Vermillion River Watershed Joint Powers Organization

Fluvial Geomorphic Assessment of North Creek and Middle Creek, Dakota County, MN: Final Report

January 6, 2012

Prepared for:

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1. Executive Summary

The Vermillion River Watershed Joint Powers Organization (VRWJPO) contracted with Inter-Fluve Inc. to conduct a fluvial geomorphic assessment of the North Creek and Middle Creek subwatersheds. The North and Middle Creek subwatersheds are in the headwaters of the Vermillion River watershed in western Dakota County. The goals of this rapid geomorphic assessment were to:

1. Understand the stream bank stability throughout the subwatersheds
2. Identify grade control points, knickpoints, and areas of accelerated erosion
3. Characterize aquatic and riparian habitat throughout the subwatersheds
4. Identify opportunities for restoring geomorphic processes and habitat conditions
    a. Integrate restoration projects with the North Creek Greenway Master Plan

North Creek and its tributaries have a stream length of 14.1 miles, and Middle Creek and its tributaries are 24.5 miles long. The geomorphic assessment noted information such as soils, streamflow, stream bed grain size, infrastructure, land use, and vegetation. We also researched the history and geology of the watersheds. The bedrock in both subwatersheds is primarily Prairie Du Chien Dolomite and St. Peter Sandstone. The surficial geology is more varied, and the different substrates helped determine the land use. The headwaters of both creeks were historically marsh and wetland surrounded by prairie with some forest. Agriculture and residential development have caused the channels to be straightened in many areas, reduced the infiltration rates of the surrounding landscape, and reduced the amount of riparian buffer lining the stream banks.

Inter-Fluve identified 42 potential projects in the North Creek subwatershed and 46 potential projects in the Middle Creek subwatershed. We have also created a ranking system so the projects can be prioritized based on both impact and cost. The highest scoring projects in both subwatersheds involved:

1. Restoring sections of straightened channels to more natural, sinuous channels
2. Restoring the riparian buffer
3. Providing stormwater storage near the headwaters
4. Eliminating fish passage barriers in the lower portions of the watersheds

Overall, we recommend focusing on riparian buffer and stormwater retention projects in the upper portions of the Creeks and channel restoration and fish passage in the lower portions. Segments of both North and Middle Creek have already been restored, so we recommend connecting future restoration projects with those efforts. We also make recommendations for integrating the North and Middle Creek restoration projects with the North Creek Greenway initiative and capitalizing on the educational and recreational opportunities that intact river systems provide.

The lower reaches of both Creeks have been designated as trout streams by the Minnesota Department of Natural Resources. The possibility exists to increase the amount of cold and cool water habitat in both subwatersheds, particularly North Creek. With near-surface groundwater in some locations, we recommend ways to create cold water refugia for trout and other cold water species.

Many of our recommended projects along North and Middle Creeks will require landowner permission. We have suggested proceeding with the restoration projects in three phases. The first phase would complete stormwater retention, improved fish passage, and channel and riparian restoration on publically owned land. The second phase would involve extensive public outreach and working with landowners to attempt to find mutually agreeable solutions. The third phase would focus on stormwater retention and riparian buffers in the upper reaches of Middle Creek.

This report provides, in more detail, a synopsis of the existing and historical data that exists for the two subwatersheds and the results of the geomorphic assessment. It also summarizes the recommended projects for each subwatershed and provides general recommendations as well as a ranking system for prioritizing the projects.

Table of Contents

2. Introduction

In the summer of 2011, the Vermillion River Watershed Joint Powers Organization (VRWJPO) contracted with Inter-Fluve to conduct a fluvial geomorphic assessment of the North Creek and Middle Creek subwatersheds. These subwatersheds are in the headwaters of the Vermillion River watershed in western Dakota County and are an important influence on the habitat potential and water quality of the Vermillion River watershed (Figure 1). The goals of this rapid assessment were to improve our understanding of stream bank stability throughout the subwatersheds; identify grade control points, knickpoints, areas of accelerated erosion, and habitat quality issues; and identify opportunities where restoring geomorphic processes and habitat conditions would be beneficial.

The report that follows is a summary of the data collected and the potential restoration and management projects identified along North Creek, Middle Creek, and associated tributaries. In early 2011, Inter-Fluve completed a similar geomorphic assessment along Etter Creek, Ravenna Coulees and their tributaries for the VRWJPO. This document is set up in a similar format to allow the VRWJPO to efficiently read through the results and analyses of this assessment. As in the prior report, individual reach descriptions, channel reconnaissance forms, potential project forms, detailed scoring sheets for the potential project, and potential project maps have been placed in the appendices:

- Appendix A: Review of Geomorphology Principles
- Appendix B: Management Recommendations - Description of Project Types
- Appendix C: Reach Descriptions
- Appendix D: Channel Reconnaissance Forms
- Appendix E: Potential Project Forms
- Appendix F: Detailed scoring sheets for the potential projects
- Appendix G: Detailed maps of the potential projects

Inter-Fluve conducted the fluvial geomorphic assessment in July 2011. During the assessment, we identified 42 potential restoration projects in the North Creek subwatershed and 46 potential restoration projects in the Middle Creek subwatershed. In order to prioritize these projects for funding allocation, we developed a ranking system for the restoration projects. This ranking system scores potential stream project sites based on 13 metrics (Table 1). Each metric contributes a value of 1 through 7 for the site, and the total of all of the metrics is the potential project score. Each project can be ranked by a single metric or multiple metrics, so priority can be a result of any combination of metrics chosen by the VRWJPO staff. For this assessment, we added a metric called Greenway Benefit. The North Creek Greenway Master Plan was completed in the spring of 2011 with many recommendations for biking/walking/running paths connecting communities within the North Creek subwatershed as well as access points, historical informational signs, lighting, benches, etc. We added the Greenway Benefit metric as a way to evaluate the opportunity for geomorphic and habitat restoration to coincide with the Greenway construction. Restored river and wetland systems will increase the species diversity in these areas, which will increase the recreational opportunities (birding, fishing, viewing wildlife and wildflowers) for people using the Greenway.

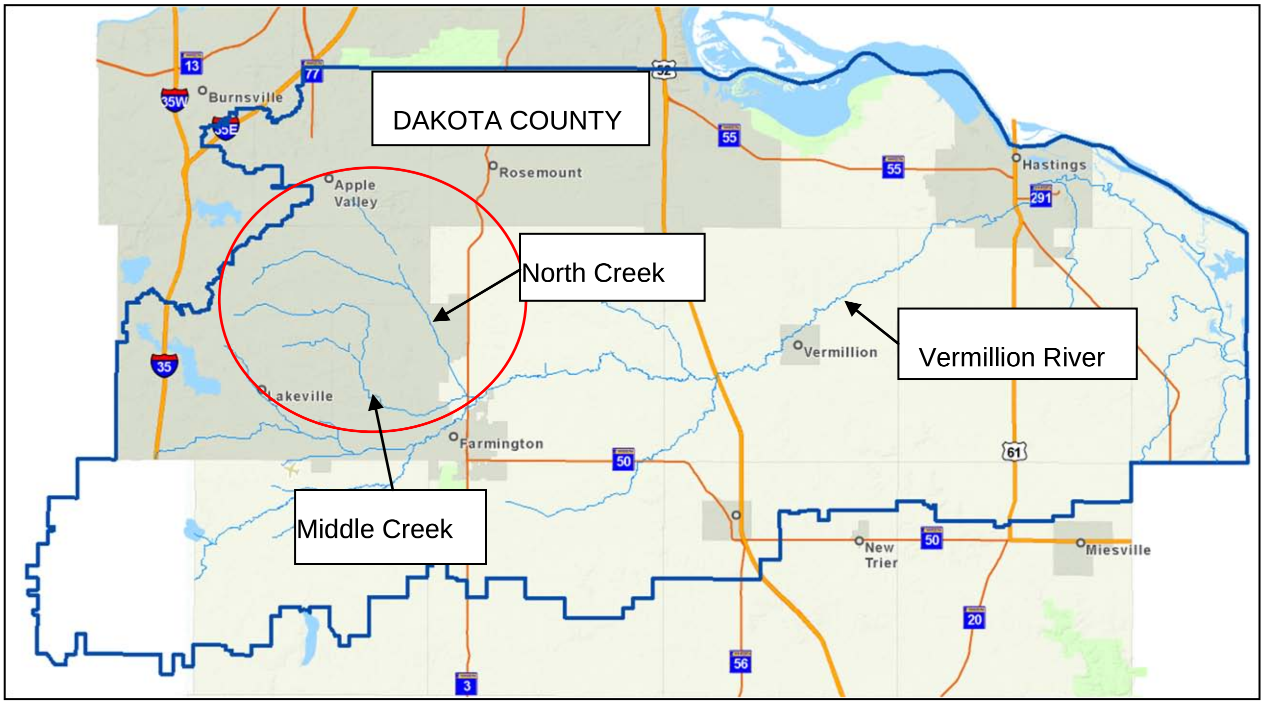

Figure 1: The North Creek and Middle Creek subwatersheds are on the western edge of Dakota County (blue polygon). Map modified from the VRWJPO.

Summary of Vermillion River Watershed Standards

The VRWJPO adopted a Watershed Management Plan in 2005 and a set of amended Standards in 2008. The Standards are water quality outcomes that were put in place to guide activities in the Vermillion River watershed and cover six topics:

- Floodplain Alteration
- Wetland Alteration
- Buffers
- Stormwater Management
- Drainage Alteration
- Agriculture

The criteria associated with each of these Standards regulates all new development in the watershed including commercial, residential, and industrial construction, road crossings, drainage systems, and river and habitat restoration. Having these Standards in place is extremely important for maintaining high quality aquatic and riparian habitat and improving habitat elsewhere. During our assessment of the North and Middle Creek subwatersheds, we observed recently-constructed residential and commercial developments, and all of these have associated stormwater detention basins to catch and filter runoff before it enters the stream system. It is unknown if these stormwater basins are sufficient to capture the amount of stormwater produced. In addition, older developments do not have these stormwater basins. Much of the mainstem of North Creek upstream of Pilot Knob Road flows through older developments with little to no stormwater management.

Sufficient riparian buffers are essential for high quality aquatic and riparian habitat, and the VRWJPO developed a classification scheme for waterways and wetlands with associated standards for buffer widths. The largest buffer is provided for the Conservation Corridor Lower and Upper Reaches with 150-ft average, and 100-ft minimum, buffer width. A 100-ft average and 65-ft minimum buffer width is required for Principal Connector channels in an Aquatic Corridor, and if the Principal Connector is a designated trout stream, the buffer must be at least 100 ft. A 50-ft average and 35-ft minimum buffer width is required for Tributary Connectors in the Aquatic Corridor. Water Quality Corridors require the smallest buffer at 30-ft average and 20-ft minimum widths (VRWJPO, 2008). North Creek, Middle Creek, and Middle Creek Tributary 7 are classified as Principal Connectors with the lower portions of North Creek, Middle Creek, and all of Tributary 1 being classified as trout streams (Figure 2). Elsewhere, the channels are either Tributary Connectors, Water Quality Corridors, or are unclassified. While development may not be occurring within these buffers, good riparian buffers are still not prevalent as landowners maintain lawns, gardens, and fields to the edges of the channel.

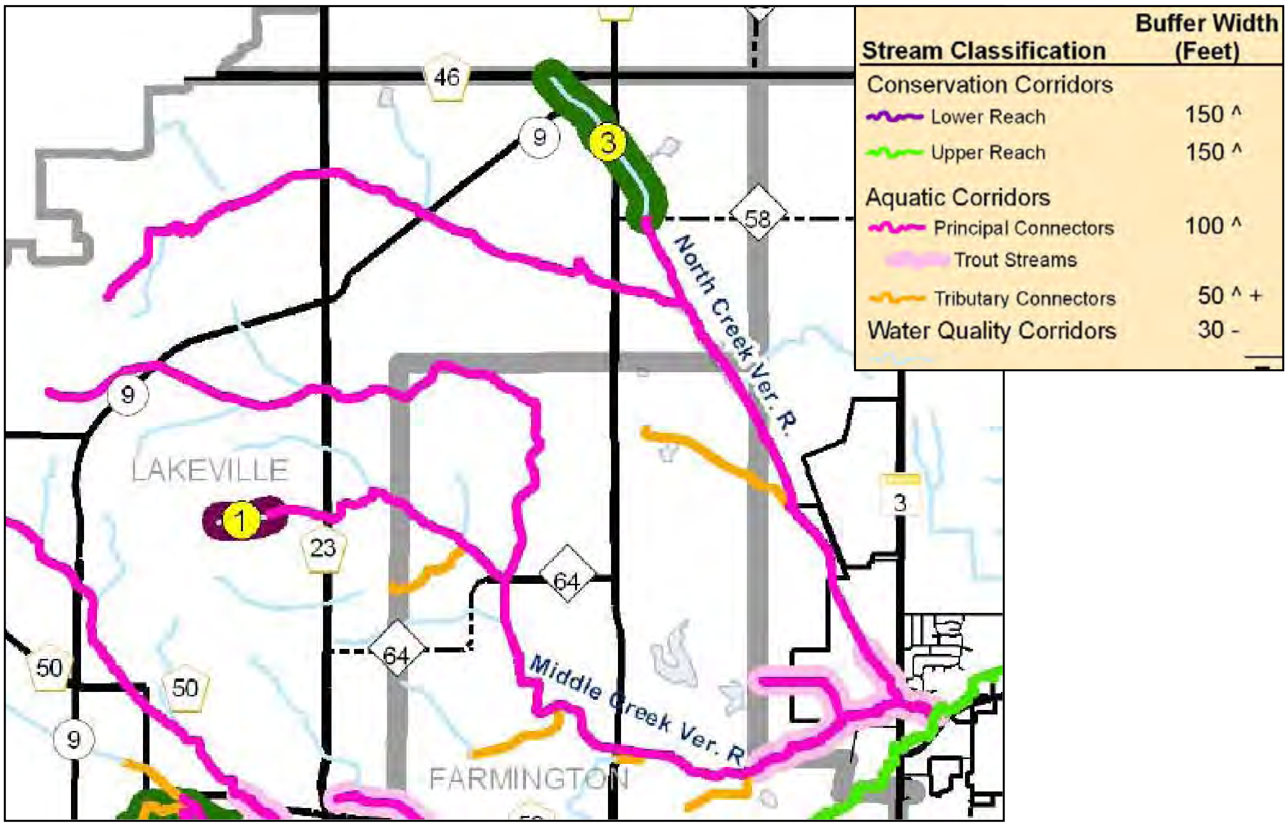

Figure 2: Stream classification and buffer width standards for North and Middle Creeks surveyed in this study (modified from VRWJPO, 2006).

3. Data Collection / Methods

3.1. Existing Data

Inter-Fluve personnel collected and analyzed existing information about the North Creek and Middle Creek subwatersheds, including aerial photographs, plat maps, and geologic maps. Additionally, staff analyzed aerial photographs in a GIS to determine reach breaks based on land use and changes in valley form, soils, longitudinal profile, planform, and road crossings.

North Creek and Middle Creek are located within the western portion of Dakota County. The two rivers join just north of Farmington on the west side of Hwy 3/Chippendale Ave and drain directly to the Vermillion River just east of Hwy 3 (Figure 1). These subwatersheds flow through a variety of dense wooded forests, wetlands, backyard gullies and farm fields (Figure 3).

