DITCH 20 WETLAND RESTORATION FEASIBILITY STUDY TO BENEFIT DOWNSTREAM WATER QUALITY

A summary-length version of this report is also available

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Summary

This feasibility study identified and evaluated projects that will reduce phosphorus export from lands adjacent to Ditch 20, thereby benefitting water quality in downstream impaired waterbodies including Typo Lake, Martin Lake, the Sunrise River, and the St. Croix River. A number of projects were explored in-depth, and ultimately narrowed to a list of four projects which were feasible and supported by landowners. Concept designs and cost estimates were developed, and projects were ranked by cost effectiveness relative to phosphorus reduction. This report discusses elements related to the feasibility of these projects and serves as a resource for local water planners responsible for project implementation. Those planners will need to consider the science and financial considerations presented herein, as well as other technical, social, and political factors.

Ditch 20 lies in southeastern Isanti County, Minnesota (Figure 1). County Ditch 20 and 13 join and become Data Creek. Data Creek flows into Typo Lake, which in turn flows to Martin Lake. Ultimately, these waters flow to the Sunrise River and St. Croix River.

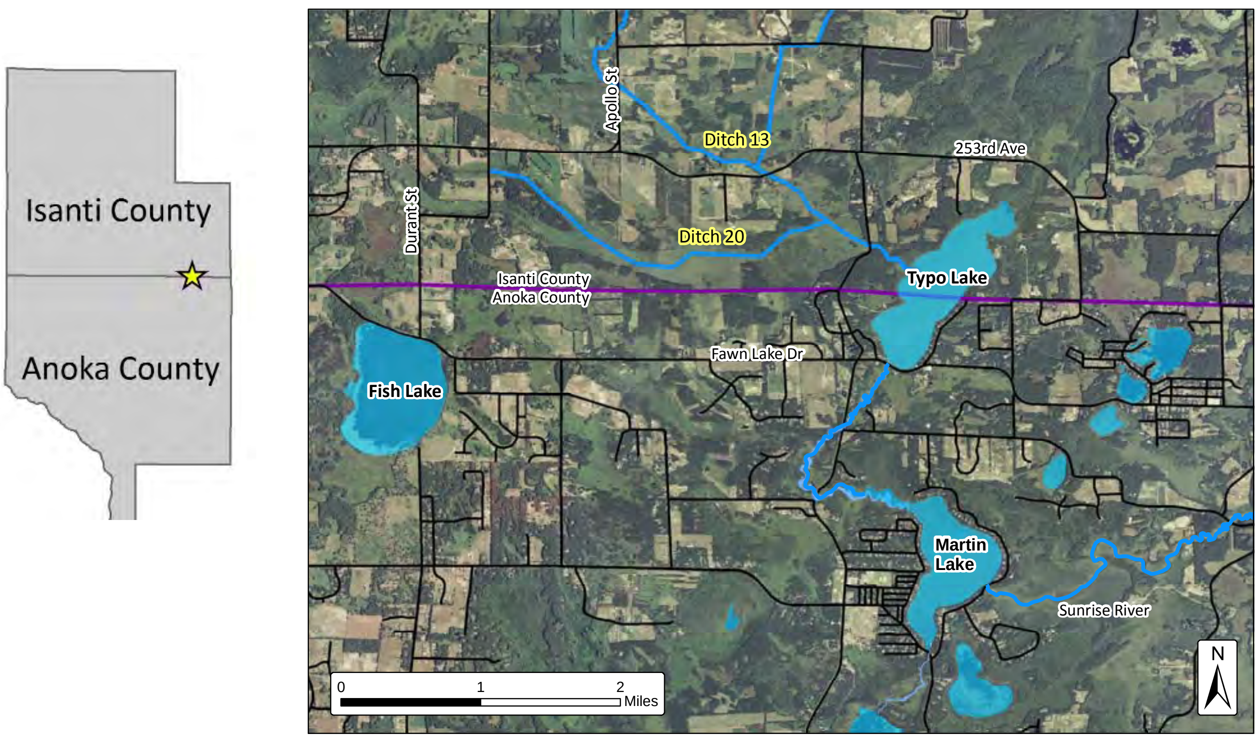


FIGURE 1 FEASIBILITY STUDY LOCATION

Many of the waterways in this system are "impaired" – not meeting state water quality standards for nutrients, pH, turbidity and related factors. In Total Maximum Daily Load (TMDL) studies for Martin and Typo Lakes, Ditch 20 was identified as a significant contributor of phosphorus to these impaired waters. Phosphorus is the pollutant driving most impairments in these waters.

Ditch 20, and its lateral ditches, serve as a pathway for export of phosphorus from adjacent peatlands. Peat soils are phosphorus rich. That phosphorus can be mobilized several ways. First, the ditches create alternating conditions of drying and rewetting in the surrounding peatlands. During dry periods, wetland soils are oxidized and aerobic decomposition of soil organic matter increases, which increases the potential for those soils to release phosphorus. When the water table rises, that phosphorus can be transported to the ditch via subsurface flow. Second, long periods with saturated conditions can create anoxic conditions in the peat. These low oxygen conditions result in iron being reduced from its ferric to ferrous form. The ferric form holds phosphorus; the ferrous form releases it. The relative magnitude of these phosphorus mobilization methods is unknown, but both appear to occur. Strategies to improve water quality should include reducing the drainage scope and effect of the ditch which exports this phosphorus, while capturing some of the mobile phosphorus already in the waterway.

A XPSWMM hydrologic model of the Ditch 20 drainage area was created to evaluate a variety of possible water quality improvement projects. The model included a network of flow paths, structures (e.g. culverts), and land uses. The model was calibrated to field-collected flow and water quality measurements.

A number of water quality improvement projects were identified and ultimately narrowed to a list of four project that included lateral ditch plugs, ditch channel weirs and settling ponds. These projects appeared feasible and had landowner support. The first two would restore wetland hydrology to portions of the drained area. The third, settling ponds, would be aimed at capturing the approximately 50% of phosphorus attached to particles (i.e. particulate phosphorus).

These four possible water quality improvement projects were added to the XP-SWMM model and manipulated to determine appropriate sizing and placement. Because both hydrologic and water quality parameters were required for this study, the XPSWMM model was paired with a P8 water quality model and literature research to estimate phosphorus reductions.

Costs of each project were estimated. Total project costs included construction, operations and maintenance for the life of the project. Cost allowances were also provided for legal and design work.

Concept designs for modeled projects were developed by an engineer are provided in Appendix A. The placement and sizing of the projects optimizes their performance and keeps most hydrologic impacts on one property where the landowner is supportive. Final designs would be needed before construction. Recommended project locations and cost-effectiveness rankings those projects are presented in Figure 2 and Table 1.

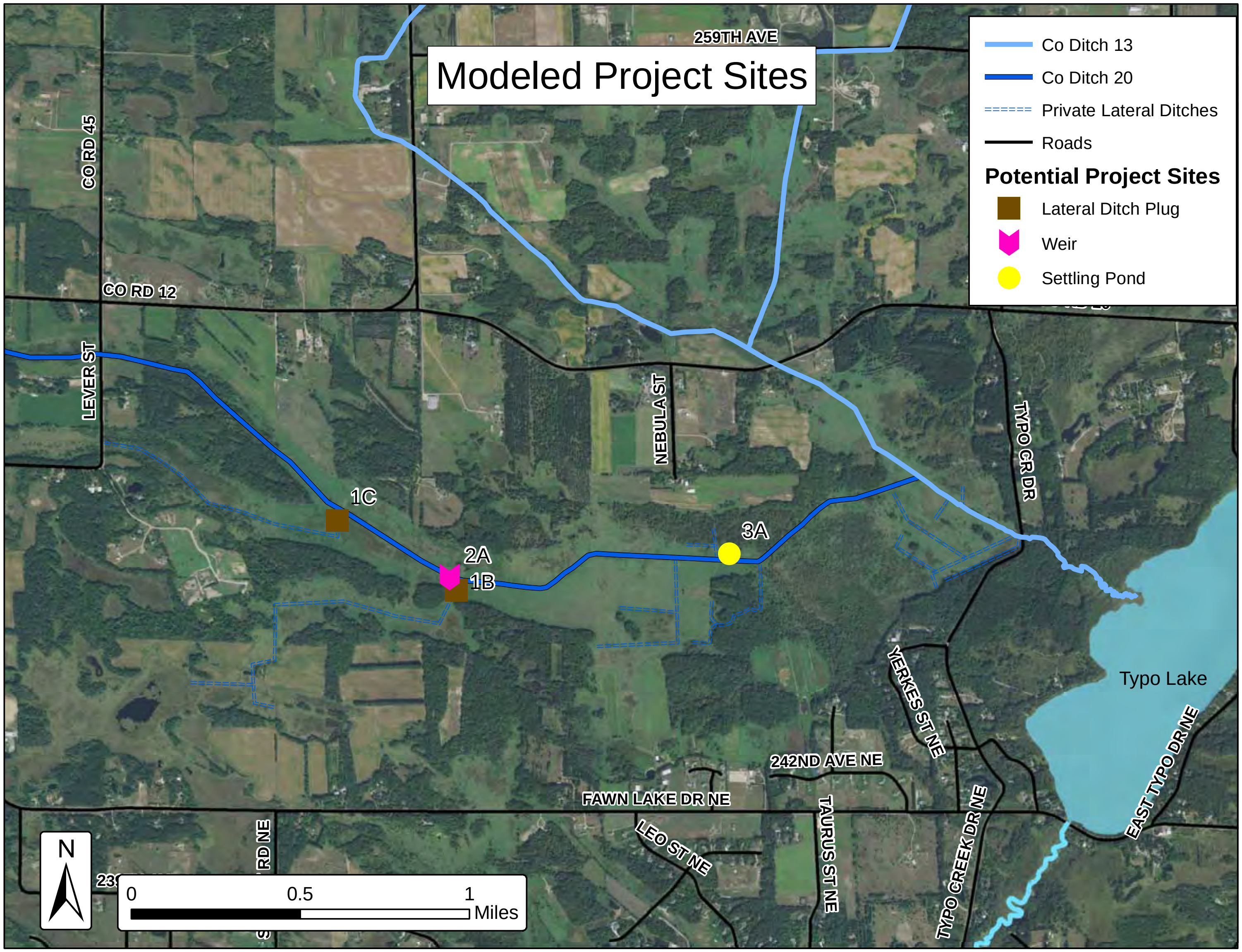


FIGURE 2 MODELED WATER QUALITY IMPROVEMENT PROJECT LOCATIONS

TABLE 1 – COST-EFFECTIVENESS ANALYSIS OF DITCH 20 MODELED WATER QUALITY PROJECTS

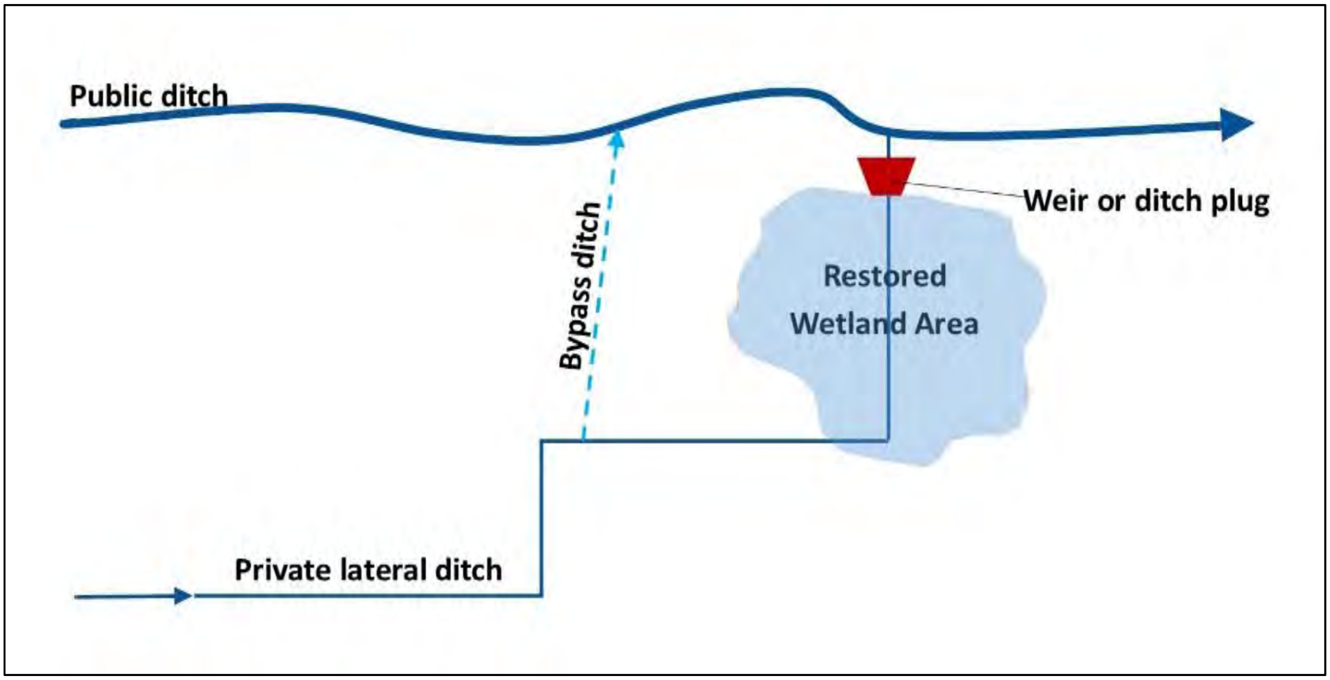
The blue shaded column indicates cost per pound of total phosphorus (TP) reduction. Where applicable, projects are listed with and without an optional bypass ditch that maintains upstream drainage. Costs below $500/lb of TP are most favorable. When selecting projects to construct, political, social, legal, and scientific uncertainties must be considered.

				Estimated Costs						
Project ID	Project	Desciption	TP reduction (lbs/yr)	Construction	Final Design/ Engineering	Legal (easements, permitting, etc)	Maintenance (over 30 yrs)	Total Cost Including 30 Years of Maintenance	Est Cost per lb-TP Removed over 30-yr lifespan	Certainty of TP Reduction Outcomes
2A-no bypass	Weir - WITHOUT Bypass Ditch	Weir in public ditch, maintaining higher water in 21.55 acres.	114.57	$20,174	$2,017	$13,000	$15,200	$50,391	**$14.66**	Low-Mod
1B-no bypass	Lateral Ditch Plug - WITHOUT Bypass Ditch	Plug private lateral ditch restoring 10.86 ac of wetland.	103.62	$18,806	$1,881	$13,000	$15,200	$48,887	**$15.73**	Low-Mod
1C-no bypass	Lateral Ditch Plug - WITHOUT Bypass Ditch	Plug private lateral ditch restoring 7.72 ac of wetland.	86.96	$18,806	$1,881	$13,000	$15,200	$48,887	**$18.74**	Low-Mod
1B-with bypass	Lateral Ditch Plug - WITH Bypass Ditch	Plug private lateral ditch restoring 10.86 ac of wetland. Upstream drainage maintained with new bypass ditch.	103.62	$43,366	$4,337	$13,000	$15,200	$75,903	**$24.42**	Low*
1C-with bypass	Lateral Ditch Plug - WITH Bypass Ditch	Plug private lateral ditch restoring 7.72 ac of wetland. Upstream drainage maintained with new bypass ditch.	86.96	$39,726	$3,973	$13,000	$15,200	$71,899	**$27.56**	Low*
2A-with bypass	Weir - WITH Bypass Ditch	Weir in public ditch, maintaining higher water in 21.55 acres. Upstream drainage maintained withnew bypass ditch.	114.57	$93,674	$9,367	$13,000	$15,200	$131,241	**$38.18**	Low*
3A	Settling Pond	6.5' deep, 1.31 acre settling pond on private property that is in-line with the public ditch and does not affect flows or water levels.	117.58	$126,952	$12,695	$21,000	$52,400	$213,047	**$60.40**	Moderate

* Pollutant reduction estimates assume entire upstream drainage is treated by the proposed project. Bypass ditches would result in a lesser area being treated. Bypass ditches may also result in additional drainage, depending on depth dug, counteracting some phosphorus reductions acheived by the project.

The lateral ditch blocks and ditch weir are considered with and without bypass ditches. Bypass ditches are an option to maintain upstream drainage. If, during final design, a project is found to have drainage impacts on upstream properties that want their drainage maintained, a bypass ditch could alleviate that concern. Figure 3 shows a bypass ditch concept wherein a new ditch is dug around the restored wetland created by a ditch plug or weir. An implication is that the restored wetland would no longer treat all upstream water, and therefore pollutant reduction estimates would likely be reduced. Also, poorer nutrient removals by the project are likely if the bypass ditch is dug to the original ditch depth, resulting in greater drainage in areas near the bypass ditch that offsets pollutant reductions achieved by the restored wetland.

FIGURE 3 CONCEPTUAL DEPICTION OF A BYPASS DITCH FOR LATERAL DITCH PLUG OR WEIR PROJECTS
The bypass ditch ensures continued upstream drainage while allowing restoration of wetland hydrology, but may increase phosphorus loading.



Aside from cost effectiveness of these projects, watershed managers should consider the uncertainty of phosphorus reduction and the range of possible costs before installations. As previously noted, if bypass ditches are required they may reduce actual phosphorus reductions achieved. Furthermore, lateral ditch plug and ditch weir projects are known to have wide ranges of actual pollutant reductions. Some such projects elsewhere have actually caused phosphorus export increases due to more continuously wet anoxic conditions. While the pollutant reductions in this report are best estimates, there is substantial risk that these projects will achieve lesser benefits, and could even result in phosphorus increases.

All of the projects have substantial hurdles to cross before construction. Legal steps needed include wetland permitting, procedures required under State ditch law, and access easements to the project sites. Securing an entity to take long term maintenance responsibility may be challenge. Construction may experience difficulties associated with work at remote and wet sites.

Watershed managers also need to consider recent water quality results. Recent monitoring has found lower phosphorus levels in the ditch relative to historic monitoring in the early 2000's. There have been no notable land use or other changes in the contributing drainage area that can easily explain this improvement in water quality. This observation may make projects at Ditch 20 a lower priority. Future monitoring may be warranted to periodically check for the return of decreased water quality.

Wetland banking may be good way to approach the lateral ditch plug and weir projects in light of the regulatory and construction challenges, pollution reduction uncertainties and recent water monitoring results. Wetland banking is the creation/restoration of wetlands, the credits for which may be sold to others who negatively impacts wetlands under State wetland law, thereby resulting in a no-net-loss of wetlands statewide. The Minnesota Board of Water and Soil Resources (BWSR) offers landowners with several options for restoring wetlands on their property and receiving payment for those wetland credits. Approaching the ditch plugs and weirs in this report as wetland restorations with secondary water quality benefits would provide a financing option and technical assistance from experts BWSR.

Regardless of whether any of the projects are installed, maintenance cleaning of Ditch 20 and its associated lateral ditches should be avoided. Over time, these ditches have filled with sediment, plants, and other debris that has reduced their drainage scope and effect. If these ditches are cleaned in a way that increases their drainage scope and effect, it would likely have a strong negative effect on the water quality of downstream impaired lakes, streams and rivers by increasing phosphorus export.

Location and Watershed History

Ditch 20 is located along the Anoka and Isanti County boundary (Figure 1), and its contributing drainage area spans both counties (Figure 6). Ditch 20 and its adjacent peatland floodplain are the primary target for this study. The area of interest has low relief (Figure 4, Figure 5) and has a watershed of roughly 2,000 acres (Figure 6). The area is dominated by peat soils. It includes some public properties but is predominantly private properties (Figure 7).

Ditch 20 is a relatively small ditch, roughly five feet wide, with water depths typically 1-3 feet deep. Following modest storms, the change in ditch water levels was small, primarily because land uses in the watershed generate little runoff. The area near the ditch was historically used for agricultural production but now has little active farming. Land use in the watershed is primarily residential and forested/wetland with some recreational activities occurring, such as hunting and smaller agricultural operations.

Ditch 20 is a tributary, along with Ditch 13 (see Figure 1), of Data Creek, which drains to Typo Lake and accounts for approximately 70-75% of the water budget of the lake (Schurbon 2012). Typo Lake is 280 acres in size and has a maximum depth of six feet. It has highly degraded water quality with excess amounts of phosphorus and algae. Martin Lake, just downstream of Typo Lake also has poor water quality. Both of these lakes, the stream connecting them, and the downstream waters of the Sunrise and St. Croix Rivers are all listed as "impaired" by the Minnesota Pollution Control Agency. Recent TMDL studies have found Ditch 20 exports large amounts of phosphorus and solids to Typo Lake (Schurbon 2012).

The Ditch 20 watershed has changed dramatically from pre-European settlement conditions. The 1849 land survey shows the area as a “tamarack swamp.” However, the first aerial photographs available (1938) show few trees, active haying and a network of ditches. By the 1960’s and through today, conditions in the watershed have transitioned away from haying and agriculture to seemingly benign land uses from a water quality standpoint. Current conditions show that approximately 1/3 of the land in the watershed is cultivated. However, very little land within 500 feet of the ditch is farmed for row crops. Much of the farmed land is hayed, which requires little fertilizer or tillage. Largely, the subwatershed has natural grassland and forests as cover, with scattered homes.

The most notable landscape change to this area is ditching. Most ditching occurred between 1900 and 1910. The official profile maps of Ditch 20, stored by Isanti County, are dated 1916. Additional private lateral ditches were dug as late as the 1950’s, according to current landowners. These ditches allowed agriculture in otherwise saturated peatlands, but remaining wet conditions were likely challenging for regular access and farming.

