake is unique to Iowa in that it was the first artificial lake constructed in the County Conservation Board system. It is named after the Hannen family who sold the land to the Benton County Conservation Board. Hannen Lake and the associated park are located four miles southwest of Blairstown. The lake is the main feature of the park that has over 8,000 annual visitors who use the park for fishing, swimming and camping.

When built in 1960, the lake was constructed to be 49 acres with a maximum depth of 27.5 feet. In 2005, the surface area had decreased to 37 acres with a maximum depth of 21 feet. Originially the watershed was assessed to measure a drainage area of 603 acres (Figure 2.1). For modeling purposes a newer Light Detection and Ranging (LiDAR) coverage was used that assessed this watershed at 628 acres.

2.1. The Hannen Lake Watershed

Land Use. The watershed is mostly in agricultural land use with the exception of the park. The dominant agricultural uses in the watershed include pasture, grazed pasture and row crop. Hannen Park comprises 180 acres within the watershed. The lake has benefited from an active watershed group and involvement of Benton County officials to promote and preserve the lake. An ongoing conservation project partially funded by an EPA 319 grant has allowed the watershed group to work with local landowners to install many erosion and nutrient control structures and practices along with outreach and education advancements within the watershed.

Soils and topography. Hannen sits in a transitional zone between two landform / ecoregions of Iowa. The Iowan Surface ecoregion is a geologically complex region located between the bedrock-dominated landforms of the Paleozic Plateau/Coulee Section (52b) and the relatively recent glacial drift landforms of the Des Moines Lobe (47b). The southern and southeastern border of this region is irregular and crossed by major northwest- to southeast-trending stream valleys. In the northern portion of the region, the glacial deposits are thin, and shallow limestone bedrock creates karst features such as sinkholes and sags. There are no natural lakes of glacial origin in this region, but overflow areas and backwater ponds occur on some of the larger river channels, contributing to some diversity of aquatic habitat and a large number of fish species.

The Southern Iowa Drift Plain consists of loess deposits on well drained plains and open low hills. Loess deposits tend to be thinner than those found to the west, generally less than 25 feet in depth except along the Missouri River where deposits are thicker. Potential natural vegetation is a mosaic of mostly tallgrass prairie and areas of oak-hickory forest.

The major soil association within the watershed is the Fayette-Downs association. The association includes the Atterberry, Downs, Fayette and Nodaway-Redford complex soils. These are gently sloping to very steep well drained soils on uplands. The association reflects the more hilly landforms found at the boundary of the two ecoregions. The soils are formed in the deep loess.

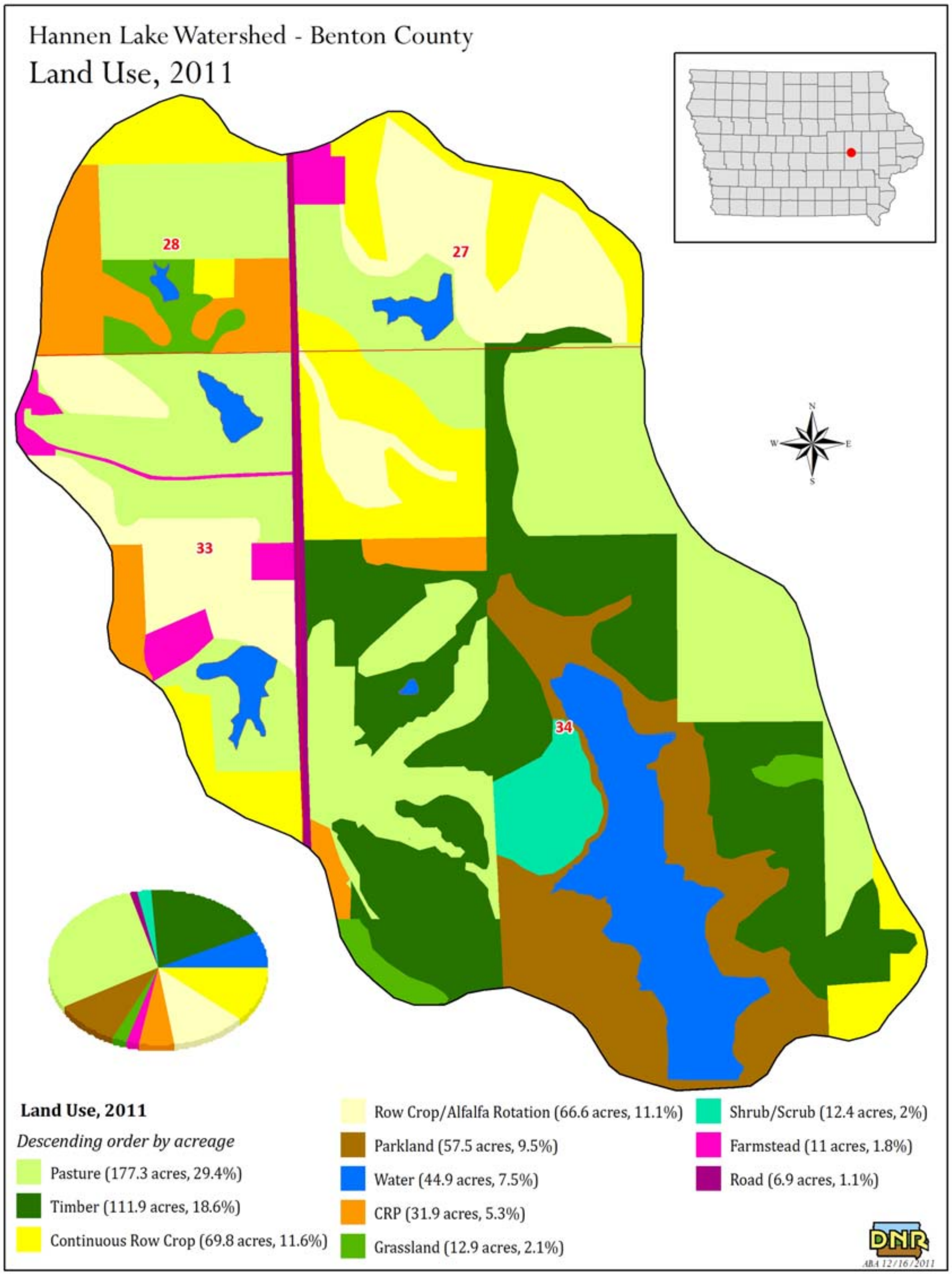

Figure 2.1. Hannen Lake Watershed and landuse.

Land Use. Land use within the watershed is comprised of 55 percent agricultural use (grazed and ungrazed pasture, farmstead and row crop), 30% is within Volga Park and the other 15 percent includes CRP, roads, grassland and small ponds. Areas without permanently established vegetation along with un-vegetated understory within timber will be sources of sediment attached phosphorus into the lake.

Climate. Benton County experiences its warmest month in July with an average high of 85 degrees and average low of 63 degrees. The coldest month is typically January with an average high of 29 degrees and an average low of 10 degrees. The average annual rainfall is 35.92 with the wettest month being June with an average of 4.85 inches and the driest being January with a monthly average of 1.06 inches.

Hannen Lake Watershed work. Hannen Lake and its watershed had both been the focus of several projects over the years. The lake itself has been dredged twice (1989, 2004), however, spoils from these dredging events were used to build an island in the northern portion of the lake to attract geese away from the public use areas. Although this locks the sediment and attached phosphorus from being stirred up with in the lake, it still is within the waterbody and is most likely slowly filtering back into the lake bottom. Furthermore, this feature successfully attracted geese to roost there, which continues to add phosphorus to the lake via fecal matter. Additionally, work was completed through funding provided by the Federal 319 program to put watershed BMPs in place to reduce sediment and external phosphorous loading.

Prior to the project, a land assessment was completed and a resulting RUSLE (Revised Universal Soil Loss Equation) model was developed. While the RUSLE was not used for the final development of this TMDL it did provide a good conceptual model going into model development. The RULSE model indicated an estimated sheet and rill erosion of 1,976 tons per year (Figure 2.2) with a sediment delivery of 576 tons of sediment per year to the lake (Figure 2.3).

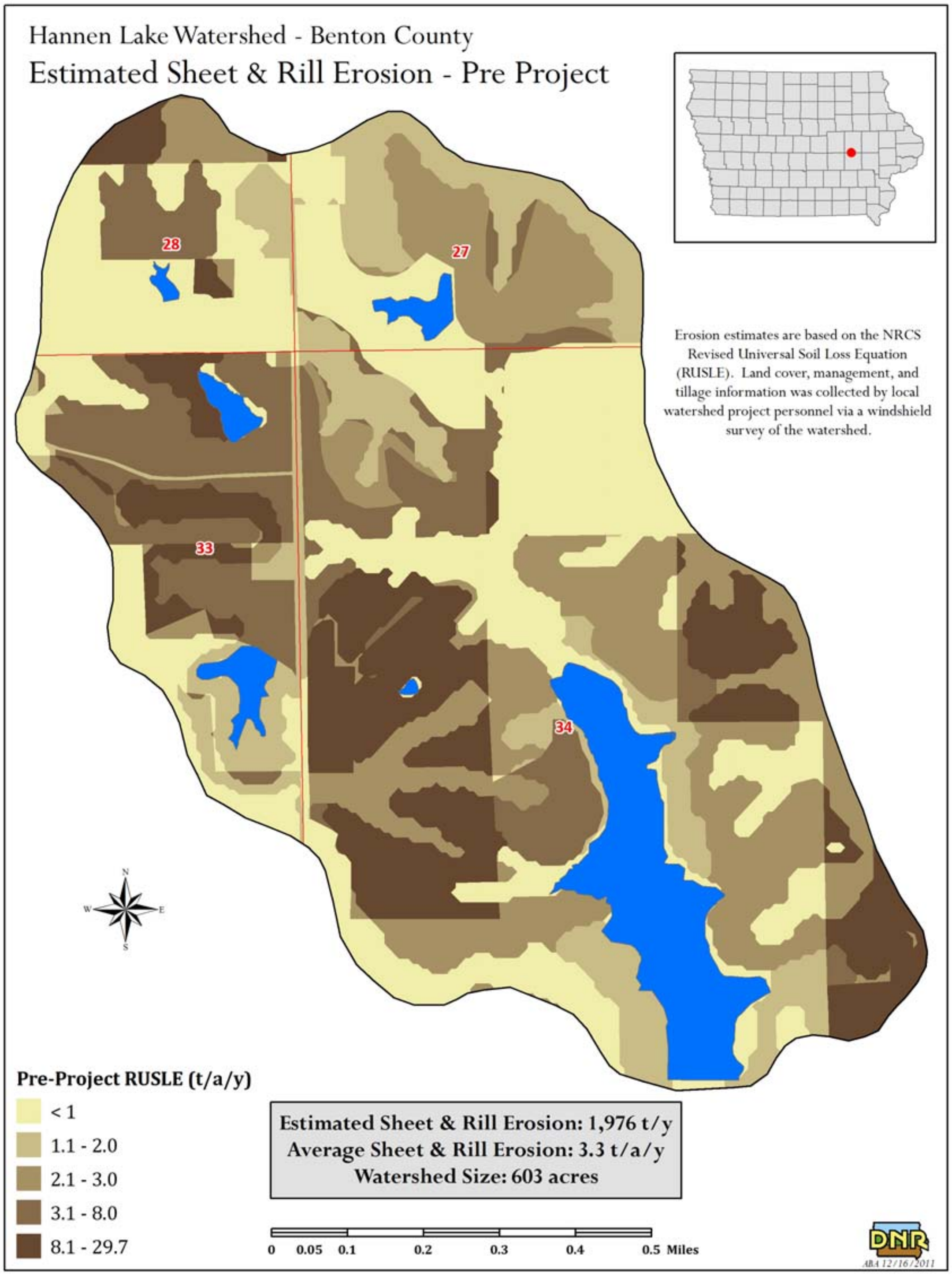

Figure 2.2. Pre-project sediment loss due to sheet and rill erosion.