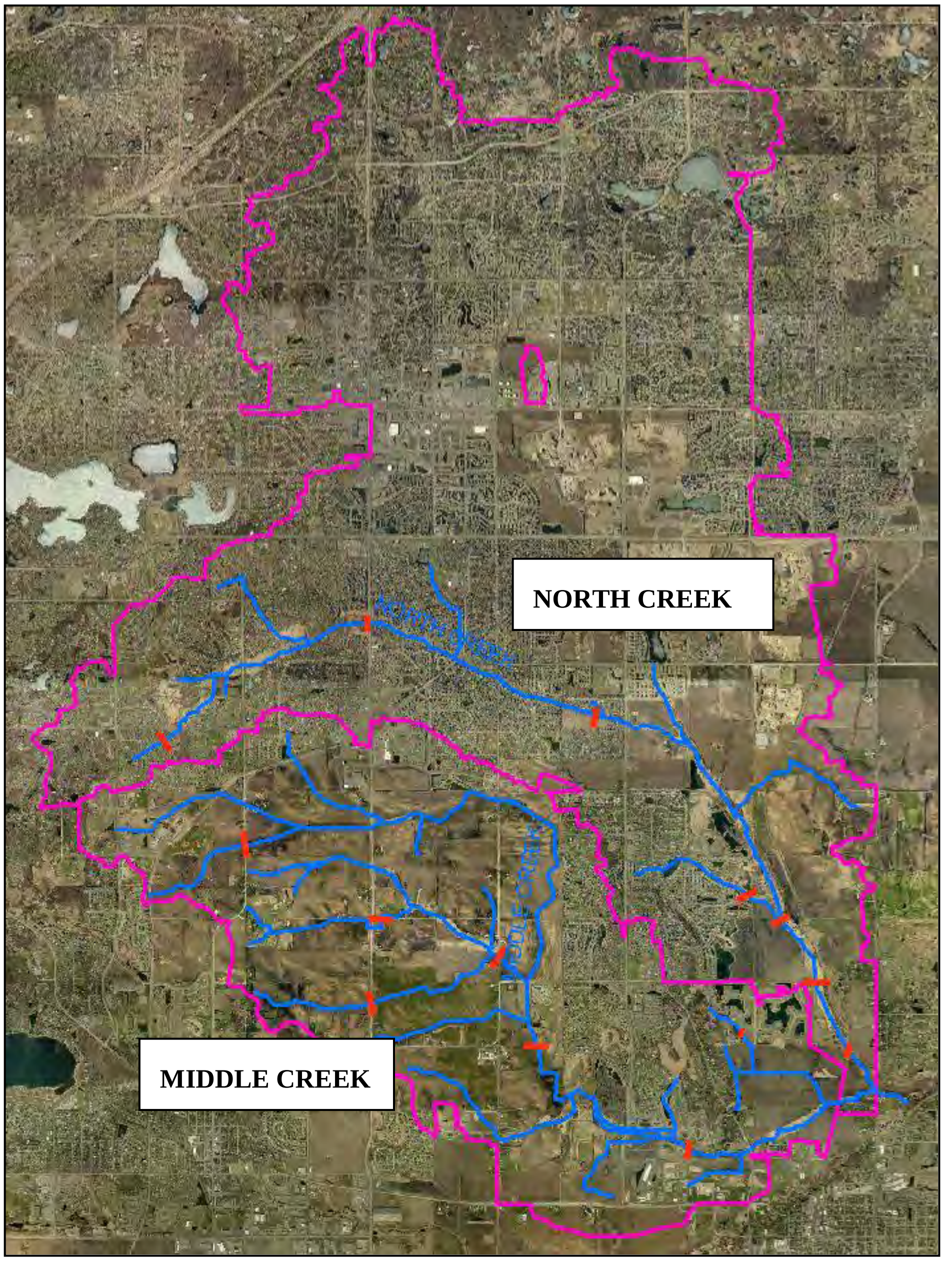

Figure 3: The North Creek and Middle Creek subwatersheds (pink polygons).

The first land surveys in Dakota County resulted in plat maps from 1855. Later USGS topographic maps (1957, 1974, 1985) and aerial photos (1937, 1951, 1964, 1974, 1991, 1997, and nearly every year since 2000) show more detail and also show the channel and land use changes that have occurred. The 1855 maps show much shorter lengths of both North Creek and Middle Creek (Figure 4), but in later topographic maps, the streams in the upper portions of the subwatersheds are identified as intermittent followed by perennial (Figure 5).

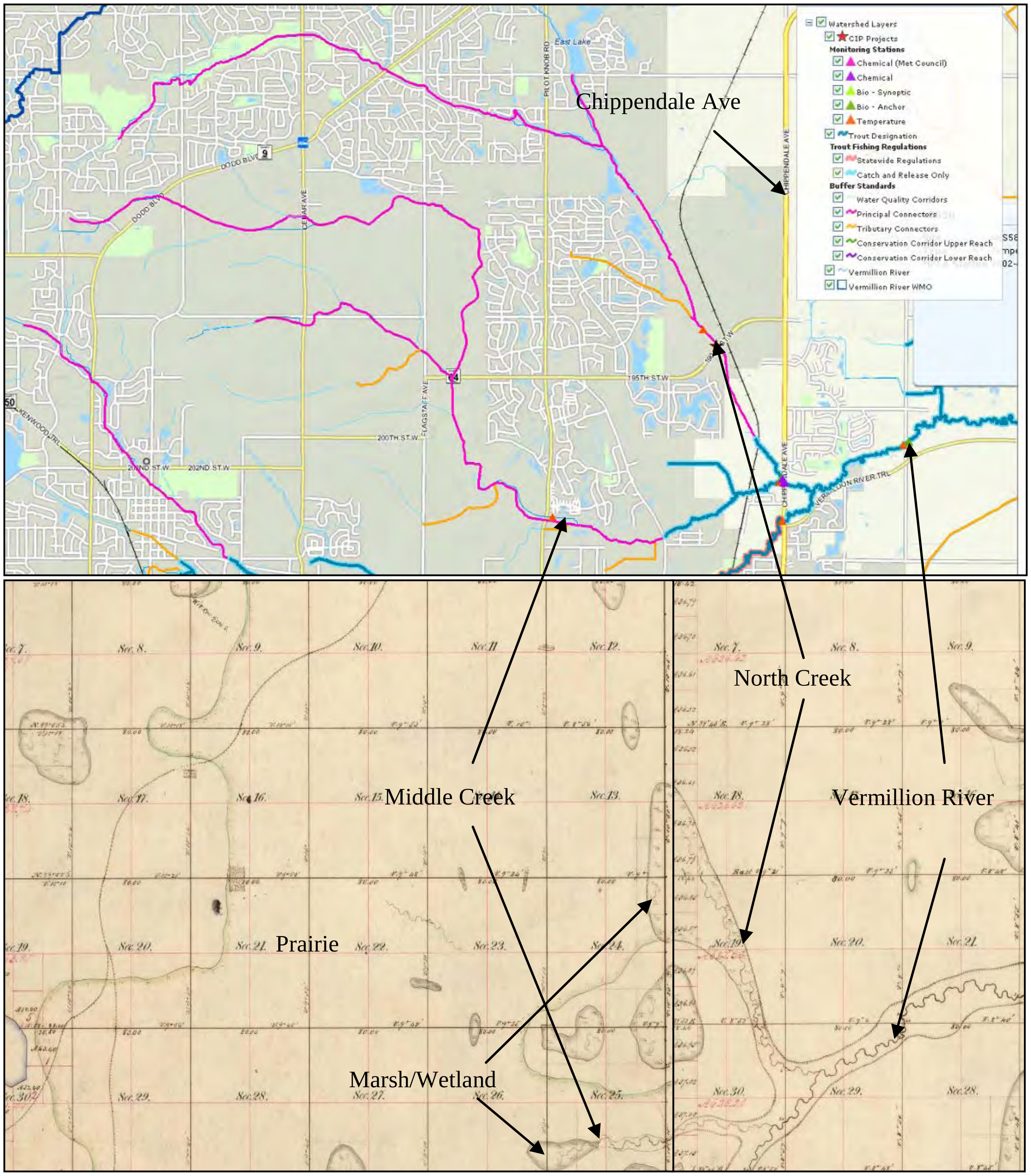

Figure 4: Comparison of current conditions (top) with the plat maps created in 1855 (bottom). The green polygons on the plat maps were identified as prairie.

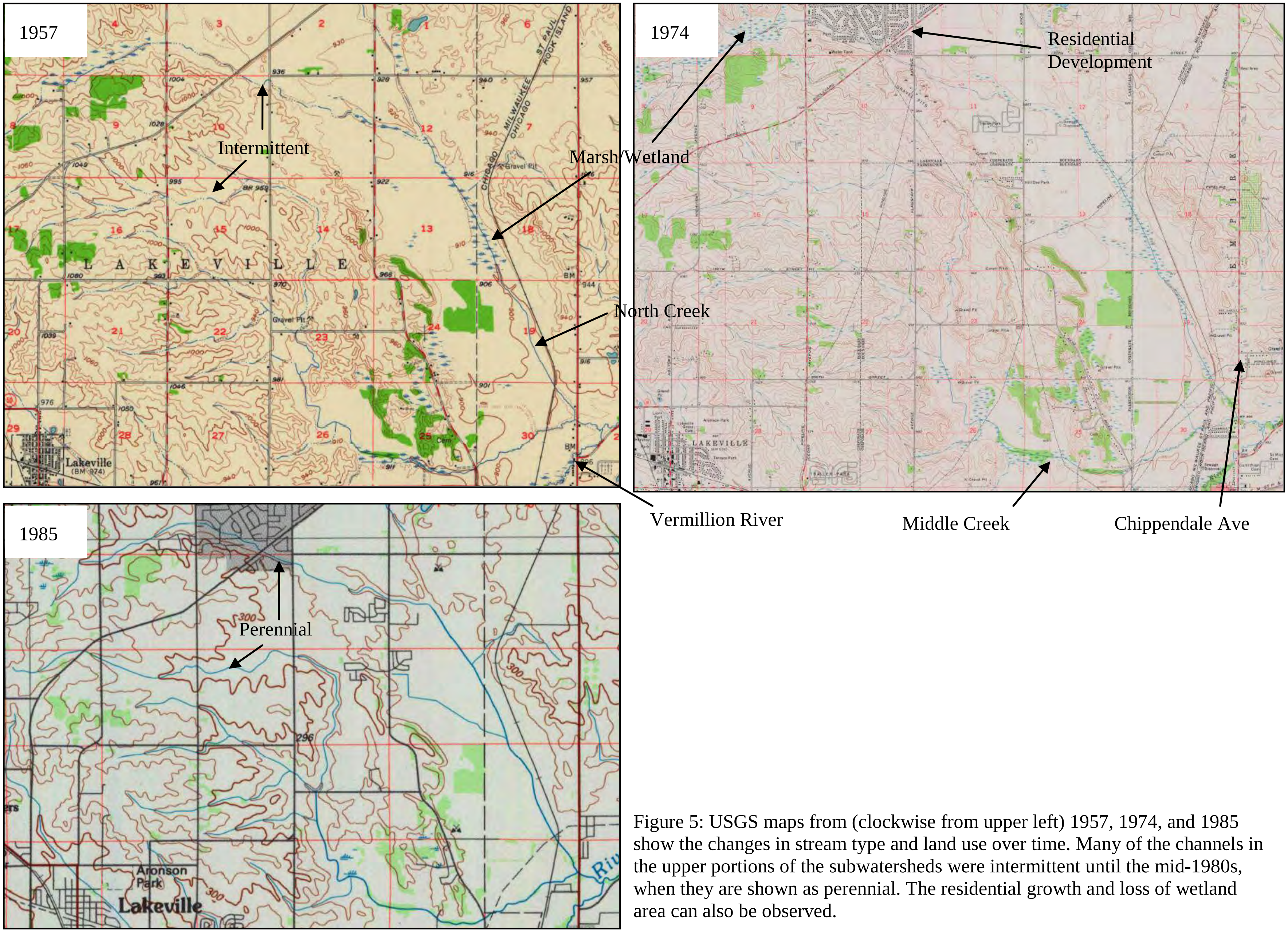

Figure 5: USGS maps from (clockwise from upper left) 1957, 1974, and 1985 show the changes in stream type and land use over time. Many of the channels in the upper portions of the subwatersheds were intermittent until the mid-1980s, when they are shown as perennial. The residential growth and loss of wetland area can also be observed.

The majority of the subwatersheds were considered prairie in 1855. The headwaters (as mapped in 1855) of Middle Creek and much of North Creek were identified as marsh or wetland. The stream channels were sinuous, similar to the lower portions of present-day Middle Creek and the Vermillion River. By the first air photos in 1937, the majority of both subwatersheds had been cleared for agriculture, but the streams were mostly intact and remained sinuous (Figure 6). By the 1950s along North Creek, and later along Middle Creek, the meandering wetland streams were being converted into ditches and small, intermittent streams became incised perennial waterways. Agriculture remained the dominant land use through most of the 20th century. Beginning in the 1970s, however, residential development began increasing and by the early 1990s, large portions of the North Creek subwatershed and lands surrounding these subwatersheds had been developed (Figure 7). Today, the farms within the Middle Creek subwatershed are nearly surrounded by relatively dense residential development.

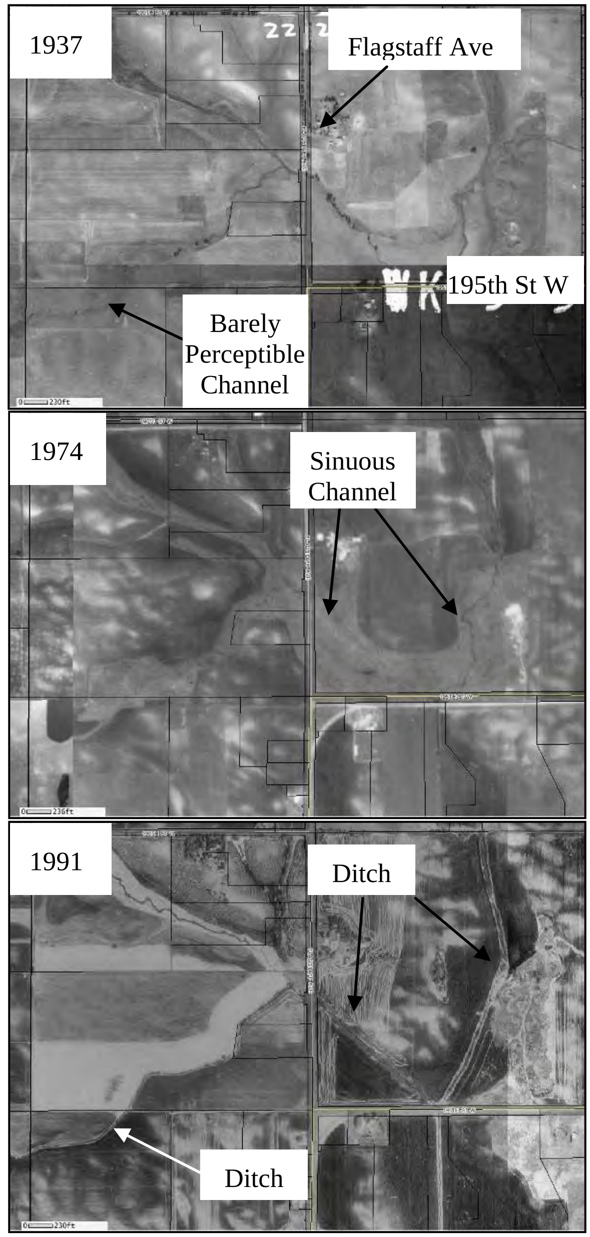

Figure 6: Air photos from (top to bottom) 1937, 1974, and 1991 showing Middle Creek channel changes from minor, intermittent, sinuous channel in 1937 to larger ditches in 1991. Upstream of 195th St W, Middle Creek is joined by Tributary 7 from the northwest.