Figure 4 Photos From the Ditch 20 Vicinity

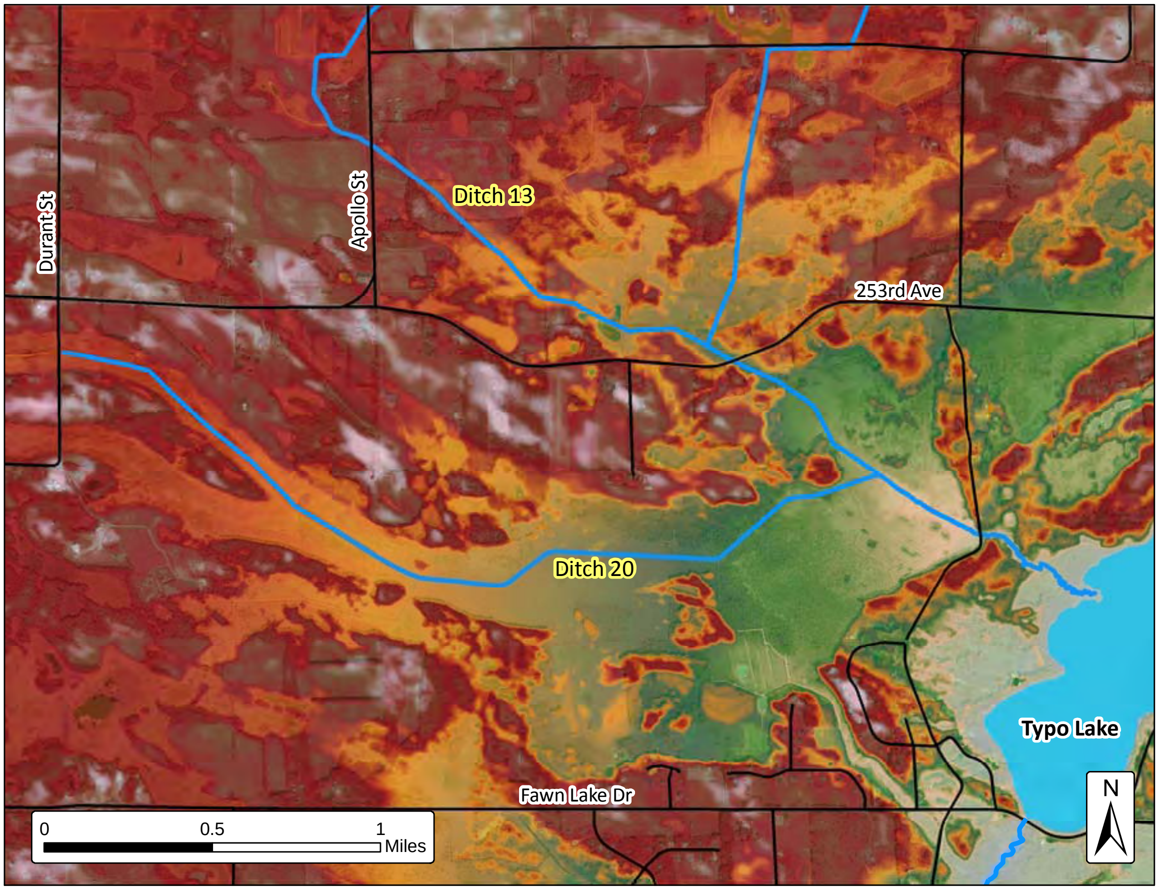


FIGURE 5 LIDAR LAND ELEVATIONS COLORIZED DEPICTION

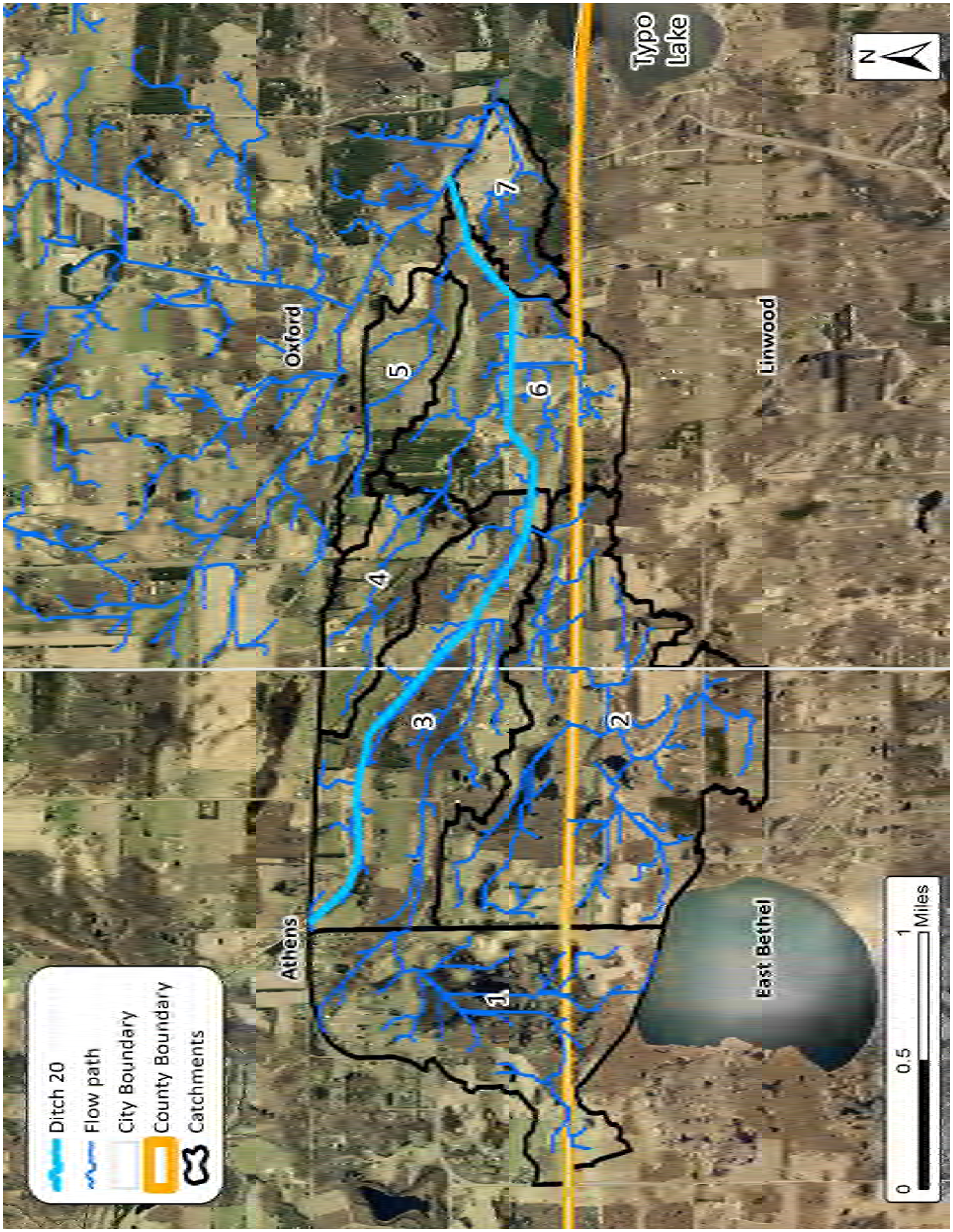


FIGURE 6 FLOW PATHS OF DITCH 20

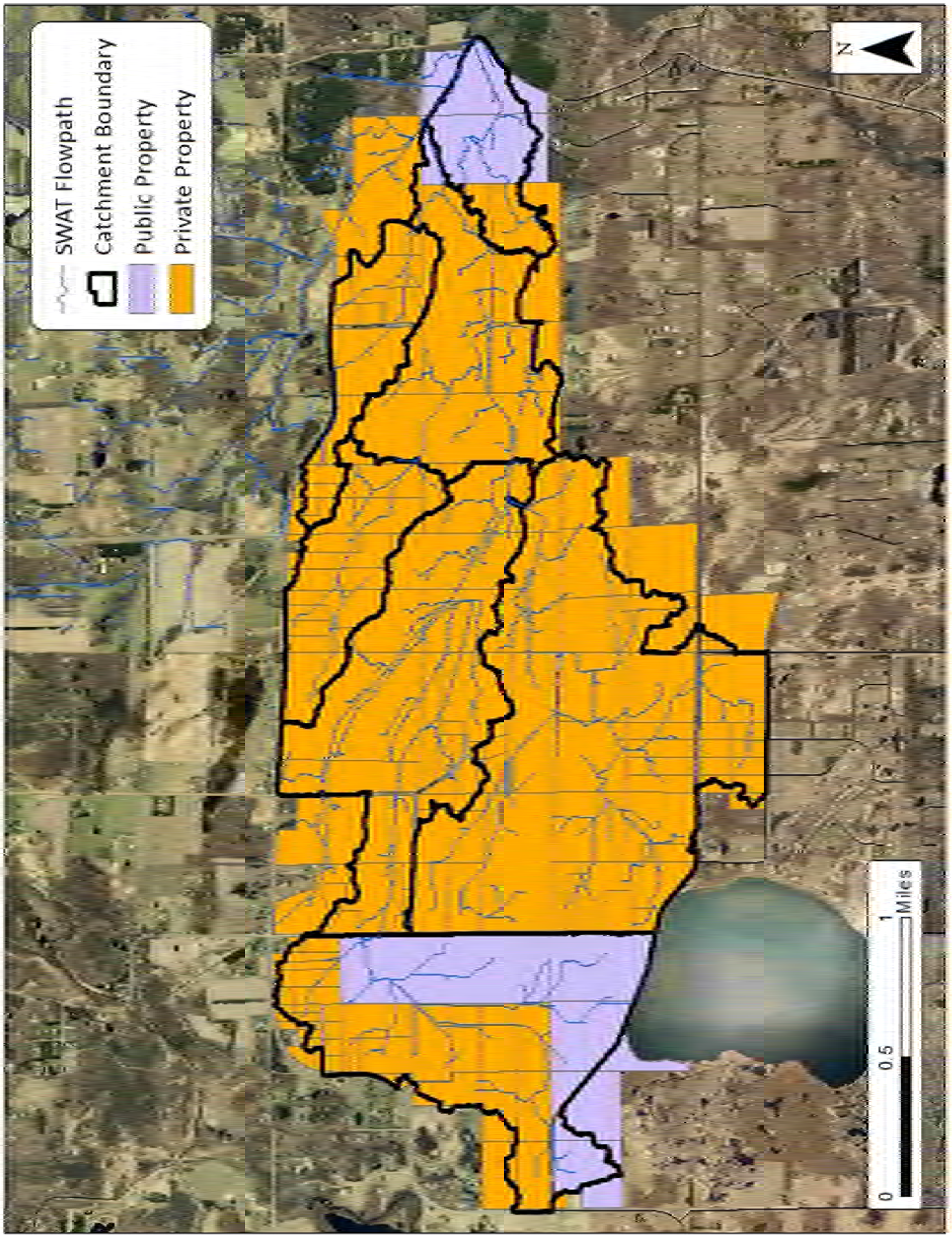


FIGURE 7 PRIVATE AND PUBLIC PARCELS IN THE DITCH 20 WATERSHED

History of Study

Monitoring and study of Ditch 20 began in 2001 by the Anoka Conservation District and Sunrise River Watershed Management Organization. The purpose of study at that time was to identify sources of phosphorus to Typo Lake and downstream waterbodies. Monitoring occurred again in 2003 and 2007. High phosphorus levels were observed.

The high phosphorus in this seemingly benign landscape were surprising. Mechanisms of phosphorus export from Ditch 20 were studied over the course of six years. This included sampling during a variety of climatological conditions, upstream-to-downstream testing and soil testing. Multiple mechanisms were identified that contribute to the increased phosphorus export, including aerobic decomposition of peat soils, periodic re-wetting, effective drainage of soil water and bank sloughing. This monitoring and research is reported in the 2007 Water Almanac from the Anoka Conservation District (see www.AnokaSWCD.org), and is summarized below.

The root cause of the phosphorus export from the wetland soils is ditching though peat soils. Historically, these wetlands were likely a more closed system, perhaps with a dispersed or small drainage channels. In this condition, phosphorus was relatively trapped within the wetlands. Ditching through those wetlands opened a path for phosphorus export to downstream waterbodies and made the area more prone to drying and rewetting.

In order to move toward installation water quality improvement projects, a feasibility study of possible project types was needed. The Anoka Conservation District secured a 2015 Clean Water Land and Legacy Grant from the MN Board of Water and Soil Resources. That grant funded the study reported in this document.

Water Monitoring

Between 2001 and 2017 a variety of water monitoring was conducted throughout the Ditch 20 system to understand water quality and inform the models used in this feasibility study (Figure 8). This monitoring included grab samples for water quality analyses, stream water level tracking, stream flow measurements, continuous tracking of water levels in nearby surficial groundwater and soil nutrient testing.

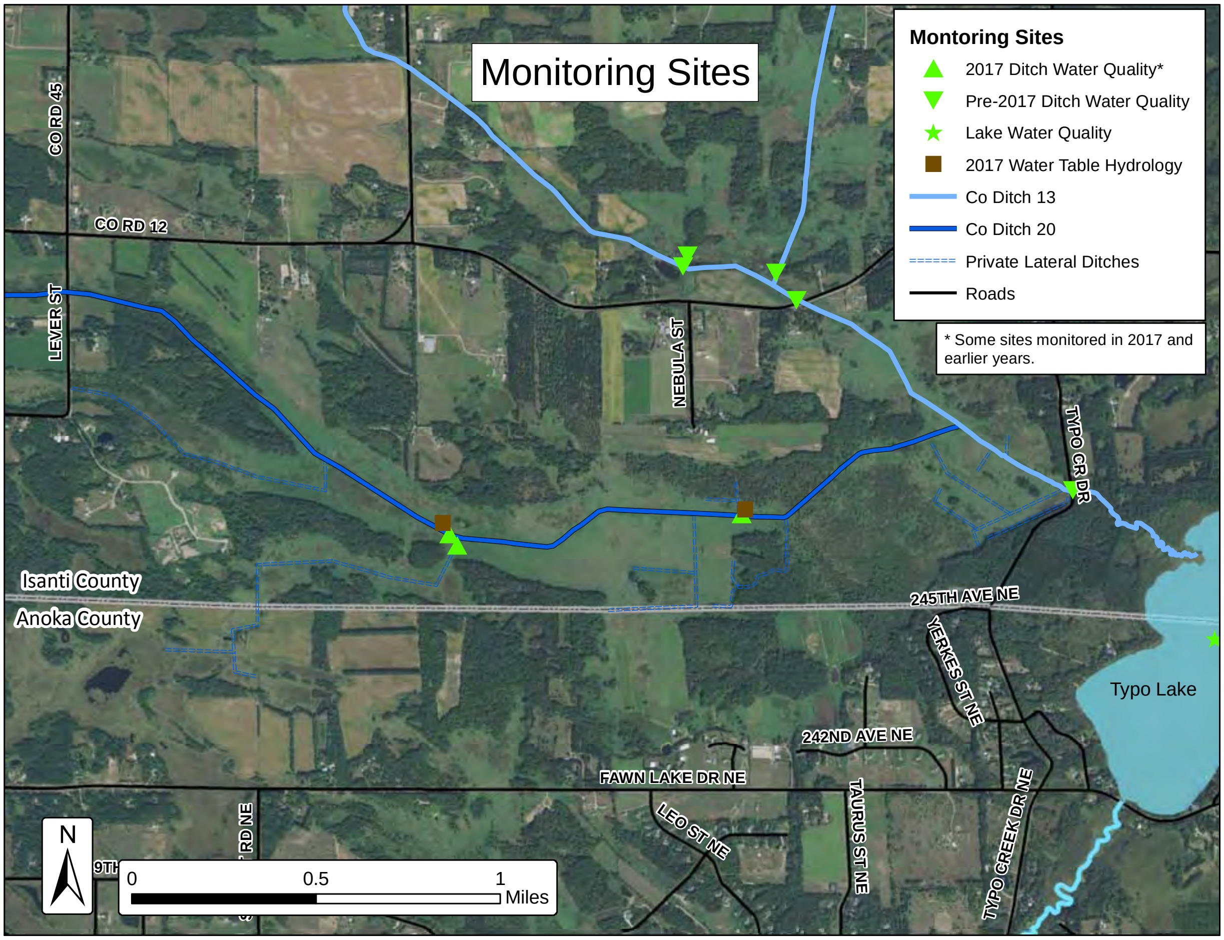


FIGURE 8 MAP OF DITCH 20 WATER MONITORING SITES

The earliest water quality monitoring in 2001 found phosphorus levels in Ditch 20 were as much as 7 times higher than today's phosphorus standard for streams (Figure 9). This is unusual, given that the landscape contains few typical pollutant sources such as urbanization or agriculture. Instead, Ditch 20 is in the middle of wide lowlands with peat soils and natural habitats. These observations prompted additional monitoring.

Over time, water quality monitoring has found progressively lower phosphorus levels in Ditch 20 (Figure 9). Most recently, in 2017, phosphorus levels are near the state water quality standard for stream of 100 µg/L. It is unknown why water quality has improved. These observations may mean that Ditch 20 is now a lower priority for watershed managers.

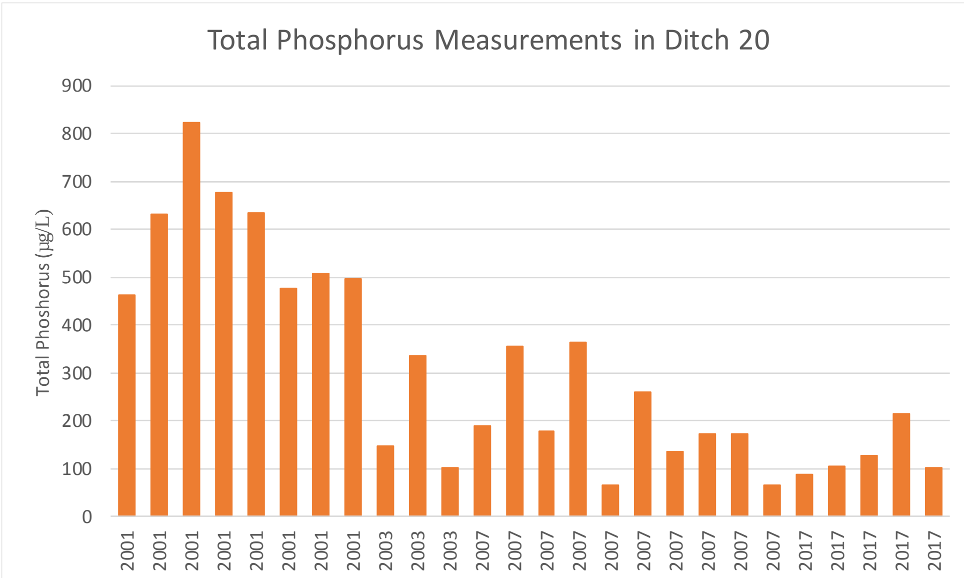


FIGURE 9 TIME SERIES OF TOTAL PHOSPHORUS (P) MEASUREMENT IN DITCH 20
All measurements are from the farthest downstream monitored location on Ditch 20, just upstream of the confluence with Ditch 13 (see Figure 8).

To begin to identify phosphorus hotspots (reaches of the stream where phosphorus increases most) we did upstream-to-downstream testing in 2017 at three locations (Figure 8). We found that neither dissolved nor total phosphorus increased among these sites (Figure 10). Phosphorus appears to be from dispersed sources.

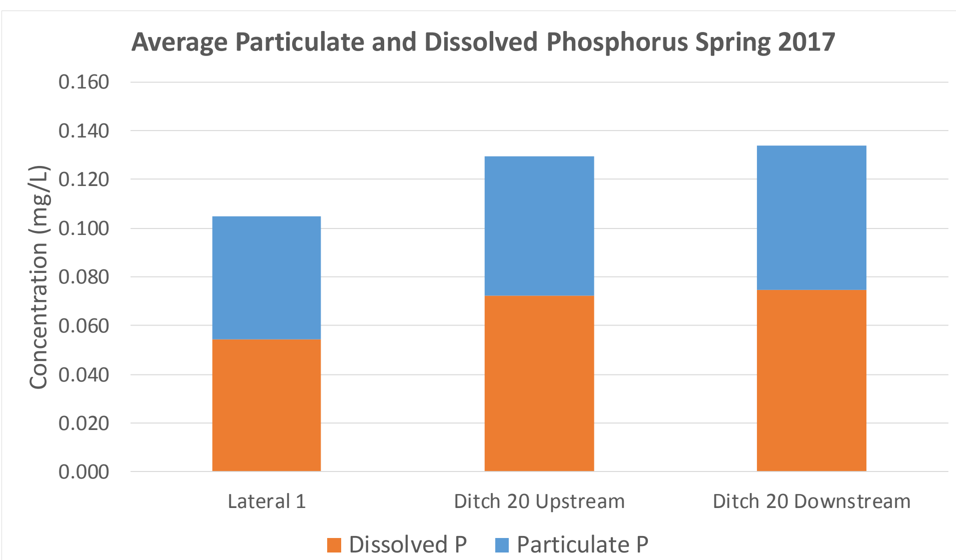


FIGURE 10 PHOSPHORUS LEVELS IN 2017 AT UPSTREAM AND DOWNSTREAM SITES ON DITCH 20
The upstream site is the location of the 2A possible project site (see Figure 8). The downstream site is at the 3A possible project site. The lateral ditch sampled enters Ditch 20 at the 2A location.

The relative amounts of dissolved and particulate phosphorus were measured in 2017 (Figure 10). We found that approximately half of the total phosphorus was dissolved and half was particulate. While one might suspect that particulate phosphorus is from eroding soils, this is not always the case. In situations where phosphorus is made mobile by anoxic conditions in peat soils the particulate phosphorus fraction has been observed at 40-45% (Kjaergaard et al. 2012).

Hydrological monitoring has occurred in Ditch 20 in multiple years. Most recently and pertinent for this report, four flow measurements were taken at two Ditch 20 main stem sites in 2017 (Figure 8). The purpose of these measurements was to understand the range of flows experienced and calibrate the XP-SWMM model. At the upstream site flows ranged from 1.21 cubic feet per second (cfs) to 7.54 cfs. At the downstream site flows ranged from 3.05 to 15.47 cfs, and were about twice that of the upstream site during moderate to lower flows.

In 2017 the shallow water table was monitored at two locations (see Figure 8). Perforated 40-inch long wells were placed 80-90 feet north of the ditch (Figure 13). Each included a water level data logger (Remote Data Systems model WL-40). Water levels were recorded every 4 hours (Figure 11). Equipment malfunctions caused loss of data in mid-summer. In available data we observed that, at least in 2017, the water table was often 15 inches below the ground surface, but was as low as nearly 25 inches below the surface and was above ground level following a 4”+ rainfall in early October. Overall, it appears that hydrology is near the criteria for classification as a wetland under the MN Wetland Conservation Act.

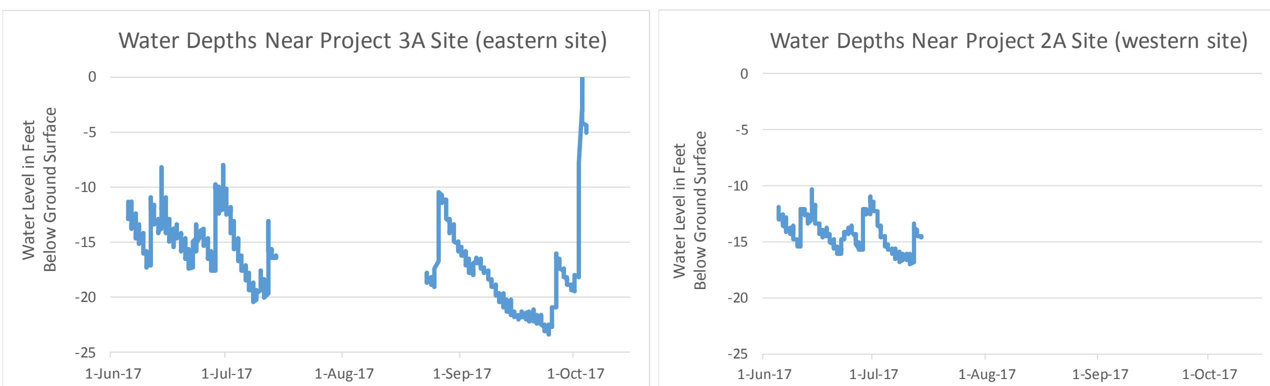


FIGURE 11 WATER TABLE MONITORING RESULTS

We collected soil samples from a depth of 12 inches in 2017 and had them analyzed by a State-approved laboratory. Samples were taken at the two locations where water table monitoring occurred (Figure 8). One sample was taken on the north and one on the south side of the ditch for a total of four samples. As received, the soils had phosphorus of 249 and 262 mg/Kg at the west site and 529.7 and 564.6 mg/Kg at the east site. By comparison, the dried soil results were 1290 and 1480 mg/Kg for the west site and 2602 and 3134 mg/Kg for the east site. The percent iron varied from <1% to 8% amongst the samples.

In 2001 additional soil tests were conducted. These tests were also on samples from a depth of 12 inches, but were only at the eastern water table hydrology monitoring site (Figure 8). Samples were collected from two transects – one north and one south of the ditch. Samples were taken 150, 100 and 50 feet from the ditch, and also adjacent to the ditch. Total phosphorus saturation extraction tests were conducted by a State-approved laboratory. This test involves saturating the soil and measuring phosphorus levels in the resulting water. Total phosphorus extracted increased with proximity to the ditch (). This could indicate soluble phosphorus moving by subsurface flows toward the ditch.