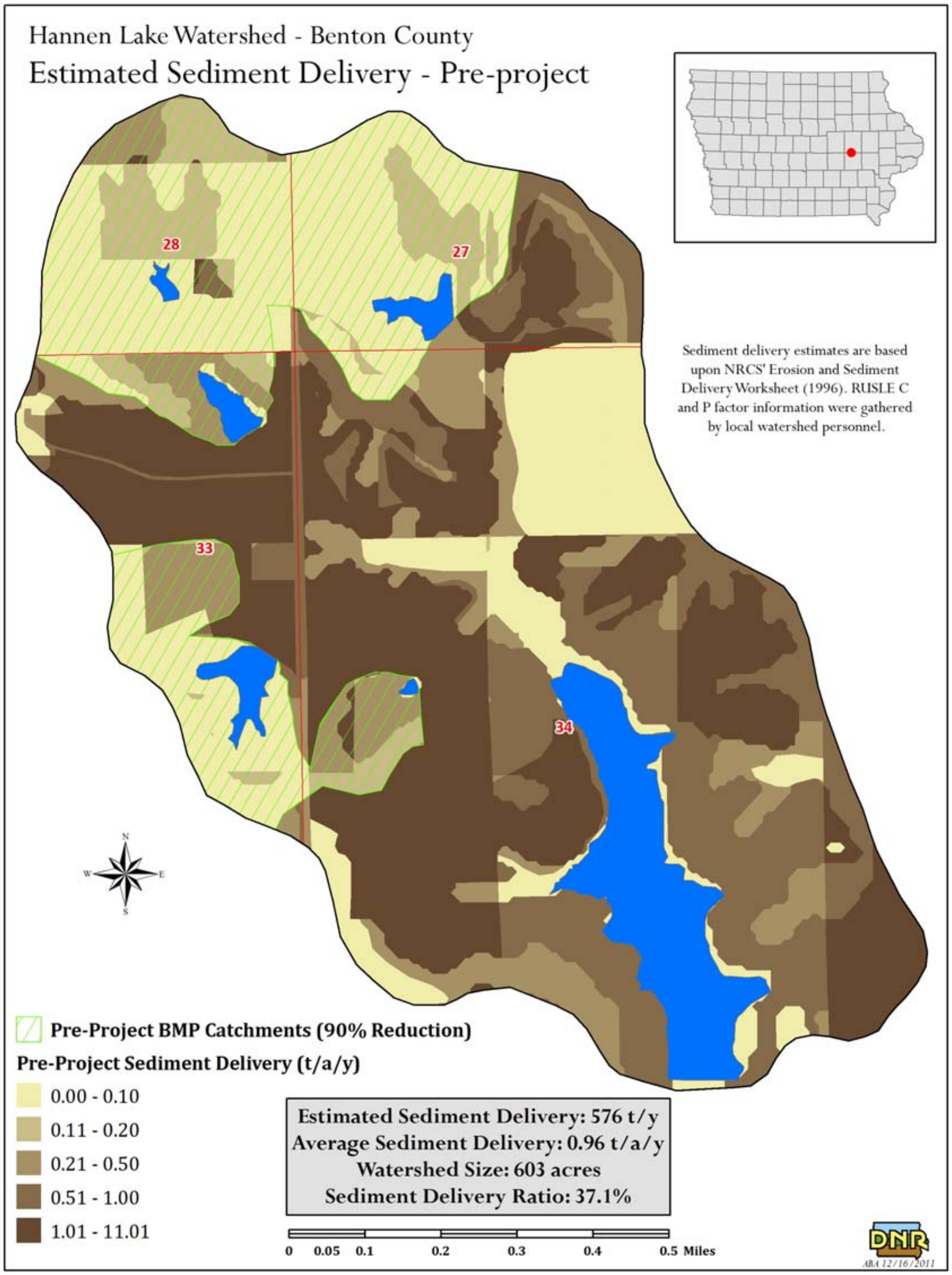

Figure 2.3. Pre-project sediment delivery to Hannen Lake.

BMPs implemented into the watershed included retention ponds and sediment basins, brush management, pasture planting and shoreline protection (Figure 2.4). The resulting estimated post project sheet and rill erosion and sediment delivery are 1,422 tons per year and 399 tons per year respectively (Figures 2.5 and 2.6).

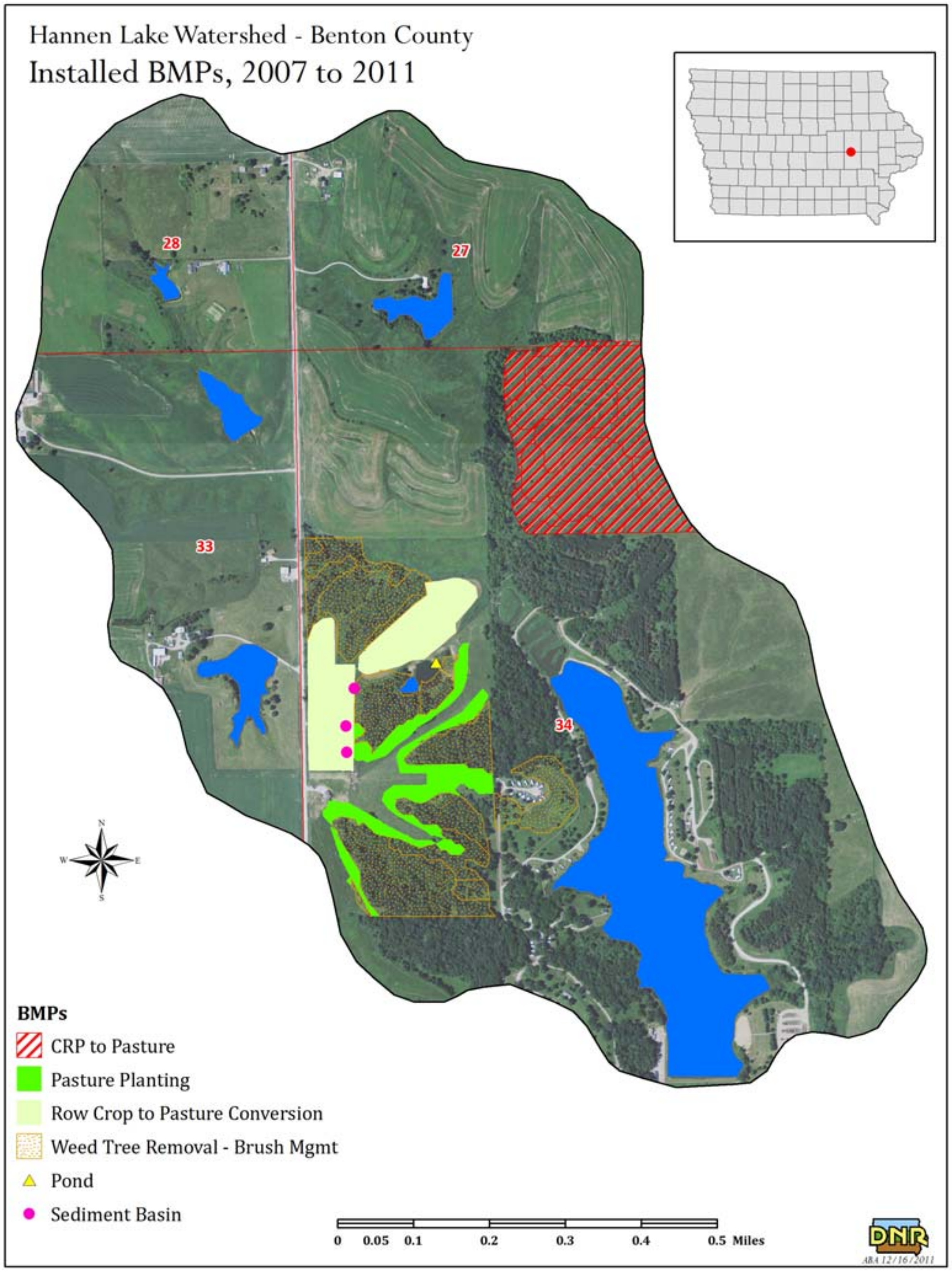

Figure 2.4. BMPs installed under 319 grant.