On the 1855 plat maps, the surveyors also noted the channel widths, in units of 'links.' A link was 7.92 inches (0.66 ft) and 100 links made up a chain. In 1855, the surveyors measured North Creek, Middle Creek, and the Vermillion River to be 6 (3.96 ft), 8 (5.28 ft), and 20 (13.2 ft) links in width, respectively. In most cases, these streams/rivers are more than double this width today, suggesting that significant channel widening has occurred due to increased hydrology, changes in channel planform, and/or inaccurate measurements. To check the accuracy of the stream width measurements, we compared the dimensions of the sections on air photos in GIS with the plat maps. Each Section, as indicated on the plat maps, was measured as 80 chains, or 1 mile. The Section boundaries today are identified easily, because roads have been built on many of the boundaries. The Sections as measured in GIS also measure 1 mile, suggesting that the stream width measurements on the plat maps may be accurate.

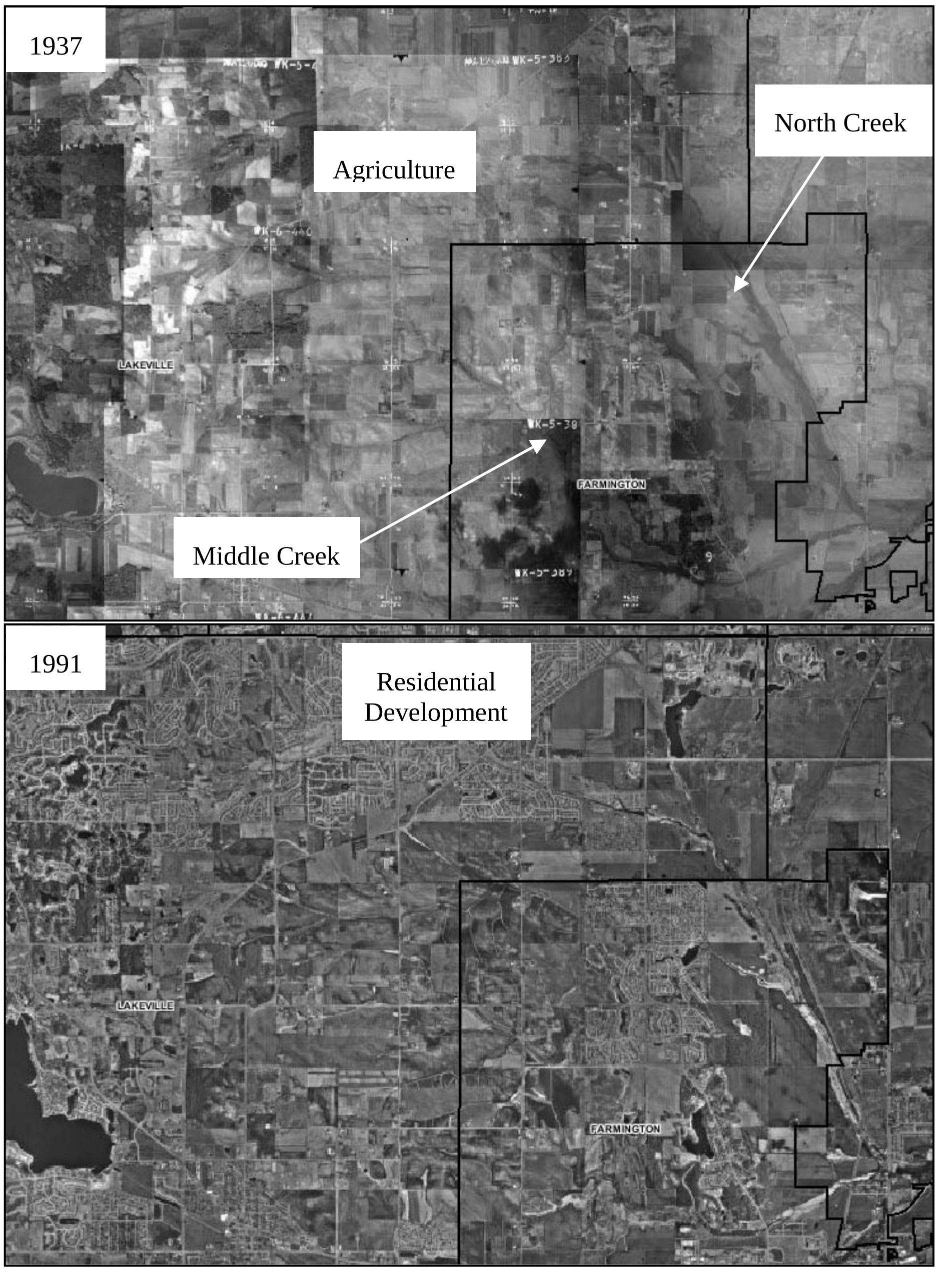

Figure 7: Land use change within the North and Middle Creek subwatersheds from agriculture in 1937 (top) to residential development in 1991 (bottom).

Although the 1855 plat maps are not comprehensive and may not be exact representations of the conditions in 1855, they do provide some insight into the land-use and ecosystems within the subwatersheds as well as the relative significance of the stream channels at that time. Using these and other topographic maps and air photos, we analyzed land use and channel changes that have occurred. While much of the forested and prairie land was initially converted to agriculture, many areas are now residential development. These changes in land-use are likely the primary causes for much of the channel widening, incision, and erosion observed within the subwatersheds today. The conversion of large tracts of marsh and wetland to agriculture or residential development eliminates the natural stormwater retention capabilities of the watersheds. Clearing the land for agriculture reduces the infiltration rates and speeds the flow of rainwater and snowmelt off of fields and into the stream channels. In many locations, the surficial geology of multiple feet of loess overlying till provides little soil support against the high flux of water that occurred after the land use changes. In the upper portions of the subwatersheds, the streams were likely small and intermittent prior to settlement, only carrying water during flood events. The increased water flow and decreased channel length due to ditching has resulted in excessive erosion and channel incision, particularly in the hillier loess-dominated areas of the upper Middle Creek subwatershed.

The bedrock of the North and Middle Creek subwatersheds is primarily Prairie Du Chien Dolomite and St. Peter Sandstone (Mossler, 1990). The lower halves of the North and Middle Creek subwatersheds, as well as Middle Creek Tributary 7, consist of Prairie Du Chien Dolomite. The remainder of the watersheds, and particularly the headwaters, are primarily St. Peter Sandstone. St. Peter Sandstone consists of fine- to medium-grained quartz sandstone over multicolored layers of sandstone, siltstone, and shale. The Prairie Du Chien Group consists of thin bedded, sandy dolostone with thin layers of sandstone and chert. Between Middle Creek and North Creek, a portion of the watersheds consist of the Platteville (fine-grained dolostone and limestone) and Glenwood (green, sandy shale) Formations. Bedrock outcrops were not observed in the channels or in the alluvial valleys of the North and Middle Creeks and their tributaries.

The surficial geology is more varied than the bedrock geology. The North Creek subwatershed consists primarily of mixed outwash including sand, loamy sand, and gravel (Hobbs et al., 1990). In the middle portion of North Creek, however, from approximately Stn 7000 to 18000, the alluvial valley consists of organics including peat and organic-rich silt and clay. The surficial geology may be why this area has been left largely undeveloped with little agriculture, though the channel has been straightened into a ditch.

The lower portions of the Middle Creek subwatershed are primarily mixed outwash as well. The alluvial valley of Middle Creek, however, is floodplain alluvium consisting of mostly sand from its mouth to approximately the confluence with Tributary 7 upstream of 195th St W. Outside of this floodplain alluvium, large portions of the watershed upstream of Pilot Knob Rd have loess deposits greater than 5 ft in thickness. Elsewhere, loess deposits may be less than 5 ft in thickness, but are not identified on the surficial map. All Middle Creek and tributary channels upstream of about 195th St W flow through this loess, which consists of unbedded silt and fine sand mixed with clay. Underlying the loess deposits are multiple geologic groups. The eastern portion of the Middle Creek subwatershed consists primarily of Superior Lobe outwash gravel and sand under the loess. The middle of the subwatershed consists of Pre-Late Wisconsinan Old Gray Till, which has two layers. The upper layer consists of friable loam to fine sandy loam while the lower till consists of firm loam to clay loam. The western portion of the Middle Creek subwatershed consists of Des Moines Lobe thin-mantled till, similar to the till described above.

3.2. Fluvial Geomorphology

Inter-Fluve geomorphologists walked most of the lengths of North Creek, Middle Creek, and their tributaries. Portions of the upper subwatersheds were assessed at road crossings as the streams were barely perceptible, channel conditions did not change, and no problems were identified. North Creek is approximately 8.8 miles in length, but its 5 tributaries and associated drainages add 5.3 miles for a total stream length of 14.1 miles in the North Creek subwatershed. Middle Creek is approximately 9.5 miles in length, but its 9 tributaries and associated drainages add 15 miles for a total stream length of 24.5 miles in the Middle Creek subwatershed. We noted information on soils, streamflow, stream bed grain size, infrastructure, land use, and vegetation for each reach on reconnaissance forms. We also took digital photographs at many locations along each reach, at all road crossings, of all culverts, and of all potential restoration projects.

Inter-Fluve scientists developed the reconnaissance form, and it includes information on general channel and fluvial geomorphic conditions, sediment composition, depositional features, riparian vegetation and floodplain morphology, channel stability, channel geometry, and human impacts on the channel and floodplain (Appendix D). A sketch of a cross-section at a location typical for the reach is provided as well as a brief summary of conditions and a list of potential restoration projects. Appendix C provides a description of each reach based on these forms.

3.3. Project Identification

Inter-Fluve staff identified potential projects in the field and evaluated and ranked the projects based on 13 metrics (Table 1). In this system, the scoring refers mainly to the degree that a completed project will affect each metric. For example, an infrastructure risk score of 1 reflects that if nothing is done, there will still be no risk to infrastructure from channel instability. The lack of risk could be because no infrastructure exists at the site or the risk is extremely low. Conversely, a score of 7 indicates that if nothing is done, public safety and property are under imminent risk. This assessment included an evaluation of all culverts and road crossings for corrosion or decay as well as for their effect on local hydrology. Other metrics gauge the effect of potential projects on channel stability, ecological benefit, and nutrient loading. Because of the interconnectivity of river systems, Inter-Fluve believes strongly that watershed restoration and management should focus on the headwaters and move in a downstream direction. To incorporate this science into the project ranking, we have ranked headwaters projects higher, and scores decrease with distance from the headwaters.

Potentially expensive projects are scored lower, as are more complicated, larger projects. Sediment and nutrient loading, erosion control, and public education metrics are reflective of project size, and thus the ranking system allows for some cost versus benefit analysis. A relatively inexpensive project that can restore a large area or length of stream with manageable design and permitting will score among the highest under this system. The VRWJPO should use this ranking as a guide to determine the projects that accomplish its goals and objectives and stay within the available budget. Appendix E includes all of the potential project forms that describe each project, recommend management and restoration solutions, provide the metric scores, and include pictures of the problem area.

Table 1: Metrics for scoring potential projects.

Metric Score:	*1*	*3*	*5*	*7*
Infrastructure risk	No risk to infrastructure with no action, or no infrastructure present	Low to moderate infrastructure risk and minimal risk to public safety with no action, or inf. value <$100,000	Infrastructure at moderate but not immediate risk, moderate public safety risk, or infrastructure value <$200,000	Infrastructure at high or immanent risk of failure with no action. Public safety at risk or infrastructure value >$200,000
Erosion/channel stability	Minimal improvement to overall stream stability and function, <250 ft of channel bank	Low to moderate improvement of 250-1000 ft of channel bank	Moderate improvement 1000-2500 ft of channel bank	Significant improvement to overall stream stability and function or >2500 ft
Project complexity	Groundwater and surface water issues, professional specialty design services required, heavy oversight, major earthwork, EAW/EIS permitting	Surface water restoration, engineering plans required, earthwork involved, significant permitting	Moderately complex, no specialty engineering required, minor earthwork, some basic permitting	Elementary solution, shelf design, volunteer and hand labor implementation, no permits
Location	Mouth to lower ¼ of watershed	Lower 1/4 to 1/2 of watershed	1/2 to upper 3/4 of watershed	Upper 3/4 to headwaters
Sediment/nutrient loading	No load reduction resulting	Some minor reduction in sediment pollution, increased filtration of nutrients	Moderate reduction in bank erosion and surface runoff entering stream through buffer or other BMPs > 30 ft	Major erosion control through significant BMP installation, stormwater detention, infiltration or buffer filter.
Project cost	> $300K	$201 - $300K	$51 - 200K	$0 - $50K
Aesthetic impact	No impact	Low impact	Moderate positive impact	High positive impact
Fish Passage	No impact on fish passage	Low impact (eg. improve depth through culvert, minimal velocity reduction)	Moderate impact (removes perch or other small barrier, natural bottom culvert replacement)	High impact (dam removal)
Property Ownership	-7: not allowed; not cooperative	0: unknown	7: access approved; cooperative	
Public Education	No public education value	Low value - Poor site access, difficult to see, small project	Moderate value - Good access, moderate demonstration value	High value - Easy access, cooperating landowner, good demonstration and high visual impact
In-stream Ecological Benefit	No in-stream ecological benefit	Low benefit - Spot location, small size	Moderate benefit - subreach based, moderate sized project	High benefit - Reach based, >1000 ft of stream
Riparian Ecological Benefit	No riparian ecological benefit	Low benefit - Spot location, small size	Moderate benefit - subreach based, moderate sized project	High benefit - Reach based, large riparian areas, floodplain scale
Greenway Benefit	Not within Greenway/No Beneficial Impact	'Long-Term Project' area; low-use; improved buffer width >30ft	'2nd priority Project' area; improved buffer width >100ft; moderate use; subreach-scale benefits	'1st priority project' area; reach-scale improvement; near high-use areas; wide buffers

4. Summary of Restoration Projects

We identified 88 areas in the North Creek and Middle Creek subwatersheds with some degree of geomorphic or ecological problem; 42 of the potential projects are located in the North Creek subwatershed and 46 are located in Middle Creek (Table 2, 3, 4, 5; Figure 8; see Appendix F for full scoring spreadsheets; see Appendix G for detailed maps).

These subwatersheds are similar to the South Creek subwatershed and many of the geomorphic and habitat problems are similar. The channels are generally low-gradient, although some bank erosion and incision is occurring in the upper portions of the Middle Creek and North Creek subwatersheds. The land-use is primarily agriculture in the Middle Creek subwatershed and residential in the North Creek watershed. Long stretches of the North and Middle Creek subwatersheds contain channels that have been historically straightened into ditches with little riparian vegetation or buffer from row crops or residential development. The hydrology has increased throughout due to reduced infiltration and lack of stormwater retention.

The majority of projects in the North and Middle Creek subwatersheds were natural channel restoration, floodplain and riparian management, and crossings (see Appendix B for discussion of project types). The highest scoring projects involved restoring long sections of straightened channels to more natural sinuous wetland channels, restoring the riparian buffers to long stretches of channel, providing stormwater storage near the headwaters, and eliminating fish passage barriers in the lower portions of the watersheds.

Historical land use involved clearing the land for agricultural use and channelizing the creeks to maximize the cropland and minimize flooding. Agricultural land has decreased infiltration capacity, resulting in larger quantities of rainwater reaching the creeks more quickly. With residential development increasing in the later decades of the 20th century, more land became impermeable, forcing even more water into the streams following storms. Increased water flow to the streams caused incision and bank erosion as the channels adjusted to the changing conditions. This instability is still apparent and still occurring in some of the steeper portions of the subwatersheds.