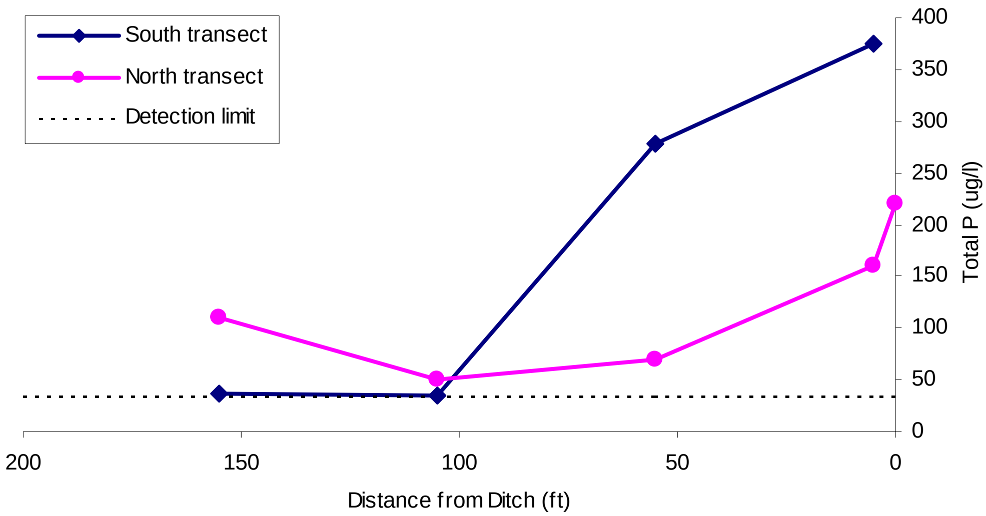


FIGURE 12 RESULTS OF SOIL TOTAL PHOSPHORUS EXTRACTS AT DITCH 20

Additional detailed reporting of water monitoring is in 2001, 2007 and 2017 Anoka County Water Almanacs available from the Anoka Conservation District (www.AnokaSWCD.org).

Understanding of Phosphorus Sources

To understand phosphorus sources to Ditch 20, the Anoka Conservation District and its consultant conducted a literature review, consulted with experts at the University of Minnesota, reviewed of historic aerial photos and used monitoring data. Few possible sources exist that can explain the high phosphorus concentrations observed in the early 2000's. Ditched peat soils appear to be the primary phosphorus source to Ditch 20. There are several mechanisms by which soil phosphorus might be mobilized into the ditch, and it appears that several may be occurring, depending upon conditions.

Land uses and surface runoff that are often primary phosphorus sources are largely absent in the Ditch 20 subwatershed. The area near the ditch was historically used for agricultural production but now has little active farming. There are few impervious surfaces. Stormwater drainage conveyances are nearly entirely absent. Land use is primarily residential and forested/wetland with some recreational activities occurring, such as hunting and smaller agricultural operations. Following modest storms, the change in ditch water levels was hardly noticeable, primarily because land uses in the watershed generate little runoff.

Monitoring data supported the theory that discrete land uses were not responsible for most phosphorus export. Monitoring in upstream and downstream areas indicated phosphorus sources were diffuse. Monitoring of a lateral ditch downstream from the only feedlot in the subwatershed did not find elevated phosphorus or *E. coli* bacteria. It appears that land uses are not the source of most phosphorus.

The Ditch 20 drainage area is dominated by peat soil, which can be a phosphorus source (Figure 13). Peat has much higher phosphorus levels than other soils because it is mainly plant material in various states of decomposition (Kjaergaard 2012). Peat soils are not able to hold phosphorus as tightly as it can be held in soils with higher mineral content (Kjaergaard 2012).

The phosphorus in peat soils can become mobile in at least two ways. The first is during alternating drying and wetting periods (Koltz and Lin 2001; Turner and Haygarth 2001), which were found to occur in the study area. During dry periods aerobic decomposition of the soils occur, which is faster than anaerobic decomposition. Decomposition results in some phosphorus becoming mobile and rewetting moves the phosphorus through the soil profile. Also, when the soil dries or freezes, microbes may experience osmotic shock, which often results in the release of phosphorus, mostly in the organic form. Rewetting of the dried or frozen soils moves this phosphorus as well. This phosphorus moves to the ditch by subsurface flow and the release peak is often three to four days after the rewetting event (Koltz and Lin 2001; Turner and Haybarth 2001).

The second circumstances that can release phosphorus from peat is continuously wet conditions (Ardón et al 2010; Fisher and Acreman 2004). Under continuously saturated conditions iron, to which phosphorus binds, is changed from its ferric to its ferrous (reduced) form. This form cannot hold phosphorus as tightly. While one might suspect that phosphorus released in this manner would be primarily dissolved, this is not always the case. In situations where phosphorus is made mobile by anoxic conditions in peat soils the particulate phosphorus fraction has been observed at 40-45% (Kjaergaard et al. 2012). The particulate phosphorus fraction in Ditch 20 was approximately 50%.

FIGURE 13 FOUR FT DEEP SOIL BORING AT DITCH 20 ILLUSTRATING THE DOMINANCE OF PEAT SOILS

A review of the monitoring data found that Ditch 20 total phosphorus partially supports the theory that reducing conditions (continuously wet) were driving phosphorus mobilization. The highest observed total phosphorus were in spring 2001, which was exceptionally wet. During drought conditions in 2007, total phosphorus was much lower. However, there is no apparent correlation between water level in the ditch and observed total phosphorus (Figure 14). Longer term moisture conditions may be more important than water level in the ditch on an individual sampling day.

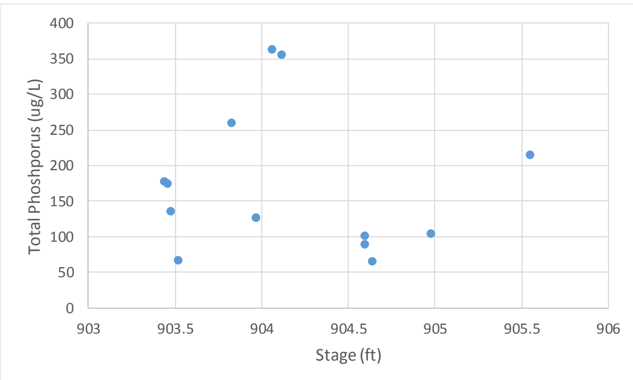


FIGURE 14 TOTAL PHOSPHORUS VS DITCH 20 WATER STAGE IN 2007 AND 2017
Measurements are from the easternmost (farthest downstream) monitoring site on Ditch 20 (see Figure 8).

The theory that drying and rewetting of ditched peatland soils were a primary source of phosphorus was explored in 2007. Water monitoring occurred during dry, storm and post storm rewetting conditions. If the soils were releasing large amounts of phosphorus due to decomposition or osmotic shock of microbes during dry conditions and that phosphorus was mobilized during the return of wet conditions, we expected to find the highest phosphorus a few days after storms. The results were mixed, and while these mechanisms may be at work it was clear that other mechanisms were also important.

During 2007 and 2017 the phosphorus form was tested in order to give further insight into alternating drying and rewetting as a driver of phosphorus export. Total phosphorus, dissolved phosphorus and ortho-phosphorus were simultaneously measured. If alternating drying and rewetting is driving phosphorus release from the peat soils in the area, then literature indicates that most of the phosphorus present should be dissolved phosphorus (Turner and Haygarth 2001). These tests found that 65-74% of the phosphorus was attached to particles and 26%-35% was dissolved phosphorus. In 2017 dissolved and particulate forms were approximately evenly split. Dissolved phosphorus was the lowest during rewetting periods, and higher during dry conditions. While drying and rewetting may play a role, other phosphorus release mechanisms appear to be at work too.

So, while the mechanisms by which peat soils may be exporting phosphorus are not well understood it appears that much of the Ditch 20 phosphorus is from ditched peatland soils through multiple mechanisms. It may be that both continuously wet and alternating dry/wet conditions contribute to phosphorus mobilization. However, because phosphorus is abundant in peat soils (described as seemingly “unlimited” by Kjaergaard 2012), the management strategy of trying to lock up or capture all the phosphorus is impractical. A likely better strategy is to focus on reducing the drainage scope and effect of the ditch which exports this phosphorus, along with practices that capture some of the phosphorus that will inevitably still reach the ditch.

Based on this understanding, this study sought to identify practices that will reduce the area drained by ditches, dampen water level fluctuations and capture particulate phosphorus. We recognize that if wetland hydrology is restored, phosphorus release may actually increase for a short period (a few years) due to continuously wet conditions (Kjaergaard 2012). Selection of projects for construction must consider long term water quality reductions, odds of underperformance, secondary benefits like wildlife habitat, social and political factors.

Watershed Modeling

A XPSWMM hydrologic model of the Ditch 20 drainage was created to evaluate the impact of possible projects (Figure 15). The model includes a network of flow paths and drainage areas delineated with a Soil and Water Assessment Tool (SWAT) model, structures like culverts, and land uses. It also includes LiDAR elevation data (Figure 5). This model was calibrated to field-collected flow and water quality measurements. Possible projects were added to the model and manipulated to determine appropriate sizing and placement.

Using local climatological data, we ran the model for a variety of storm event sizes. After ensuring the model acceptably matched field observed conditions, we added possible water quality improvement projects to the model. The hydrological impacts, such as increased area of ponded water, from each possible water quality project were estimated through this process. In this way we could examine the extent of hydrologic impacts, and vary the size or design of projects such that impacts would remain on properties with willing landowners. The concept designs in Appendix A depict these areas of hydrologic impact.

We estimated water quality benefits of each potential project using the XP-SWMM model, a P8 model and primary literature research. XP-SWMM is primarily a hydrologic model. Its results can be paired with a P8 model that estimates water quality benefits for certain types of projects such as settling ponds. For ditch plugs and weirs to restore wetland hydrology, a strong model does not exist to estimate phosphorus reductions. In those cases we used primary literature to estimate likely nutrient reductions and gain a sense of the nutrient reduction variability that other similar projects have experienced. All modeling for this project was done by Civil Methods, Inc.

FIGURE 15 XP-SWMM MODEL OF DITCH 20 SHOWING REACHES AND NODES

Stakeholder and Landowner Outreach

Because cooperation from a number of partners is critical for installation of any water quality improvement project, we conducted several levels of outreach. Target audiences were landowners where water quality projects could be installed, other landowners in the subwatershed, and local governmental units. Our study findings and recommendations reflect stakeholder feedback received.

Because most projects would occur on private lands, we conducted one-on-one and group outreach to landowners. Several landowners allowed us to access the ditch through their property for this study. Whenever we identified a possible water quality project location, we began dialog directly with that landowner. We reached out to all landowners in the subwatershed through public meetings in April and September 2017 at Oxford Town Hall.

One of the landowners in the subwatershed is the State of Minnesota. We communicated with them directly. The primary contact was MN DNR Area Wildlife Manager Tim Marion.

Other stakeholders involved included:

- The Martin Lakers Association - This group was kept updated through presentations at their annual meeting. The lake association provided partial study funding.
- Sunrise River Watershed Management Organization – The SRWMO provided partial study funding, was updated periodically at their regular meetings and had a representative attend a project public meeting.
- Oxford Township - The township was kept updated through written and oral communications. The township had an official that attended informational public meetings.

- Isanti County – Isanti County staff and commissioners were kept updated through written and oral communications. Staff and/or a county commissioner attended public informational meetings. Staff collaborated directly on this study and were given in-person updates. The County's Water Plan Task Force was provided a summary report.
- Isanti Soil and Water Conservation District – The SWCD was involved similar to Isanti County.

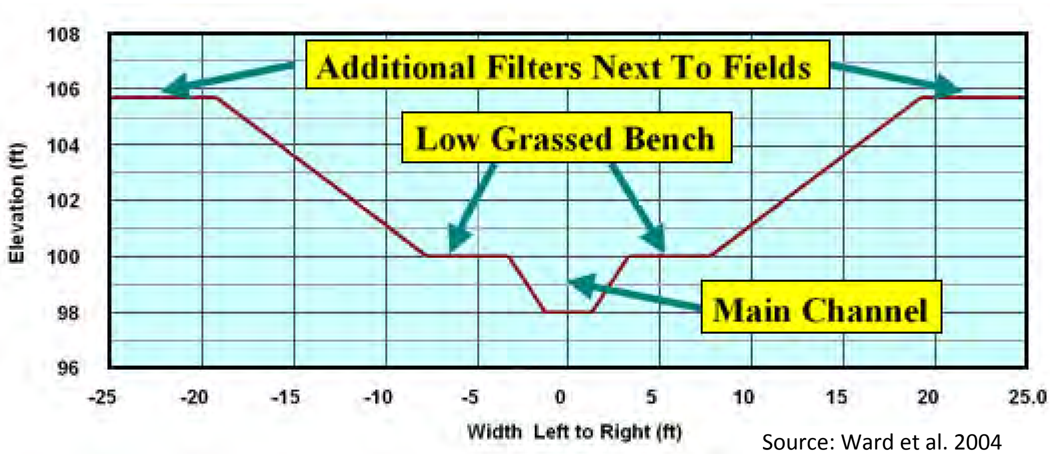
Project Types Considered but Not Selected

This study was an investigative process wherein a number of possible means to improving water quality were explored. Listed below are some project types that were explored but not selected for final analysis.

Two-Stage Ditch

Two-stage ditches are designed to have a main ditch channel and benches above the main channel to mimic the floodplain that is in a natural stream (Figure 16). These benches are built 2-3 feet above the bottom of the main channel and about 10 feet wide on each side (Ward et al. 2004). This design intends to reduce the scouring and the flooding that conventional ditches can cause (Ward et al. 2004). Lower velocity will reduce the amount of solids and particle-bound phosphorus the ditch will be able to transport. Two-stage ditches also handle a larger volume of water so the occurrence of flooding will be reduced.

Two-stage ditches were not selected for in-depth consideration in this study because the natural landscape already provides similar benefits. Ditch 20 runs through a large floodplain and the ditch itself is mostly <3 feet deep. During high water, the ditch spills into this broad floodplain, providing benefits similar to or better than a two-stage ditch.



Source: Ward et al. 2004

FIGURE 16 TWO-STAGE DITCH DESIGN

Oxygen Dosing

Phosphorus naturally bound to iron can be released under anoxic (low oxygen) conditions. In some instances, managers may choose to aerate a waterway to ensure that this does not happen, or to encourage re-binding of phosphorus to iron, calcium or aluminum. This strategy was not chosen for Ditch 20 because oxygen levels were sufficiently high in the stream. Oxygenating the surficial water table to maintain aerobic conditions in buried peats is impractical.

Alum

Alum, or aluminum sulfate, is a powder or liquid substance used to bind phosphorus in place, making it unavailable for biological processes and export. Treatments of lakes, continuous dosing of streams and land application can occur. Alum application on the peatland surface was not selected for in-depth consideration because of the large area (hundreds of acres potentially) that would need to be treated and because much of the phosphorus is below the ground surface. Alum dosing of the ditch was not considered because local management entities felt the large expense and maintenance costs were beyond reasonable possibility. Also, that treatment would need to continue indefinitely because it does not address the source.

Biomass Removal by Haying

Through haying, vegetative biomass and its associated phosphorus can be removed. This strategy was not chosen for Ditch 20 because the scale that it would need to occur at is unrealistically large, and because the soil phosphorus pool is believed to be so large it could not be removed in a fathomable period of time. Practically, haying this area is difficult because tractors can get deeply stuck in the soggy peat floodplain. While haying by landowners can be encouraged, it should not be viewed as a realistic solution unless done extensively over exceptionally long periods of time.

Typo Creek Drive Road Realignment BMPs

In 2017 Oxford Township began planning realignment of Typo Creek Drive. The project location is at the road's crossing of County Ditch 20 (also called Data Creek at this location) next to the parking lot for the Schubring Wildlife Management Area. This is the last road crossing before the ditch empties into Typo Lake and therefore could be an ideal location for water quality treatment because a practice at this location could treat the entire Ditch 20 drainage (plus all of Ditch 13, a tributary). Oxford Township was willing to consider ways that the road realignment might be constructed to better address water quality.

Due to a dangerous curve in the current road, the road will be realigned westward into wetland in the Schubring Wildlife Management Area. Ditch 20 will still flow under the road embankment. Two water quality treatment approaches were considered with the new roadway including: (a) an iron-enhanced sand filter bench to filter solids and remove dissolved phosphorus and (b) weir to maintain more consistent water levels.

These concepts were rejected for hydrological reasons. Any practice at this location would need to be able to maintain storm flow rates for the large upstream drainage that included both Ditch 13 and Ditch 20. Therefore, a much larger practice would be required, but approximately half of the water treated would be from Ditch 13 which is not the target. While overflows, bypasses and similar strategies could ensure large flows could be passed, there remained concern that any increased water levels could affect a number of homes in the vicinity. Many nearby properties have low back yards. There was strong opposition from at least one landowner to any water level altering projects in this vicinity.

From a financial timing standpoint, this project concept had problems too. Any project at this location would be most cost effective if installed during road realignment. Road construction is anticipated in 2018 and there was no reasonable expectation that water quality project funds could be secured by that time.

Ditch Abandonment

While the drainage Ditch 20 provides through a peatland appears to cause negative water quality, abandoning that ditch today is impractical. From a legal standpoint, Minnesota Ditch laws (see Appendix B for a summary) assures continued drainage benefits for benefitted landowners. Practically, landowners would likely object if uses of their land were negatively affected by plugging the entire ditch system. It is more reasonable to consider weirs or ditch plugs that reduce drainage in a small, well-defined area.

Settling Pond in the Schubring Wildlife Management Area

A concept design was prepared for a 3.94 acre, 6.5 foot deep, settling pond within the Schubring Wildlife Management Area (Figure 17). The pond would be in-line with the ditch, and therefore not affect hydrology. It would target the approximately 50% of phosphorus that is attached to particles.

This project was rejected due to landowner wishes and feasibility concerns. The MN DNR, which owns the land, expressed that this project concept was not consistent with their wishes for the land. The location is also likely impractical because it has poor access, requiring traversing hummocky wetlands with standing water much of the time to get to the site. Construction in these conditions would also be difficult. Permitting from a wetland law standpoint would be difficult as well (see discussion below on the settling pond concept at a different location that was not rejected).

A location for this project closer to Typo Creek Drive is possible, but would require a much bigger pond. The location depicted in Figure 17 is the downstream most extent of Ditch 20. Locations nearer to Typo Creek Drive would need to also handle Ditch 13 flow volumes, necessitating a pond that is double or larger in size.

A cost and pollution reduction estimate were completed for this concept. The estimated cost is $626,450 plus $62,645 for design and engineering, for a total of $751,740. The drainage to this pond has an estimated annual total phosphorus loading of 1,141.9 lbs. The estimated total phosphorus reduction from this project is 315.16 lbs/year. The cost per pound of phosphorus reduced is likely <$100, which is good cost effectiveness. Nonetheless, the concept was rejected due to feasibility concerns and lack of a willing owner.

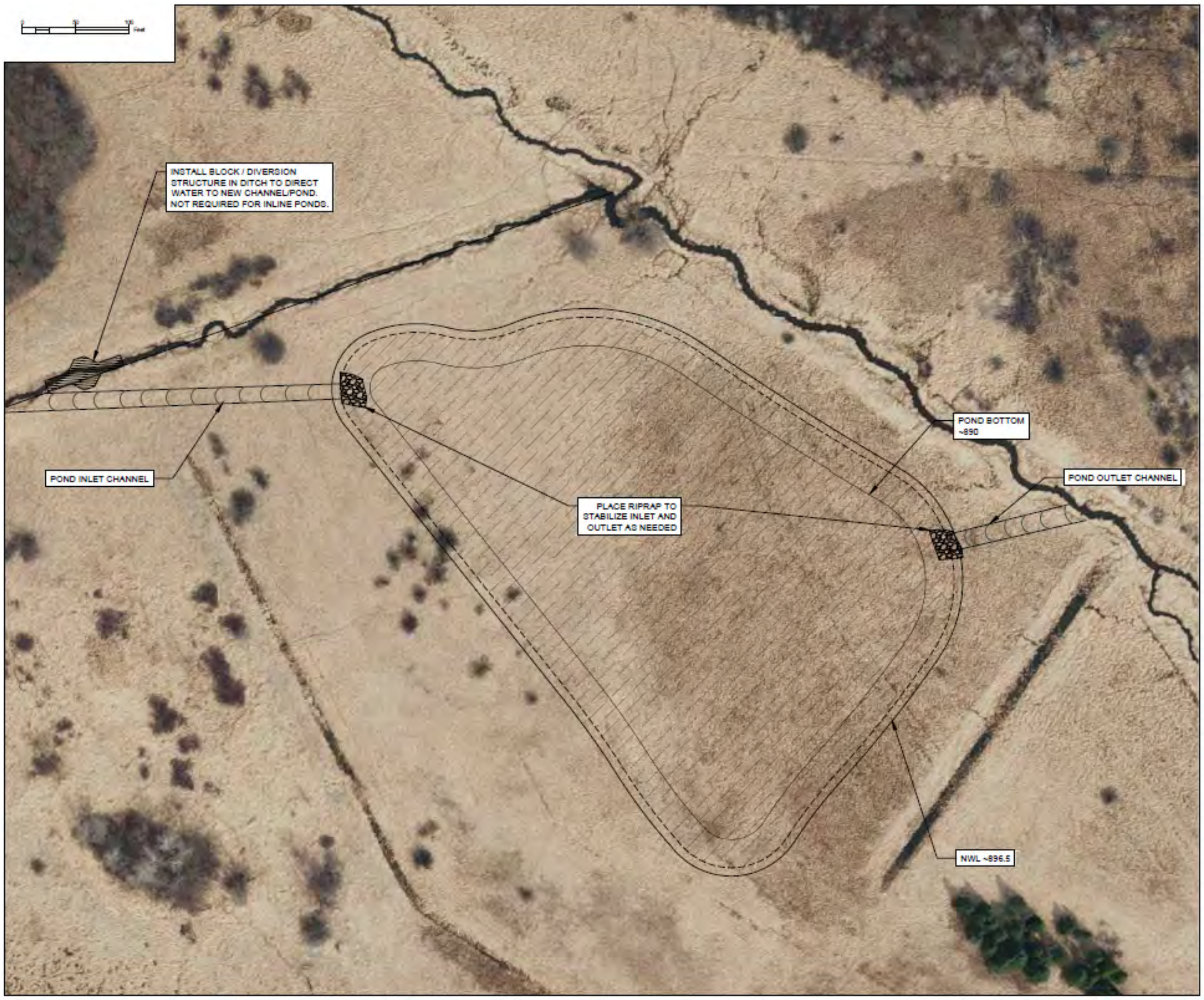


FIGURE 17 REJECTED CONCEPT FOR A SETTLING POND WITHIN THE SCHUBRING WILDLIFE MANAGEMENT AREA
The location is west (upstream) of Typo Creek Drive and adjacent to the confluence of Ditch 20 and Ditch 13. Full details are on file at the Anoka Conservation District.

Lateral Ditch Plug

Several locations for lateral ditch plugs were explored. Two are presented below as potential projects. One was rejected by the landowner who did not wish to create wetter conditions on that portion of his property. The rejected location is at the UTM coordinates x=491119.9 y=143988.2.

A concept design and cost estimate were completed for this project. A two foot high ditch plug was considered, which would restore wetland hydrology to 23.06 acres and treat a 17.9 drainage area. Phosphorus reduction estimates were 0.54 lb/year dissolved phosphorus, 1.76 lb/year particulate phosphorus and 2.3 lb/year total phosphorus. This is lower than other lateral ditch plugs considered because the drainage area is smaller. The estimated costs were $18,806 without a bypass ditch and $43,366 with a bypass ditch. 10% should be added for engineering.