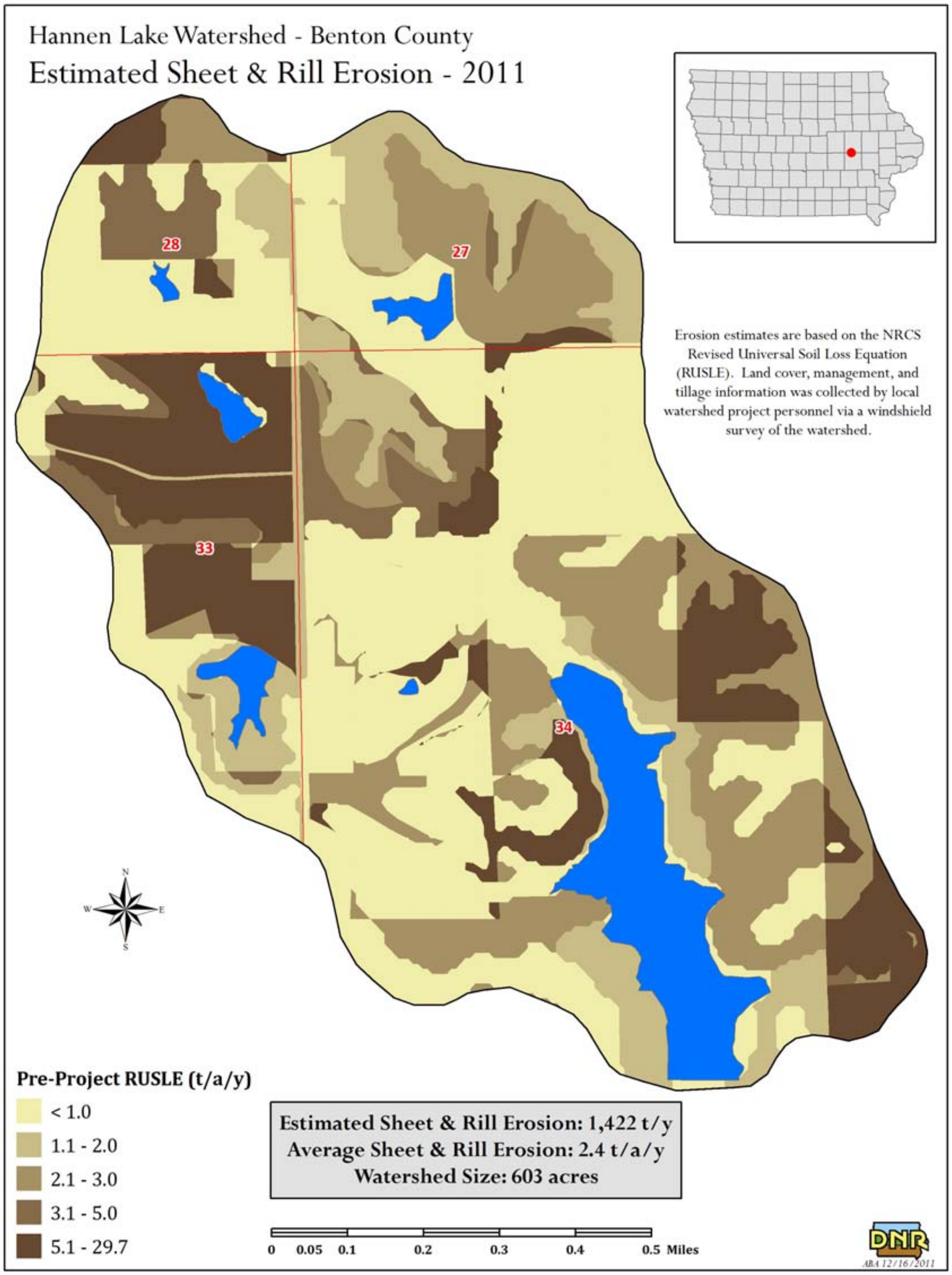

Figure 2.5. Post project sediment loss due to sheet and rill erosion.

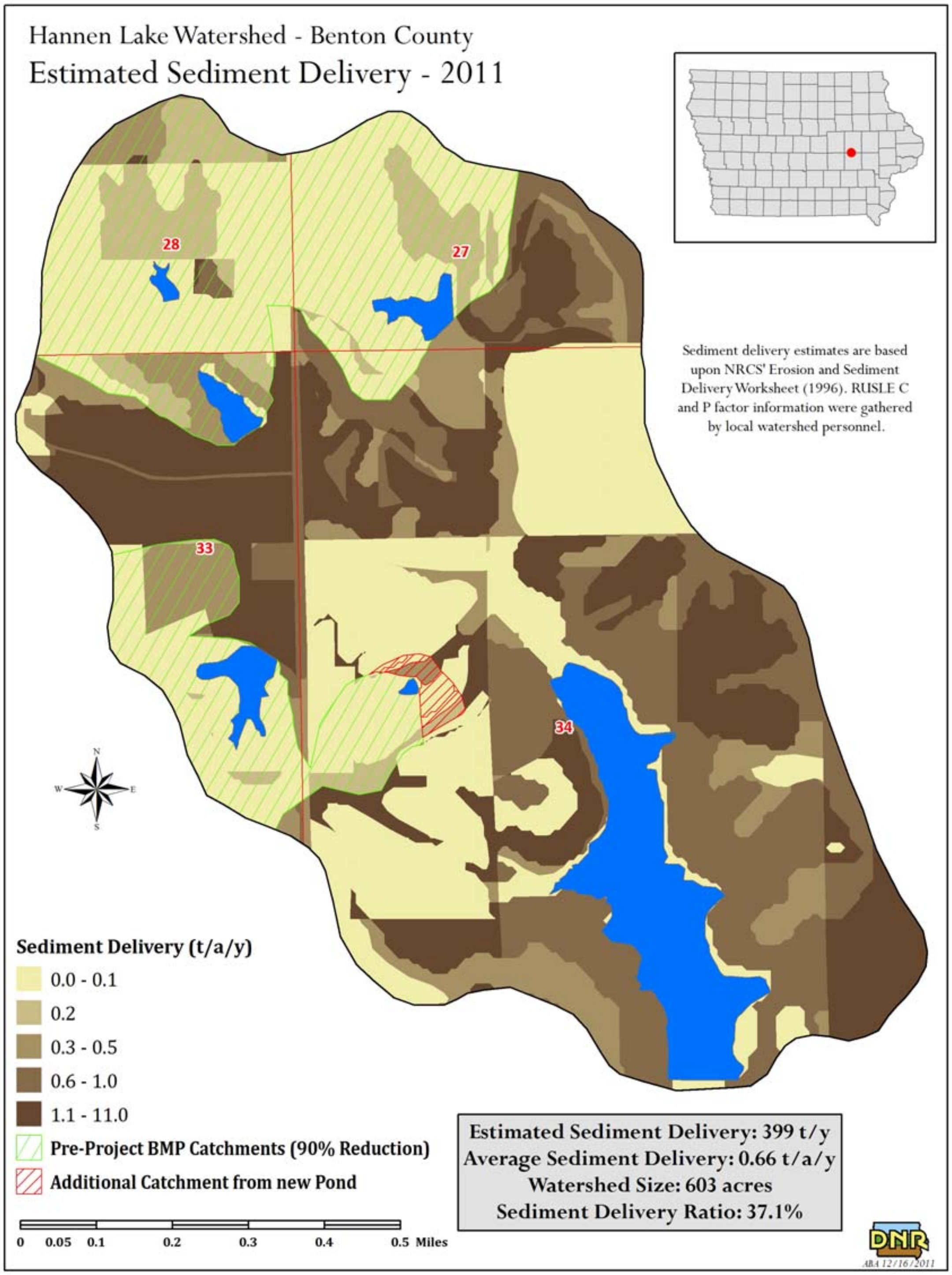

Figure 2.6. Post project sediment delivery to Hannen Lake.

3. Total Maximum Daily Load (TMDL) for Hannen Lake

A Total Maximum Daily Load (TMDL) is required for Hannen Lake by the Federal Clean Water Act. This chapter will quantify the maximum amount of phosphorus that Hannen Lake can tolerate without causing violations of the state's water quality standards.

3.1. Problem Identification

Data sources. Assessment is based on: (1) results of the statewide survey of Iowa lakes conducted from 2004 through 2007 by Iowa State University (ISU), (2) results of the statewide ambient lake monitoring program conducted from 2005 through 2008 by State Hygienic Laboratory (SHL), and (3) information from the IDNR Fisheries Bureau.

Interpreting Hannen Lake data. Although Hannen Lake is impaired due to excessive algal blooms and pH, both can be related to excessive phosphorus delivered via sediment. Water entering Hannen Lake is mostly from runoff with only a small amount coming directly from precipitation. However, very little water flows out of the lake, trapping the sediment and phosphorus within the lake. Figures 3.1 and 3.2 illustrate the relationships between the phosphorous concentration of the lake and the secchi depth, pH and concentration of chlorophyll-a from resulting algal blooms. The resulting algal blooms reduce the transparency of the water and reduce the secchi depth. This blooms make for aesthetically objectionable conditions for swimming or boating.

When phosphorus is applied to fields, either as fertilizer or manure, it clings to soil until used by crops. Soil loss can vary within a watershed depending on several factors such as: best management practices, plant cover, slope, rainfall, etc. This variation can be seen using the Revised Universal Soil Loss Equation (RUSLE) to estimate soil loss. When this soil is washed away during heavy rains, the phosphorus is transported with the soil. In many cases, a portion of this sediment will be delivered into the lake. Another source of phosphorus in lakes is geese manure. Geese manure can be directly deposited into a lake or on the beaches where it enters the lake very quickly. After delivery into the lake, the phosphorus serves as a nutrient source for algal blooms. These blooms can lead to numerous water quality problems for the lake.

Photosynthesis performed by algal blooms also increases the pH of water by removing carbon dioxide reducing the amount of carbonic acid within the water. The ability of sediment to retain phosphorus is highly dependent on pH, and higher pH (i.e. >6.5) causes more phosphorus to be released from the sediment to the water.

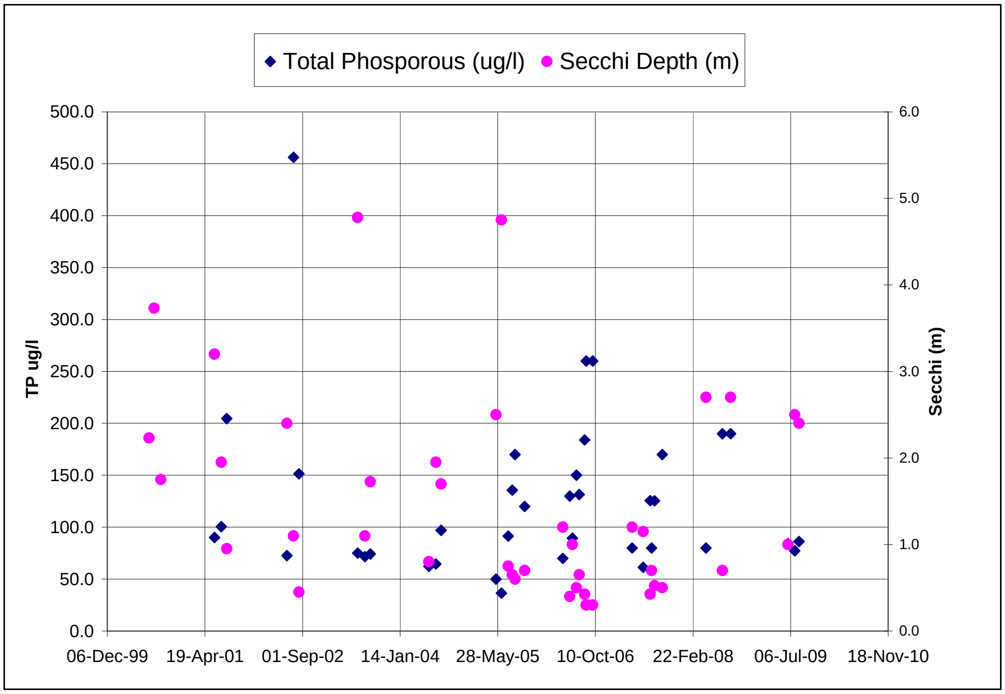

Figure 3.1. There is an inverse relationship between secchi depth and total phosphorous. This suggests that secchi depth decreases with increased TP, indicating water clarity diminishes with increased phosphorous concentration.