While challenging and costly, natural channel restoration has the potential to improve the natural fluvial functions of the stream and floodplains and dramatically improve habitat in large sections of the subwatersheds. One of the biggest challenges with this type of restoration is obtaining landowner permission and cooperation. A small section of North Creek has recently been restored with a more sinuous planform and riparian plantings. Multiple miles upstream and downstream of this restored section are ideal for further natural channel restoration: the wetland buffer on either side of the channel is wide, cold groundwater seeps in from the wetlands, and only a few small fish passage barriers exist between these areas and the Vermillion River. With the removal of the fish passage barriers, North Creek could provide miles of cold- or cool-water fish habitat, wide wetland habitat with stormwater retention capabilities, and a great opportunity to expand the North Creek Greenway.

Upstream portions of North Creek flow through residential neighborhoods with landowners that maintain mowed lawns to the edge, or within a few feet of the edge, of the channel. Throughout the Middle Creek watershed, riparian buffers are often less than 10 ft between row crops and the channels. The lack of riparian buffer reduces the infiltration time and increases the potential for fertilizers, pesticides, herbicides, and other household contaminants to flow unchecked into the channels, thus reducing water quality. Stormwater and floods wash any chemicals applied to these fields into the channels. In addition, stormwater and floods wash large quantities of fine-grained sediment from the fields into the channels. This results in decreased water quality during many periods of the year. Increasing riparian buffers and planting native riparian trees, shrubs, and forbs could increase water quality by dramatically decreasing the amount of contaminants (including fine-grained sediment) that reach the channels.

Stormwater retention or detention basins could significantly slow the release of water downstream following storms in many areas of these subwatersheds. Expansive wetlands historically served this purpose (see plat maps from 1855 in Figure 4). In some locations in the headwaters of North Creek, the effectiveness of large wetlands has been minimized because the channels have incised and no longer flood the wetlands. With channel restoration, these wetlands could be re-activated and provide stormwater retention. In the Middle Creek subwatershed, road prisms and topography may assist in the feasibility of stormwater basins. Construction of basins in these areas would require the full cooperation of the farmers who own and operate much of the land. Basins could be a beneficial solution for all stakeholders, however, because large portions of the farms are currently flooded during storm events. By converting portions of cropland to stormwater basins, some cropland will be lost but cropland downstream could be flooded less frequently. Stormwater basins would also reduce the excessive sediment flux downstream, reduce bank erosion and incision, and slow the release of warm stormwater into the channels.

Many of the culverts under private driveway crossings or farm roads in these subwatersheds are undersized, steep, and/or perched. These conditions result in nearly complete barriers to fish passage. In the lower half of North Creek multiple complete fish passage barriers exist, preventing fish and other aquatic species from moving upstream into potential habitat. Some of the farm road crossings may not be actively used and could be completely removed with the landowner permission. Elsewhere, culverts under roads are often large enough, but the bottoms of these culverts are wide and flat with no natural substrate. In the event of low-flow conditions, water depth could present a fish passage barrier at these locations. By consolidating low flows into one of multiple culverts, a portion of one culvert, or installing gravel and cobbles and other natural substrate, fish would have a better opportunity to pass through these crossings during low-flow conditions.

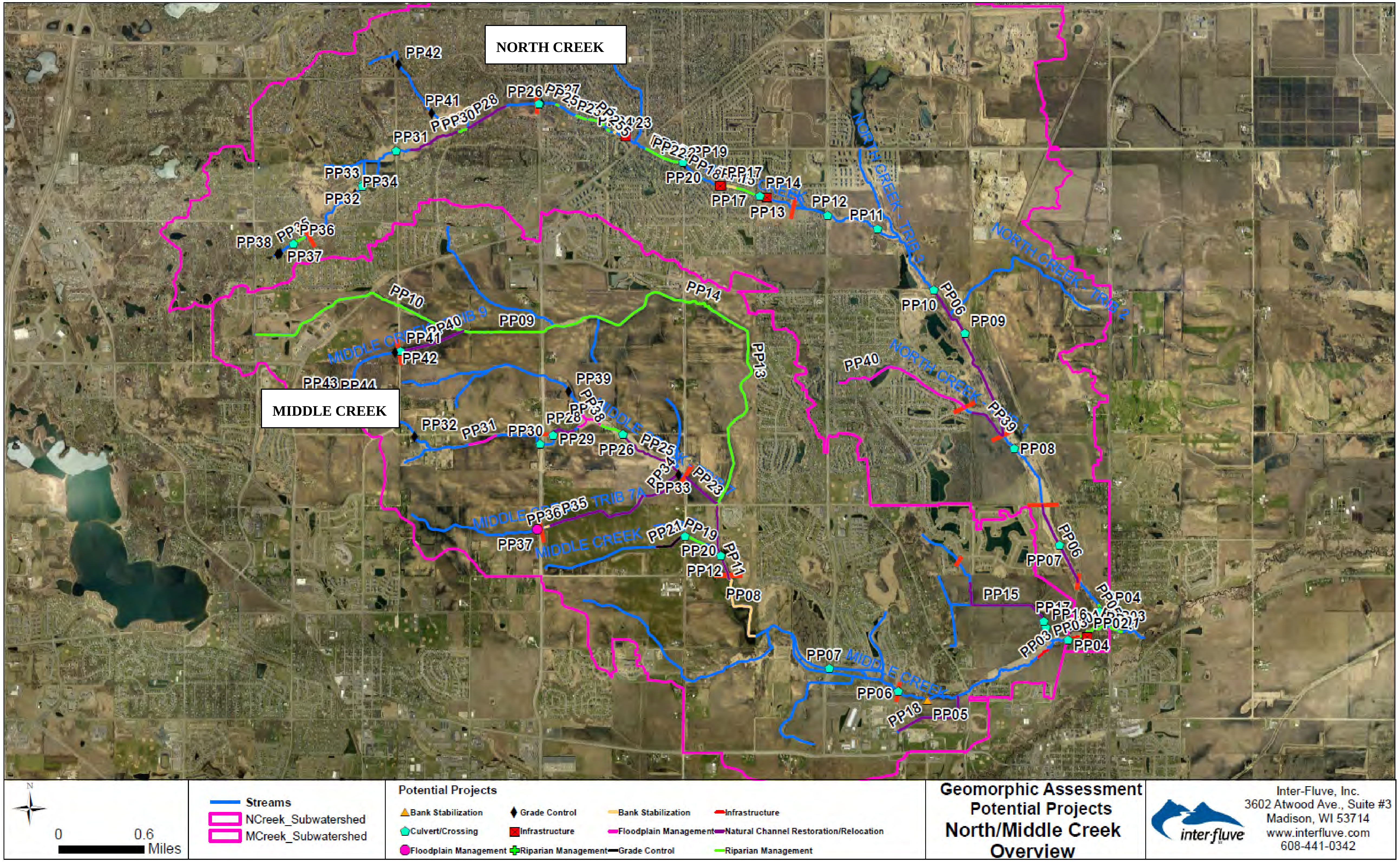

Figure 8: Overview of potential projects in the study area.

Table 2: Summary of potential restoration and management projects with scores. Projects are on North Creek. T = Tributary; C = culvert/crossing; B = bank stabilization; R = riparian management; F = floodplain management; G = grade control.

Project Number	Location	Primary Project Type	Total Score	Description
PP01	1,075-1,200	R	34	No riparian buffer
PP02	1,300-1,550	R	38	No riparian buffer
PP03	2,000	I	28	Failed metal foot bridge needs to be removed
PP04	2,325	C	36	Undersized culvert is perched and limits fish passage; erosion on downstream side of crossing due to overtopping
PP05	2,500-2,600	R	34	Little to no riparian buffer
PP06	3,800-7,000; 10,150-16,500	N	56	Straightened channel lacks geomorphic complexity and canopy cover
PP07	5,375	C	36	Undersized culvert prevents fish passage
PP08	9,500	C	34	3-undersized culvert during high flows causing overtopping of the road
PP09	14,400	C	34	4-undersized culverts have failed due to debris blocking the inlets. The crossing is nearly washed out and the culverts should be removed
PP10	16,500	C	34	Old bridge with an I-beam in the main channel should be removed
PP11	20,100	C	55	3.5-ft tall dam could be removed as it is a complete fish barrier
PP12	22,200	C	45	3, 10x6-ft concrete box culverts lack quality fish passage
PP13	24,625	I	41	Minor erosion below perched stormwater pipe
PP14	24,900	C	45	3, 12x6-ft concrete box culverts with flat bottoms present difficult fish passage during low flows
PP15	25,100-26,600	R	57	Limited buffer and potential for Greenway Benefit
PP16	25,850-26,150	B	51	Bank erosion
PP17	26,400-26,450	I	47	Erosion/incision around 2-stormwater pipes
PP18	27,200-27,400	R	47	No or little riparian buffer
PP19	28,050	G	47	~4-ft drop across 30-ft riprap cascade is a potentially prevents fish passage
PP20	28,150	C	39	6-ft pipe is perched and likely a fish passage barrier
PP21	28,200-29,600	R	55	Limited buffer and potential for Greenway Benefit
PP22	28,200-28,500; 28,700-28, 900	R	53	No riparian buffer
PP23	30,550	I	47	2-ft sewer pipe is ~2-ft above channel bed
PP24	30,975-31,000	B	47	Bank erosion
PP25	31,200-31,300; 31,500-31,600; 31,700-32,100; 32,000-32,100; 32,200-32,600; 33,350-33,450	R	46	No riparian buffer
PP26	34,000	G	36	2.5-ft riprap drop presents a fish passage barrier
PP27	34,100	C	43	3, 5-ft concrete pipes are a complete fish passage barrier
PP28	35,350-36,950	N	65	Straightened channel provides little geomorphic or habitat complexity and lacks significant buffer
PP29	37,000-39,400	N	67	Incision is causing significant bank erosion; 4 knickpoints totaling ~4.5-ft of drop
PP30	37,050-37,350	R	49	No riparian buffer
PP31	40,000	C	41	6x3-ft concrete box presents a partial fish passage barrier

PP32	42,250	C	47	Undersized culvert was recently overwhelmed and flows eroded the road
PP33	42,350	C	47	Undersized culvert is perched presenting a fish passage barrier
PP34	42,750	G	39	1.5-ft knickpoint
PP35	45,500-46,000	R	49	Little to no riparian buffer causing minor bank erosion
PP36	46,000	C	45	Grouted riprap apron on perched culvert have failed
PP37	46,600	G	49	2-ft knickpoint causing minor bank erosion
PP38	46,700	G	37	2-ft knickpoint

Table 3: Summary of potential restoration and management projects with scores. Projects are on North Creek Tributaries. T = Tributary; C = culvert/crossing; B = bank stabilization; R = riparian management; F = floodplain management; G = grade control.

Project Number	Location	Primary Project Type	Total Score	Description
PP39	0-1,500	N	44	Straightened ditch lacks adequate habitat complexity
PP40	1,900-7,200	F	45	Stormwater basins warm water to more than 80°F
PP41	1,800	G	39	Multiple knickpoints
PP42	4,000	G	45	2 knickpoints downstream of Highview Ave.

Table 4: Summary of potential restoration and management projects with scores. Projects are on Middle Creek. T = Tributary; C = culvert/crossing; B = bank stabilization; R = riparian management; F = floodplain management; G = grade control.

Project Number	Location	Primary Project Type	Total Score	Description
PP01	0-1,900	R	46	Little to no riparian buffer
PP02	1200	I	30	Support cable for a utility pole is loose in the channel
PP03	1,500-1,900; 3,100-3,600	I	36	Trash in the channel should be removed
PP04	1950	C	35	Downstream railroad bridge support is broken
PP05	8800	B	30	Bank erosion
PP06	10000	C	32	2 corrugated metal culverts are slightly compressed and there is some erosion of the surrounding riprap
PP07	13,050	C	39	Concrete box culverts potentially lacks fish passage during low flows
PP08	16,700-19,800	B	57	Unrestricted cattle grazing has eroded banks and decreased water quality
PP09	19,700-50,200	N	57	Straightened ditch lacks geomorphic and habitat complexity
PP10	19,700-50,200	R	61	Little to no riparian buffer
PP11	19,700-22,500	N	63	Restored channel not connected to main channel
PP12	20,650	C	55	Partially or fully blocked culvert at dirt farm road has 4.5-ft of bank erosion
PP13	28,500-28,700	R	40	No riparian buffer
PP14	31,200-32,500	R	43	Unrestricted cattle grazing has eroded banks and little to no riparian buffer

Table 5: Summary of potential restoration and management projects with scores. Projects are on Middle Creek Tributaries. T = Tributary; C = culvert/crossing; B = bank stabilization; R = riparian management; F = floodplain management; G = grade control.

Project Number	Location	Primary Project Type	Total Score	Description
PP15-Trib 1	600-4,700	N	**44**	Straightened channel exists within decent riparian corridor but provides little geomorphic complexity
PP16-Trib 1	600	C	**34**	2 undersized, perched concrete pipes under farm road
PP17-Trib 1	850	C	**34**	2 undersized, partially buried pipes under farm road
PP18-Trib 2	0-3,100	N	**36**	Straightened ditch provides little habitat variability
PP19-Trib 6	500-1,200	R	**38**	Little canopy cover
PP20-Trib 6	1,300	C	**43**	Debris piled on trash grates at culvert inlet create a fish passage barrier
PP21-Trib 6	1,400-2,500	G	**46**	Multiple knickpoints, a dam, and trash suggest active incision and present fish passage barriers
PP22-Trib 6	1,400-2,500	F	**42**	Unrestricted cattle grazing has eroded banks and decreased water quality
PP23-Trib 6	0-1,500	N	**37**	Straightened ditch provides little geomorphic or habitat complexity
PP24-Trib 6	1,800-6,600	R	**44**	No canopy cover
PP25-Trib 7	1,800-4,500	N	**46**	Straightened channel is actively incising and lacks habitat complexity
PP26-Trib 7	4,550	C	**41**	Undersized culvert has resulted in overtopping of the dirt road leading to rilling and erosion
PP27-Trib 7	5,500-6,600	F	**46**	Unrestricted cattle grazing has caused some bank erosions and decreased water quality
PP28-Trib 7	6,800-7,600	N	**42**	Multiple knickpoints with one ~100-ft downstream of 190^{th} St. W crossing
PP29-Trib 7	7,750	C	**39**	Channel is steep upstream of culvert potentially causing a partial fish passage barrier
PP30-Trib 7	8,550	C	**40**	Knickpoints downstream and upstream of culvert suggest active vertical instability
PP31-Trib 7	10,450-11,500	F	**44**	Channel has moved into corn field
PP32-Trib 7	13,950	G	**32**	Knickpoint ~10-ft downstream from culvert under 190^{th} St. W
PP33-Trib 7	50	G	**30**	Multiple knickpoints
PP34-Trib 7	0-2,100	N	**40**	Straightened channel is actively incising and lacks habitat complexity
PP35-Trib 7A	2,100-5,750	N	**50**	Straightened ditch provides little geomorphic or habitat complexity; no canopy cover
PP36-Trib 7A	5,750-5,900	B	**36**	Active incision has resulted in bank erosion and channel widening
PP37-Trib 7A	6,200	F	**46**	Potential for a stormwater basin
PP38-Trib 7A	0-700	F	**46**	Unrestricted cattle grazing has caused some bank erosions and decreased water quality; no canopy cover
PP39-Trib 7A	1,350	G	**34**	Knickpoint downstream of Cedar Ave
PP40-Trib 7B	0-2,500	N	**52**	4-ft incision has resulted in bank erosion and channel widening
PP41-Trib 7B	2,500	C	**51**	Riprap on the downstream end of perched culvert has been displaced by large flows
PP42-Trib 9	2,700	G	**44**	Knickpoint
PP43-Trib 9	5,550	F	**36**	Knickpoint near channel could undermine a drain tiling
PP44-Trib 9	5,850	G	**40**	Multiple knickpoints

5. Evaluation of Previously Restored Sections of North Creek and Middle Creek

More than 3000 ft of sinuous channel was completed in 2009 along North Creek between Stns 7000 and 10,100 (Figure 9). In addition to increasing channel sinuosity, deep pools and point bars were constructed and native riparian vegetation was planted. A farm road at Stn 9500 was retained as the landowner would like to use it for potential future development to the east of the channel. Because this road and the culverts were not replaced, the restored channel between Stn 8900 and 10,100 was never activated, although the downstream ends of these channels are open and connected. Once this road can be removed or the culverts replaced with larger culverts, the restored channel should be activated as soon as possible.