BMP Descriptions

Four projects of three types appeared feasible and received detailed investigation. Specific project sites have been identified (Figure 18). They included two lateral ditch plugs, one ditch channel weir and one settling pond. The first two project types would restore wetland hydrology to portions of the drained area and capture some solids using ditch plugs or weirs. The third, settling ponds, would be aimed only at capturing phosphorus that is attached to particles (monitoring found ~50% of phosphorus is particulate). The landowners at each site are receptive to these projects. General descriptions of each BMP type are on the following pages and descriptions of individual projects follow thereafter. Concept designs for individual projects are provided as Appendix A.

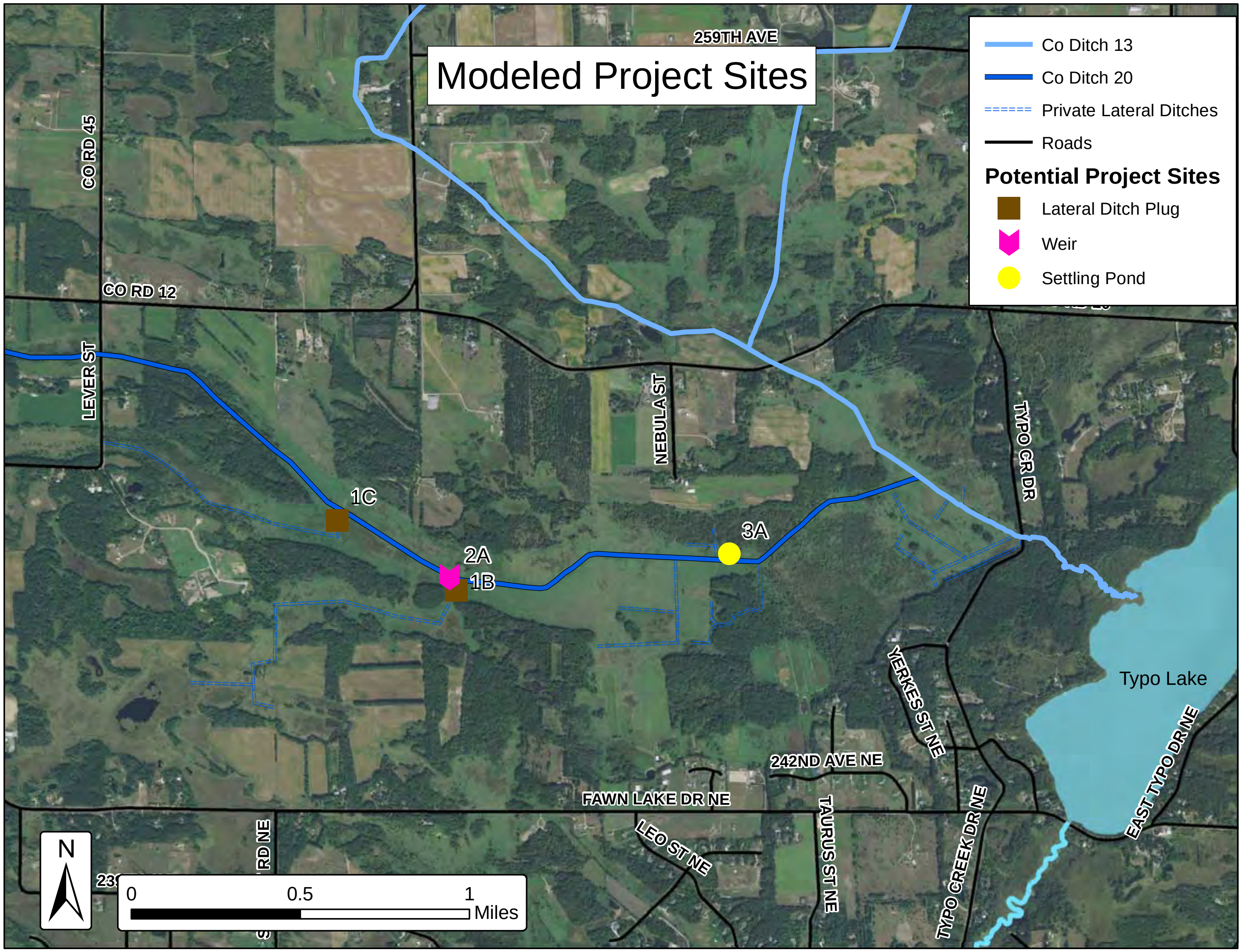


FIGURE 18 MODELED WATER QUALITY IMPROVEMENT PROJECT LOCATIONS

Lateral Ditch Plugs

Lateral ditch plugs involve using a structure to block drainage of small private lateral ditches. We modeled lateral ditch plugs at 2 locations (Figure 18, projects 1B and 1C) that would raise water levels 2 feet during base flow conditions impacting 11 and 8 acres respectively (see Appendix A for concept designs). Water would be raised to approximately ground level. During storm conditions, a somewhat larger footprint of impounded water would occur (see Appendix A).

Source: MN Wetland Restoration Guide, BWSR

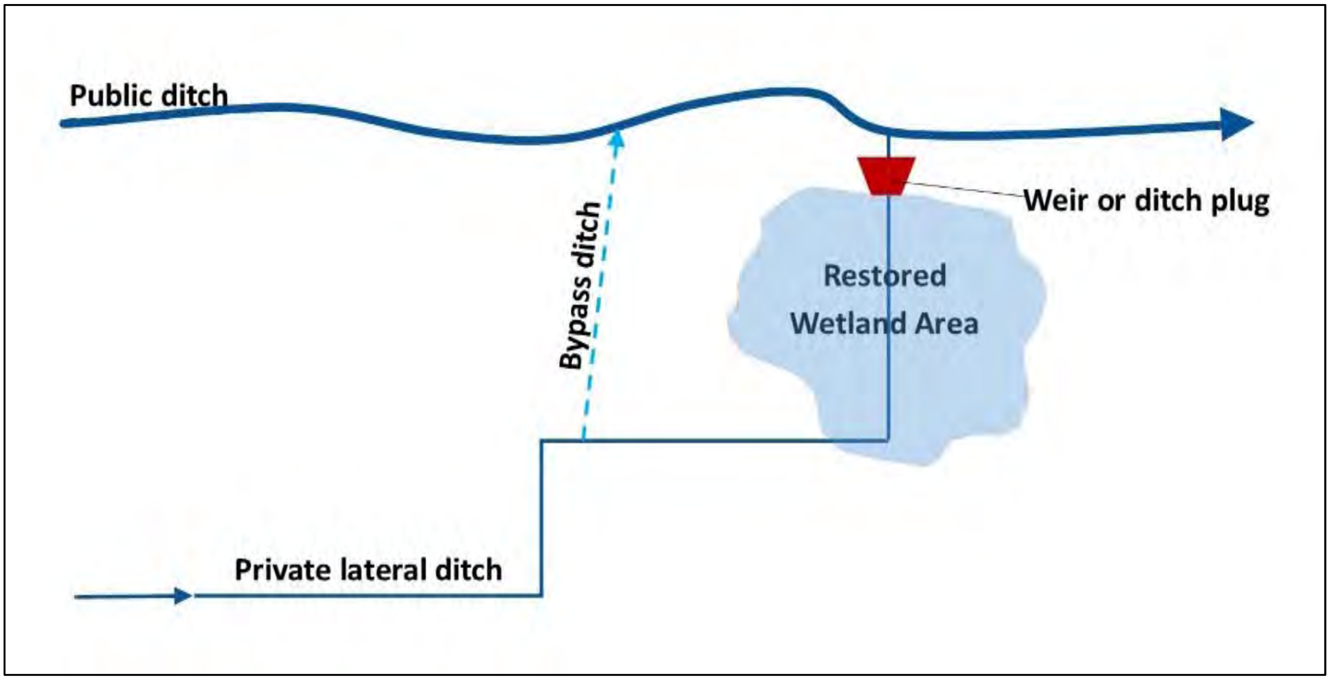
FIGURE 19 EXAMPLE OF AN EARTHEN LATERAL DITCH PLUG INSTALLATION

Ditch plugs can be constructed of several different materials. Most simply, an earthen plug was considered to fill the ditch (Figure 19). Fixed height weirs of sheet metal or other material are an option. Adjustable height weirs might be used in instances where waterfowl management is a goal, and particularly where pooling of water across a greater area can occur without objection from neighboring landowners.

While we have positioned the proposed lateral ditch plugs where they will entirely or mostly impact a single landowner who has already expressed support, the final design must further analyze the extent of impacts. If the lateral ditch plug would impact drainage for upstream properties that do not want their drainage changed, this concern could be addressed by digging a new bypass ditch around the wetland that is restored by the ditch block (see concept in

Figure 20).

FIGURE 20 CONCEPTUAL DEPICTION OF A BYPASS DITCH FOR LATERAL DITCH PLUG OR WEIR PROJECTS
The bypass ditch ensures continued upstream drainage while allowing restoration of wetland hydrology, but may increase phosphorus loading.



This project type offers total phosphorus reductions in at least two ways. Most importantly, they reduce the area of peat wetland drained by the ditches. Within that area with restored wetland hydrology, wetter conditions would be maintained in the soils to reduce phosphorus release that occurs during alternating drying and wetting. Secondly, settling of particles carrying phosphorus will occur in the pooled area.

There are two ways in which this project may increase phosphorus export. First, if a new bypass ditch is required (discussed below) and dug to the original/historic ditch profile, it may increase drainage impacts overall. The result may be greater phosphorus drainage from the peat soils. Second, within the restored wetland area continuously wet conditions may create anoxic conditions wherein bound phosphorus is released from iron, calcium or aluminum. Other studies (Kjaergaard 2012) have found this phosphorus export increase can be temporary, but lasts years.

Caution is needed when considering the pollution reduction estimate for this project type, as found in Table 2. That estimate assumes all upstream drainage is treated by the practice. If a bypass ditch is dug around the practice to maintain upstream drainage, much of the upstream water is not treated and actual phosphorus reductions will be much less.

Lateral ditch blocks would face regulatory and construction challenges. Permitting will be time consuming and require additional research, monitoring or modeling. Permitting will likely include the Minnesota Wetland Conservation Act administered by Isanti County (detailed in Appendix C) and Section 404(d) of the Clean Water Act administered by the US Army Corps of Engineers. Ditch law may also have implications (see Appendix B). Construction on wetland soils can be challenging and require additional measures for stable work platforms. Access easements may need to be secured, unless this is done as an entirely private project.

Despite its challenges, lateral ditch plug concepts are highly cost effective at phosphorus reduction (see Table 2) and provides habitat benefits. Wetland banking may be a reasonable way to achieve successful installation. Credits for restored wetlands are sold to others on a state-run exchange who are draining or filling wetland under State law and need to create new wetlands to offset the loss. The wetland banking process is lengthy (usually several years) but offers a financial incentive to landowners. The MN Board of Water and Soil Resources offers to lead the wetland restoration process for a willing landowner.

Ditch 20 Weir

A weir on the main stem of Ditch 20 would involve a metal or similar structure with features that allow water level adjustment. This project type is similar to a lateral ditch plug, but recognizes that additional functionality and ability to control water levels is needed because it is on the main stem of a county ditch and drainage for upstream areas must be maintained.

A mechanical weir with adjustable stop logs may be the preferred construction option (see Figure 21). In this design, managers would be able to actively manage water levels, such as by lowering the overflow elevation in spring when the largest volumes of water might be expected. Also, if managers ever wanted to revert the system to its pre-project condition they could simply remove the stoplogs.

Source: MN Wetland Restoration Guide, BWSR

FIGURE 21 EXAMPLE WEIR WITH STOP LOGS TO ADJUST WATER LEVEL

This project offers total phosphorus reductions in the same ways as the lateral ditch plugs. Most importantly, these projects reduce the area of peat wetland drained by the ditches. Within that area with restored wetland hydrology, wetter conditions would be maintained in the soils to reduce phosphorus release that occurs during alternating drying and wetting. Additionally, some settling of particles carrying phosphorus will occur.

There are two ways in which this project may increase phosphorus export. First, if a new bypass ditch is required and dug to the original/historic ditch profile, it may increase drainage impacts overall. The result may be greater phosphorus drainage from the peat soils. Second, within the restored wetland area continuously wet conditions may create anoxic conditions wherein bound phosphorus is released from iron, calcium or aluminum. Other studies (Kjaergaard 2012) have found this phosphorus export increase can be temporary, but lasts years.

Caution is also needed when considering the pollution reduction estimate for this project found in Table 2. That estimate assumes all upstream drainage is treated by the practice. If a bypass ditch is dug around the practice, much of the upstream water is not treated and actual phosphorus reductions will be much less.

From a legal and drainage rights standpoint, this is more complex than the lateral ditch plugs. A Ditch 20 weir would face regulatory and construction challenges because it has implications for upstream drainage. Also, because of its status as a county ditch, there are additional legal proceedings and approvals needed for this project (see Appendix B). In the likely event that upstream landowners want their drainage maintained, the most likely solution is to dig a new bypass ditch around the wetland area being restored (concept in

Figure 20). A bypass ditch would add substantial construction cost is added and as noted above, and pollution reductions will be reduced because the project will no longer treat all upstream water.

Permitting will be time consuming and require additional research, monitoring or modeling. Permitting will likely include the Minnesota Wetland Conservation Act administered by Isanti County (detailed in Appendix C) and Section 404(d) of the Clean Water Act administered by the US Army Corps of Engineers. Construction on wetland soils can be challenging and require additional measures for stable work platforms. Access easements would likely be a necessity, as well as an entity to own and maintain the weir structure.

Like the lateral ditch plugs, wetland banking may be a reasonable way to achieve successful installation. Credits for restored wetlands are sold to others on a state-run exchange who are draining or filling wetland under State law and need to create new wetlands to offset the loss. The wetland banking process is lengthy (usually several years) but offers a financial incentive to landowners. The MN Board of Water and Soil Resources offers to lead the wetland restoration process for a willing landowner.

Settling Pond

A settling pond at one location was evaluated. This project would target the approximately 50% of phosphorus that is attached to particles. A settling pond offers good cost effectiveness at phosphorus removal, but not as good as lateral ditch plugs or a Ditch 20 weir (Table 2).

FIGURE 6. EXAMPLE EXCAVATED SETTLING POND.
Source: MN Wetland Restoration Guide. BWSR

We considered flow-through settling ponds alongside of Ditch 20. The ditch would be routed through the pond (see Appendix A for concept design). It is preferable for this pond to be in the downstream reaches of Ditch 20 so it is treating the greatest drainage area. Depths of at least 6 feet are preferred to maximize particle capture and maximize the time interval between pond cleanouts.

Construction of a settling pond would be challenging in a number of ways. From a permitting standpoint, building settling ponds in wetlands may be frowned upon by regulators (see Appendix C), and the activity may not receive required permits. From a construction standpoint, such a large excavation on soggy, unstable ground will likely require temporary roads and work platforms for machinery. From a maintenance standpoint, removing accumulated sediment may be infrequent (every 10-30 years) but it will be expensive (maintenance costs are included in lifespan costs of Table 2).

Project Concepts and Analyses

The following pages contain concepts and analyses of the four projects that were modeled, plus one concept that combines two of the projects. Discussion includes the project type, location, and cost and effectiveness at removing phosphorus. Also presented below is a general discussion of feasibility, cost-effectiveness ranking of all projects, and uncertainty discussion.

Feasibility Considerations

Only feasible projects are featured in this report. To be considered feasible, a project:

- Had landowner support.
- Engineering concepts that could reasonably be constructed.
- Reasonable assurance the project would achieve pollutant reductions.

The four modeled projects met these criteria. Cost-benefit ranking was done for these four projects. Others were presented briefly as "project types considered but not selected."

Factors that generally increase the feasibility of all these projects include:

- Small drainage area of the ditch or project site.
- Large parcels sizes, and the ability to scale project sizes such that impacts are only on parcels where landowners allow it.
- Impacted lands are idle and close to wetland hydrology already.
- The possibility of wetland restoration credit banking as a funding mechanism.

All four projects would face large hurdles, including:

- Drainage needs to be maintained for upstream landowners who want it. While bypass ditches can accomplish this, they add substantial expense.
- Any new bypass ditches dug around restored wetland to maintain drainage would likely be dug to the original profile of Ditch 20, and therefore have a greater drainage and negative water quality impact than Ditch 20 currently.
- Remote construction sites, often on unstable soils. While work in winter can address some concerns, building temporary roads, working in water and similar challenges may be encountered and will raise costs.
- Phosphorus reduction estimates for lateral ditch plugs or a weir assume all upstream drainage is treated by the practice. If a bypass ditch is dug around the practice, much of the upstream water is not treated and actual phosphorus reductions will be much less.
- Phosphorus reduction from lateral ditch plugs and weirs contains a degree of uncertainty. While these projects are aimed at ending cycles of drying and rewetting that can drive phosphorus release, research at Ditch 20 has indicated this is perhaps only partially responsible for phosphorus mobilization. Projects that create more continuously wet conditions can sometimes result in phosphorus discharge increases.
- Lack of an identified entity to own and maintain the structures.
- Access easements will need to be purchased or donated for all project sites, as they are located on private lands.
- Permitting will be time consuming and require additional research, monitoring or modeling. Permitting will likely include the Minnesota Wetland Conservation Act and local mining ordinances (for pond excavations) administered by Isanti County, and Section 404(d) of the Clean Water Act administered by the US Army Corps of Engineers.

Cost-Effectiveness Analysis and Ranking

Costs of each project are divided by the estimated phosphorus reduction over a 30-year project lifespan to yield a cost-effectiveness comparison among projects. Costs for construction and engineering were provided by the engineer for this feasibility study. Costs for legal expenses associated with permitting and maintenance access were estimated by the Anoka Conservation District (ACD). ACD also estimated maintenance costs over a 30-year practice lifespan. All of these costs were added to yield a total project cost.

Benefits were calculated as pounds of total phosphorus reduction annually achieved by the project. These estimations were made through a XP-SWMM hydrologic model paired with a P8 water quality model. For wetland restoration projects (ditch plugs and weirs), which are not a strength of water quality models, primary literature was referenced to determine appropriate phosphorus removal rates. In these cases we used 46% removal of particulate phosphorus and 12% removal of dissolved phosphorus.

Table 2 summarizes the cost effectiveness rankings of modeled projects. All of the projects are highly cost effective by this numeric ranking. The ranking does not consider political, social or other factors that must be weighed by watershed managers. It uses best estimates of phosphorus reduction, but managers must also consider uncertainty inherent in these numbers, particularly for lateral ditch plugs and weirs that result in wetland restoration.

Cost per pound of phosphorus removed for each of the four feasible projects is in Table 2. In urban settings, ACD has found that any projects costing less than $500 per pound of phosphorus removed are highly favorable. Projects between $500 and $1,000 are moderate. All of the Ditch 20 projects fall in the most favorable category.

The lateral ditch plugs and weir projects have the best cost-effectiveness rankings, while the settling pond has higher (but still favorable) costs per pound of phosphorus removed (Table 2). The permitting/legal likelihood is highest for lateral ditch plugs, lesser for a Ditch 20 weir and lowest for a settling pond. This information suggests that implementation efforts for these projects should begin with lateral ditch plugs, then Ditch 20 weir, and lastly the settling pond.

TABLE 2 COST-BENEFIT ANALYSIS OF DITCH 20 POTENTIAL WATER QUALITY PROJECTS

The blue shaded column indicates cost per pound of total phosphorus (TP) reduction. Where applicable, projects are listed with and without an optional bypass ditch that maintains upstream drainage. Costs below $500/lb of TP are most favorable. When selecting projects to construct, political, social, legal, and scientific uncertainties must be considered.

				Estimated Costs						
Project ID	Project	Desciption	TP reduction (lbs/yr)	Construction	Final Design/ Engineering	Legal (easements, permitting, etc)	Maintenance (over 30 yrs)	Total Cost Including 30 Years of Maintenance	Est Cost per lb-TP Removed over 30-yr lifespan	Certainty of TP Reduction Outcomes
2A-no bypass	Weir - WITHOUT Bypass Ditch	Weir in public ditch, maintaining higher water in 21.55 acres.	114.57	$20,174	$2,017	$13,000	$15,200	$50,391	**$14.66**	Low-Mod
1B-no bypass	Lateral Ditch Plug - WITHOUT Bypass Ditch	Plug private lateral ditch restoring 10.86 ac of wetland.	103.62	$18,806	$1,881	$13,000	$15,200	$48,887	**$15.73**	Low-Mod
1C-no bypass	Lateral Ditch Plug - WITHOUT Bypass Ditch	Plug private lateral ditch restoring 7.72 ac of wetland.	86.96	$18,806	$1,881	$13,000	$15,200	$48,887	**$18.74**	Low-Mod
1B-with bypass	Lateral Ditch Plug - WITH Bypass Ditch	Plug private lateral ditch restoring 10.86 ac of wetland. Upstream drainage maintained with new bypass ditch.	103.62	$43,366	$4,337	$13,000	$15,200	$75,903	**$24.42**	Low*
1C-with bypass	Lateral Ditch Plug - WITH Bypass Ditch	Plug private lateral ditch restoring 7.72 ac of wetland. Upstream drainage maintained with new bypass ditch.	86.96	$39,726	$3,973	$13,000	$15,200	$71,899	**$27.56**	Low*
2A-with bypass	Weir - WITH Bypass Ditch	Weir in public ditch, maintaining higher water in 21.55 acres. Upstream drainage maintained withnew bypass ditch.	114.57	$93,674	$9,367	$13,000	$15,200	$131,241	**$38.18**	Low*
3A	Settling Pond	6.5' deep, 1.31 acre settling pond on private property that is in-line with the public ditch and does not affect flows or water levels.	117.58	$126,952	$12,695	$21,000	$52,400	$213,047	**$60.40**	Moderate

* Pollutant reduction estimates assume entire upstream drainage is treated by the proposed project. Bypass ditches would result in a lesser area being treated. Bypass ditches may also result in additional drainage, depending on depth dug, counteracting some phosphorus reductions acheived by the project.

Uncertainty in Phosphorus Reduction Estimates

The phosphorus reduction estimates in this report are best estimates. There is high confidence in this estimate for settling ponds, but poorer certainty for wetland restorations (lateral ditch plugs and ditch weirs). Watershed managers should consider this uncertainty in their implementation planning to ensure the best results are achieved.

Settling pond phosphorus reductions were provided by our XP-SWMM and P8 models. This practice is well-understood and handled by models. The actual reductions achieved by an installed project should be similar to those presented in Table 2.

Phosphorus reductions from wetland restoration projects (lateral ditch plugs and ditch weir) are not as well handled by our models. Sources of uncertainty include variation in observed reductions elsewhere, possible mechanisms of phosphorus increase upon wetland restoration and the impacts of any bypass ditch that would vary depending upon ambient water levels. We used literature mid-range particulate phosphorus reductions of 44% and dissolved phosphorus reductions of 12% (Fisher and Acreman 2004, Braskerud 2005, Woltemade 2000, others reviewed by the project engineer). Actual reductions achieved by an installed project could vary widely.

Researchers studying similar projects have found widely varying pollutant reductions from wetland restorations (Braskerud et al. 2005, Koskiaho et al. 2003, Fisher and Acreman 2004). The range of reported outcomes have been approximately +20% (i.e. a phosphorus increase) to -80%. Soil type, hydrology, wetland type, wetland size relative to contributing drainage area and many other factors appear to impact results.

It has been widely observed that total phosphorus export can increase after restoration of wetlands to a continuously saturated condition due to reducing conditions (Ardón et al. 2010, Kjaergaard 2012, Litaor et al. 2005, Meissner et al. 2008, Moore and Reddy 1994, Pant et al. 2002, Sallade and Sims 1997, Young and Ross 2001). This occurs primarily because iron, to which much phosphorus is bound, is converted from its ferric to its ferrous (reduced) form, which is less able to hold phosphorus. This increased phosphorus release may continue for years (Ardón et al. 2010), but subsequent reductions may occur.