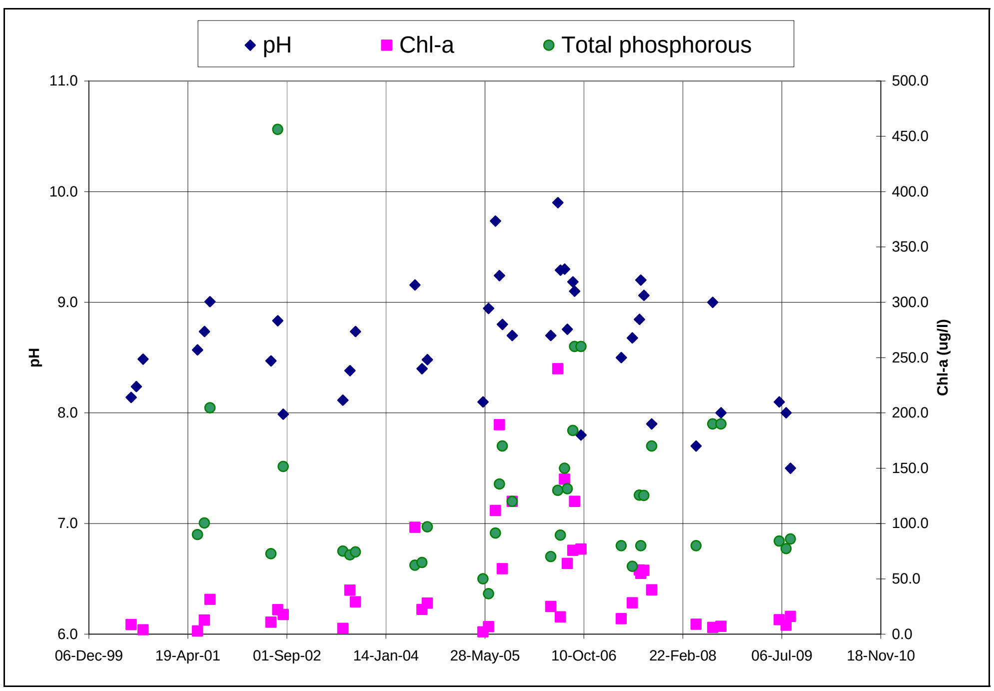

Figure 3.2. With increases of TP increases in Chl-a and pH were also observed as a result of increased algal blooms and by removing carbon dioxide reducing the amount of carbonic acid within the water.

Carlson's Trophic State Index. Carlson's Trophic State Index (TSI) can be used to relate algae (as measured by chlorophyll-a), transparency, and total phosphorus to one another (Carlson 1977). It can also be used as a guide to establish water quality improvement targets. Increasing TSI values generally correspond to decreasing water quality conditions (Table 3.1). The TSI values for Hannen Lake regularly exceed values of 60 or more (Figure 3.3) placing it in the eutrophic state.

Table 3.1 Changes in temperate lake attributes according to trophic state.

TSI Value	Attributes	Primary Contact Recreation	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	warm water fisheries only; percid fishery; bass may be dominant
60-70	blue green algae dominate; algal scums and macrophyte problems occur	weeds, algal scums, and low transparency discourage swimming and boating	Centrarchid fishery
70-80	hyper-eutrophy (light limited). Dense algae and macrophytes	weeds, algal scums, and low transparency discourage swimming and boating	Cyprinid fishery (e.g., common carp and other rough fish)
>80	algal scums; few macrophytes	algal scums, and low transparency discourage swimming and boating	rough fish dominate; summer fish kills possible

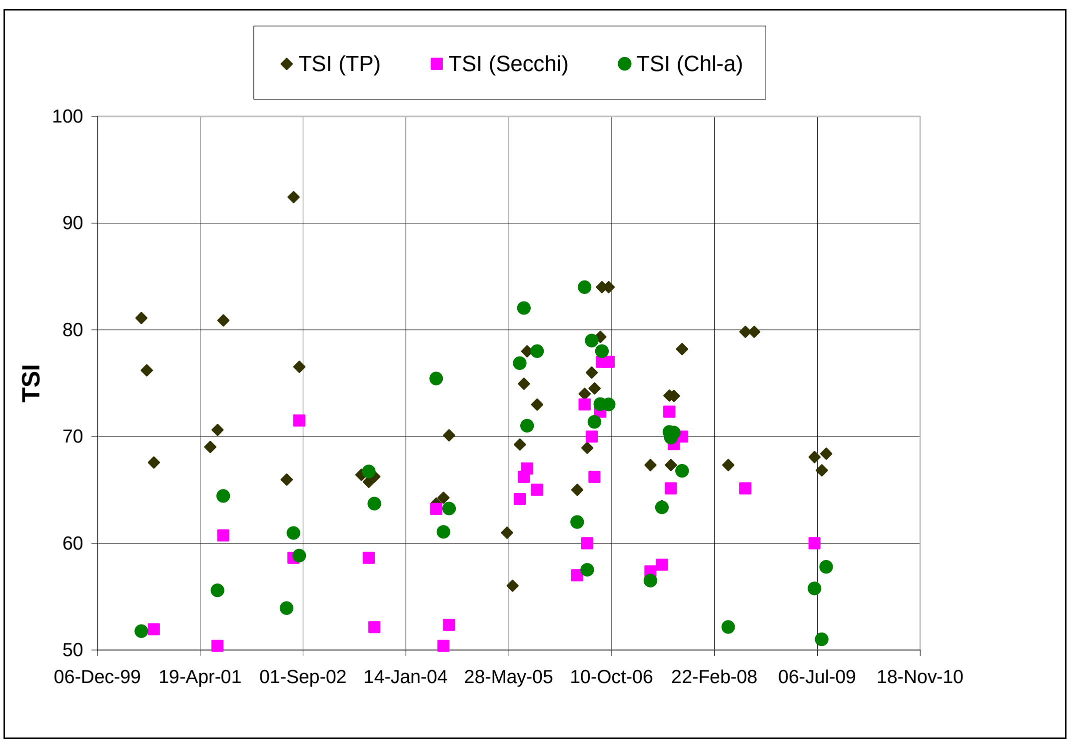

Figure 3.3. Increasing TSI values generally correspond to decreasing water quality conditions.

3.2. TMDL Target

General description of the pollutant. While some studies have suggested that control of both nitrogen and phosphorus may be needed to limit eutrophication in some lakes, phosphorus control is thought to be the critical factor in mitigating eutrophication in Lake Hanned. If phosphorus reductions are attained and algal blooms continue to impair designated uses nitrogen reduction controls may also be needed. The TMDL for algae and pH is based on in-lake targets, which will be achieved by reducing phosphorus loads to the lake (Bachman et.al. 1980, 1994).

Selection of environmental conditions. The critical period for the occurrence of algal blooms resulting from high phosphorus levels in the lake is the growing season (April through September). However, long-term phosphorus loads lead to buildup of phosphorus in the reservoir and contribute to blooms regardless of when phosphorus first enters the lake. Additionally, the combined watershed and in-lake modeling approach using EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL) and BATHTUB lends itself to analysis of annual average conditions. Therefore, both existing and allowable TP loads to Lake Hannen are expressed as annual averages. Phosphorus loads are also expressed as daily maximums to comply with EPA guidance.

Decision criteria for water quality standards attainment. The narrative criteria in the water quality standards require that Lake Hannen be free from "aesthetically objectionable conditions." The chlorophyll-a TSI must not exceed 65. The primary metric for water quality standards attainment set forth in this TMDL is obtaining/maintaining a chlorophyll-a TSI of no greater than 63, which corresponds to a chlorophyll-a concentration of 27.2 ug/L. IDNR will de-list the impairment if the chlorophyll-a TSI is 63 or less in two consecutive 303(d) listing cycles, per the methodology IDNR uses to develop the Integrated Report. They are also based on meeting Iowa Water Quality Standards for pH as given in Chapter 61 of the Water Quality Standards. For pH, the value shall not be less than 6.5 nor greater than 9.0.

3.3. Pollution Source Assessment

Existing load. Average annual simulations of hydrology and pollutant loading were developed using the STEPL model (Version 4.1). STEPL was developed by Tetra Tech, for the US EPA Office of Water, and has been utilized extensively in the United States for TMDL development and watershed planning. Model description and parameterization are described in detail in Appendix D.

The existing load based on the 2002-2009 mean TP is estimated to be 648.6 lbs/year of phosphorus based on a median in-lake concentration of 127.2 ug/l. The total load is comprised of an external load of 522.1 lbs/year and an internal load of 126.5 lbs/year of phosphorous. A complete discussion of this model, including sources can be found in Appendix D.

Departure from load capacity. The target phosphorus load to achieve the desired TSI for chlorophyll-a (63) is 137.7 lbs/year. The current load is 648.6 lbs/year. The difference is 510.8 lbs/year requiring a 79 percent reduction.

Identification of pollutant sources. The total phosphorus load within Hannen Lake is comprised of an external and internal load. The external load consists of phosphorus attached to sediment and dissolved phosphorus entering the waterbody via tributaries or runoff. The internal load consists of phosphorus that is trapped in the lake and recycled between sediments and the water column via in-lake processes.

Separating how much of the total load is external verses internal is difficult for a system like Hannen Lake. First, the lake has no permanently flowing tributaries coming into the lake. Therefore, the only incoming water is from overland flow and direct precipitation. A small gully tributary to the north does flow during storm events contributing bringing in some sediment and phosphorus, but since flow is not continuous, contribution of phosphorous from tributaries is impossible to quantify.

Water leaves the lake via a box weir. However, flow out of the weir is not continuous as the lake level will drop below the weir during dry periods.

Allowance for increases in pollutant loads. As there are no anticipated changes in landuse with in the watershed there are no allowances for increases in pollutant loads for this watershed.

3.4. Pollutant Allocation

The TMDL is based on a target concentration of a TSI (Chl-a) of 63 two consecutive years resulting in an inlake concentration of 27 ug/l of phosphorous. Modeling indicates this translates into a target load of 137.7 lbs per year or a daily load of 1.5 lbs of phosphorus.

Margin of safety. An explicit margin of safety of 10 percent was employed resulting in an MOS of 13.8 lbs/year or 0.15 lbs/day.

Wasteload allocation. There are no permitted discharges in Hannen Lake, therefore, the WLA is set to zero.

Load allocation. The remainder (Ninety percent) of the load is allocated to non-point sources, therefore the LA is set at 123.9 lbs/year or 1.36 lbs/day of phosphorous.

3.5. TMDL Summary

The following equation represents the total maximum daily load (TMDL) and its components for Hannen Lake:

TMDL = Load Allocation (non-point sources and background) + Wasteload Allocation (point sources) + Margin of Safety (either explicit or implicit)

Expressed annually:

Total Phosphorus $TMDL_{annual}$ = LA (123.9. lbs/year) + WLA (0.0 lbs/year) + MOS (13.8 lbs/year) = 137.7 lbs/year of phosphorous.

Expressed as daily:

Total Phosphorus $TMDL_{daily\ concentration}$ = LA (1.36 lbs/day) + WLA (0.0 lbs /day) + MOS (0.15 lbs/day) = 1.51 lbs/day

4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that technical guidance and support are critical to achieving the goals outlined in this WQIP. Therefore, this plan is included to be used by local professionals, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) listed below represent a comprehensive list of tools that may help achieve water quality goals if applied in an appropriate manner; however, it is up to land managers, citizens, and local conservation technicians to determine exactly how best to implement them.

4.1. General Approach & Reasonable Timeline

Initiative and action by local landowners and citizens are crucial to improving the overall health of any watershed, but this is especially true of the Hannen Lake watershed where most of the land is privately owned. Watershed work and improvements to the lake should proceed in conjunction with a comprehensive monitoring system that will adequately characterize daily, seasonal, and annual pollutant loadings in the lake as improvements to the watershed are made.