It was in this restored section of North Creek that the temperature differences between the main channel and pockets of groundwater seeps first became apparent. The water temperature in the main, active channel was 10-20° F warmer than the water temperature in the inactive channels. The cold water in the abandoned channel and in the un-activated new channel provides cold-water refugia for aquatic species and tempers the warm water in the main channel. This cold water resource should be evaluated for use in future restoration projects in this area. When restoration can continue, efforts should be made to retain a connection to these groundwater sources rather than being completely filled in or abandoned. Large wood placed in these old channels could provide valuable cover and in-stream habitat.

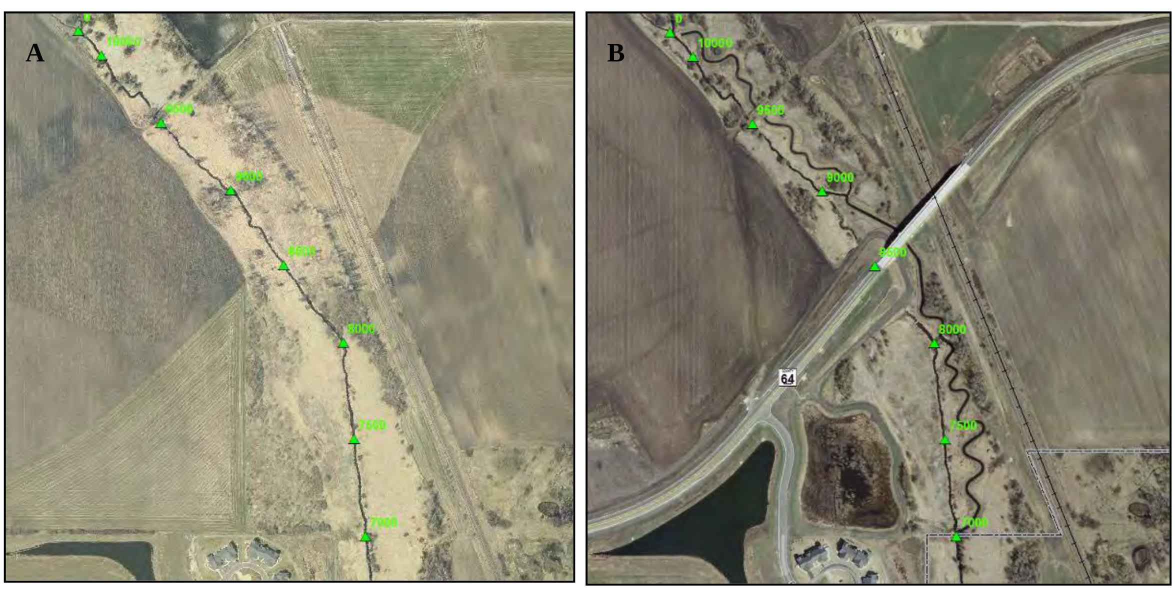

Figure 9: North Creek (A) before restoration in 2008 and (B) after restoration in 2010.

More than 2500 ft of sinuous channel was constructed on Middle Creek in 2006 to replace the straightened ditch between Stn 19,900 and 22,500 (Figure 10). The planform and channel dimensions appear well-designed and appropriate for the increased hydrology. The sinuosity is similar to the historic sinuosity, which is still apparent in downstream reaches of Middle Creek and in historic air photos. The channel is also wider to accommodate the larger flows that occur today. The channel bed elevation was built higher than the existing ditch elevation so that the floodplains could be activated. At the same time as the channel construction, the culverts under 195th St W were replaced to accommodate both the existing ditch elevation and the restored channel elevation. Concerns were raised, however, about the impact of the higher culvert and channel elevation on water elevations and the ability to drain fields upstream of the road. These concerns have not been resolved, so the restored channel has not been activated and remains dry except during large flood events. One possible solution could be to purchase the impacted land upstream of the road and modify the inlet to the culvert to create a stormwater basin. This could be a way to slow flows and trap sediment.

While agriculture had been active for many years, air photo analysis suggests that North Creek may have remained a meandering wetland channel until sometime between 1937 and 1951 (Figure 11). By 1951, North Creek had become a straightened channel that remained in the same alignment until the restoration project in 2009. On Middle Creek, the transformation from meandering channel to straightened ditch did not occur until between 1951 and 1964 (Figure 12). Portions of this new ditch were more than 1000 ft to the west of its original alignment. This likely partially explains the severe incision in the ditch as well as the severe incision in the tributary to the west.

Figure 10: Middle Creek showing the sinuous restored channel that has not been activated. Water still flows through the straightened ditch. The large building in the upper right is the Farmington Elementary School.

Figure 11: In 1937, the portion of North Creek that was restored in 2009 was barely perceptible meandering wetland channel. By 1951, the channel had been straightened into a ditch.

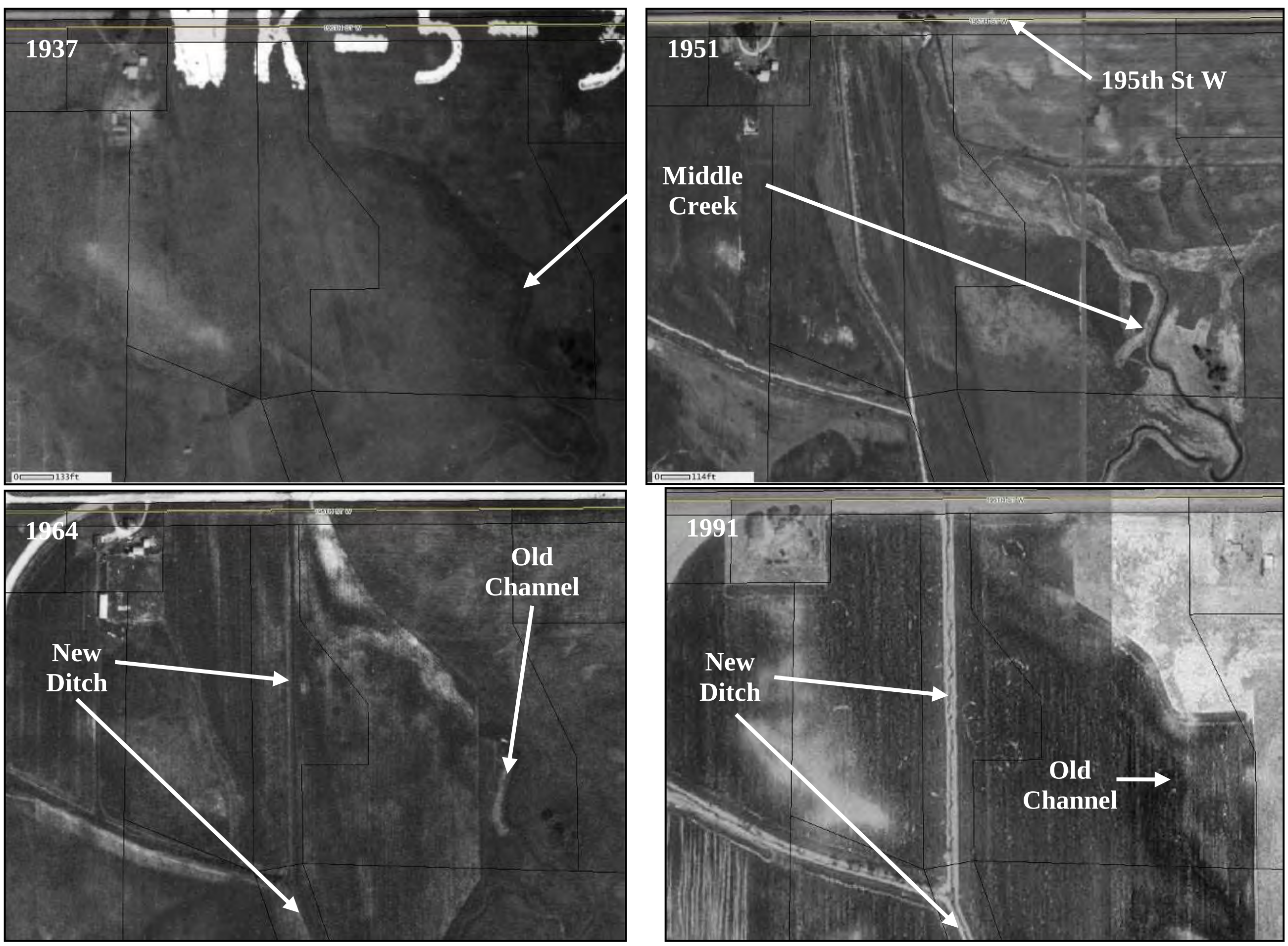

Figure 12: The Middle Creek restoration site was sinuous until sometime between 1951 (top right) and 1964 (bottom left). While the old channel scar is nearly gone by 1991 and the straightened ditch is obvious.

6. Potential for Coordination with the North Creek Greenway

Restoration in the North and Middle Creek subwatersheds should be integrated and coordinated with the North Creek Greenway plans. North Creek provides the greatest opportunity to mutually benefit the Greenway and river restoration. Downstream of Pilot Knob Road, most of the more than four miles of North Creek would benefit from channel and wetland restoration. The riparian buffer throughout this reach is more than 100 ft on either side of the channel. Because unfettered channel and floodplain connection is extremely beneficial for river and riparian health as well as flood retention, we do not recommend the construction of paths that would cut off and isolate portions of the wetlands. However, paths could be constructed near the edges of the wetlands. Another alternative is to build raised paths, or boardwalks, throughout the wetlands. The raised paths would enhance educational and recreational opportunities as visitors would be provided a more intimate connection to the river and wetland. These paths could be constructed on timber piles with minimal impact to the wetland.

Upstream of Pilot Knob Rd (Stn 22,200 to Stn 31,100), the City of Lakeville owns the majority of land on both sides of the channel. In many locations, parks have been built near the channel between residential neighborhoods. Dirt and paved paths exist for nearly this entire length of channel adjacent to North Creek. Connecting the paths associated with the North Creek Greenway to these paths would be easy and very beneficial. Upstream of Stn 31,100, North Creek flows through wide wetlands or parks, almost all of which are owned by the City of Lakeville. Paths could be built on the edges of these wetlands or as raised paths through the wetlands, as described above, to connect the city parks and the headwaters of North Creek to the North Creek Greenway.

By extending the Greenway from the headwaters to the mouth, educational opportunities abound surrounding ecological topics. Possible subjects to be discussed on interpretive signs include: importance of the headwaters, purpose of wetlands, importance of riparian buffers, in-stream habitat, riparian bird life, native riparian vegetation, trout or fish species, etc.

Middle Creek does not provide nearly as many opportunities for integration with the Greenway primarily because most of the land adjacent to the streams is privately owned. Most of the private land is farmed up to, or close to, the edge of the channel. Many of these landowners may not be amenable to giving up land for paths that would be accessible to the public. If landowners were amenable to giving up land for publically accessible paths, however, this could actually provide an excellent opportunity to form a better connection between the farming and non-farming communities. The Greenway paths could be built between an expanded riparian buffer and the row crops. Although residents of Dakota County and visitors from outside Dakota County may live near farms, many likely have little interaction or connection with these farms, the farmers, and the animals and crops on the farms. Informational signs along these paths could explain the history of each particular farm, crops grown, methods of farming, animals living on the farms, the process of delivering the foods from the farms to the typical Dakota County kitchen, costs associated with farming, benefits of a riparian buffer, and benefits of limiting livestock access to river channels.

Without extensive landowner cooperation in the Middle Creek subwatershed, some opportunity for Greenway integration still exists in the lower sections of Middle Creek. From the mouth of Middle Creek at North Creek and Chippendale Ave to Akin Rd approximately 7100 ft upstream, the channel winds through a wide wetland corridor. The natural sinuosity in this section is fairly intact and farming and development, with the exception of the right bank in the lower section of Middle Creek, is typically more than 100 ft from the channel. This provides an opportunity to connect trails along North Creek and Chippendale Ave to trails along Akin Rd and beyond.

7. General Recommendations and Conclusions

The North and Middle Creek channels and subwatersheds have been dramatically altered since agriculture and settlement began in the mid-1800s. Prairies and forestland were cleared and wetlands were filled in for agriculture, river channels were straightened and the dimensions altered, and portions of farmland were later converted to residential development. All of this has significantly impacted the aquatic habitat in a number of ways. Warm stormwater more rapidly enters the stream networks carrying many chemicals applied to lawns and crops as well as sediment from farms and streets. Wetlands have either been eliminated or are no longer fully functional, resulting in the loss of stormwater retention capacity and wetland habitat. Riparian vegetation is generally either non-existent or consists of the invasive reed canary grass. While most of the watersheds were likely prairie, portions of the riparian corridors were likely forested or contained occasional trees. The lack of trees today results in poor canopy cover, reduced shading, and reduced woody recruitment in the channel and the loss of resultant aquatic habitat.

A few factors within these subwatersheds are positive and will help the chances of successful geomorphic and habitat restoration. Throughout these subwatersheds, the groundwater table is very close to the surface, and groundwater seeping into the channels is common. This source of cold water counters the warmer water that emanates from the headwaters as a result of impervious surfaces, decreased infiltration, and a lack of riparian buffers. To address the warm water from the upper portions of the subwatersheds, we recommend focusing on restoring riparian buffers and/or instream retention/detention basins along the upper sections of both North Creek and Middle Creek. These are sections for which no channels were identified in the 1855 plat maps and which were later identified as intermittent in early USGS topographic maps.

To improve instream and riparian habitat and natural geomorphic form and function, we recommend focusing channel restoration efforts in locations that were historically (based on 1855 maps) sinuous channel with perennial flows. In many locations, particularly along the lower half of North Creek, wide stretches of wetland remain. This provides the opportunity to increase the channel sinuosity and reactivate the wetlands without impacting infrastructure or agriculture. The lower portions of Middle Creek retain their historic sinuosity and can provide planform conditions to replicate in North Creek. Landowner permission and cooperation will be a challenge throughout these subwatersheds, but North Creek has more public lands along the river and long stretches of the river have wide, undeveloped wetlands adjacent to the river even if they are privately owned.

7.1. North Creek

The most significant issues within the North Creek subwatershed are lack of stormwater retention in the headwaters (including lack of riparian buffer in areas), lack of habitat complexity throughout, and fish passage barriers throughout.