The likelihood of reducing conditions creating phosphorus release following wetland restoration is highest in peat soils compared to sandy soils because the high organic content and decomposition drive oxygen levels lower (Kjaergaard 2012). Therefore, the risk of phosphorus export increases after wetland restorations at Ditch 20 seems high. Arguably the water table is already so high that the soils are already often saturated and any additional increases in phosphorus export would be minimal, but the full benefits estimated in this report's analysis may not be achieved.

Restored riparian wetlands, such as along Ditch 20, have been found to be slightly less effective at nutrient retention than isolated swamps and marshes (Fisher and Acreman 2004). This is due to shorter water residence times in the riparian wetlands and other factors. Also, flow into riparian wetlands may only occur during flood conditions, meaning a lesser volume of water is treated. Wetland restorations at Ditch 20 should be mindful of this, and be designed to achieve the longest possible water residence times, have long flow paths and have flows into the wetland in most conditions. Still, the extent to which this can be achieved in <20 acre projects is limited.

If bypass ditches are installed with wetland restorations, the phosphorus reductions in this report will almost certainly be an over estimate. Those phosphorus reduction estimates assume that all drainage upstream of a project flows to that project. If a bypass ditch is dug to maintain upstream drainage, only a portion of the drainage will be treated. The portion treated would vary by the design and climatological conditions. On the other hand, the portion that is treated will likely have a longer residence time for greater phosphorus removal.

Deep bypass ditches also may work counter to water quality goals by draining new areas of peatland. A bypass ditch is likely to be dug to the depth/profile of the original Ditch 20 construction in the early 1900's. That construction would have a greater drainage scope and effect than the current condition of Ditch 20 or laterals. This greater water drainage is likely to carry with it phosphorus.

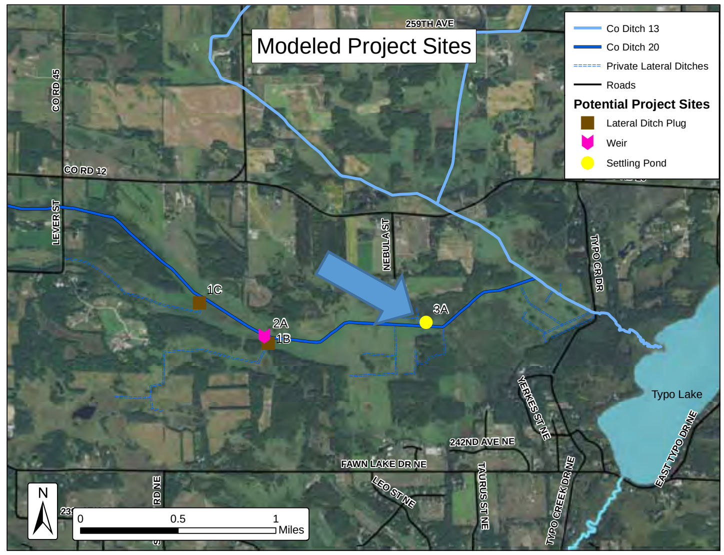
Despite uncertainty, the wetland restoration projects in this report deserve consideration. As estimated, they are very cost effective and offer substantial wildlife benefits. Watershed managers are advised to pursue these projects, but to install one or two initially and then monitor the outcomes to better inform subsequent projects.

Project Descriptions

On the following pages are one-page descriptions of each modeled project.

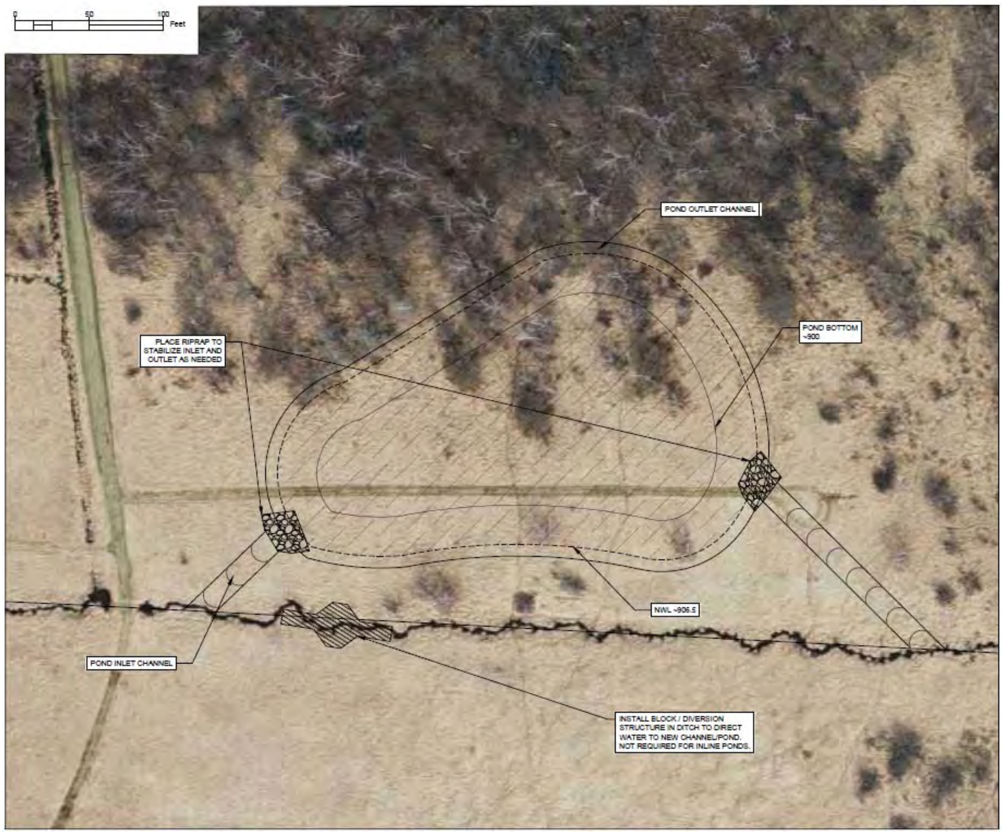
Project ID: 3-A

Settling Pond



Project Concept – Ditch 20 would be diverted into a newly-created 1.31 acre settling pond. The modeled pond depth was 6.5 feet. The pond would be dug in lowlands along the ditch. A full concept design is in Appendix A.

Location – North side of the main stem of Ditch 20 0.6 miles upstream of the confluence with Ditch 13.



Property Ownership – Private

Estimated cost - $213,047

Estimated phosphorus removal – 117.58 lbs/yr

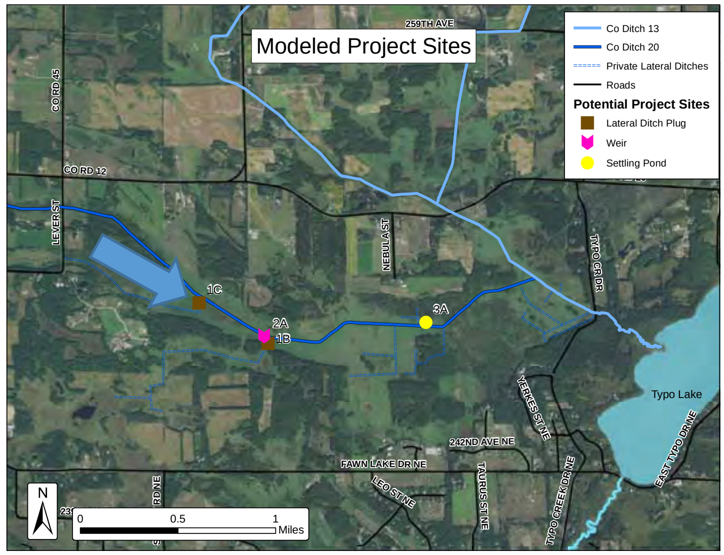
Estimated cost per pound of phosphorus removed - $60.40

Site Specific Information – The site is accessed from the north through field and trail. While access is generally good, reinforcement of the trail would be needed for construction equipment. The landowner, who supports this project, has expressed interest in any excavated soils being disposed of on nearby fields. Maintenance access and easements would be needed.

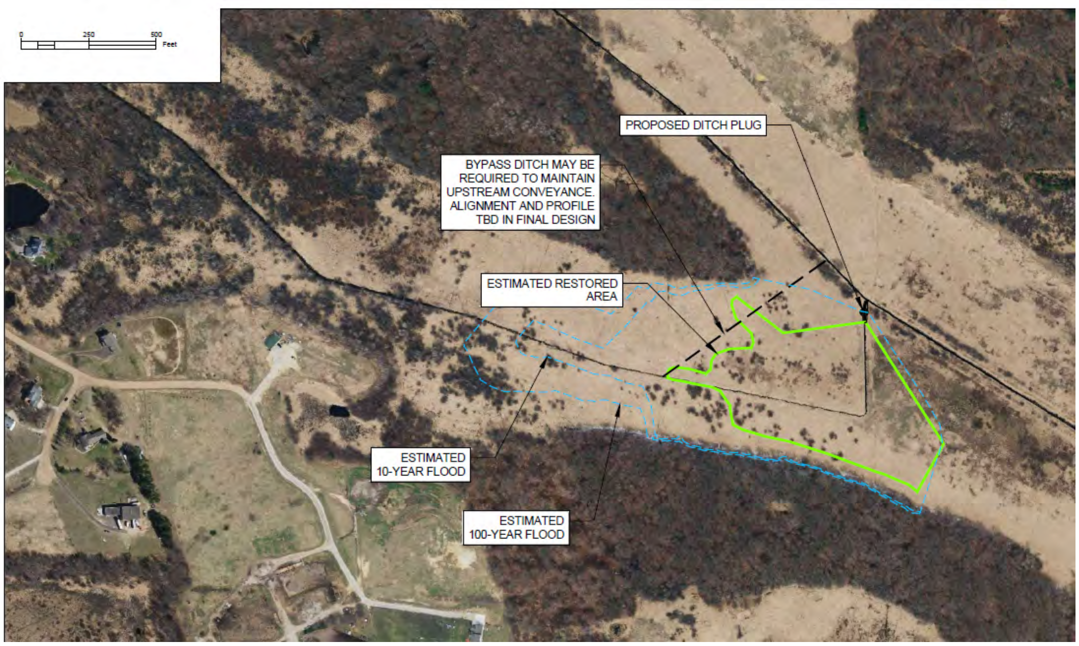
Concept design – See Appendix A.

Project ID: 1-C

Lateral Ditch Plug



Project Concept – A private lateral ditch would be plugged with an earthen plug near its confluence with Ditch 20. It would raise water levels 1.76 feet to approximately ground level. During base flow conditions newly saturated conditions would cover 7.72 acres. During storm conditions, a somewhat larger footprint of impounded water would occur.



Location – South side of the main stem of Ditch 20 1.9 ditch-miles upstream of the confluence with Ditch 13 and 0.9 ditch-miles downstream of Lever Street.

Property Ownership – Private

Estimated cost - $48,887 without a bypass ditch. $71,899 with bypass ditch.

Estimated phosphorus removal – 86.96 lbs/yr

Estimated cost per pound of phosphorus removed - $18.74 without a bypass ditch. $27.56 with a bypass ditch.

Site Specific Information – The site is accessed from the north across fields and lowlands. The landowner has expressed concern about being able to access their uplands to the south of the project site after construction.

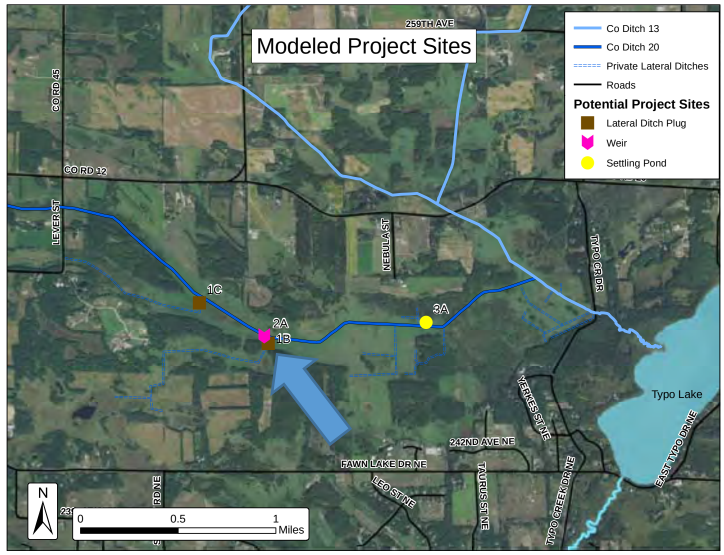
The sizing of this project as shown in the concept design is aimed at keeping most or all hydrologic impacts on a single property. As designed, the hydrologic impact would approach the west property line. The final design must further consider this impact and include discussions with all possibly impacted landowners.

If the final design caused unwanted reduction in drainage for upstream properties, a bypass ditch would be needed. A separate cost estimate is provided for this option. It would likely reduce pollutant removals proportionate to the drainage area that would bypass.

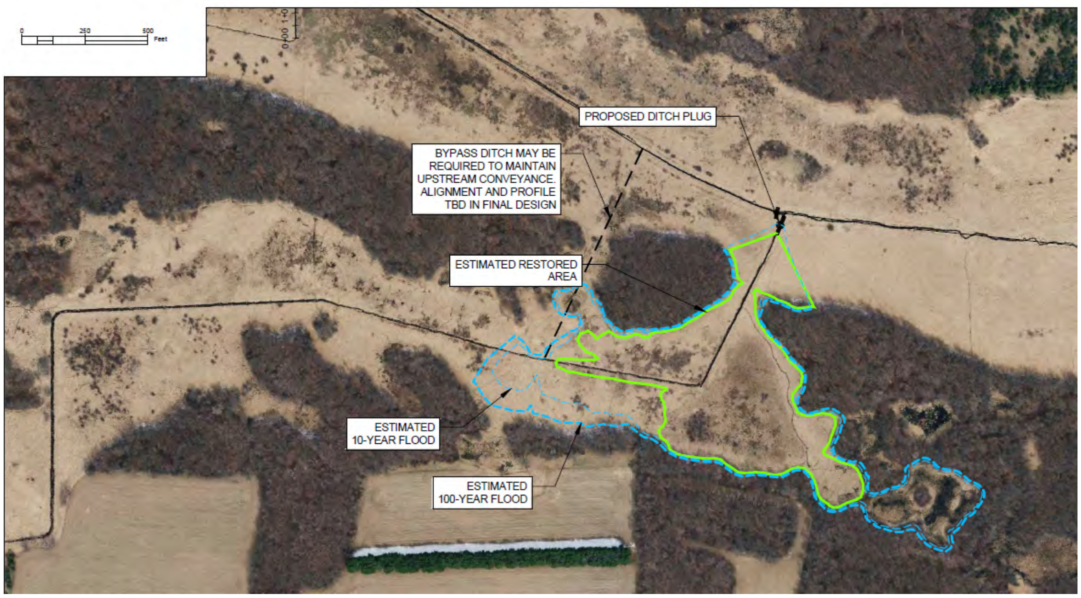
Maintenance access and easements would be needed for this project.

Project ID: 1-B

Lateral Ditch Plug



Project Concept – A private lateral ditch would be plugged with an earthen plug near its confluence with Ditch 20. It would raise water levels 1.99 feet to approximately ground level. During base flow conditions newly saturated conditions would cover 11 acres. During storm conditions, a somewhat larger footprint of impounded water would occur.



Location – South side of the main stem of Ditch 20 1.5 ditch-miles upstream of the confluence with Ditch 13 and 1.3 ditch-miles downstream of Lever Street.

Property Ownership – Private

Estimated cost - $48,887 without a bypass ditch. $75,903 with bypass ditch.

Estimated phosphorus removal – 103.62 lbs/yr

Estimated cost per pound of phosphorus removed - $15.73 without a bypass ditch. $24.42 with a bypass ditch.

Site Specific Information – The site is accessed from the north across fields and lowlands. Some trails from a residential driveway do exist, but they would need to be extended, widened or reinforced for construction and maintenance access.

The sizing of this project as shown in the concept design is aimed at keeping most or all hydrologic impacts on a single property. As designed, the hydrologic impact would approach the west property line. The final design must further examine this impact area and include discussions with all possibly impacted landowners. If water were impounded to greater depths (see discussion below) the likelihood of hydrologic impacts on adjacent properties will increase.

If the final design caused unwanted reduction in drainage for upstream properties, a bypass ditch would be needed. A separate cost estimate is provided for this option. It would likely reduce pollutant removals proportionate to the drainage area that would bypass.

The landowner has expressed strong interest in managing the impounded water for waterfowl and concern about being able to access their uplands to the south of the project site after construction. For them to participate in construction of this project they would insist on the following additions to the current concept design:

- Access to uplands. Construction of a berm road across newly saturated lands would be needed to provide access from their home north of Ditch 20 to islands of upland south of Ditch 20.
- Adjustable weir. An adjustable weir is desired instead of an earthen ditch plug to allow manipulation of water levels for waterfowl.
- Higher weir. The adjustable weir should have a maximum elevation higher than the earthen ditch plug in the current concept design to impound water to a greater depth. The extent of this impounded water, particularly onto any adjacent properties, would need to be evaluated. A possible positive affect of greater water depths is that it may shift the plant community away from the undesirable reed canary grass which currently dominates to more desirable native species.
- Berms to tie weir to uplands. The berms span between the weir and adjacent uplands to prevent water from going around the weir, which would be higher than the current land surface. The dikes should have a a vinyl or HDPE sheet pile core to prevent burrowing damage by muskrats.
- Maintenance platforms. The berms and especially the weir and should have a mainteannce platform capable of supporting a backhoe or similar equipment.
- Place weir on Ditch 20. Instead of placing the weir on the private lateral ditch the landowner wishes the weir to be placed on the main stem of Ditch 20 just downstream of its confluence with the private ditch. In this way, it would regulate flow in both Ditch 20 and the private lateral ditch.

Many of these elements the landowner wishes to see are illustrated in the landowner-provided Figure 22 below.

Each of these landowner requested items will add cost and possible legal complexity. Added costs have not been estimated. From a permitting standpoint, adding fill for berms, access roads and maintenance platforms may be eligible for exemptions in the MN Wetland Conservation Act related to wildlife habitat restoration. However, the State wetland banking programs, which are a likely funding source, may not see these as necessary components to meet their goals. The cost of adding all of the landowner-requested items may increase the total cost several-fold.

Maintenance access and easements would be needed for this project.

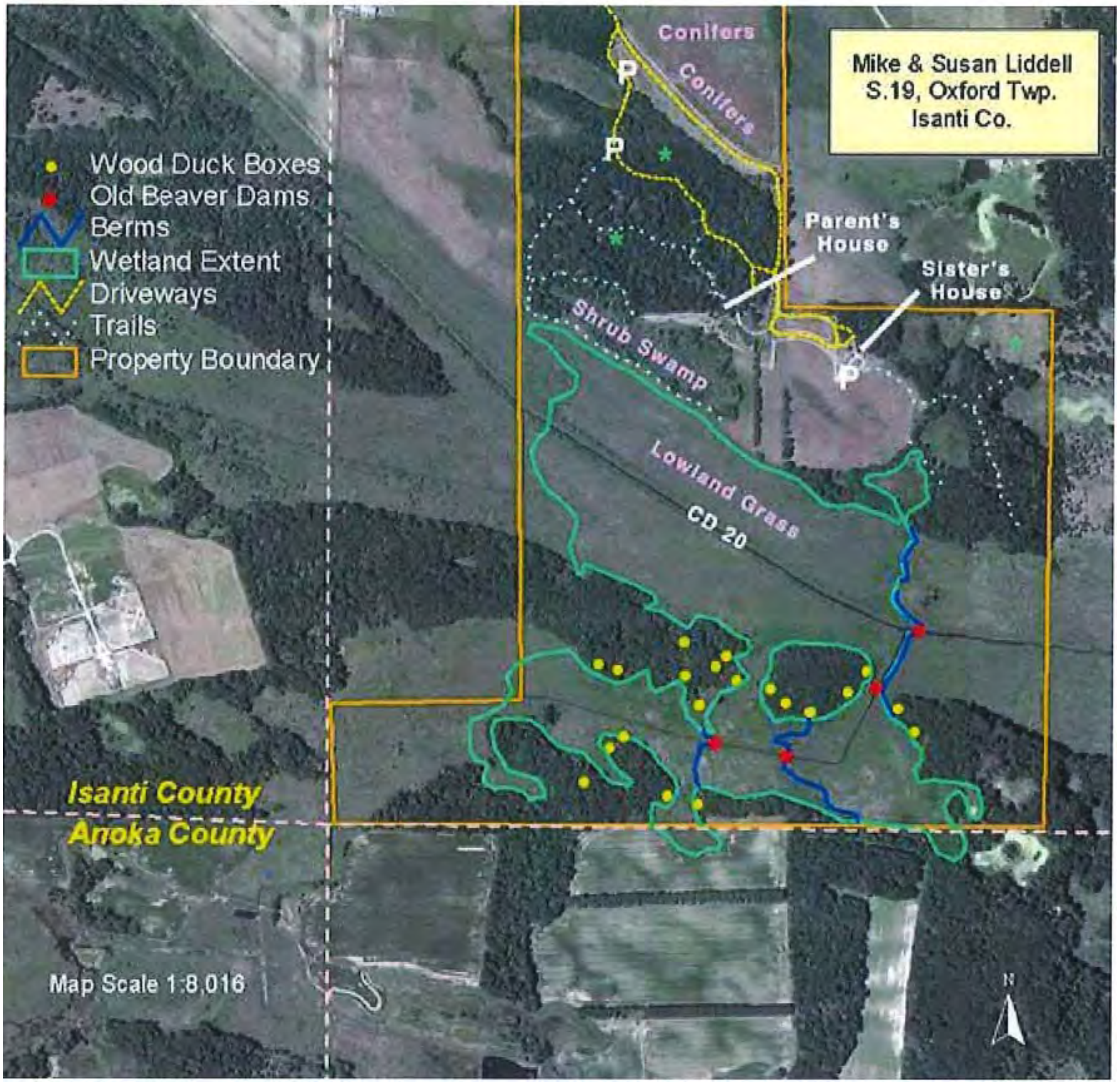
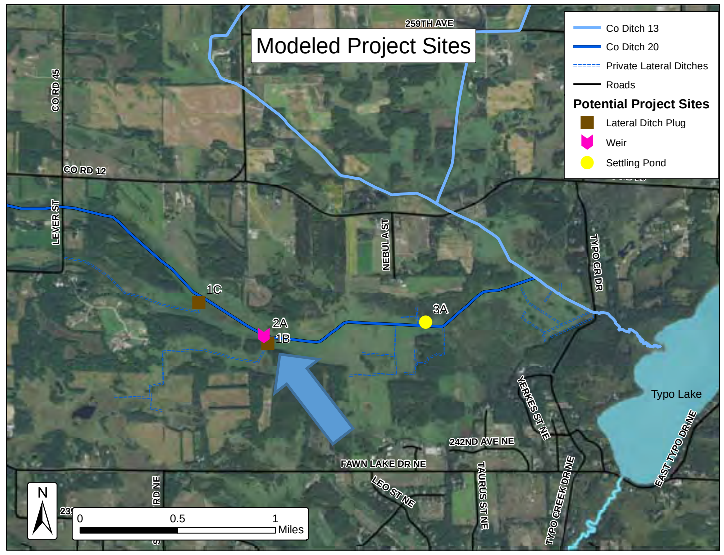


FIGURE 22 LANDOWNER'S DEPICTION

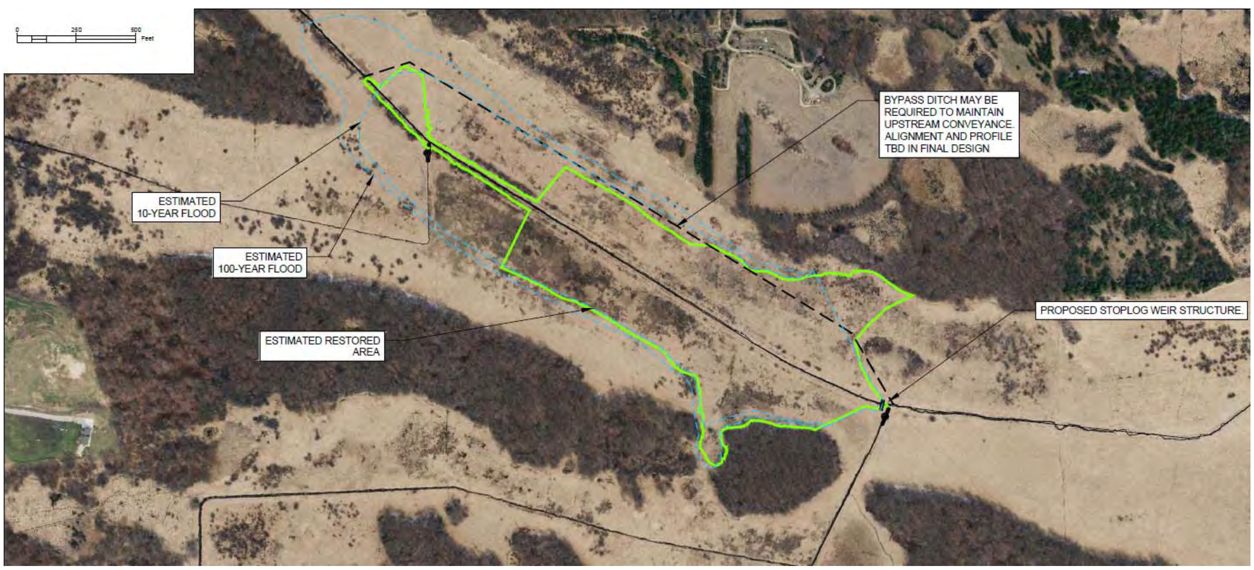
Berms and weirs landowner would like to see for waterfowl management and access to islands of upland. Note that a variable crest weir would be placed on the main stem of Ditch 20, which has the effect of combining projects 1B and 2A (see separate project sheet for this concept).