4.2. Best Management Practices

Water quality problems within Hannen Lake stem from excess phosphorus within the lake, which is delivered from the land and internally recycled. The main delivery mechanism is phosphorus attached to sediment entering the lake as stormwater runoff. Therefore, to decrease the phosphorus delivered to the lake, it is necessary to reduce the sediment delivered to the lake. Since pasture and crop land are the dominate uses of the land within the watershed, reductions can come from conservation practices that reduce bare ground cover and slow sediment loss and delivery. This includes using buffer strips, terraces, contour farming, water and sediment control structures, cover crops, sediment basins and grassed waterways.

During the course of the federally funded 319 project, many practices aimed at reducing sediment loss were put in place. As time goes on water quality monitoring must continue to assess what effects these BMPs have on water quality (see Section 5). Additionally, as indicated by the current RUSLE calculation (Figure 4.1), forestry and parkland management might be needed to establish good ground cover beneath the tree canopy. Many times tree canopies can become so dense that under growth cannot establish. During heavy rains, erosion under the canopy can occur, including gully formation.

The forest undergrowth should be evaluated, especially on the steeper slopes, to see if a forest management plan is needed. Once this evaluation is completed, areas lacking in undergrowth should be identified and attempts to establish groundcover made. Gully formations should also be identified and structures or practices put in place to slow formation.

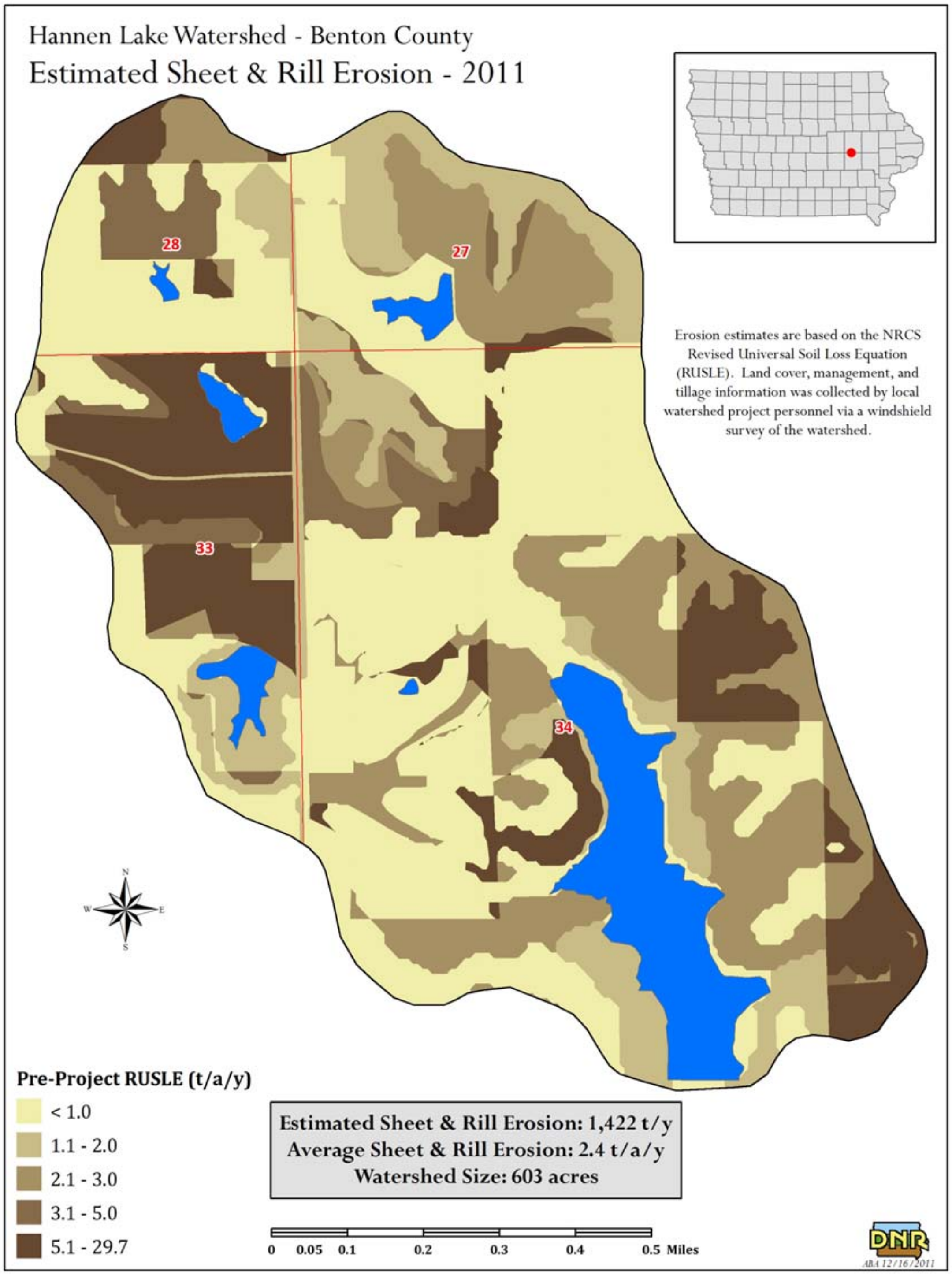

Figure 4.1 The current RUSLE maps depict areas directly west of the and north of the lake where a forestry or park management plan might be beneficial.

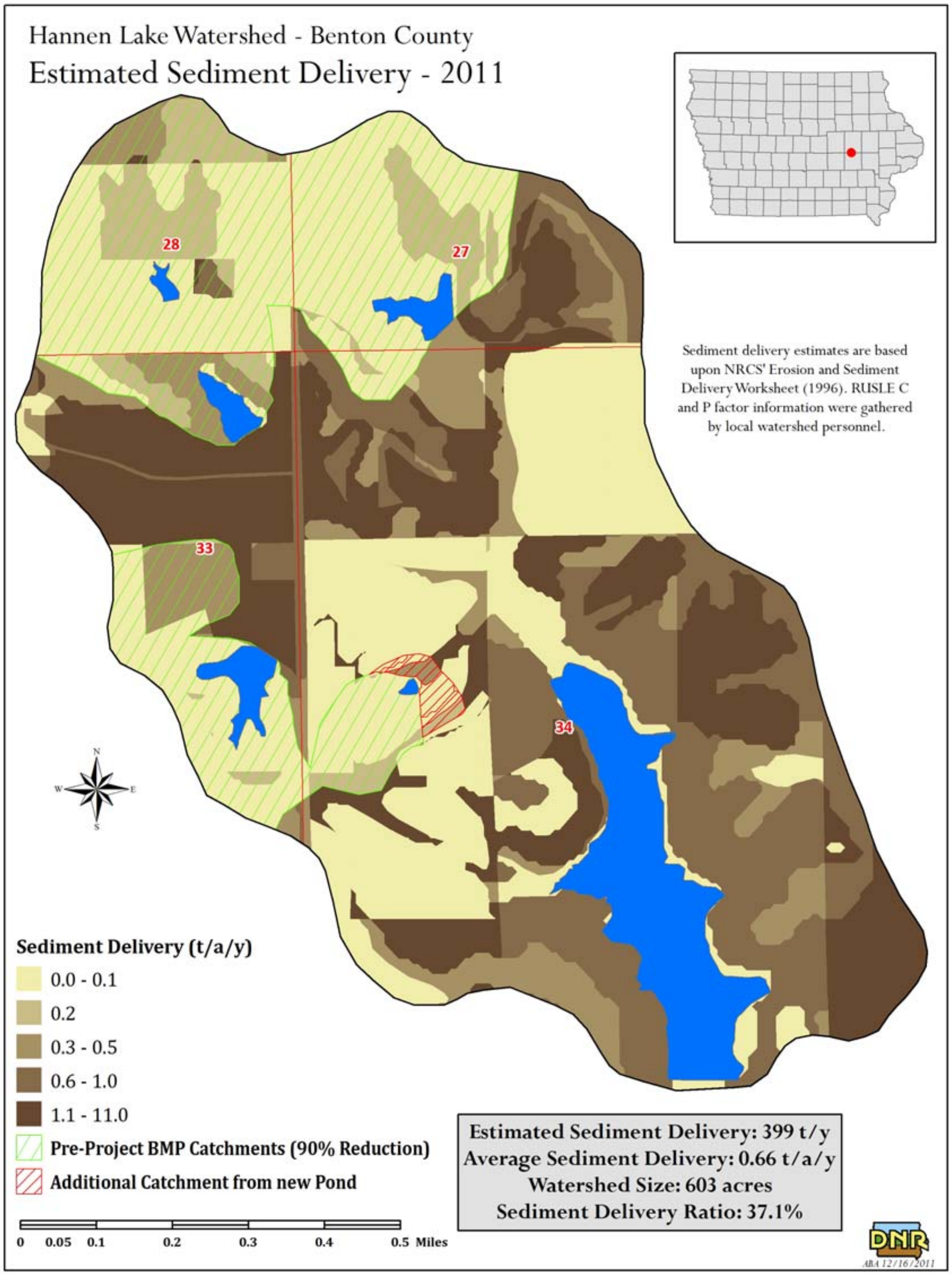

Figure 4.2 The current sediment delivery map also depicts areas directly west of the and north of the lake where a forestry or park management plan might be beneficial.

Additional forest and parkland assessments and planning coupled with in-lake restoration will also be necessary. The park has experienced flooding in recent years (2008-2010) and the heavy rains may have increased gully formation within the forested areas of the park. Surveying parkland and forest land for gully and rill erosion and thickness of understory would allow for the development of plans to remediate the gullies and restore lost understory. Managing gully erosion and maintaining a healthy understory would cut down on sediment delivery.

Modeling indicates approximately 27 percent of the phosphorous loading is from internal recycling of the lake. Remediating some of the internal load will require dredging of Hannen Lake and taking the dredged material out of the watershed. The lake itself has been dredged twice (1989, 2004), however, spoils from these dredging events were used to build an island in the northern portion of the lake to attract geese away from the public use areas. Geese manure is high in phosphorus and directly deposited into the lake. Therefore, removing the structures built with previously dredged materials and discouraging geese from inhabiting the lake will also help with improving water quality.

5. Monitoring Plan

Water quality monitoring is a critical element in assessing the current status of water resources and the historical trends. Furthermore, monitoring is necessary to track the effectiveness of water quality improvements made in the watershed and document the status of the waterbody in terms of achieving total maximum daily loads.

5.1. Monitoring Plan to Track TMDL Effectiveness

Currently, Hannen Lake water quality is monitored three times a year during the critical period of May to September. These water samples are used to track annual water quality trends and conditions. This sampling effort is completed by the Iowa State University Limnology Department as part of a statewide lake sampling program. Effects of the implementation of BMPs and any future lake dredging will be evaluated through data collected via this sampling program.

5.2. Idealized Plan for Future Watershed Projects

The purpose of this section is to outline what an appropriate monitoring plan would look like for the Hannen Lake Watershed if there were no logistical or financial restraints (Table 5.1).

Table 5.1. Idealized monitoring plan for Hannen Lake.