Fish sampling conducted in 2010 near the confluence with Middle Creek resulted in an Index of Biotic Integrity (IBI) score of 'good' due to the species diversity and fish populations (Brian Nerbonne, MN DNR, pers. comm. Jan 3, 2012). While tolerant species made up 41% of the fish, the species identified included trout (MPCA 'coldwater' species) and pearl dace (MPCA 'coolwater' species). While the Minnesota Department of Natural Resources have identified the lower ~4000 ft of North Creek as a trout stream, the opportunity exists for quality cold-water habitat for trout and native coldwater species from the mouth to Pilot Knob Rd, more than 4 miles upstream.

As discussed above, this portion of North Creek was identified as sinuous channel flowing through a wetland in the 1855 maps, suggesting that cold groundwater is very close to the ground surface. Between the mouth and Pilot Knob Rd, North Creek has now been straightened into a ditch, but 100-200 ft on either side of the channel is currently wetland and not being farmed or developed. This wide riparian buffer provides the opportunity to increase channel sinuosity, improve wetland and riparian vegetation, and re-activate the wetlands. The 1855 plat maps, historic air photos, and the lower portions of Middle Creek provide a template for a more natural channel planform (Figure 13).

A portion of North Creek has already been restored, between Stn 7000 and 10,000, and this restoration has provided insights to the restoration potential. In the restored section, a new sinuous channel was built and the old straightened channels were blocked off in a few locations or remained open on the downstream end. While the water temperatures in the new sinuous channel were in the mid 70s (°F), the temperatures in the abandoned channels were in the mid 50s. This suggests that the abandoned channels are receiving cold groundwater from beneath the wetland. These abandoned channels could provide excellent backwater and alcove habitat and cold-water refugia. In future restoration projects, side channels, off-channel pools, alcoves, and backwaters should be incorporated so as to benefit from this cold water.

While more than 4 miles of North Creek has the potential for excellent cold-water habitat as described above, multiple complete fish passage barriers within this section exist. Three culverts under driveways and farm roads between the mouth and Stn 10,000 are steep and undersized, while a small dam at Stn 20,050 prevents further upstream passage. Two of the undersized culverts that present complete passage barriers are downstream of the recently restored channel. Prior to, or concurrent with, any future channel restoration, these barriers should be removed or replaced with larger culverts or bridges.

Figure 13: (A) Lower Middle Creek showing sinuous channel left largely untouched since settlement demand in the mid-1800s. North Creek (B) before and (C) after restoration. The sinuosity and channel geometry is more uniform that on Middle Creek, but the meander width and wavelength are similar.

Within the headwaters of North Creek are long stretches of channel in wide wetlands with no development or farming. The channel through many of these wetlands has incised and widened to adjust for the increased hydrology due to the residential developments nearby. This incision has eliminated or reduced the connection between the channel and the wetlands, thus reducing the capacity for flood storage in the wetlands.

A couple of options exist for increasing the flood storage capacity in these areas: 1) If fish passage and habitat are not a priority in this portion of the watershed, culverts could be built in a few locations that would allow water to continue flowing in the channel during low flows. During flooding conditions water would back up in the channel, and flood waters would spread throughout the wetlands, slowing the movement of warm stormwater downstream. Historic topo maps indicate that these upper channels were intermittent through wetlands. Therefore, fish passage may not be the highest priority here and the headwaters could instead be utilized for stormwater storage. 2) If fish passage and habitat are a priority throughout these reaches, the channels could be restored to a more sinuous planform and raised through the construction of riffles and pools to an elevation just below the wetland surface. The restored channels would provide high-quality aquatic habitat and, during floods, water would spread out through the wetlands providing stormwater retention. This option is more costly as it involves a large amount of channel construction, but it also provides additional miles of restored fluvial conditions and habitat. These large wetland areas are primarily town land, so individual landowners will not be directly impacted.

In the upper portions of North Creek that flow through residential development, the lack of riparian buffer is an important issue with stormwater retention as well as habitat implications. While it would be beneficial to have a 15-20 ft buffer (ideally more) from the top of each bank, a proposal to create this buffer would impact many landowners and may be difficult to obtain public support. There are also trees in the developments that do provide some shade. Because of the number of landowners involved, focusing on improving stormwater retention with retention or detention basins in the residential developments may require fewer resources than creating an adequate buffer through these reaches.

Restoration of the lower portions of North Creek would tie in very well with the North Creek Greenway Master Plan. Trails could be built throughout the riparian corridor and informational signs could be installed to educate recreationists about the restoration process. If Greenway plans were to expand, the multitude of public lands and city parks in the upper North Creek drainage provide an opportunity to connect existing trails in residential neighborhoods and parks.

7.2. Middle Creek

Much of the Middle Creek subwatershed consists of straightened ditches through agricultural land. The lower 7000 ft have been designated as a trout stream by the Minnesota Department of Natural Resources. This section of Middle Creek has retained its historic sinuous planform and also has a wide riparian buffer, though much of this buffer is likely no longer a functioning wetland due to channel incision. Between Akin Rd (Stn 7100) and Pilot Knob Rd (Stn 13,000), the channel changes from a sinuous planform to a straightened channel through wide, active wetlands. These wetlands are in the same area identified as marsh in the 1855 plat maps and in later topo maps. In 1855, this marsh was the headwaters of Middle Creek, with no channels identified upstream. In the later topo maps, upstream channels were identified as intermittent. While more than 20 miles of perennial channel in Middle Creek and its tributaries exist upstream today, this area historically likely consisted of rolling hills covered with prairie or forest with small, intermittent drainages that only carried water during rain events. Today, the rolling hills are used for agriculture and the drainages are deep, straightened ditches for carrying water downstream as quickly as possible.

While substantial trout and other fish habitat could exist throughout the watershed with extensive channel restoration and an increase in riparian buffers, it may be more beneficial to dedicate some of the headwater streams to stormwater retention/detention to slow the stormwater flow and decrease or slow the warm water, sediment, and chemical inputs to the channels. Natural channel restoration, increasing riparian buffer widths, and building stormwater basins will all require substantial landowner cooperation in an area where some landowners have expressed frustration with restoration projects in the past. It may be a good strategy to make small land purchases and focus on stormwater basins and buffers upstream of 195th St W where the plat maps and topo maps suggested only small intermittent streams existed prior to settlement. These sections of stream may not have had substantial fish populations historically and therefore focusing on fish may not be appropriate here.

Reducing the water volumes and velocities through the Middle Creek subwatershed, however, may be beneficial for agricultural practices and habitat alike. During our survey, a large rain event resulted in extensive flooding in all channels. While the storm only lasted for half of one day, water levels raised rapidly, flooded fields, and backed up at road crossings. Crops were inundated, and soils were washed into the channel causing the water to turn dark brown. In some areas, channels had changed locations due to previous storm events and were flowing through the crop rows. The construction of stormwater basins and/or the increase of riparian buffers could substantially reduce this flooding potential.

Some of the areas in the subwatershed, in particular between Flagstaff Ave and 190th St W on Tributary 7, have wide riparian buffers with native grasses and other forbs (along with the invasive reed canary grass). In many cases these wide riparian areas were wet even when the river was not flooding, indicating that they currently provide some retention capacity. The water quality and riparian and aquatic habitat would benefit greatly throughout the subwatershed if more reaches of the channels had wide riparian buffers such as these.

7.3. Conclusions

While many portions of the Middle and North Creek subwatersheds have minimal aquatic and riparian habitat, these subwatersheds have the potential to provide extensive cold-water aquatic habitat, wide wetlands and riparian habitat, and improved stormwater retention that would improve water quality throughout the watersheds and the Vermillion River. To realize this potential, sufficient funding, careful planning, and significant public outreach will be necessary. The following priority list provides a possible way to proceed. However, these priorities can be altered depending on the goals and objectives of the project partners.

Phase 1:

- Provide stormwater retention in the headwaters of North Creek within the publically owned wetlands and parks
- Remove fish passage barriers or replace culverts with larger culverts and bridges:
    - North Creek PP04: Stn 2300 - undersized culvert
    - North Creek PP07: Stn 5400 - undersized culvert
    - North Creek PP08: Stn 9500 - blocked culverts within recently restored section
    - North Creek PP12: Stn 22,200 - small dam
    - Middle Creek Tributary 1 PP16 and PP17: Stns 600 and 850 respectively - undersized, perched, and ineffective culverts under potentially unused farm roads in a trout-classified stream
- Restore natural sinuosity, channel geometry, wetland and riparian vegetation, and wetland functionality:
    - North Creek PP06: Stn 3800-16,500 - complete channel restoration within wide riparian wetland buffer; activate remainder of recently restored section; take advantage of the cold groundwater by building side channels, backwaters, alcoves, groundwater galleries, and off-channel pools
    - Middle Creek Tributary 1 PP15: improve low flow channel, increase habitat potential and variability

Phase 2:

- Public outreach - reach out to landowners, discuss the issues, understand their concerns
    - Identify farmers and landowners within the Vermillion River watershed that have cooperated on restoration projects and have had a positive experience

    - Ask these farmers to assist in the public outreach
    - Describe to the landowners the options for compensation, alternative methods of farming, and the restoration ideas
- Identify and remedy the issues preventing the activation of the recently restored channels on North and Middle Creek; consider a stormwater basin upstream of the North Creek site (would require some land acquisition)

Phase 3:

- Improve stormwater retention and infiltration upstream of 195th St W on Middle Creek and the tributaries:
    - Increase riparian buffers throughout with native riparian trees, shrubs, and forbs
    - Build detention/retention basins throughout the headwaters where appropriate

8. References

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APPENDIX A: Review of Geomorphology Principles

In order to fully visualize and understand the problems occurring in the North and Middle Creek subwatersheds, it is important to have a basic understanding of fluvial geomorphology. This section discusses the principles behind fluvial processes. Stable stream systems are in a delicate balance between the processes of erosion and deposition. Streams are continually moving sediment eroded from the bed and banks in high velocity areas such as the outside of meander bends and around logs and other stream features. In the slow water at the inside of meander bends or in slack water pools, some of this material is deposited. This process of erosion and deposition results in the migration of rivers within their floodplains. The process by which streams meander slowly within the confines of a floodplain is called *dynamic equilibrium* and refers mainly to this balance of sediment erosion and deposition. Streams typically have reaches that fall along the continuum of degradation (eroding) to aggradation (depositing) at any one time in the scale of channel evolution. The location and character of these individual reaches changes over time. When a stream channel is in equilibrium, it may move across the floodplain, erode and deposit sediment, but general planform geometry, cross-sectional shape, and slope remain relatively constant over human lifetimes.

Many factors can influence this equilibrium by altering the input of sediment and the quantity and timing of runoff. These factors include soil types, rooted vegetation that holds soil in place, flashy flows that erode banks, large rainfall events or increased sediment pollution that deposits sand or other fine sediment in the channel. When a channel loses its equilibrium due to changes in flood power and sediment load, it can in turn lose essential habitat features. The fundamental channel shaping variables in balance are slope, discharge (amount of water flow per time), sediment load and sediment size. The balance between the amount/size of sediment and slope/discharge is manifested in complex drainage networks of streams with a specific channel area and slope. Any change in one of the variables can upset this balance, resulting in either aggradation or degradation of the channel.

For example, given that the primary function of streams and rivers is to transport water and sediment downstream, changes in land use that affect the timing of runoff can affect sediment transport. Clearing of watershed forests, row crop agriculture and urban development cause storm water to reach the stream channel faster, and increase the peak discharge in the stream.

Geomorphically, an increase in stream discharge might result in an increase in channel incision or lateral bank erosion, and hence, the amount of sediment being transported downstream. These changes may also result in changes to channel slope. The stream's evolution will persist until it reaches a new dynamic equilibrium between the channel shape, slope, and pattern (Schumm 1984, Leopold et al. 1964).

In a comprehensive geomorphic assessment, the physical attributes of the stream channel are measured to determine its geomorphic stability and the processes and factors responsible for that instability. Parameters typically measured include channel planform and profile, cross-section geometry, slope, watershed landuse, riparian vegetation, soils, and channel erosion.

Channel dimension

The cross-sectional size and shape of a stream are products of evolutionary processes that have, over time, determined what channel size is necessary to accommodate the most frequent floods. Several parameters can be used to determine the effect of channel shape on stream flow, including channel width, depth, width to depth ratio, wetted perimeter (the length of cross-section perimeter contacting water), hydraulic radius (cross-sectional area divided by wetted perimeter), and channel roughness. The bankfull surface is a common measure used to scale cross-section features to allow for comparisons with different sections within the same watershed or in different watersheds. In a natural river in equilibrium, the bankfull surface is at the top of the banks, the point where water begins to spill out onto the floodplain. In rivers not in equilibrium, the bankfull surface can occur elsewhere on the cross-section.

Channel planform

Flowing water is constantly encountering friction from streambed and banks, and the energy of the stream is dissipated through work. This work is

Figure A-1: 2003 aerial photograph showing the sinuous nature of the Minnesota River. Flow is from south to north.

manifested mainly as the entrainment or movement of soil and sediment particles. Energy in linear systems such as rivers is dissipated in the manner that minimizes work (the rate of energy loss), the sine wave form. The energy of a straight line is thus dissipated over a lower slope by the formation of sinuosity, or the typical “S” shape of stream channels (Figure A-1). The erosion and deposition of sediment balanced by the resistance of particles to erosion causes and maintains this condition. Sinuosity can be measured as either the stream slope/valley slope, or the thalweg length/valley length, where the thalweg is the highest energy point (usually approximated by the deepest point) in the stream channel (Leopold 1994).

Channel profile

The gradient or slope of a stream channel is directly related to its cross-sectional geometry, soils, and planform geometry. Higher gradient streams in hilly or mountainous areas tend to have a lower sinuosity and dissipate energy over turbulent step-pools of harder substrates whereas low gradient streams such as those common to the Midwest have a higher sinuosity and dissipate energy through lower slopes and regular riffle pool sequences. Degradation of streambeds caused by disturbance is problematic, for unlike lateral bank erosion that tends to be localized, changes in bed elevation can be felt over several miles. Channel incision, or downcutting, generally migrates upstream until a stable gradient is achieved.

Channel stability

As discussed in the above paragraphs, a channel in equilibrium may erode and deposit without being considered unstable. Some erosion in stream channels is normal, and a channel in dynamic equilibrium, balancing erosion with sediment transport, is considered stable. The stability of channel planform and profile are dependent on many factors, including soils, roughness, slope, and disturbance. The *vertical stability* of a channel refers to the state of incision or aggradation of the streambed.

Figure A-2: A headcut and incised channel on a small stream in Scott County.

Vertical instability often follows a certain pattern whereby changes in the bed elevation of a stream are translated upstream through a series of small vertical drops called *knickpoints* or *headcuts*. This situation can arise from the straightening of streams and an associated decrease in channel length or by direct changes in the bed elevation of a stream (eg. improper road crossing installation or decreased bed elevation in a main channel). This process of downcutting is called *incision*. A waterfall would be an extreme example of a knickpoint in bedrock. As a headcut moves upstream, the stream becomes more incised and the flood energy increases as more and more volume is confined to an incised or *entrenched* channel (Figure A-2). Whereas prior to incision, the stream was able to dissipate its energy over a wide floodplain, after incision this energy is concentrated. Following incision, the stream typically begins to erode laterally with the end result being new floodplain formation at a lower grade. The Schumm channel evolution model demonstrates how a headcut creates an incised channel that becomes laterally unstable and eventually forms a new stable channel at a lower elevation (Figure A-3).

Channels in equilibrium provide structure and complexity to support habitat for aquatic species. When a channel becomes unstable, aquatic species have a difficult time adjusting to rapidly changing conditions. Erosion and incision can remove habitat features, and deposition can fill pools and cover spawning gravels.