Project ID: 2-A

Main Stem Ditch 20 Weir



Project Concept – The main stem of Ditch 20 would be plugged with adjustable height weir just upstream of the confluence of Ditch 20 with the private lateral ditch that is the subject of project 1B. It would raise water levels 2.6 feet to approximately ground level. During base flow conditions newly saturated conditions would cover 21.55 acres. During storm conditions, a somewhat larger footprint of impounded water would occur.



Location – On the main stem of Ditch 20 1.5 ditch-miles upstream of the confluence with Ditch 13 and 1.3 ditch-miles downstream of Lever Street. Weir would be upstream of the confluence of the nearby private lateral ditch, however we also present a concept for putting the weir downstream of this confluence.

Property Ownership – Private

Estimated cost - $50,390 without a bypass ditch. $131,241 with bypass ditch.

Estimated phosphorus removal – 114.57 lbs/yr

Estimated cost per pound of phosphorus removed - $14.66 without a bypass ditch. $38.18 with a bypass ditch.

Site Specific Information –

The site is accessed from the north across fields and lowlands. Some trails from a residential driveway do exist, but they would need to be extended, widened or reinforced for construction and maintenance access. Maintenance access and easements would be needed for this project.

The sizing of this project as shown in the concept design is aimed at keeping most or all hydrologic impacts on two properties with willing landowners (owner of this site and owner of project 1C land). As designed, the hydrologic impact would approach the next property upstream where the landowner is not interested. The final design must further examine this impact area and include discussions with all possibly impacted landowners.

A bypass drainage ditch would likely be needed for this project because it is a county ditch serving a number of properties which may want continued drainage (see concept in Figure 20). A bypass ditch would ensure upstream properties continue to have the same drainage post-project. Addition of a bypass ditch would likely reduce pollutant removals proportionate to the drainage area that would bypass. Cost estimates are provided both with and without a bypass ditch.

As noted in earlier discussion and the appendices, the legal and drainage challenges of this project in a public ditch are substantial. However, the Ditch 20 weir concept is highly cost effective at phosphorus reduction and provides habitat benefits.

Project Variation - An alternate weir placement is possible that would accomplish projects 2A and 1B simultaneously (Figure 23). If a weir were placed just downstream of the lateral ditch (project 2A places it upstream), wetland would be restored along both the lateral ditch and Ditch 20. Such an arrangement would require willing landowners throughout both areas, and perhaps bypass ditches around restored wetlands. This option would likely have costs similar to project 2A but benefits similar to the sum of 2A and 1B. This option is favored by the owner.

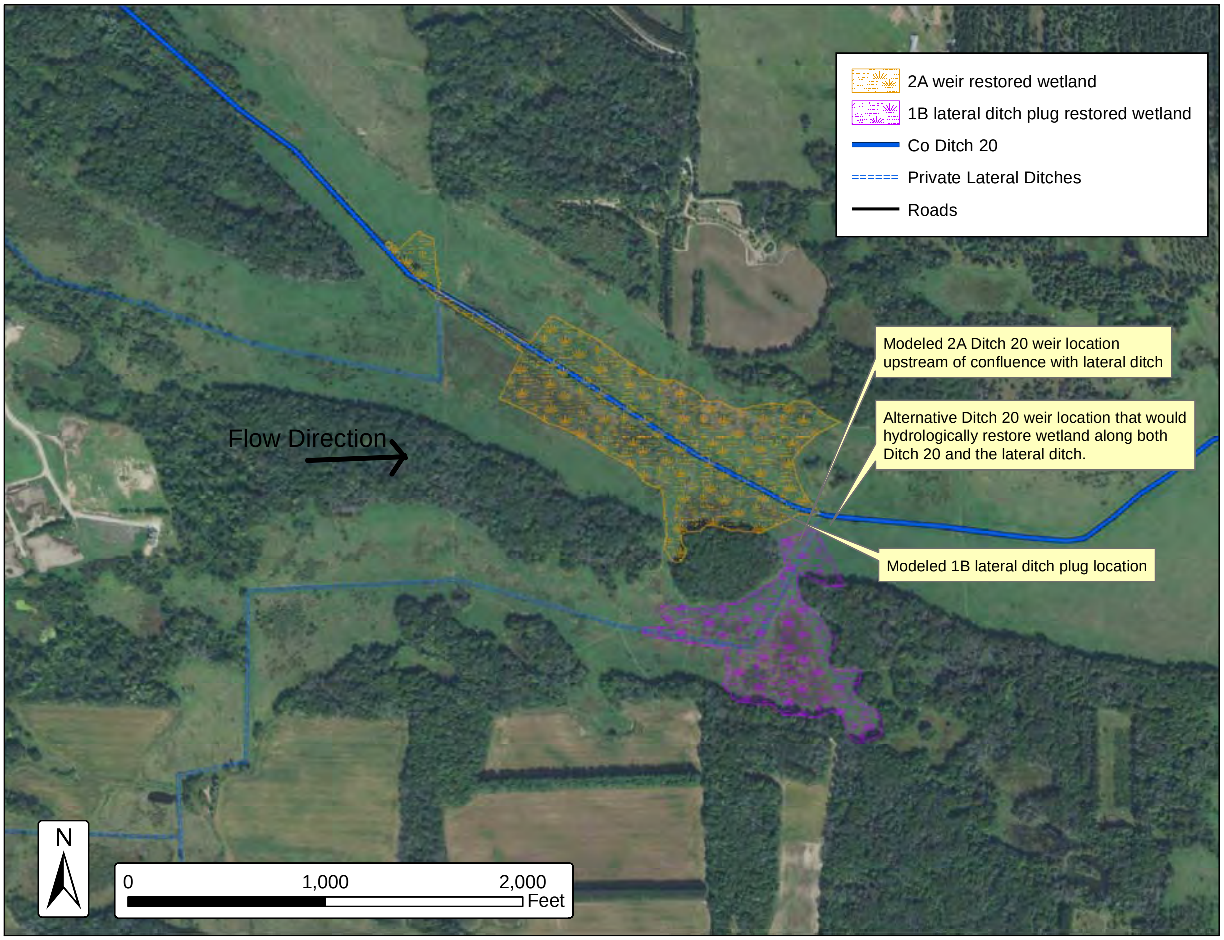


FIGURE 23 OPTION FOR A DITCH 20 WEIR PLACEMENT THAT COMBINES PROJECTS 2A AND 1B
See Figure 18 for general location of projects 2A and 1B. Placing a weir downstream of Ditch 20's confluence with a lateral ditch would restore wetland areas of both project 2A and 1B with a single structure. Bypass ditches to maintain upstream drainage may be needed for each waterway.

Conclusions

- **Favorable projects.** Four feasible projects with landowner support were identified. Each has low costs per pound of phosphorus reduction.
- **Uncertainty in phosphorus reduction.** While the phosphorus reduction estimates for the lateral ditch plug and ditch weir projects are reasonable estimates, these project types inherently have variable results.
- **Install, then monitor.** Because a range of actual phosphorus reductions may be achieved by these projects, it is recommended to install some, monitor effectiveness, and then consider additional installations.
- **Permitting, construction and other challenges.** If any of these projects are pursued, each will require substantial work to reach completion. Reasonable cost estimates are provided, but unforeseen permitting issues, access easement challenges, and similar would affect final costs.
- **Wetland banking approach to installation.** The lateral ditch plug and Ditch 20 weir projects might be best approached as wetland banking. Revenue from sale of wetland credits offers a possible financing mechanism or landowner incentive. The MN Board of Water and Soil Resources has developed options wherein their expert staff would lead the wetland restoration process. Vegetative restoration might be the most difficult aspect near Ditch 20 due to the abundance of the aggressive weed reed canary grass.
- **Lower observed phosphorus may reduce project priorities.** The most recent water monitoring of Ditch 20 has found lower phosphorus concentrations than previously observed. If these levels are maintained, projects at Ditch 20 may become a lower priority for watershed managers.
- **Avoid cleaning the ditch.** Cleaning or re-excavating Ditch 20 and its tributaries should be discouraged. These ditches are probably not at their original depth/profile and have filled in to some unknown extent over time. This has lessened the drainage capacity, presumably with water quality benefits. If the ditch were cleaned to a deeper profile, cycles of drying and wetting that drive phosphorus release, as well as the acreage drained by the ditch, would likely increase and negatively impact downstream waterways.

Local water planners should consider this report's findings when doing comprehensive planning. The water planners include Isanti County, the Sunrise River Watershed Management Organization, the Anoka Conservation District and Isanti Soil and Water Conservation District. Each organization has multi-year management plans that prioritize projects to be built. The Ditch 20 projects should be considered and balanced with other priorities. If included in local water plans and 10-25% locally funded, these projects could compete for state grants that could provide the remainder of needed funding.

Acknowledgements

This feasibility study was completed with an Accelerated Implementation Clean Water Fund grant from the MN Board of Water and Soil Resources. Funds are from the Clean Water Land and Legacy Amendment.

Other funding was from the Sunrise River Watershed Management Organization and the Martin Lakers Association.

Collaborative input was provided to the Anoka Conservation District by:

Landowners, who informed this feasibility study with their intimate knowledge of the lands and waters, and thoughtfully considered project concepts that might apply to their own property

Dr. Chris Lenhart, University of Minnesota

Isanti County

Isanti Soil and Water Conservation District

MN Department of Natural Resources

MN Board of Water and Soil Resources, particularly engineer Tom Wenzel

This project's consulting engineer was Civil Methods, Inc.

References

Ardón, M., S. Montanari, J.L. Morse, M.W. Doyle, and E.S Bernhardt. 2010. Phosphorus export from a restored wetland ecosystem in response to natural and experimental hydrologic fluctuations. Journal of Geophysical Research. 115, G04031.

Braskerud, B.C, K.S. Tonderski, B. Wedding, R. Bakke, A.-G.B. Blankenberg, B. Ulen and J. Koskiaho. 2005. Can constructed wetlands reduce the diffuse phosphorus loads to eutrophic water in cold temperature regions? Journal of Environmental Quality. 34:2145-2155.

Dunne, E.J. and K.R. Reddy. 2005. Phosphorus biogeochemistry of wetlands in agricultural watersheds. In Dunne, Reddy and Carton, *Nutrient Management in Agricultural Watersheds: A Wetlands Solution (pp 105-119)*. Wageningen Academic Publishers, 2005.

Fisher, J. and M.C. Acreman. 2004. Wetland nutrient removal: a review of the evidence. Hydrology and Earth System Sciences. 8(4): 673-685.

Kjaergaard, C., L. Heiberg, H. Jensen and H.C. Hansen. 2012. Phosphorus mobilization in rewetted peat and sand at variable flow rate and redox regimes. Geoderma. 173-174 (2012) 311-321.

Koltz, R.L. and S.A. Linn. 2001. Influence of factors associated with water level drawdown on phosphorus release from sediments. Lake and Reservoir Management. 17(1): 48-54.

Koskiaho, J., P. Ekholm, M. Räty, J. Riihimäki, M. Puustinen. 2003. Retaining agricultural nutrients in constructed wetlands – experiences under boreal conditions. Ecological Engineering. 20: 89-103.

Litaor, M.I., O. Reichmann, K. Auerswald, A. Haim, M. Shenker. 2004. Sorption characteristics of phosphorus in peat soils of a semiarid altered wetland. Soil Sci. Soc. Am. J. 69, 1658-1665.

Meissner, R., P. Leinweber, H. Rupp, M. Shenker, M.I. Litaor, S. Robinson, A. Schliting, J. Koen. 2008. Mitigation of diffuse phosphorus pollution during rewetting of fen peat soils: a trans-European case study. Water Air Soil Pollut. 188, 111-126.

Moore, P.A. and K.R. Reddy. 1994. Role of Eh and pH on phosphorus geochemistry in sediments of Lake Okeechobee, Florida. Journal of Environmental Quality. 23, 955-964.

Pant, H.K., V.D. Nair, K.R. Reddy, D.A. Graetz, R.R. Villapando. 2002. Influence of flooding on phosphorus mobility in manure-impacted soil. Journal of Environmental Quality. 31, 1399-1405.

Sallade, Y.E. and J.T. Sims. 1997. Phosphorus transformations in the sediments of Delaware’s agricultural drainageways: II, effect of reducing conditions on phosphorus release. J. Environmental Quality. 26, 1579-1588.

Schurbon, J., Minnesota Pollution Control Agency and Emmons and Olivier Resources, Inc. 2012. Typo Lake and Martin Lake TMDL. Web.

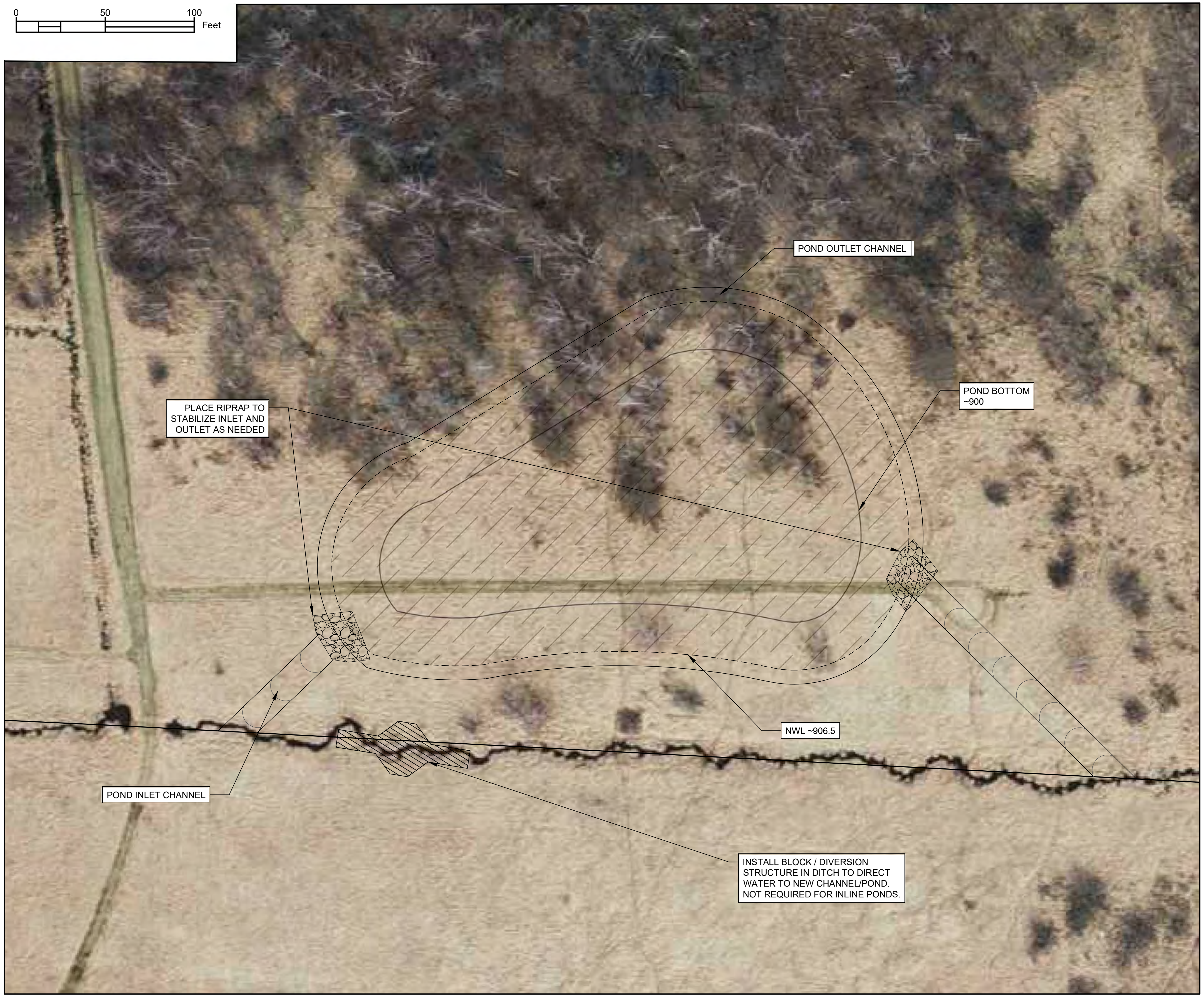
Turner, B.L. and P.M. Haygarth. 2001. Phosphorus solubilization in rewetted soils. Nature. 411:256.

Ward, A. D., Mecklenburg, D., Powell, G. E., Brown, L. C., & Jayakaran, A. C. 2004. Designing two-stage agricultural drainage ditches. In *Drainage VIII, 21-24 March 2004* (p. 1). American Society of Agricultural and Biological Engineers.

Woltemade, C.J. 2000. Ability of restored wetlands to reduce nitrogen and phosphorus concentrations in agricultural drainage water. Journal of Soil and Water Conservation. 53(3) 303-309.

Young, E.O., and D.S. Ross. 2001. Phosphate release from seasonally flooded soils: a laboratory microcosm study. Journal of Environmental Quality. 30, 91-101.

Appendix A: Concept Designs for Modeled Water Quality Projects



N

0 30 60 Feet

GENERAL NOTES:

1. Calculation of preliminary costs accounts for the requirement to transport excavated material for disposal on the nearest available upland. The pond location (to be determined through consultation with landowners and other stakeholders) will significantly impact the transport and disposal costs.
2. Ditch plug construction shall follow guidelines laid out in the Minnesota Wetland Restoration Guide, Technical Guidance Document, "Blocking and Filling Surface Drainage Ditches".
3. P removal estimates based on runs of P8 water quality model.
4. Planning-level estimates of P concentrations in runoff were determined based on water quality samples taken from several different years. The average concentration of samples from each year were calculated, and the median annual average concentration was used for estimating loads.
5. Pond location shown is for illustrative purposes only. Final pond location will impact access, ownership, and inlet/outlet configuration.
6. Easements or similar arrangement will be required in order to ensure long term pond operation, access, maintenance, etc.