Component	Sample Frequency	Parameters/Details
1. Water chemistry sampling	Bi-weekly from March to November	All common parameters listed in Appendix A of the Iowa Water Monitoring Plan 2000 (http://wqm.igsb.uiowa.edu/publications/plan2000.htm)
2. Plant and Fish Inventory	Annually	Monitoring should be done to track improvement in aquatic plant and fish varieties and evaluate DO tolerance of species.
3. Continuous dissolved oxygen	Continuously (6-minute intervals) from June to October	Dissolved oxygen autosampler deployment according to SHL protocols

Component one of this monitoring plan would be consistent with Iowa's current Ambient Water Quality Monitoring plan. At a bare minimum samples should be collected at this frequency throughout the specified time period. This allows for tracking of long term water quality changes during critical periods and provides data necessary for determining actions needed to keep water quality improving.

Component two, plant and fish inventories, provides data on the overall health of the lake. Water quality can vary greatly in a short amount of time especially in regards to dissolved oxygen. Large swings or dips in DO might not be evident in bi-weekly sampling. By looking at the biota, DO stress becomes more evident since some species will not thrive in low DO conditions while others are tolerant of low DO. A shift toward a low DO tolerant population would indicate this is occurring within the lake. While Hannen Lake is not currently impaired for low DO, it is a common occurrence in lakes subject to algal blooms.

This plays directly into component three of the monitoring plan which would place a DO autosampler in the lake during critical periods. This would provide a much more detailed picture of what happens on a diurnal basis within the lake and also during algal blooms and die off.

Grab samples should be gathered in lake while sampler deployment can occur in lake or near a fixed structure such as the discharge weir at the outlet of the lake (Figure 5.1).

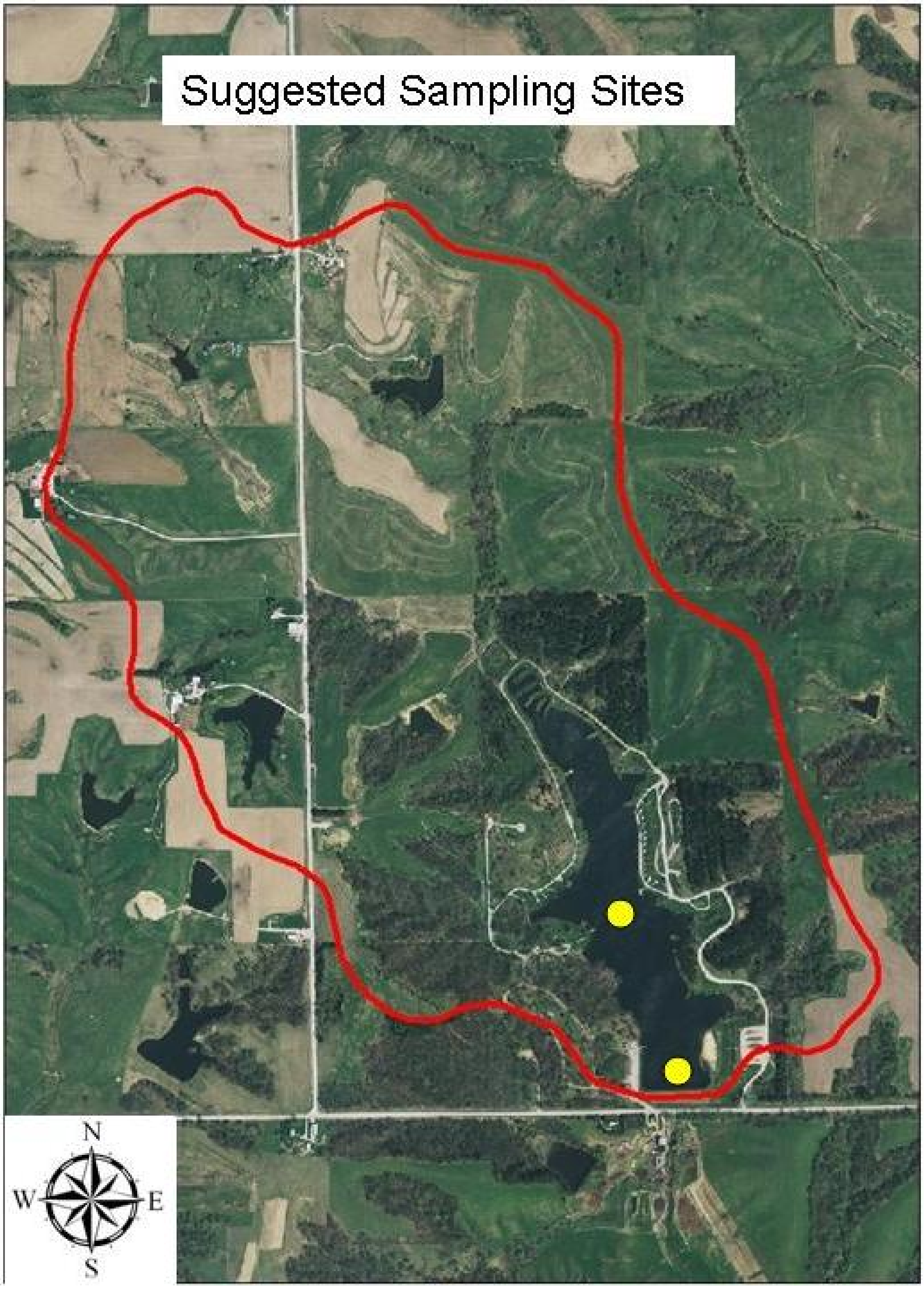

Figure 5.1. Suggested sample and autosampler deployment sites.

6. Public Participation

Public involvement is important in the TMDL process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Hannen Lake. During the development of this TMDL, efforts were made to ensure that local stakeholders were involved in the development of this WQIP.

6.1. Public Meetings

A public meeting was held on May 24th from 6 to 8 pm at the Belle Plaine Community Center in Belle Plaine Iowa. Attendees included members of Benton County Conservation Board, park employees and private land owners.

6.2. Written Comments

No written comments were received during the public comment period.

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8. Appendices

Appendix A --- Glossary of Terms and Acronyms

303(d) list: Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface water bodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."

305(b) assessment: Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public water bodies ability to support their general and designated uses. Those bodies of water which are found to be not supporting or just partially supporting their uses are placed on the 303(d) list.

319: Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.

AFO: Animal Feeding Operation. A livestock operation, either open or confined, where animals are kept in small areas (unlike pastures) allowing manure and feed become concentrated.

Base flow: The fraction of discharge (flow) in a river which comes from ground water.

BMIBI: Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.

BMP: Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.

CAFO: Confinement Animal Feeding Operation. An animal feeding operation in which livestock are confined and totally covered by a roof, and not allowed to discharge manure to a water of the state.

Credible data law: Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate.

Cyanobacteria (blue-green algae): Members of the phytoplankton community that are not true algae but can photosynthesize. Some species can be toxic to humans and pets.

Designated use(s): Refer to the type of economic, social, or ecologic activities that a specific water body is intended to support. See Appendix B for a description of all general and designated uses.

DNR (or IDNR): Iowa Department of Natural Resources.

Ecoregion: A system used to classify geographic areas based on similar physical characteristics such as soils and geologic material, terrain, and drainage features.

EPA (or USEPA): United States Environmental Protection Agency.

FIBI: Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.

FSA: Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.

General use(s): Refer to narrative water quality criteria that all public water bodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.

GIS: Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.

Gully erosion: Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.

HEL: Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land which has the potential for long term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.

Integrated report: Refers to a comprehensive document which combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public water bodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.

LA: Load Allocation. The fraction of the total pollutant load of a water body which is assigned to all combined *nonpoint sources* in a watershed. (The total pollutant load is the sum of the waste load and load allocations.)

Load: The total amount (mass) of a particular pollutant in a waterbody.

MOS: Margin of Safety. In a total maximum daily load (TMDL) report, it is a set-aside amount of a pollutant load to allow for any uncertainties in the data or modeling.

MS4 Permit: Municipal Separate Storm Sewer System Permit. An NPDES license required for some cities and universities which obligates them to ensure adequate water quality and monitoring of runoff from urban storm water and construction sites, as well as public participation and outreach.

Nonpoint source pollution: A collective term for contaminants which originate from a diffuse source.

NPDES: National Pollution Discharge Elimination System, which allows a facility (e.g. an industry, or a wastewater treatment plant) to discharge to a water of the United States under regulated conditions.

NRCS: Natural Resources Conservation Service (United States Department of Agriculture). Federal agency which provides technical assistance for the conservation and enhancement of natural resources.

Periphyton: Algae that are attached to substrates (rocks, sediment, wood, and other living organisms).

Phytoplankton: Collective term for all self-feeding (photosynthetic) organisms which provide the basis for the aquatic food chain. Includes many types of algae and cyanobacteria.

Point source pollution: A collective term for contaminants which originate from a specific point, such as an outfall pipe. Point sources are generally regulated by an NPDES permit.

PPB: Parts per Billion. A measure of concentration which is the same as micrograms per liter (µg/l).

PPM: Parts per Million. A measure of concentration which is the same as milligrams per liter (mg/l).

Riparian: Refers to site conditions that occur near water, including specific physical, chemical, and biological characteristics that differ from upland (dry) sites.

RUSLE: Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.

Secchi disk: A device used to measure transparency in water bodies. The greater the secchi depth (measured in meters), the more transparent the water.

Sediment delivery ratio: A value, expressed as a percent, which is used to describe the fraction of gross soil erosion which actually reaches a water body of concern.

Seston: All particulate matter (organic and inorganic) in the water column.

Sheet & rill erosion Soil loss which occurs diffusely over large, generally flat areas of land.

SI: Stressor Identification. A process by which the specific cause(s) of a biological impairment to a water body can be determined from cause-and-effect relationships.

Storm flow (or stormwater): The fraction of discharge (flow) in a river which arrived as surface runoff directly caused by a precipitation event. *Storm water* generally refers to runoff which is routed through some artificial channel or structure, often in urban areas.

STP: Sewage Treatment Plant. General term for a facility that processes municipal sewage into effluent suitable for release to public waters.

SWCD: Soil and Water Conservation District. Agency which provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.

TMDL: Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a water body can tolerate while still meeting its general and designated uses.

TSI (or Carlson's TSI): Trophic State Index. A standardized scoring system (scale of 0-100) used to characterize the amount of algal biomass in a lake or wetland.

TSS: Total Suspended Solids. The quantitative measure of seston, all materials, organic and inorganic, which are held in the water column.

Turbidity: The degree of cloudiness or murkiness of water caused by suspended particles.

UAA: Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular water body. (See Appendix B for a description of all general and designated uses.)

UHL: University Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring and impaired water assessments.

USGS: United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's water bodies.

Watershed: The land (measured in units of surface area) which drains water to a particular body of water or outlet.

WLA: Waste Load Allocation. The fraction of waterbody loading capacity assigned to point sources in a watershed. Alternatively, the allowable pollutant load that an NPDES permitted facility may discharge without exceeding water quality standards.

WQS: Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.

WWTP: Waste Water Treatment Plant. General term for a facility which processes municipal, industrial, or agricultural waste into effluent suitable for release to public waters or land application.