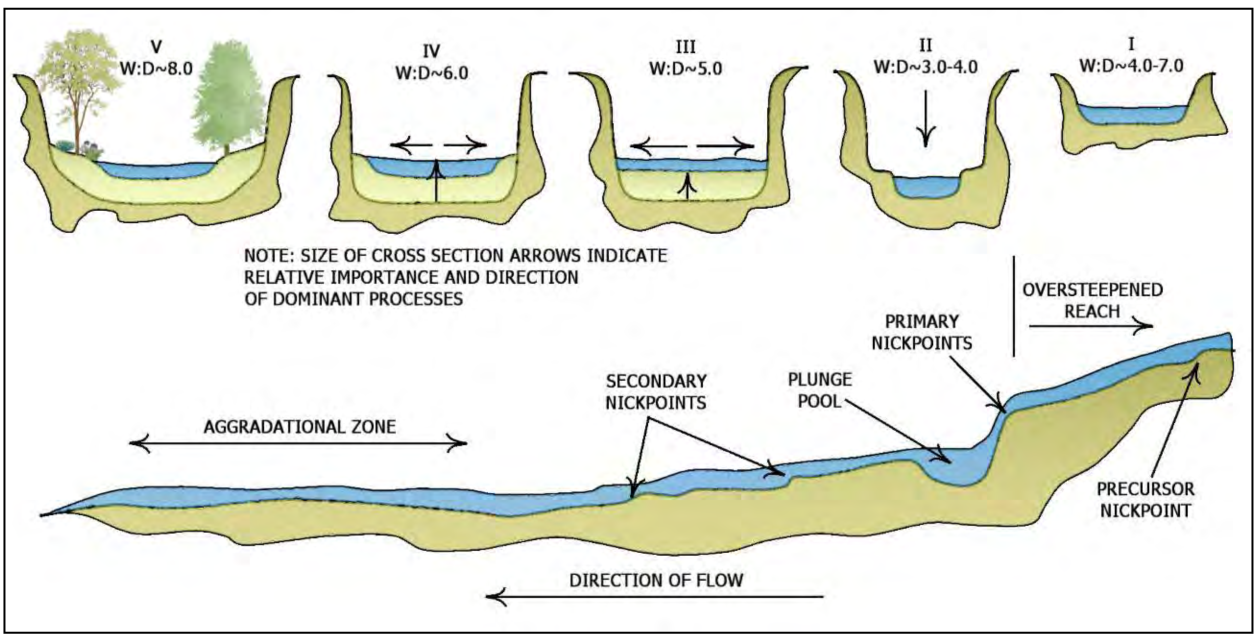


Figure A-3: The Schumm channel evolution model (modified from Schumm, 1984).

In a reconnaissance-level fluvial geomorphic assessment, a stream is examined for signs of channel instability such as active headcuts, bank erosion and channel scour, bed sediment type and stability, type, age and stability of bank and bar vegetation, algae, macrophyte and macroinvertebrate populations, type and sorting of various depositional features, floodplain deposition, type and consolidation of floodplain soils, and bank erodibility.

Sediment transport

One of the most common misconceptions about streams is that erosion is inherently bad. As discussed above, the dynamic equilibrium of streams involves the opposing forces of erosion and deposition, and this process is normal when equilibrium is maintained. As streams flow, particularly during rainfall or snowmelt events, they entrain particles from the channel bottom and banks. Particles small enough to become suspended in the water column are called *washload*, while particles that move along the channel bottom are called *bedload*. Together, these components make up the sediment transported in the channel. When this balance of erosion and deposition is upset by changing landuse, streams respond in various ways depending on the change. For instance, after clear cut logging, runoff from rainfall reaches the stream faster and the erosive power of a stream can increase, causing excessive incision and/or bank erosion in some areas. As that sediment moves downstream, it will eventually come to areas of low gradient and will be dropped out of the water column. Thus streams can erode excessively in some areas and deposit excess sediment in other areas of the same system. Both consequences of a disturbed sediment equilibrium can have detrimental effects on fish and wildlife habitat.

APPENDIX B: Management Recommendations

The following descriptions outline the project types shown in the Priority Project ranking system. Many projects involve some aspect of more than one of the types listed.

<u>Grade Control</u>

In reaches with extreme incision or active downcutting, grade control is often prudent. Grade control involves the installation of an armored riffle or drop structure placed to prevent any further incision from traveling upstream. Grade controls can be discrete weirs, concrete structures or armored riffles (Figure B-1). Inter-Fluve recommends the latter in natural stream systems to avoid blocking fish passage and to maintain natural geomorphic function.

Figure B-1. The above photos show a riffle-pool channel (A) just after and (B) 2 years after construction. Grade controlling riffles can be built either in conjunction with armored banks to prevent channel migration, or with sediment input in mind, so that as the stream moves laterally, new riffle lobes will form (photos Inter-Fluve).

<u>Floodplain Management</u>

Floodplain management projects vary considerably, but include expansion of riparian buffers, removal of infrastructure, and stormwater management. New development must capture stormwater and encourage as much infiltration as possible or the stream will experience a sharp decline in water quality. Building retention or detention basins or retrofitting existing stormwater systems will help improve water quality and prevent incision and erosion problems. Conservation farming practices, as described in the main body of the report above, would also fall into this project type. Changing the farming practices would help slow the movement of water into the stream channels and increase infiltration.

Riparian Management

One way of improving filtration of nutrients, reducing stream temperature and restoring the connectivity of green corridors is to revegetate streambanks and riparian areas where row cropping and urban development have encroached on the channel. Revegetation projects are relatively simple to institute and can be inexpensive. Plants can be purchased through local NRCS or nurseries and can be planted using volunteer labor.

When the forest canopy is removed the channel is exposed to more direct sunlight, and removal of soil binding tree roots can result in major bank erosion. Organisms dependent on forest leaf litter for energy can be impacted, and fertilizer from expanding lawns likely drain directly and quickly into the channel, resulting in increased algal growth and decreased oxygen levels. The streamside natural area is critical to the connectivity of watersheds. Migratory birds and other animals use these green corridors through their range or to migrate seasonally. Removal of these buffers fragments habitat for already stressed organisms. This pattern can be reversed, however, by increasing natural buffers of both native grasses and forested riparian areas.

It is extremely important to buffer even small ditches and channels. Water pollution in rivers is cumulative. Once you have poor water quality, it does not generally improve with distance downstream. Any attempts at reforestation should consider the impact of exotic species such as reed canary grass and buckthorn. Special measures such as removal and herbicide treatment must be taken before establishing native species.

Crossing

Where continuous water flow is available for fish passage, culverts must be well-placed and partially buried to provide in-stream habitat and limit perching. Perching is caused by either incorrect placement of the culvert above the downstream channel bed or by incision traveling upstream and causing the channel bed below the culvert to downcut. Most warmwater

Figure B-2: Bottomless arch that is partially buried for better habitat and fish passage conditions.

fish have poor leaping ability, so even a six inch perch can present problems. Perched culverts can be made passable by raising the channel bed downstream, backwatering through the culvert or by replacing the culvert. Culvert replacement should consider bottomless arch options or culverts that are partially buried to mimic a natural channel bottom (Figure B-2).

Low flows can present a passage barrier at any culvert, and this is not only a function of the culvert design, but also the hydrology of the system. During midsummer, when flows are very low, all culverts may be impassible. Low flow can be concentrated or backwatered through a culvert to minimize passage problems. For instance, flow up to a certain elevation can be easily diverted (eg. low concrete weir) into one box of a double box culvert, essentially doubling the amount of water in the culvert at low flow.

Bank Stabilization

Bank stabilization projects in urban and agricultural areas seek to minimize soil loss and prevent stream channel migration and property loss. Urban and agricultural streams are often in a state of flux; the streams are trying to adjust their cross-section (get bigger) to accommodate the increase in flows.

In general, bank stabilization should consider infrastructure constraints, future channel migration patterns, and riparian buffer protection. A simple bank restoration project is to plant trees away from the eroding bank and allow those trees to grow to maturity before the channel has a chance to erode to their base. By the time the channel has moved, the trees will be large enough to provide deep rooted bank stabilization. The most successful trees for this purpose would be cottonwood, black willow and silver maple, all common riparian or "wet feet" trees capable of withstanding frequent inundation. Another approach is to provide some toe protection in the form of rock or encapsulated gravel combined with planting. Rock is sized or protected such that it remains stable long enough for vegetation to grow. Bioengineering fabrics can be used to provide structural stabilization and to prevent the piping of

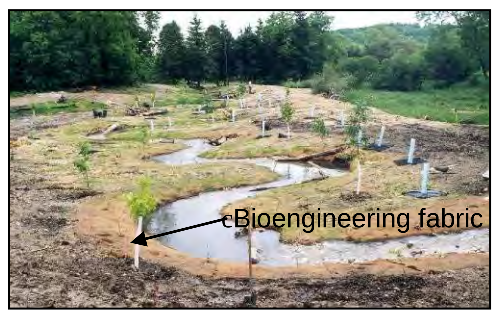


Figure B-3: Grasses are beginning to grow through biodegradable bioengineering fabric along this restored stream (photograph: Inter-Fluve).

soils during high flow. These materials biodegrade once the vegetation is established (Figure B-3). A combination of rock toe protection, geocells, and fabric are often useful for large, steep banks (Figure B-4).

Figure B-4: Rock toe, stacked geocells, and fabric at hart Park, Milwaukee.

The least expensive bank stabilization is simply for landowners to leave the stream alone. New and existing landowners in forested reaches should be encouraged to remove exotics such as buckthorn and garlic mustard but to otherwise leave the streamside vegetation to manage itself (Figure B-5). This encourages natural stabilization and habitat formation. In most cases, our best intentions are actually detrimental to the stream environment. Erosion and deposition of streambank sediment are the essential physical forces behind stream and floodplain formation. Some degree of bank erosion is natural. When watershed changes or riparian landuse practices cause the stream to be out of equilibrium, however, abnormal erosion rates can result. What constitutes abnormal erosion is somewhat subjective and depends on sediment pollution concerns, habitat degradation, and concerns over nearby infrastructure such as roads, houses and underground conduits. Prior to undertaking a project, it is therefore important to obtain professional opinions from land managers, geomorphologists, and engineers. If the erosion appears dramatic, but the erosion rate is extremely low, there may be no real basis for a stabilization project. Conversely, erosion may not appear dramatic, but the rate may be high, requiring some immediate stabilization. Determining the risk of no action is extremely important.

Figure B-5: The root structure of trees hold the bank material together to stabilize the banks against rapid erosion.

Often, people see a downed tree, or a scour area around a rootwad or tree base, and associate bank erosion with trees. In fact, had the tree not been there until it fell, the bank would have probably eroded at a much greater rate. Box elder trees are primary colonizers and are very quick to establish in areas where trees have fallen and clearings result. This association of box elder with unstable banks also leads to the misconception that box elders, and thus all trees, cause erosion. Common riparian trees have evolved over time to do just the opposite. Eastern cottonwood, black willow and silver maple, our three most common streamside trees, have evolved deep, water searching root systems to provide for added stability in the dynamic streamside environment. Black willow roots can travel dozens of feet up and downstream, creating an extremely well-armored bank.

Native grasses provide adequate streambank root protection down to approximately 3 to 4 feet and are useful in smaller streams or areas where prairie restoration makes sense. Larger streams or incised channels with banks taller than 3 feet need deeper and stronger root protection. No vegetation can provide long term stability beyond five feet of streambank height, and the root protection is then limited to trees and grasses in the upper banks. The Minnesota River is a good example of this dynamic.

Project type – Natural channel restoration/ Relocation

Channel relocation is also called natural channel restoration, natural channel design, or re-meandering and all involve actually building a portion of stream channel different from the existing plan and profile. Inter-Fluve typically refers to channel relocation projects when discussing the movement of a channel to avoid some planned infrastructure. For instance, when new roads are constructed, it is sometimes cost effective to move a stream channel out of the path of the road or to construct a more stable crossing alignment. These situations are often good opportunities to restore channelized reaches into a more geomorphically and ecologically stable configuration (Figure B-6).

Figure B-6. This segment of Spring Creek in the Black Hills was relocated and restored as part of new highway construction (photo Inter-Fluve).

Natural channel restoration projects involve the construction of a meandering channel with habitat and geomorphic features mimicking natural forms. Gravitational forces, the rotation of the earth, and the friction of water on soil all combine to cause flowing water to assume a sinuous planform. Steeper streams in rockier terrain tend to be straighter and dissipate energy readily through cascading riffles or waterfalls. Lower down in the watershed, or in flatter areas like the Midwest, streams erode slowly through sand, silt and loam to form lazy, winding rivers and streams. Minnesota has several million acres of drained land, with over 80% of that drainage achieved through ditches and channelized stream segments. It is very likely that all ditches with perennial flow were at one time meandering streams, and many of our dry summer ditches were at one time intermittent stream channels or wetlands. Restoring the geomorphic function of these ditches through natural channel restoration can lead to dramatic improvements in habitat and water quality (Figure B-7). Ditches are generally deeper and more incised than their sinuous predecessors. Incised streams move flood water quickly, and they do so by concentrating more of the flood flow in a large channel rather than across the floodplain. By adding sinuosity, we can decrease the slope of the channel and in some cases raise the bed of the stream, thereby reconnecting the stream with its former floodplain. Restoring floodplain connectivity slows the exit of water off of the land and allows for greater infiltration, higher baseflows, lower stream temperatures and lower peak flood flows. Restoring incised ditches can be accomplished in three main ways. The first and most inexpensive way is to introduce roughness elements that encourage the formation of a sinuous channel inside the ditch cross-section, essentially using natural forces to carve out a floodplain over a long period of time. The other methods involve either lowering the floodplain through excavation, or raising the channel bed. Clearly, restoring meanders to a stream requires that the

Figure B-7. This segment of Trout Creek on the Oneida Reservation was channelized in the early 1900s (top). The restored segment (bottom) involved floodplain excavation, woody debris habitat installation and native plantings (photo Inter-Fluve).

stream occupy a wider swath of land than did the straightened ditch. In areas where little or no buffer currently exists, restoration would need to include expansion of the buffer. The meander limit, or belt width of a stream, is generally a function of the watershed area and the discharge of the stream. For small headwater channels, a reasonable belt width might be in the range of 50 to 100 feet (assuming a channel top width of 15 to 30 feet).

Hydraulic modeling and hydrologic analysis are important components of stream restoration in regulatory drainages. Flood peaks spreading out on downstream farmland can actually be reduced by attenuating the flashy floods upstream through floodplain reconnection and stream restoration. Ditch construction in the Midwest typically occurs without any hydraulic modeling of flood flows to see if ditching actually accomplishes the intended goal. Computer modeling of flood elevations can now be used to determine the practical value of ditches and determine the impact of channel restoration.

Natural channel restoration involves several steps, the first of which is dewatering. Given enough floodplain width, this can be accomplished with little or no effort by simply building the new channel completely off line from the existing ditch. The new channel is constructed "in the dry" adjacent to the existing ditch. Rough channel excavation is completed, with the spoils either removed off site or stockpiled near the existing stream for later filling. Fine grading involves bank stabilization, riffle and pool construction where appropriate, and incorporation of habitat elements. Once the channel has been stabilized, either using fabric methods or by allowing vegetation to grow for a period of time, then water is diverted permanently into the new sinuous channel and the old one is filled in to the floodplain level (Figure B-8).

Figure B-8: Stream restoration in agricultural areas can sometimes involve reconstructing a new valley form or incipient floodplain (photograph: Inter-Fluve).