ESTIMATE OF QUANTITIES AND COSTS:

Item No.	Item	Estimated Quantity	Unit	Unit Cost	Total Amount
1	MOBILIZATION	1	LUMP SUM	$8,000.00	$8,000.00
2	EROSION CONTROL & RESTORATION	1	LUMP SUM	$4,500.00	$4,500.00
3	EXCAVATION AND TRANSPORT OF MATERIAL	8068	CU YD	$14.00	$112,952.00
4	INLET / OUTLET CONFIGURATION	1	LUMP SUM	$1,500.00	$1,500.00
				SUBTOTAL ESTIMATED CONSTRUCTION:	$126,952.00
				FINAL DESIGN / ENGINEERING CONTINGENCIES (10%)	$12,695.20
				CONSTRUCTION CONTINGENCIES (10%):	$12,695.20
				ESTIMATED BASE COST	**$152,342.40**

POLLUTANT REMOVAL SUMMARY:

POND MODELED IN P8 WATER QUALITY MODEL		
UPSTREAM DRAINAGE AREA	1700	ACRE
ESTIMATED ANNUAL P LOADING FROM DRAINAGE AREA (TP)	789.1	LB/YR
POND AREA @ NORMAL WATER LEVEL	1.31	ACRE
PERCENT REMOVAL BASED ON MODELING	14.90	PERCENT
ESTIMATED ANNUAL REMOVAL OF TOTAL PHOSPHORUS	**117.58**	LB/YR TP

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West St. Paul, MN 55118
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DRAFT
NOT FOR CONSTRUCTION

XXXX X XXXX
DATE: XX-XX-XXXX
LIC. NO.: XXXXX

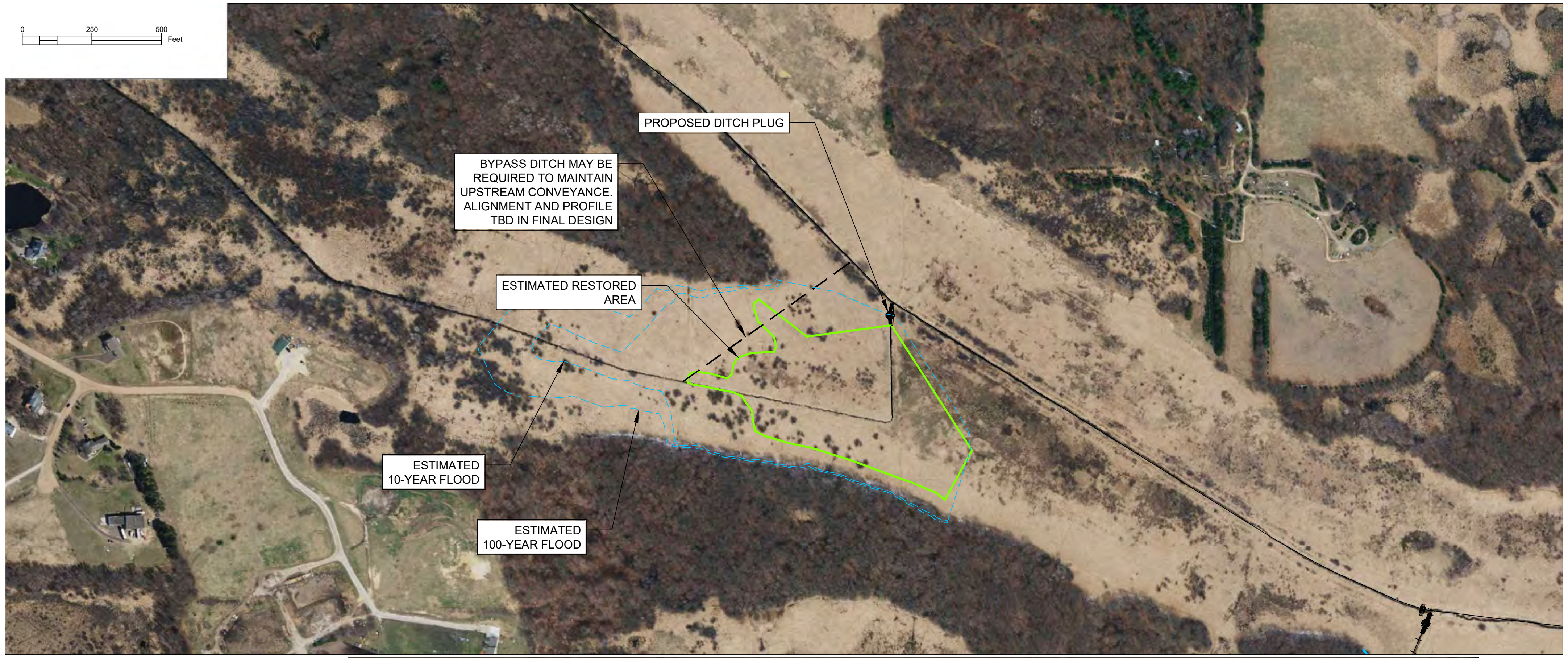
DESIGNED: XXX
DRAWN: XXX
CHECKED: XXX

DATE / REVISION:

OWNER:
ANOKA CONSERVATION DISTRICT
1318 MCKAY DR NE
HAM LAKE, MN 55304

TITLE:
3A: MATTSSON POND
DITCH 20 WETLAND RESTORATION FEASIBILITY STUDY
ISANTI COUNTY, MN

SHEET NO:
5



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0 250 500 Feet

LEGEND:

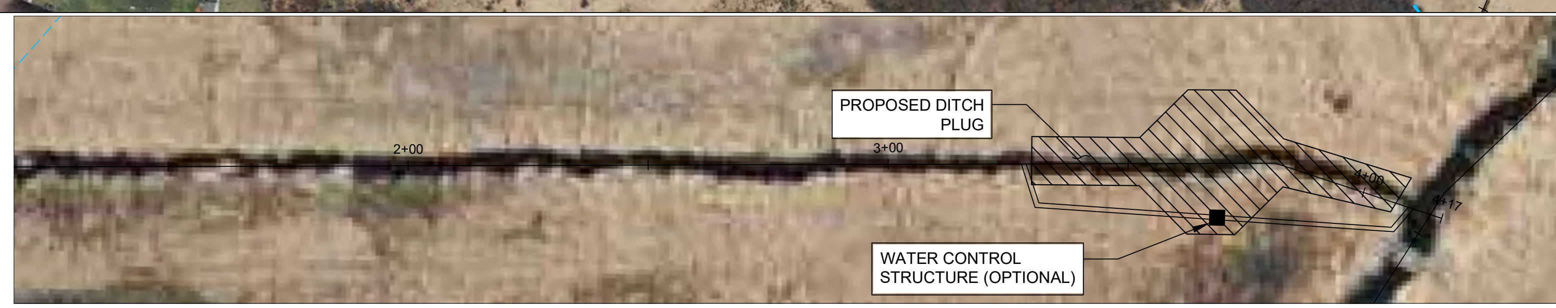
- ESTIMATED HYDROLOGIC RESTORATION AREA
- DITCH PLUG
- POTENTIAL BYPASS DITCH LOCATION
- ESTIMATED FLOOD IMPACT AREAS

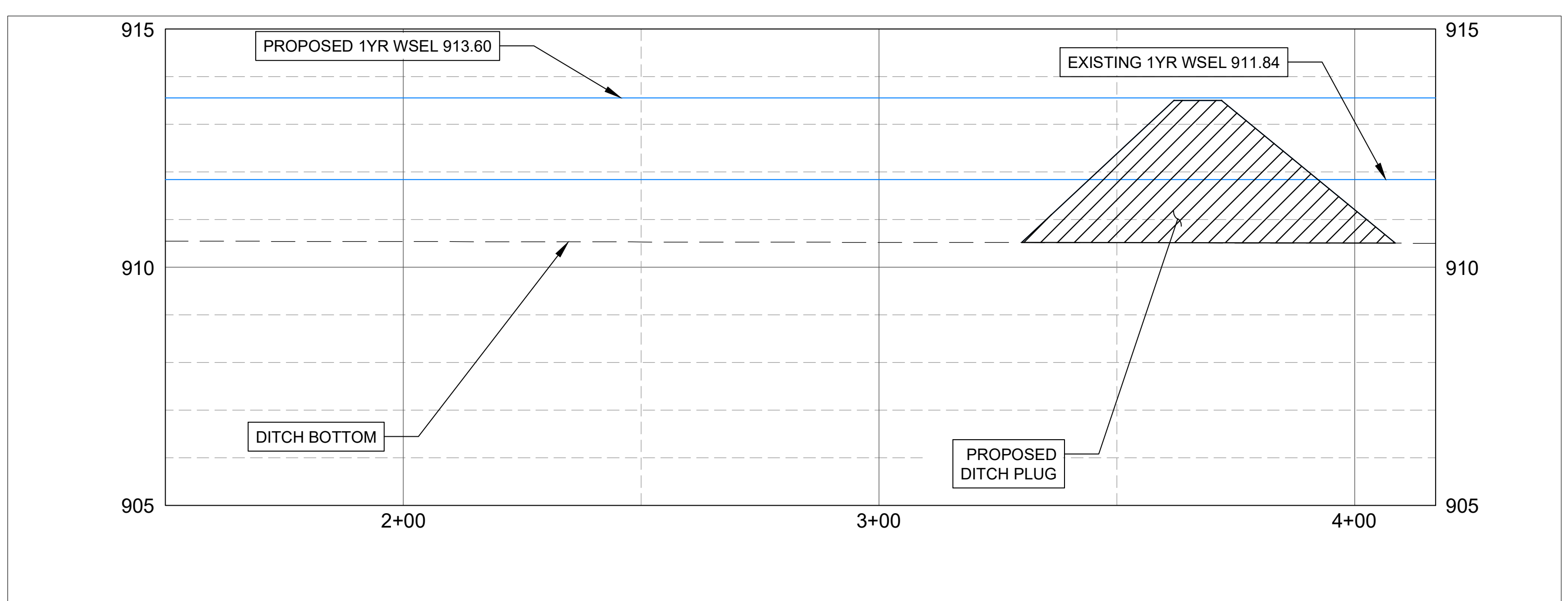
GENERAL NOTES:

1. Calculation of preliminary costs assume that adequate amounts of suitable material can be located on site for construction of the ditch plug. This must include material with an adequate amount of clay/fine material in order to effectively block flow where desired.
2. Ditch plug construction shall follow guidelines laid out in the Minnesota Wetland Restoration Guide, Technical Guidance Document, "Blocking and Filling Surface Drainage Ditches".
3. Calculation of phosphorus loading based on monitoring data, with average of 0.302 lb/acre/yr of phosphorus loading for the overall drainage area. Estimated proportions of dissolved vs. particulate phosphorus also based on monitoring data.
4. Numerous literature references were consulted in order to determine the most appropriate estimate of P removal/sequestration by restored wetlands. Based on the literature review, and considering specific elements of this watershed including location, ratio of wetland area to watershed area, and other factors, removal percentages of 46% (PP) and 12% (DP) were selected for planning purposes.
5. P removal estimates are based on a nutrient cycling model that considers the long-term viability of the wetland for sequestration of P. Short term increases in P discharge following hydrologic restoration have been reported and attributed to release of P under anoxic conditions.
6. Constructing multiple ditch plugs or other controls as part of a single project would eliminate the need for multiple mobilization fees.
7. Planning-level estimates of P concentrations in runoff were determined based on water quality samples taken from several different years. The average concentration of samples from each year were calculated, and the median annual average concentration was used for estimating loads.
8. Per discussion with BWSR, in final design it will be necessary to ensure that the ditch block does not negatively impact upstream property. An open bypass ditch alignment is depicted, as that is likely the most feasible option. Installation of a solid wall tile to convey upstream low flows may be considered, although it presents several concerns. Bypass configuration to be determined in final design. To the extent practicable low flows from upstream would continue to be directed to the restoration area, with sufficient bypass capacity to maintain drainage benefits.

Note - Optional Control Structure:

As indicated on the plan view, it may be desired to install a water control structure at the time of installation of the ditch block, in order to provide a means of releasing water from the restored area (the area upstream of the ditch block). Although not necessary in order to achieve the water quality benefits of the project, it would provide a safeguard against unintended upstream consequences by allowing drainage of the area if necessary. The ability to drain/dewater the area upstream of the ditch block can also be used for additional water quality benefits, by seasonally drawing down the water level and making more storage available to capture spring thaw runoff. It should be noted that there are feasibility concerns with these structures. They can become easily clogged in this type of landscape and they are difficult to get set at the right elevation when there is so little topographic relief.

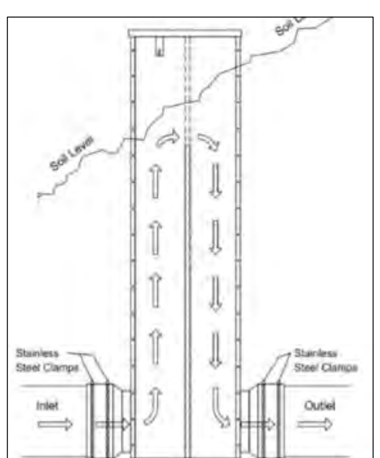




ESTIMATE OF QUANTITIES AND COSTS:

Item No.	Item	Estimated Quantity	Unit	Unit Cost	Total Amount
1	MOBILIZATION	1	LUMP SUM	$8,000.00	$8,000.00
2	CLEARING	1	EACH	$350.00	$350.00
3	EROSION CONTROL & RESTORATION	1	LUMP SUM	$3,500.00	$3,500.00
4	EXCAVATION, PLACEMENT, AND COMPACTION	133	CU YD	$20.00	$2,660.00
5	MUCK EXCAVATION	37	CU YD	$8.00	$296.00
				SUBTOTAL ESTIMATED CONSTRUCTION:	$14,806.00
				FINAL DESIGN / ENGINEERING CONTINGENCIES (10%)	$1,480.60
				CONSTRUCTION CONTINGENCIES (10%):	$1,480.60
				ESTIMATED BASE COST	$17,767.20
ALT	WATER CONTROL STRUCTURE (INSTALLED) (OPTIONAL)	1	EACH	$4,000.00	$4,000.00
ALT	BYPASS DITCH	1046	CY	$20.00	$20,920.00
				ESTIMATED COST (W/ OPTION)	$42,687.20

CONTROL STRUCTURE SKETCH



POLLUTANT REMOVAL SUMMARY:

SEE NOTES FOR DETAILS REGARDING REMOVAL CALCULATIONS

HYDROLOGICALLY RESTORED WETLAND AREA	336436	SF	7.72	ACRE
UPSTREAM DRAINAGE AREA	677.8	ACRE		
ESTIMATED ANNUAL P LOADING FROM DRAINAGE AREA	314.62	LB/YR		
ESTIMATED BREAKDOWN OF DISSOLVED VS PARTICULATE P	169.90	LB/YR DP	144.73	LB/YR PP
ESTIMATED ANNUAL REMOVAL OF DISSOLVED AND PARTICULATE P	**20.39**	LB/YR DP	**66.57**	LB/YR PP

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XXXX X XXXX

DATE: XX-XX-XXXX

LIC. NO.: XXXXX

DRAFT NOT FOR CONSTRUCTION

DESIGNED: XXX
DRAWN: XXX
CHECKED: XXX

DATE / REVISION:

OWNER:
ANOKA CONSERVATION DISTRICT
1318 MCKAY DR NE
HAM LAKE, MN 55304

TITLE:
1C: HESSE LATERAL DITCH PLUG
DITCH 20 WETLAND RESTORATION FEASIBILITY STUDY
ISANTI COUNTY, MN

SHEET NO:
3

N

0 250 500 Feet

LEGEND:

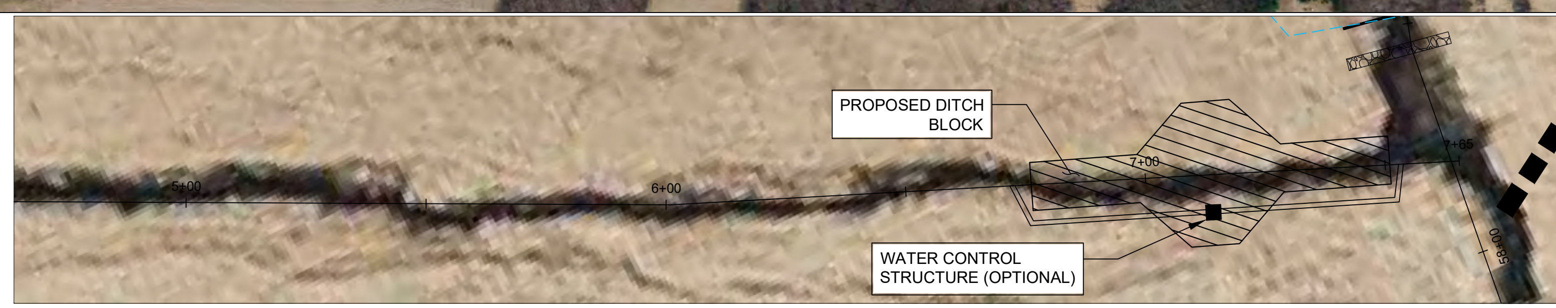
(green line)	ESTIMATED HYDROLOGIC RESTORATION AREA	(hatch)	DITCH PLUG
— — —	POTENTIAL BYPASS DITCH LOCATION	- - - -	ESTIMATED FLOOD IMPACT AREAS

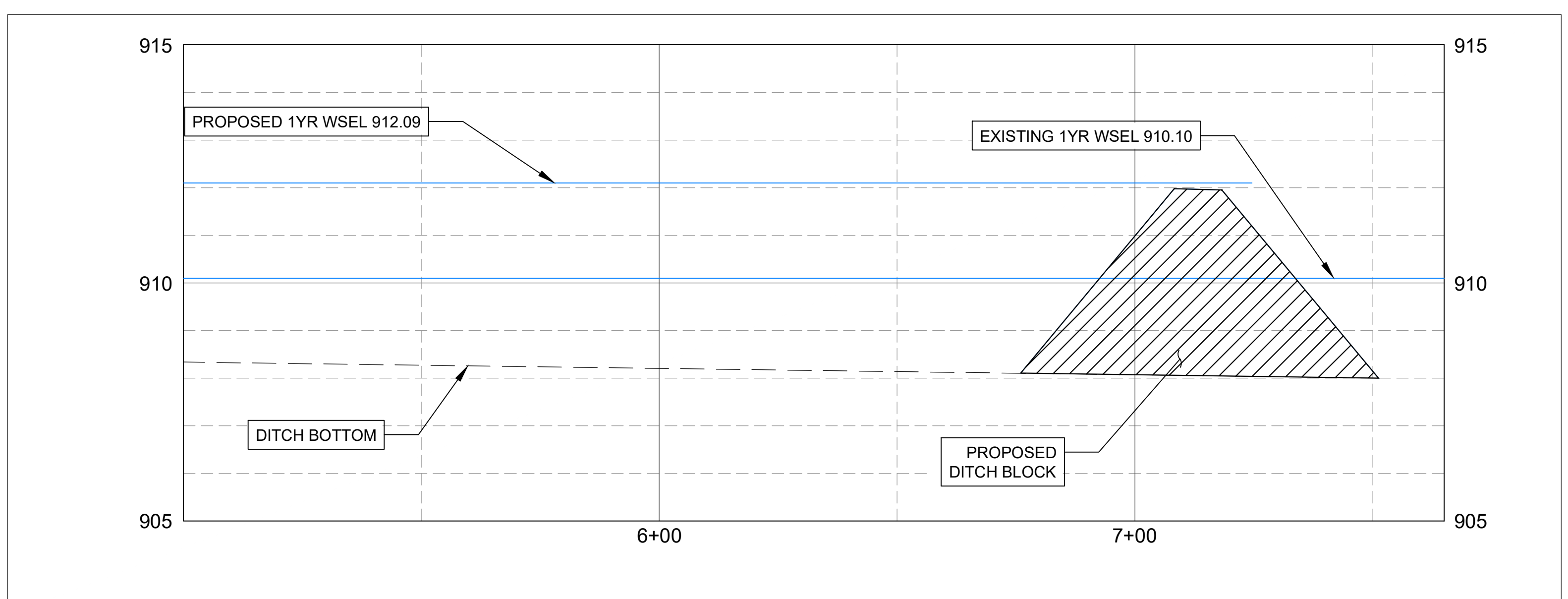
GENERAL NOTES:

1. Calculation of preliminary costs assume that adequate amounts of suitable material can be located on site for construction of the ditch plug. This must include material with an adequate amount of clay/fine material in order to effectively block flow where desired.
2. Ditch plug construction shall follow guidelines laid out in the Minnesota Wetland Restoration Guide, Technical Guidance Document, "Blocking and Filling Surface Drainage Ditches".
3. Calculation of phosphorus loading based on monitoring data, with average of 0.302 lb/acre/yr of phosphorus loading for the overall drainage area. Estimated proportions of dissolved vs. particulate phosphorus also based on monitoring data.
4. Numerous literature references were consulted in order to determine the most appropriate estimate of P removal/sequestration by restored wetlands. Based on the literature review, and considering specific elements of this watershed including location, ratio of wetland area to watershed area, and other factors, removal percentages of 46% (PP) and 12% (DP) were selected for planning purposes.
5. P removal estimates are based on a nutrient cycling model that considers the long-term viability of the wetland for sequestration of P. Short term increases in P discharge following hydrologic restoration have been reported and attributed to release of P under anoxic conditions.
6. Constructing multiple ditch plugs or other controls as part of a single project would eliminate the need for multiple mobilization fees.
7. Planning-level estimates of P concentrations in runoff were determined based on water quality samples taken from several different years. The average concentration of samples from each year were calculated, and the median annual average concentration was used for estimating loads.
8. Per discussion with BWSR, in final design it will be necessary to ensure that the ditch block does not negatively impact upstream property. An open bypass ditch alignment is depicted, as that is likely the most feasible option. Installation of a solid wall tile to convey upstream low flows may be considered, although it presents several concerns. Bypass configuration to be determined in final design. To the extent practicable low flows from upstream would continue to be directed to the restoration area, with sufficient bypass capacity to maintain drainage benefits.

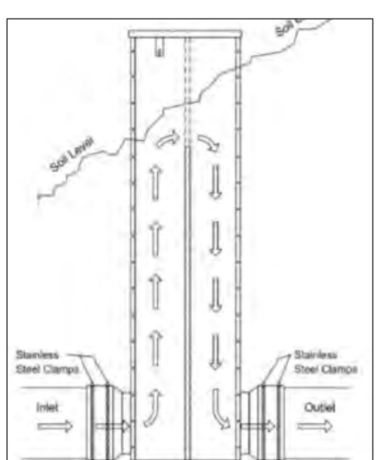
Note - Optional Control Structure:

As indicated on the plan view, it may be desired to install a water control structure at the time of installation of the ditch block, in order to provide a means of releasing water from the restored area (the area upstream of the ditch block). Although not necessary in order to achieve the water quality benefits of the project, it would provide a safeguard against unintended upstream consequences by allowing drainage of the area if necessary. The ability to drain/dewater the area upstream of the ditch block can also be used for additional water quality benefits, by seasonally drawing down the water level and making more storage available to capture spring thaw runoff. It should be noted that there are feasibility concerns with these structures. They can become easily clogged in this type of landscape and they are difficult to get set at the right elevation when there is so little topographic relief.





CONTROL STRUCTURE SKETCH



ESTIMATE OF QUANTITIES AND COSTS:

Item No.	Item	Estimated Quantity	Unit	Unit Cost	Total Amount
1	MOBILIZATION	1	LUMP SUM	$8,000.00	$8,000.00
2	CLEARING	1	EACH	$350.00	$350.00
3	EROSION CONTROL & RESTORATION	1	LUMP SUM	$3,500.00	$3,500.00
4	EXCAVATION, PLACEMENT, AND COMPACTION - LATERAL	133	CU YD	$20.00	$2,660.00
5	MUCK EXCAVATION - LATERAL	37	CU YD	$8.00	$296.00
				SUBTOTAL ESTIMATED CONSTRUCTION:	$14,806.00
				FINAL DESIGN / ENGINEERING CONTINGENCIES (10%)	$1,480.60
				CONSTRUCTION CONTINGENCIES (10%):	$1,480.60
				ESTIMATED BASE COST	**$17,767.20**
ALT	WATER CONTROL STRUCTURE (INSTALLED) (OPTIONAL)	1	EACH	$4,000.00	$4,000.00
ALT	BYPASS DITCH	1228	CU YD	$20.00	$24,560.00
				ESTIMATED COST (W/ OPTIONS)	**$46,327.20**

POLLUTANT REMOVAL SUMMARY:

SEE NOTES FOR DETAILS REGARDING REMOVAL CALCULATIONS

HYDROLOGICALLY RESTORED WETLAND AREA	473137	SF	10.86	ACRE
UPSTREAM DRAINAGE AREA	807.7	ACRE		
ESTIMATED ANNUAL P LOADING FROM DRAINAGE AREA	374.92	LB/YR		
ESTIMATED BREAKDOWN OF DISSOLVED VS PARTICULATE P	202.46	LB/YR DP	172.46	LB/YR PP
ESTIMATED ANNUAL REMOVAL OF DISSOLVED AND PARTICULATE P	**24.29**	LB/YR DP	**79.33**	LB/YR PP

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CIVIL METHODS, INC.
1551 Livingston Avenue, Suite 104
West St. Paul, MN 55118
o:763.210.5713 | www.civilmethods.com

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DRAFT NOT FOR CONSTRUCTION

XXXX X XXXX DATE: XX-XX-XXXX

LIC. NO.: XXXXX

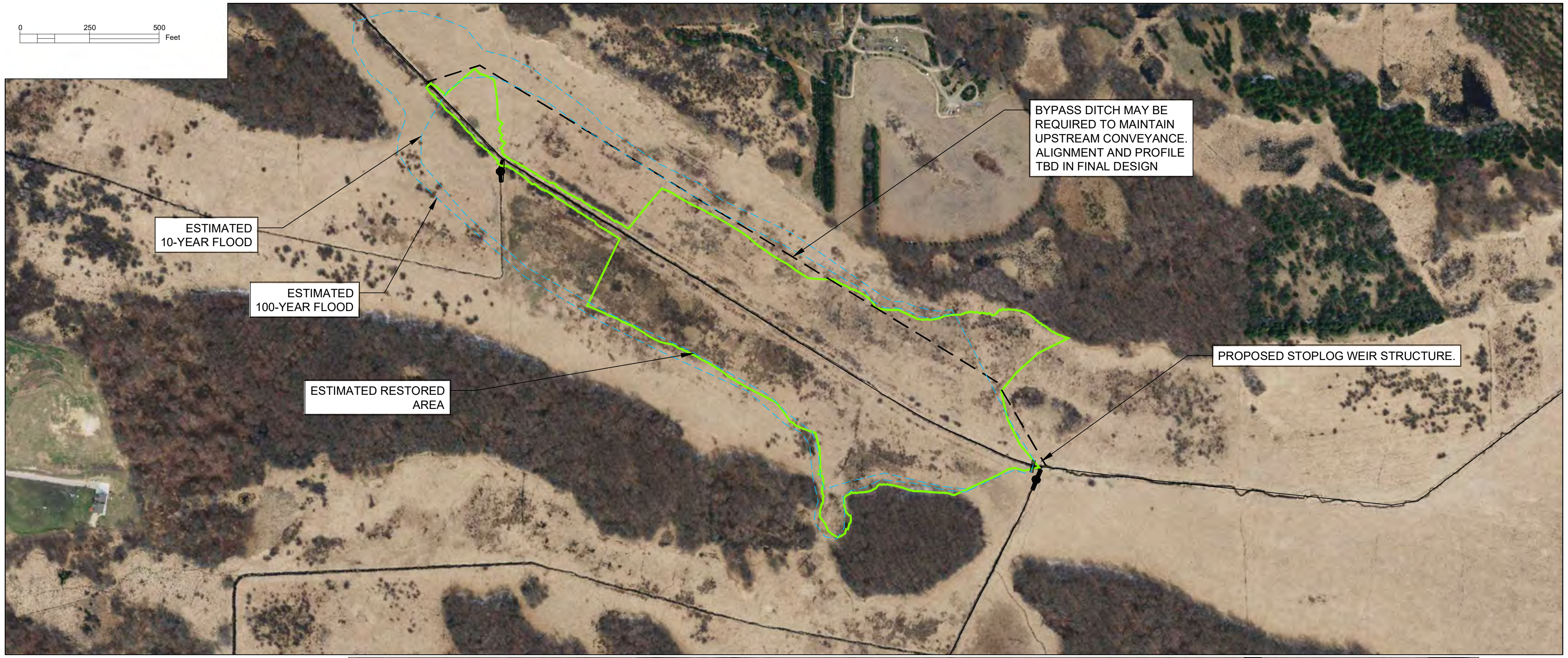
DESIGNED: XXX
DRAWN: XXX
CHECKED: XXX

DATE / REVISION:

OWNER:
ANOKA CONSERVATION DISTRICT
1318 MCKAY DR NE
HAM LAKE, MN 55304

TITLE:
1B: LIDDELL LATERAL DITCH PLUG
DITCH 20 WETLAND RESTORATION FEASIBILITY STUDY
ISANTI COUNTY, MN

SHEET NO:
2



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0 250 500 Feet

LEGEND:

ESTIMATED HYDROLOGIC RESTORATION AREA

DITCH PLUG

POTENTIAL TILE LOCATION

GENERAL NOTES:

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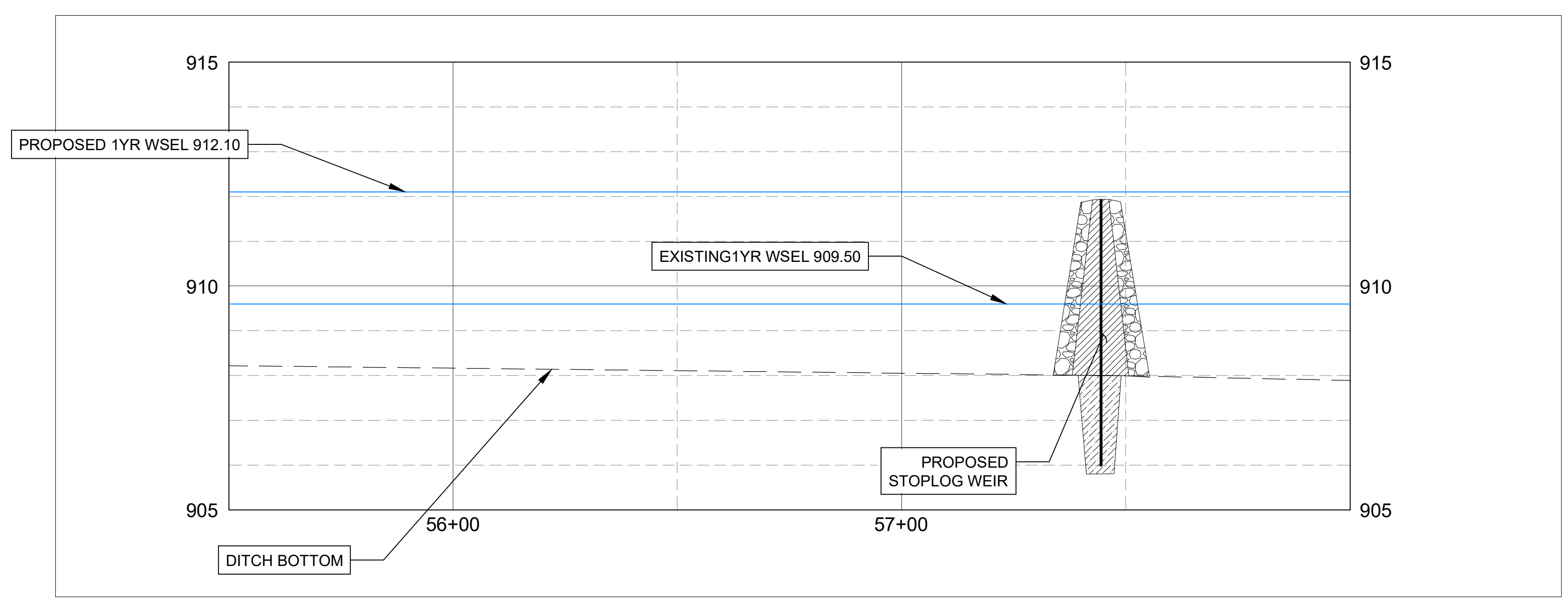

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2	CLEARING	1	EACH	$350.00	$350.00
3	EROSION CONTROL & RESTORATION	1	LUMP SUM	$3,500.00	$3,500.00
4	EXCAVATION, PLACEMENT, AND COMPACTION	84	CU YD	$20.00	$1,680.00
5	MUCK EXCAVATION	18	CU YD	$8.00	$144.00
7	WEIR MATERIALS, EXCAVATION, PLACEMENT	1	LUMP SUM	$5,500.00	$6,500.00
				SUBTOTAL ESTIMATED CONSTRUCTION:	$20,174.00
				FINAL DESIGN / ENGINEERING CONTINGENCIES (10%)	$2,017.40
				CONSTRUCTION CONTINGENCIES (10%):	$2,017.40
				ESTIMATED BASE COST	**$24,208.80**
ALT	BYPASS DITCH	3675	CY	$20.00	$73,500.00
				ESTIMATED COST (W/ OPTION)	**$97,708.80**

POLLUTANT REMOVAL SUMMARY:

SEE NOTES FOR DETAILS REGARDING REMOVAL CALCULATIONS

HYDROLOGICALLY RESTORED WETLAND AREA	938905	SF	21.55	ACRE
UPSTREAM DRAINAGE AREA	893.0	ACRE		
ESTIMATED ANNUAL P LOADING FROM DRAINAGE AREA	414.52	LB/YR		
ESTIMATED BREAKDOWN OF DISSOLVED VS PARTICULATE P	223.84	LB/YR DP	190.68	LB/YR PP
ESTIMATED ANNUAL REMOVAL OF DISSOLVED AND PARTICULATE P	**26.86**	LB/YR DP	**87.71**	LB/YR PP

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XXXX X XXXX

DATE: XX-XX-XXXX

LIC. NO.: XXXXX

DRAFT
NOT FOR CONSTRUCTION

DESIGNED: XXX
DRAWN: XXX
CHECKED: XXX

DATE / REVISION:

OWNER:
ANOKA CONSERVATION DISTRICT
1318 MCKAY DR NE
HAM LAKE, MN 55304

TITLE:
2A: LIDDELL WEIR
DITCH 20 WETLAND RESTORATION FEASIBILITY STUDY
ISANTI COUNTY, MN

SHEET NO:
4

Appendix B: Minnesota Ditch Law Discussion as it Pertains to This Study’s Findings

Legal status of County Ditch 20

County Ditch 20 is a public drainage system, and the Drainage Authority (Isanti County) has the responsibility to maintain the ditch in such a manner that it continues to provide effective and efficient drainage for benefited properties. Specific property owners may decide to allow hydrologic modifications (such as ponding or restoration of wetland groundwater hydrology) that would impact the drainage for their property. However, it must be done in a way that does not impact the drainage capacity for upstream or downstream property owners.

Relevant Ditch Law

Drainage ditch management is governed primarily by MN Statutes Chapter 103E (Drainage). Drainage projects (whether for construction of a new system or modification of an existing system) are generally initiated by way of a petition. For the hydraulic modification projects considered for County Ditch 20 (weirs, lateral ditch plugs), the petition would be initiated in the category described in Chapter 103E.227, "Impounding, Rerouting, and Diverting Drainage System Waters." This is the type of petition typically used in this situation, where an impediment is purposefully placed within the ditch, thus limiting hydraulic capacity in order to pool (impound) water for beneficial wetland purposes. A common use of this type of project and petition would be to create a wetland bank by placing a control structure on the ditch and restoring the wetland area upstream. In the case of the County Ditch 20 hydraulic modification projects, the primary goal is restoration of wetland hydrology in order to reduce pollutant discharge, and the final design may or may not meet the specific requirements for wetland banking credits, but the procedure with regard to ditch law is the same.

Ditch Law requires the Drainage Authority to maintain the system so that it provides efficient and effective drainage for benefited properties. This can be expressed in a number of ways. Historically the purpose of creating drainage ditches was largely to drain groundwater in order to allow for agricultural use. In general, that continues to be the key driving force behind ditch projects, and the main governing parameter is the control elevation, or the lowest elevation at which water can discharge freely downstream. The control elevation may be established either by a structure or directly in the ditch. With regard to the general obligation of the Drainage Authority, the required control elevation at a given location is defined by the original ditch profile, or whatever profile has been established by the Drainage Authority as official.

In addition to the control elevation and the regulation of groundwater drainage, the requirement of maintaining effective and efficient drainage can also apply to storm flow. It is important to test the ditch modification design on several larger storm events (such as the 2-year, 10-year, and 100-year storms) in order to verify that the changes have not impacted upstream and downstream properties in terms of flooding.

Legal/Regulatory Approach for County Ditch 20 Hydraulic Modification Projects

Prior to initiating a petition to impound water within the County Ditch 20 system, the original/regulatory profile of the ditch should be identified or determined, as this will serve as the baseline for comparison with the design. This information is available through Isanti County, but some work may be needed to gather all the needed information from the records, which are dated 1916 and sometimes use landmarks that are not likely present today.

With the official ditch profile established, the next step would be to initiate the petition described above, following the procedure laid out in 103E.227. This will include, among other things, notifying agencies, acquiring permits, providing concept plans, identifying likely areas of impact, and listing the sources of funding for the project. A petition of this nature can be initiated by any party, with the goal of demonstrating that the proposed project will provide benefit without diminishing the capacity of the ditch to provide the required level of drainage.

For the pond project (3A) no special measures or considerations will likely need to be taken to prevent unwanted upstream drainage impacts. The pond will not significantly alter the upstream or downstream system hydraulics, as they are anticipated to be simple flow-through ponds providing a wider, deeper area of low velocity and storage for settling to occur. While this does provide water quality benefits, it does not impound water to the extent of causing a backwater effect.

For the remaining ditch control structures (1B, 1C, and 2A), additional consideration must be given to how the installation of the practice could impact upstream landowners, and how this should be handled from the standpoint of both design and legal proceedings. The concept designs for these projects include the modeled 10- and 100-year rainfall event water levels. While the concept practices have been placed and sized to have impact on few, or just one landowner, many have potential impacts near property boundaries.

Based on discussions with BWSR staff, the most straightforward approach to restoring wetland hydrology with a lateral ditch block or ditch weir, while maintaining drainage capacity for upstream property owners, is to install a new bypass ditch at the upstream end of the restoration area which discharges back into Ditch 20 downstream of the proposed control structure. In this case, the original ditch section would need to be officially abandoned, and the new bypass ditch would take its place as a newly established drainage ditch. This approach assumes that the upstream landowners do not consent to a reduction in drainage capacity from their property. If there are additional property owners willing to allow some degree of drainage modification for the purposes of wetland restoration or water quality improvement, that should be taken into account in final design.

Note: This information was provided by Civil Methods, Inc.

Isanti County is the legal ditch authority for County Ditch 20

Appendix C: Wetland Law Discussion as it Pertains to This Study's Findings

Applicable Wetland Laws

The three project types presented in this report (weir, lateral ditch block and settling pond) would all occur areas that may be wetland and require wetland permitting. The potentially applicable laws include:

- Minnesota Ditch law in MN Statutes Chapter 103E (Drainage) administered by Isanti County (see Appendix B for discussion)
- Minnesota Wetland Conservation Act administered by Isanti County
- Section 404 of the Federal Clean Water Act administered by the US Army Corps of Engineers

Evaluation of Wetland Presence

Whether wetland laws would be applicable to projects presented in this study first requires a determination of whether jurisdictional wetlands are present at the project sites. On October 4, 2017, Anoka Conservation District (ACD) staff visited the sites of possible projects (settling pond, Ditch 20 weir and lateral ditch plugs).

Jurisdictional wetlands are determined by the presence of hydrophytic vegetation, hydric soils and hydrology meeting the criteria outlined in the 1987 Corps of Engineers Wetlands Delineation Manual. While at the possible project sites, ACD staff reviewed each of these considerations. Generally, staff reviewed the floodplain area within 300 feet of the ditch where projects were most likely to occur and wetland impacts (such as hydrological impacts, ponding) might be realized. Because the exact location of any future project is unknown, this review was performed over the general area. If any projects are pursued a more detailed and locationally-precise wetland review is needed.

Hydric soils are one diagnostic characteristic of wetlands. All potential sites for these projects have similar soils - with peats with depths of 3 feet to 5+ feet (Figure 24). Additional borings would be needed to determine exact depths because only hand boring to five feet could be performed during our investigation. Peat soils are histosols (organic soils) and classified as hydric soils. They are indicative of saturated conditions for a prolonged time during soil genesis. However, peat soils can be drained (for example by ditching) and the presence of peat does not necessarily mean an area still meets wetland criteria today.

Figure 24 Soil Profile OF Peat Adjacent to County Ditch 20

These organic soils have ramifications on drainage potential by Ditch 20. Peat depths are an extremely important parameter in determining lateral effect of a ditch (horizontal drainage capability) which can be determined with the van Schilfgaarde equation. Peat depths greater than 10 feet can reduce lateral effect dramatically to less than 50 feet while shallow peat depths can allow for lateral effect to be greater than 300 feet. If peat soils are greater than 10 feet, there is a great likelihood that most areas are not drained by the ditch and are jurisdictional wetland under the law.

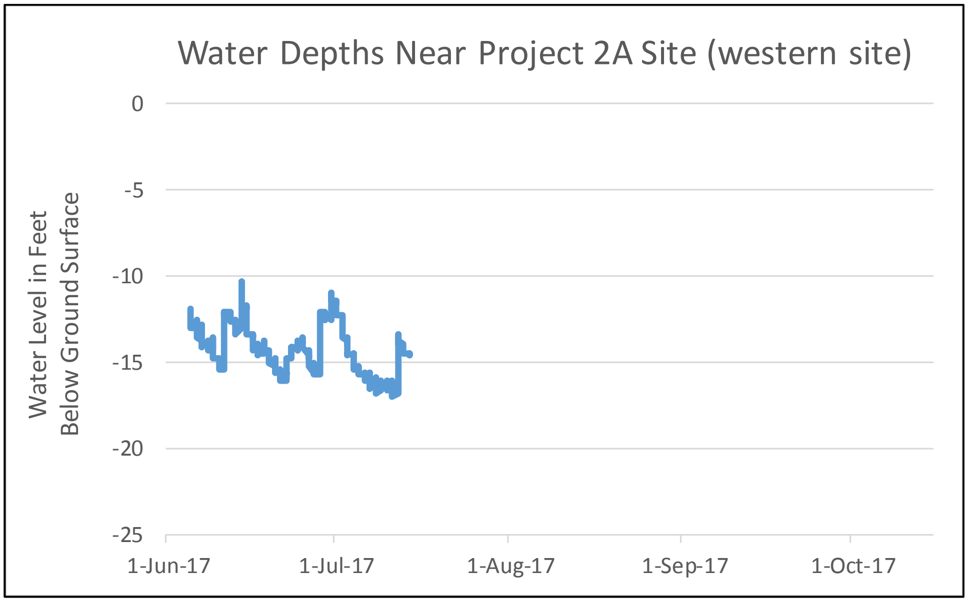
The composition of vegetation is also a wetland diagnostic factor. The vegetation was generally the same on all of the possible project sites with a predominance of reed canary grass (*Phalaris arundinacea*) and stinging nettle (*Urtica diocea*) in the herbaceous layer and mix of wetland shrubs including red osier dogwood (*Cornus sericia*), sandbar willow (*Salix interior*) and scattered bog birch (*Betula pumila*) in the shrub layer. There was minimal tree cover. Based on the predominance of hydrophytes, the site would meet the vegetation criteria for wetland.

FIGURE 25 VEGETATIVE COMMUNITY ALONG COUNTY DITCH 20

The third and last wetland diagnostic factor is hydrology. To be considered wetland, an area would be expected to have water levels within at least 12 inches of the surface for a minimum of 14 consecutive days during the growing season in most years precipitation. This is inherently difficult to observe during a short field visit but secondary indicators (e.g. water marks, drainage patterns) can be observed in the field. We also monitored subsurface water levels in the project areas.

We installed datalogging water level recorders at two locations that represented the vicinity of the possible project sites. They were placed 80 feet north of Ditch 20 at the 2A project site and 90 feet north of the ditch at the 3A project site (see Figure 8). The wells were 40 inches deep, had a screened casing and contained a WL40 model water level recorder from Remote Data Systems, Inc. One well operated from June 1 to July 14 only and then malfunctioned. The other well , operated from June 1 to July 14, malfunctioned for a few weeks, then was operational again from August 23 to October 4.

Water level depths below ground surface at the two sites were close to the threshold for wetland hydrology of 12 inches or less (Figure 26**Error! Reference source not found.**). The observed water levels varied from 10-20 inches below the surface though neither site met the 14 consecutive days criteria. However, most wetland agencies consider that the criteria would be met since the wells were in place later than the months of April and May when precipitation is relatively consistent and evapotranspiration rates are low. The Minnesota Climatology Office database indicates June, 2017 was a normal month in terms of precipitation.



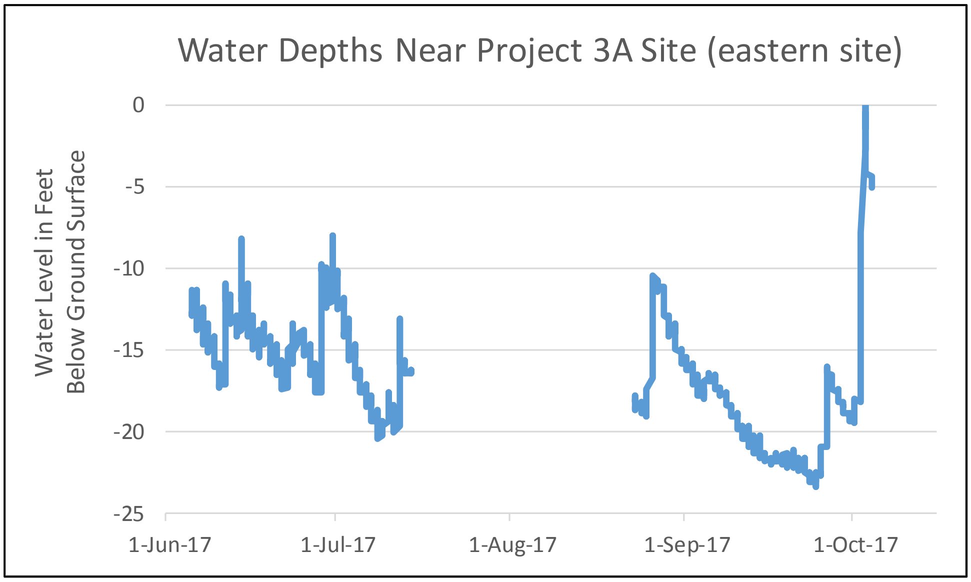


FIGURE 26 SUBSURFACE WATER DEPTHS AT TWO POSSIBLE PROJECT SITES.
Recorded with devices 80-90 feet north of Ditch 20. Note the water level increase during October 1, 2017 when a 4.81 inch rainfall occurred. See Figure 8 for monitoring site locations.

Aside from the monitored water levels in June-July and again in August-early October, we also have an observation from October 4, 2017 at the time of the field visit. The water levels ranged in the 4-6 inch range below the surface. A 4.81 inches rain event had occurred three days earlier on October 1. The ditch appeared to be at relatively normal levels but there was evidence of storm flows on the edge of the ditch (debris attached to vegetation). It appeared that the water table in the floodplain adjacent to Ditch 20 had also bounced and there had been standing water for a short time on the landscape.

In summary, the areas near Ditch 20 examined in this report are likely wetland. Soils and vegetation meet wetland criteria and though hydrology information was limited it points to meeting wetland hydrology criteria. Any future projects should expect to do additional monitoring, an onsite wetland delineation and wetland permitting.

Likelihood of Wetland Impact Permitting

Assuming the possible project areas are subject to state and federal wetland laws, we can consider how applications for permits might be received. Three project types are being considered: lateral ditch plugs, a weir in then main stem of Ditch 20 and a settling pond adjacent to the ditch. Each has unique permitting considerations and likelihood of permit issues.

Based on past permitting experience, the ditch block would be the simplest to get permitted. The ditch block would be returning the area to its original hydrologic regime and it would likely fall under the MN Wetland Conservation Act (WCA) exemption standards found in 8420.0415, No-Loss Criteria.

Any proposed weir in the main stem of Ditch 20 would be permitted similar to lateral ditch plugs from a wetland regulation standpoint. The likelihood of receiving a wetland permit is reasonably high. It is worth noting that such a project may have significant challenges with regards to ditch law, as discussed in Appendix B.

A wetland permit for the settling pond project concept may be very difficult to obtain without major revisions. Excavations in wetlands that are greater than 6.6 feet are considered conversions to non-wetland and would require wetland replacement at a 2:1 ratio. In addition, excavations greater than ½ acre at any depth are generally considered wetland conversion by the USACOE. Permitting agencies would likely react negatively to ponds excavated in wetlands for the sole purpose of allowing sediment to settle since storm ponds are not allowed in wetlands under current rules.

If any of the possible water quality projects are going to be pursued, it would be prudent to convene a Wetland Conservation Act (WCA) Technical Evaluation Panel (TEP) and US Army Corps of Engineers (USACOE) meeting with the proposed concepts and a preliminary wetland report. This would determine what additional information (well monitoring, level 2 wetland delineation, etc.) may be required. It also could answer whether the projects would be eligible for exemptions and banking credits in addition to overall permitting issues.

Wetland Banking

In Minnesota under the Wetland Conservation Act credits can be earned for creating or restoring wetland, and these credits sold to other who are filling or draining wetlands but are unable to create the required replacement wetlands. Restored wetland credits are sold by the square foot, and can be lucrative. It is a potential mechanism for funding water quality improvement projects discussed in this report.

There is reason to believe wetland banking credits would be possible for completed lateral ditch plugs, but additional review by a WCA TEP is advisable before proceeding. Credit for restoring partially drained wetlands is allowed under 8420.0526, Actions Eligible for Credit. There is potential for up to 50% credit of the wetland area restored (e.g. 10 acres restored would equal 5 acres of new wetland credit). This can be reduced by the TEP and the USACOE depending on their findings, though ditch plugs are encouraged by both agencies.

It is noteworthy that wetland banking projects require a substantial up-front investment. Before wetland credits can be sold there is a substantial monetary and time investment in monitoring, administration and construction. This investment is an important consideration in any plans to fund projects with the sale of credits from created or restored wetlands.

This information prepared by Becky Wozney, Anoka Conservation District Wetland Specialist