Zooplankton: Collective term for all animal plankton which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Appendix B --- General and Designated Uses of Iowa's Waters

Introduction

Iowa's water quality standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria by which water bodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of water body (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the water body that is being dealt with. This appendix is intended to provide information about how Iowa's water bodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, all public bodies of surface water in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because it means that not all of the criteria in the state's water quality standards apply to all water ways; rather, the criteria which apply depend on the use designation & classification of the water body.

General Use Segments

A general use segment water body is one which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use water body, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Designated Use Segments

Designated use segments are water bodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B-1) which may apply, and a water body may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Table B-1. Designated use classes for Iowa water bodies.

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
Other	HQ	High quality water	Waters with exceptional water quality
	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

Appendix C --- Water Quality Data

Date	Depth (m)	Thermocline Depth (m)	Secchi Depth (m)	Temperature (Celsius)	Dissolved Oxygen (mg/L)	pH	Conductivity (umhos/cm2)	Turbidity (NTU)	Chlorophyll a (ug/L)	Carlson's TSI (Secchi)	Carlson's TSI (Chlorophyll)	Carlson's TSI (Phosphorus)
19-May-05	6.6		2.5	17.0	7.0	8.1	353.0	6.0	2.0	47	37	61
25-Aug-05	6.3	3.6	0.6	23.6	5.2	8.8	268.0	27.0	59.0	67	71	78
13-Oct-05	6.3		0.7	16.5	8.5	8.7	290.0	17.0	120.0	65	78	73
26-Apr-06	6.5	3.7	1.2	14.8	8.8	8.7	333.0	11.0	25.0	57	62	65
05-Jul-06	6.2	1.5	0.5	27.8	10.1	9.3	270.0	42.0	140.0	70	79	76
26-Sep-06	5.6		0.3	16.3	6.6	7.8	307.0	42.0	77.0	77	73	84
13-Jun-02	6.4	2.6	2.4	24.9	7.8	8.5	374.4	188.0	10.8	47	54	66
17-Jul-02	6.1	2.0	1.1	28.2	13.6	8.8	302.8	4.7	22.1	59	61	92
14-Aug-02	6.1	4.3	0.4	23.9	5.0	8.0	326.0	21.7	17.8	72	59	77
11-Jun-03	6.4	4.6	4.8	20.5	4.5	8.1	363.0	1.8	5.2	37	47	66
17-Jul-03	6.2	4.5	1.1	26.4	9.0	8.4	357.8	5.3	39.7	59	67	66
14-Aug-03	5.4	3.7	1.7	26.6	8.7	8.7	361.8	5.8	29.2	52	64	66
09-Jun-04	6.6	2.0	0.8	25.6	12.6	9.2	306.6	16.2	96.6	63	75	64
15-Jul-04	6.4	2.4	2.0	26.1	10.6	8.4	304.3	7.8	22.3	50	61	64
11-Aug-04	6.1	4.9	1.7	22.5	8.0	8.5	606.6	11.3	27.9	52	63	70
16-Jun-05	6.2	4.0	4.8	23.3	9.0	8.9	324.6	1.6	6.7	38	49	56
21-Jul-05	6.4	2.6	0.8	28.8	6.6	9.7	277.9	15.7	111.8	64	77	69
10-Aug-05	6.2	1.8	0.6	27.4	11.7	9.2	265.6	0.6	189.3	66	82	75
14-Jun-06	6.1	3.0	1.0	20.9	8.5	9.3	294.8	22.1	15.5	60	58	69
19-Jul-06	6.0	3.0	0.6	26.5	4.8	8.8	313.2	20.7	63.9	66	71	75

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Date	Dissolved Organic Carbon (mg/L)	Inorganic Suspended Solids (mg/L)	Total Organic Carbon (mg/L)	Total Volatile Suspended Solids (mg/L)	Total Suspended Solids (mg/L)	Cyanobacteria Wet Mass (mg/L)	Phytoplankton Wet Mass (mg/L)	Zooplankton Dry Mass (mg/L)
19-May-05		1.0	6.4	1.0	1.0	1.0	4.2	438.9
25-Aug-05		4.0	10.0	8.0	12.0	27.0	32.7	156.5
13-Oct-05		1.0	10.0	10.0	10.0	9.0	33.5	90.7
26-Apr-06		3.0	6.9	3.0	7.0	0.0	8.7	42.2
05-Jul-06		2.0	17.0	19.0	22.0	441.0	445.2	852.4
26-Sep-06		6.0	18.0	12.0	18.0	39.0	43.3	14.8
13-Jun-02					7.3	56.0	105.6	347.7
17-Jul-02		7.4		6.0	13.4	112.0	118.6	63.3
14-Aug-02	10.2	4.2		11.6	15.8	21.0	21.7	22.1
11-Jun-03	10.7	<1		4.4	4.6	5.0	5.6	160.8
17-Jul-03	9.5	1.2		7.6	8.8	386.0	409.6	37.1
14-Aug-03	10.5	2.0		4.6	6.6	73.0	75.0	60.9
09-Jun-04	8.5	2.2		12.6	14.8	48.0	47.8	1516.9
15-Jul-04	5.2	<1		5.8	6.6	22.0	24.3	1194.9
11-Aug-04	6.3	3.6		5.2	8.8	24.0	27.8	67.8
16-Jun-05	6.1	2.7		1.3	4.0	1.0	1.4	77.2
21-Jul-05	7.5	2.0		6.8	8.8	10.0	15.0	14.6
10-Aug-05	8.2	7.1		12.4	19.5	12.0	28.9	14.8
14-Jun-06	9.9	1.5		<1	2.4	3.0	3.0	36.6
19-Jul-06	9.7	2.8		9.6	12.4	49.0	51.1	43.1
16-Aug-06	8.7	9.1		14.9	24.0	1051.0	1052.4	

Appendix D --- Modeling Equations and Methodology

Watershed and in-lake modeling were used in conjunction with observed water quality data to develop the Total Maximum Daily Load (TMDL) for the algae impairments to Hannen Lake. The Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1, was utilized to simulate watershed hydrology and pollutant loading. In-lake water quality simulations were performed using BATHTUB 6.14, an empirical lake and reservoir eutrophication model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Hannen Lake and its watershed. This section of the Water Quality Improvement Plan (WQIP) discusses the overall modeling approach, as well as the development of the STEPL watershed model and BATHTUB lake model.

D.1. STEPL Model Description

STEPL is a watershed-scale hydrology and water quality model developed for the U.S. Environmental Protection Agency (EPA) by Tetra Tech, Incorporated. STEPL is a long-term average annual model developed to assess the impacts of land use and best management practices on hydrology and pollutant loads. STEPL is capable of simulating a variety of pollutants, including sediment and nutrients (nitrogen and phosphorus).

Required input data is minimal if the use of county-wide soils and coarse precipitation information is acceptable to the user. If available, the user can modify soil and precipitation inputs with higher resolution and/or local soil and precipitation data. Precipitation inputs include average annual rainfall amount and rainfall correction factors that describe the intensity (i.e., runoff producing) characteristics of long-term precipitation.

Land use characteristics that affect STEPL estimates of hydrology and pollutant loading include land cover types, presence/population of agricultural animals, wildlife populations, population served by septic systems, and characteristics of urban land uses. STEPL also quantifies the impacts of manure application and best management practices (BMPs). Almost all STEPL inputs can be customized if site-specific data is available and more detail is desired.

The Hannen Lake watershed is small and has a single tributary that is only intermittent in flow. Therefore, the entire watershed was considered the only subbasin. Additionally, the lake was not segmented thereby negating the need to quantify loads from smaller subbasins.

D.2. Meteorological Input

Precipitation Data.

The STEPL model includes a pre-defined set of weather stations from which the user must choose to obtain precipitation-related model inputs. For the purpose of Hannen

Lake, the Benton County average was used. This resulted in an annual average rainfall of 35.9 inches to be used in the STEPL model and also within BATHTUB.

D.3. Watershed Characteristics

Soils and Slopes and Curve Numbers.
The hydrologic soil group (HSG) and the USLE K-factor are the critical soil parameters in the STEPL model. Watershed soils are predominantly HSG type B soils. USLE inputs were obtained from a previous RUSLE assessment completed for the Hannen Lake watershed.

USLE K-factors vary spatially and by land use. K-factors for each landuse and subwatershed are entered into the “Input” worksheet in the STEPL model.
USLE land slope (LS) factors were obtained from a previous RUSLE assessment, and were area-weighted by land use within each STEPL subwatershed.

The STEPL model includes default curve numbers (CNs) selected automatically based on HSG and land use inputs. The STEPL default CN was left in place for other land uses.

Sediment Delivery Ratio.
The total sediment load to the lake is smaller than total sheet and rill erosion because some of the eroded material is deposited in depressions, ditches, or streams before it reaches the watershed outlet (i.e., the lake). The sediment delivery ratio (SDR) is the portion of sheet and rill erosion that is transported to the watershed outlet. STEPL calculates SDR using a simple empirical formula based on drainage area (i.e., watershed size). The SDR in STEPL was calculated at 0.30.

D.4. Animals

Agricultural Animals and Manure Application.
The STEPL model utilizes livestock population data and the amount of time (in months) that manure is applied to account for nutrient loading from livestock manure sources. There are no swine, beef, dairy, or poultry operations within the shed.

Livestock Grazing.
There are no significant livestock grazing or feedlot operations in the Hannen Lake watershed.

Wildlife.
STEPL assumes that wildlife add to the manure deposited on the land surface. If animal densities are significant, nutrient concentration in runoff is increased. For Hannen Lake, an estimate of 50 geese and 8 deer per square mile were used. Both of these numbers represent over estimates. Even with overestimates of geese and deer populations, wild life contributions are relatively insignificant (in terms of nutrient loading to the lake) and do not increase STEPL nutrient runoff parameters.

Table D.1. Watershed landuse inputs for STEPL (acres).

Watershed	Urban	Cropland	Pasture	Forest	Grassland	Feedlots
W1	6.9	147.4	177.3	181.8	75.8	0

Sources determined by STEPL are given in figure D.1.

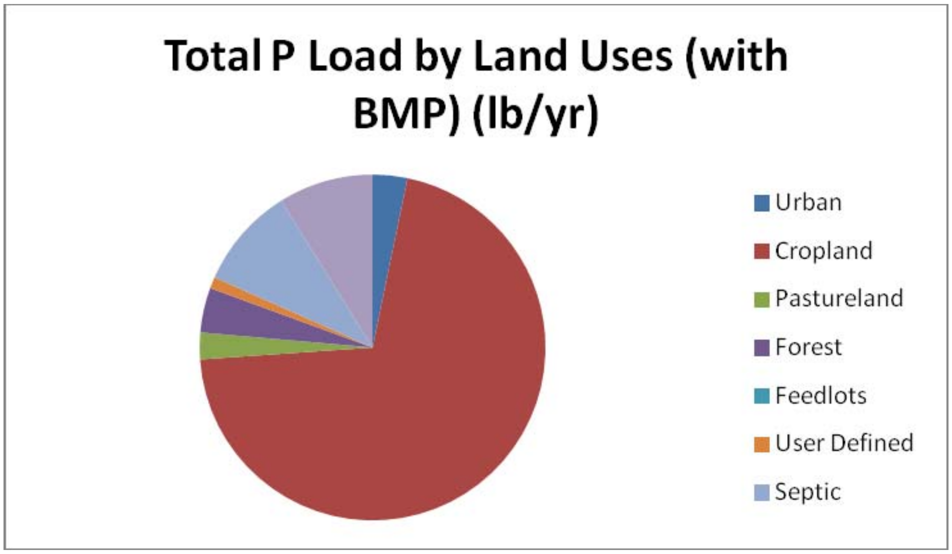

Figure D.1. Souces of TP from STEPL not including atmospheric.
*Atmospheric TP load is 9.92 lbs/yr
**User defined includes CRP, shrub and parkland classified as Grassland.

D.5. BATHTUB Model Description

A combination of modeling software packages were used to develop the Total Maximum Daily Load (TMDL) for Hannen Lake. Watershed hydrology and pollutant loading was simulated using the Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1. STEPL model development was described in detail in Appendix D of this Water Quality Improvement Plan (WQIP).

In-lake water quality simulations were performed using BATHTUB 6.14, an empirical lake and reservoir eutrophication model. This appendix of the WQIP discusses development of the BATHTUB model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Hannen Lake and its watershed.

BATHTUB is a steady-state water quality model developed by the U.S. Army Corps of Engineers that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999). Eutrophication-related parameters are expressed in terms of total phosphorus (TP), total nitrogen (TN), chlorophyll a (chl-a), and transparency. The model can distinguish between organic and inorganic forms of phosphorus and nitrogen, and simulates hypolimnetic oxygen depletion rates, if applicable/desired. Water quality predictions are based on empirical models that have been calibrated and tested for lake and reservoir applications (Walker, 1985).

D.6. Model Parameterization

BATHTUB includes several data input menus/modules to describe lake characteristics, simulation equations, and external (i.e., watershed) inputs. Data menus utilized to develop the BATHTUB model for Hannen Lake include: model selections, global variables, segment data, and tributary data. The model selections menu allows the user to specify which modeling equations (i.e., empirical relationships) are to be used in the simulation of in-lake nitrogen, phosphorus, chlorophyll-a, transparency, and other parameters. The global variables menu describes parameters consistent throughout the lake such as precipitation, evaporation, and atmospheric deposition. The segment data menu is used to describe lake morphometry, observed water quality, calibration factors, and internal loads in each segment of the lake/reservoir. The tributary data menu specifies nutrient loads to each segment using mean flow and concentration in the averaging period. The following sub-sections describe the development of the Hannen Lake BATHTUB model and report input parameters for each menu.

Model Selections.
BATHTUB includes several models for simulating in-lake nutrients and eutrophication response. For TP, TN, chlorophyll-a, and transparency, Models 1 and 2 are the most general formulations, based upon model testing results.

Table D-2 reports the models selected for each parameter used to simulate eutrophication response in Hannen Lake. Preference was given to Models 1 and 2 during evaluation of model performance and calibration. Final selection of model type was based on applicability to lake characteristics, availability of data, and agreement between predicted and observed data.

Table D-2. Model selections for Hannen Lake.

Parameter	Model No.	Model Description
Total Phosphorus	01	2^{nd} order*
Total Nitrogen	00	Not computed
Chlorophyll-a	02	P, Light, T *
Transparency	01	vs. Chl-a & Turbidity *
Longitudinal Dispersion	01	Fischer-Numeric *
Phosphorus Calibration	01	Decay rates *
Nitrogen Calibration	01	Decay rates *
Availability Factors	00	Ignore *

* Asterisks indicate BATHTUB defaults

Global Variables.
Global input data for Hannen Lake are reported in Table D-3. Global variables are independent of watershed hydrology or lake morphometry, but affect the water balance and nutrient cycling of the lake. The first global input is the averaging period. Both seasonal and annual averaging periods are appropriate, depending on site-specific

conditions. An annual averaging period was utilized to quantify existing loads and in-lake water quality, and to develop TMDL targets for Hannen Lake.

Table D-3. Global variables data for 2002-2009 simulation period.

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 year
Precipitation	35.82 in	0.91m
Evaporation	39.8 in	1.01 m
[1]Increase in Storage	0	0
[2]Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

[1]Change in lake volume from beginning to end of simulation period.
[2]From Anderson and Downing, 2006.

Segment Data.
Lake morphometry, observed water quality, calibration factors, and internal loads are all included in the segment data menu of the BATHTUB model. Separate inputs can be made for each segment of the lake or reservoir system that the user wishes to simulate. In lakes with simple morphometry and one primary tributary, simulation of the entire lake as one segment is often acceptable.

The BATHTUB model developed for Hannen Lake does not simulate dynamic conditions associated with storm events or even between individual growing seasons. Rather, the model predicts the water quality period of 2002-2009. Observed water quality data for the lake is included in Appendix C – Water Quality Data. Table D-4 lists BATHTUB segment inputs for segment 1.

Table D-4. Segment 1

Segment 1 Parameter	BATHTUB Input	Calibration Factor	CV
Surface Area (km2)	0.15	N/A	N/A
Mean Depth (m)	2.6	N/A	N/A
Length (km)	0.97	N/A	N/A
Mixed layer Depth (m)	2.6	N/A	0*
Non-Algal Turbity (1/m)	0.08	1*	0*
Total Phosphorus (ug/l)	127.2	1*	0
Chlorophyll-a (ug/l)	51.6	1*	0
Secchi Depth (m)	1.3	1.7	0
Internal Load P (mg/mg2-day)	1.05	N/A	0*

* Indicates Default

Tributary Data.
The empirical eutrophication relationships in the BATHTUB model are influenced by the global and segment parameters previously described, but are heavily driven by flow and nutrient loads from the contributing drainage area (watershed). Flow and nutrient loads

can be input to the BATHTUB model in a number of ways. Flow and nutrient loads used in the development of the Hannen Lake BATHTUB models utilize watershed hydrology and nutrient loads predicted using the STEPL model described in Appendix D. Output from STEPL includes annual average flow and nutrient loads. STEPL output requires conversion into forms compatible with BATHTUB. This includes units conversion and converting STEPL nutrient loads and flows. Tributary data are reported in table D-5.

Table D-5. Tributary inputs for BATHTUB.

Watershed	Area (ac)	Flow (hm3)	TP (ppb)
W1	589.2	0.55	424

D.7. Model Performance and Calibration

The Hannen Lake water quality model was calibrated by comparing simulated and observed local and regional data. The primary source of calibration data is the ambient lake monitoring data collected by Iowa State University (ISU) and the University of Iowa State Hygienic Laboratory (SHL) between 2002 and 2009. Calibration was an iterative process that involved running both the watershed model (STEPL) and in-lake model (BATHTUB), and refining model parameters to (1) produce simulated values that were within reasonable ranges, and (2) provide good agreement with observed water quality in Hannen Lake.

BATHTUB Calibration.
Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in hannen Lake from 2002 to 2009 in segment 1 of the BATHTUB model. Simulation of TP concentration was critical for TMDL development, as was chlorophyll-a and transparency predictions. Nitrogen constituents are less important because Hannen Lake is not nitrogen limited. Therefore, nitrogen simulations were not calibrated. The observed data was obtained as part of the ambient lake monitoring program, and is based on data reported in Appendix C. An internal load was used in the calibration to bring model TP output up to that observed in the ambient data.

BATHTUB Target Assessment.
After calibration the bathtub model was used to determine the water quality target. This was done by incrementally reducing loads of TP in both tributaries and internal loading until the desired Chl-a concentration of 27 mg/l was acheived for segment 1 resulting in a whole lake average. This was expressed as an annual load and then expressed as an average daily maximum via a statistical approach.

D.8. Calculating a Daily Expression for Phosphorus

As a result of the D.C. Circuit Court of Appeals decision in Friends of the Earth, Inc. v. EPA et al., No 05-5015 (D.C. Cir. 2006), EPA recommended all future TMDLs and associated load allocations and waste load allocations be expressed in terms of a daily time increment. Generally, TMDL analytical approaches that result in longer (non-daily) averaging periods may continue to be used to demonstrate consistency with applicable water quality criteria. However, all final TMDL submissions should include an adequate expression of daily loads in addition to any longer-term loading expression that may be developed as a result of the TMDL analysis (USEPA 2006a). In response to this ruling the EPA drafted a document "Options for Expressing Daily Loads in TMDLs" providing technical support and methods acceptable to EPA for calculating daily loads in given situations.

Establishing a total maximum daily load for Hannen Lake poses a unique challenge in that there are no permanently flowing tributaries directly feeding into the lake and all the water coming into the lake is either from overland flow or precipitation. Therefore, there is no existing flow data available for modeling this lake. The Options for Expressing Daily Loads in TMDLs document presents a similar case study in which a statistical approach is considered to be the best option for identifying a maximum daily load that corresponds to the allowable average load. The method calculates the daily maximum based on a long term average and considers variation. This method is represented by the equation:

$$MDL = LTA \times e^{[z\sigma - .05\sigma^2]}$$

Where:
MDL = maximum daily limit
LTA = long term average
z = z statistic of the probability of occurrence
$\sigma^2 = \ln(CV^2 + 1)$
CV = coefficient of variation

Table D-6 provides the multipliers and table D-7 summarizes the LTA to MDL calculation for Hannen Lake

Table D-6. Multipliers used to convert a LTA to an MDL.

Averaging Period (days)	Recurrence Interval	Z-score	Coefficient of Variation								
			0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
30	96.8%	1.849	1.41	1.89	2.39	2.87	3.30	3.67	3.99	4.26	4.48
60	98.4%	2.135	1.50	2.11	2.80	3.50	4.18	4.81	5.37	5.87	6.32
90	98.9%	2.291	1.54	2.24	3.05	3.91	4.76	5.57	6.32	7.00	7.62
120	99.2%	2.397	1.58	2.34	3.24	4.21	5.20	6.16	7.05	7.89	8.66
180	99.4%	2.541	1.62	2.47	3.51	4.66	5.87	7.06	8.20	9.29	10.3
210	99.5%	2.594	1.64	2.52	3.61	4.84	6.13	7.42	8.67	9.86	11.0
365	99.7%	2.778	1.70	2.71	4.00	5.51	7.15	8.83	10.5	12.1	13.7

Table D-7. Summary of LTA to MDL calculation for the TMDL.

Parameter	Value	Description

LTA	0.38 lbs/day	Annual Average
Z Statistic	2.778	Based on 365-day averaging period
CV	0.6	Used CV from annual TP loads
σ^2	0.31	ln (CV^2 + 1)
MDL	**1.51 lbs/day**	**TMDL expressed as daily load**

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (1.36 lbs-TP/day)
+ MOS (0.15, explicit 10 percent) = **1.51 lbs-TP/day**

For Hannen Lake, a long term load of 137 (LA+MOS) lbs per year is needed to reach the desired TSI(Chl-a) of 63 and lead to reductions in algal blooms and high pH violations. The z statistic of probability of occurrence used for this TMDL is based on an averaging period of 365 days resulting in a z-score of 2.778

Appendix E--- Public Comments

No public comments were received during the 30 day public comment period.