Natural channel restoration in farmed headwater systems can be complicated by the elevation of road crossing inverts. Many modern culvert crossings were installed flush with the bottom of the ditch at the time of construction. The elevation of the channel bottom at the time of culvert installation was more than likely much lower than the elevation of the channel bed prior to ditching, when the stream was a smaller, sinuous channel with good floodplain access. Restoration projects in agricultural areas don't typically involve raising the channel bed at road crossings, which would require replacement of the culvert to minimize or eliminate any upstream rise in flood elevation. The cost of creating an incipient floodplain on a restored stream, or raising the channel and possibly replacing crossings can limit the amount of restoration that a local group can reasonably accomplish.

New stream channel construction can vary greatly in cost between $50 and $200 per foot, depending on constraints and floodplain restoration strategies. A large project might restore a mile of stream channel, placing the cost between $200,000 and $1 million. Granting programs in the Midwest are fairly limited in their ability to fund many large projects of this type, and many coastal and Great Lakes programs are currently focused on fish passage. Hopefully, future granting programs, farm bills and state restoration programs will recognize the importance of headwater stream restoration in our agricultural watersheds.

Restoration and Ditch Law

A major obstacle in restoring headwater streams is current drainage law, governed in Minnesota by Minnesota Statutes, Chapter 103. The ideal option for restoring a farm ditch would be abandonment of the public drainage easement, which is a very difficult process in Minnesota. The State Water Resources Board (later BWSR) originally authorized the creation of watershed districts, who in turn could govern drainage systems within their geographic boundaries. County boards were required by law to assess the potential environmental and natural resources impacts of drainage projects, but much of this was done before watershed issues were deemed important to the general public. Since the 1960s, more watershed residents have raised questions about drainage and water quality, and whether the current drainage law protects the public good in the best possible way. The Clean Water Act and subsequent farm bills have placed more of an emphasis on wetland protection, but because the existing laws are designed to increase drainage, not reduce it, abandonment is still challenging. A ditch is owned by the landowners, and therefore the costs for maintenance of ditches is typically borne by the landowners. Restoration in regulatory ditches typically involves either full abandonment, partial abandonment, and impoundment. Full abandonment requires initiation by landowners, a signed petition by 51% of the landowners assessed for the system, and final approval by the authority. This is usually done in urban areas where the ditch is no longer in existence or in areas with few landowners. Abandonment through the RIM program is possible but often requires an engineering study and some drainage modifications to prevent downstream flooding from worsening. Partial abandonment is not usually done because the drainage authority can be lost if some portion of the system is abandoned. Installation of water control structures to restore wetland conditions is also a possibility, but those structures must be maintained by the landowner.

Two alternative ways of restoring floodplains and streams within existing ditch law have been demonstrated by the Minnesota DNR and others. The first involves *ditch improvement*, whereby a channelized ditch can be confined within parallel berms running along both sides of the channel dozens or hundreds of feet from the channel center (Figure B-9). Within these berms, a lower floodplain can be excavated or the channel raised and a meandering stream restored. The second involves *diversion for public benefit*, whereby both ends of a segment are blocked and the ditch is then no longer maintained. A meandering channel can then be built off line from the existing ditch.

Wetland restoration as floodplain management ties directly into the discussion of ditch management and natural channel restoration. Although there are a few small wetlands in the watershed, a central ditch and its associated tile lines still drain the landscape. Wetland restoration is a good method of improving water storage in reaches with only ephemeral flows. Wetland restoration and/or wetland stream restoration would need to include managing tile drainage and minimizing or eliminating ditch drainage so that water stays on the wetland longer. In recent projects completed with the Oneida Tribe in Green Bay, Wisconsin, Inter-Fluve has combined wetland and stream restoration with buffer management in headwater tributaries to a small agricultural stream. In just four years, the water quality of the system has improved to the point where trout will be re-introduced (Snitgen and Melchior 2007). Many such examples of a headwater restoration approach can be found around the Midwest. The flow of water during wet times of the year, natural ground water flow, hyporheic flow and abundant wetland vegetation combine to eliminate any increase in water temperature before the water flows downstream. The ability to reintroduce trout into a system with newly restored wetlands and stream is evidence that water temperatures remained low.

A major obstacle to native plant wetland restoration is the ubiquitous presence of reed canary grass (*Phalaris arudinacea*), giant reed grass (*Phragmites australis*) and cattail (*Typha angustifolia*). These invasive species have taken over most of the wetlands in the Midwest, with reed canary grass often colonizing disturbed sites to become monoculture. The fecundity of these plants, their ease of seed spreading, and their proximity to moving water make wetland restoration with native plants extremely difficult. However, the hydrologic benefits of invaded wetlands still remain. Eventually, better methods will be discovered that will help improve the diversity of restored wetlands and minimize invasion by exotic species.

Figure B-9: Restoration of a ditch within levees to create a meandering stream with a vegetated riparian buffer (courtesy of L. Aadland, MN DNR).

APPENDIX C: Reach descriptions of existing conditions for the North Creek and Middle Creek subwatersheds

Existing Conditions

Inter-Fluve geomorphologists conducted a rapid geomorphic assessment of the North Creek and Middle Creek subwatersheds in Dakota County. Channels were divided into reaches based on channel planform, slope, bedforms, riparian characteristics, and adjacent land use. The mainstem of North Creek was divided into five reaches, and the five tributaries to North Creek were divided into six reaches (Figure C-1). The mainstem of Middle Creek was divided into three reaches, and the nine tributaries to Middle Creek were divided into 16 reaches (Table C-1).

Table C-1: Reach lengths for the North Creek and Middle Creek subwatesheds.

North Creek			Middle Creek			
Reach	**Length (miles)**	**Stn of Confluence (ft)**	**Reach**	**Length (miles)**	**Stn of Confluence (ft)**	**Notes**
1	0.7		1	1.9		Joins North Creek
2	3.7		2	1.9		
2A	0.6		3	5.7		
3	2.0					
4	2.1					
5	0.3					
Total (main)	8.8		**Total (main)**	9.5		
Trib 1, Reach 1	0.4	10,150	Trib 1, Reach 1	1.1	2,525	
Trib 1, Reach 2	1.0		Trib 1, Reach 2	0.3		
Trib 2	1.3	15,350	Trib 2	0.6	7,550	
Trib 3	0.7	19,175	Trib 3	0.5	10,850	
Trib 4	0.9	30,100	Trib 4	1.1	11,450	
Trib 5	1.1	37,000	Trib 5	1.0	16,125	
			Trib 6	1.3	20,950	
			Trib 7, Reach 1	0.3	22,625	
			Trib 7, Reach 2	1.2		
			Trib 7, Reach 3	1.3		
			Trib 7A, Reach 1	1.1	1,800	Joins Trib 7
			Trib 7A, Reach 2	1.0		
			Trib 7B	1.5	6,100	Joins Trib 7
			Trib 8	1.2	38,075	
			Trib 9, Reach 1	0.5	41,550	
			Trib 9, Reach 2	0.9		
Total (tribs)	5.3		**Total (tribs)**	15.0		
Total	14.1		**Total**	24.5		

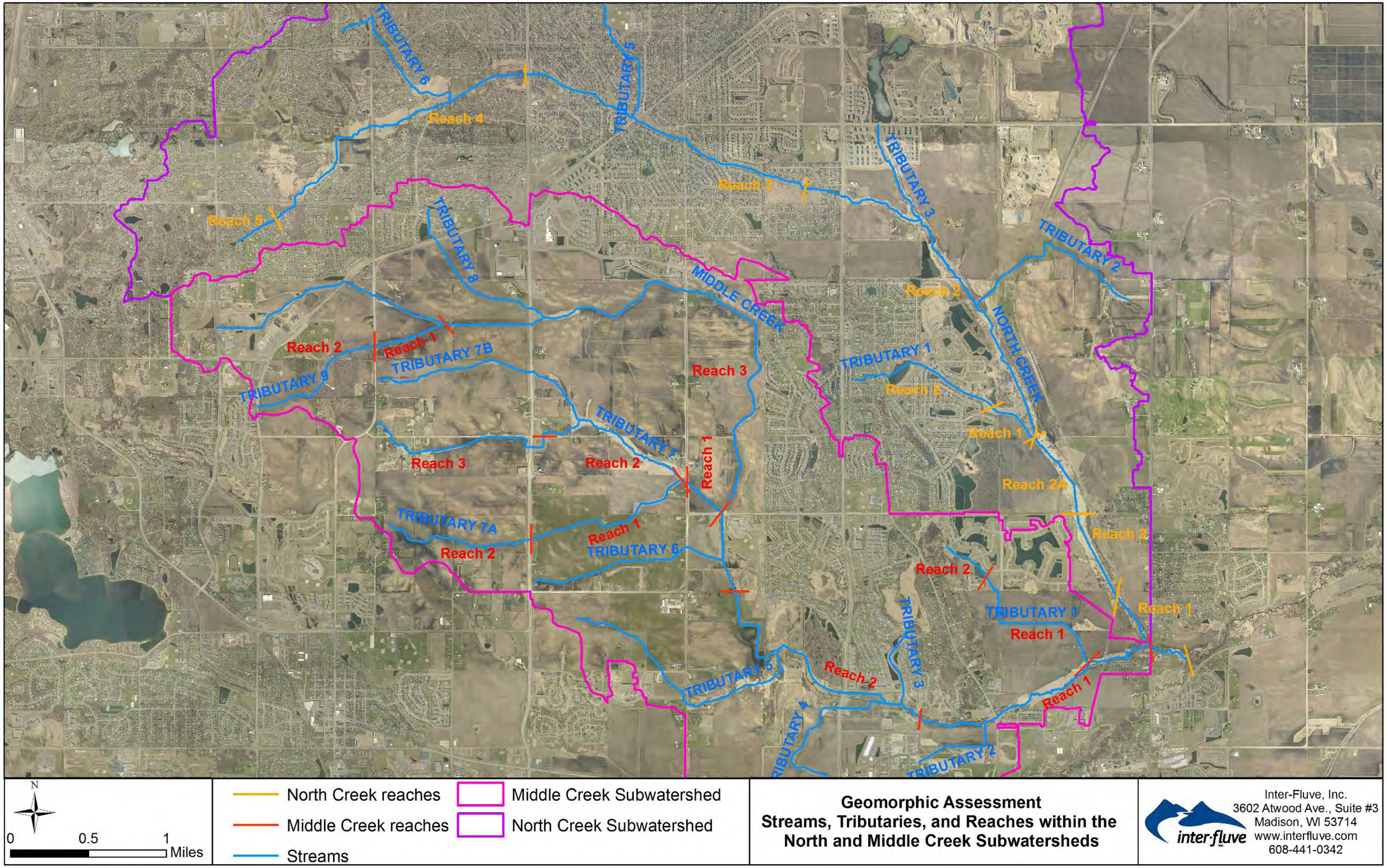


Figure C-1: Streams and stream reaches of North Creek, Middle Creek, and their tributaries.

1.0 North Creek

The 8.8 miles of North Creek were divided into five reaches with one subsection within reach 2. The five main reaches averaged 1.8 miles in length but ranged from 0.3 to 3.7 miles. North Creek mostly flows through residential neighborhoods and parks in the headwaters upstream of Pilot Knob Road. Downstream of Pilot Knob Road down to the railroad tracks (Station 3800), North Creek flows through open wetlands dominated by reed canary grass, Canada thistle and nettles. From the railroad tracks downstream to the mouth of North Creek, the channel flows through segments with thick canopy cover and open fields filled with the invasive reed canary grass. Much of the upper watershed has mowed lawns that come to the edge of the banks causing erosion, surface runoff and sediment pollution.

1.1 North Creek, Reach 1

Reach 1 of North Creek is a partially forested sinuous channel with some relatively straight sections that extend 3,800 feet from its confluence with the Vermillion River. The channel geometry is relatively consistent and the channel is stable with little noticeable bank erosion or incision. The channel bed is primarily composed of sand and silt, though the lower portions of the reach near the Vermillion River contain gravel in the main channel with the finer grained material on the edges. The channel banks are primarily composed of dark silty loam. Vegetation varies between long segments dominated by reed canary grass with no canopy cover and segments with large cottonwoods, willows, and other riparian trees that provide thick canopy cover and excellent shade and riparian habitat (Figure C-2). In general, this reach is in relatively good condition, although one culvert is undersized and presents a partial fish passage barrier.

Figure C-2: North Creek, Reach 1 (Top) Stn 2,300 looking upstream at undersized culvert; (middle) Stn 2,700 looking upstream at wooded section; (bottom) Stn 3,250 looking upstream at section heavy with reed canary grass and lacking canopy cover.

1.2 North Creek, Reach 2 & 2A

Reach 2 descriptions of North Creek have been split into two sections. Reach 2 is 19,700ft long and flows from station 23,500 to station 3,800. Reach 2A is within Reach 2 and is 3,150ft long and flows from station 10,150 to station 7,000. This stretch was restored between 2008 and 2010; both sections can be seen from an aerial photo (Figure C-3).

Figure C-3: Aerial view of Reach 2A.

Figure C-4: North Creek, Reach 2; (top) Stn 5,375 looking upstream at the abundant reed canary grass; (middle) Stn 8,500 looking downstream from the 190^{th} bridge; (bottom) Stn 14,700 looking upstream at the cattails.

1.2a North Creek, Reach 2

Reach 2, upstream and downstream of 2A, consists primarily of a straightened channel through wide, grassy wetlands (Figure C-4). Upstream of Stn 16,500 the channel becomes slightly more sinuous, but the channel geometry is similar to the rest of the reach and the surrounding habitat is the same. The channel bed is primarily composed of fine sand and silt, though thalwegs with higher velocity contain small gravel and coarse sand.

The banks are nearly vertical and, in many locations, undercut with reed canary grass overhanging the channel. The channel banks are primarily composed of dark silty loam. The channel is in the middle of a wide (200-700 ft) wetland dominated by reed canary grass, Canada thistle, and nettle. Throughout the wetland, however, are patches of sedges, rushes and occasional willow shrubs, ash, and buckthorn. Portions of the wetland are spongy, and small channels course through in some locations.

In general, this reach has a great deal of restoration potential. The width of the wetland provides an opportunity to increase the sinuosity, build small side channels and off-channel pools, and provide recreational opportunities through the North Creek Greenway Project. Cold groundwater seeps into the wetland and channel throughout. This groundwater is apparent in the restored section where the water in the abandoned channels is 10-15°F cooler than the main, restored channel. The cooler temperatures indicate that cold groundwater is seeping into this reach but is being diluted by the warmer water from upstream. The wide wetland provides the opportunity to tap into this cold-water resource and provide habitat for all life cycles of cold-water species even when the main channel is warmer.

Between Stn 4500 and 14,500, remnants of a ~2-ft tall earthen berm were identified 200-300 ft to the east of the channel. Pools of warm water with duckweed lay on the far side of these berms, which appeared to separate the grass-dominated wetland from the riparian forest that consisted of cottonwood, willow, and ash. The riparian forest was between the wetland and farm fields. Flood debris and flow paths indicated that flooding does go through gaps in the berm and overtops some of the farm roads. If flooding of farm fields is a concern, a berm could be constructed near the edges of the farm fields to allow the channel to migrate and the wetland to be fully functional.

Figure C-5: North Creek, Reach 2A; Stn 7,700 looking downstream of new channel.

1.2b North Creek, Reach 2A

Reach 2A is the portion of Reach 2 that was restored since 2008. The restored channel planform is more sinuous and has relatively consistent channel geometry, 12-15 ft wide and 4-5 ft deep (Figure C-5). Deep scour pools were created on the outside of bends, and sandy point bars were created or have developed on the inside of bends. The channel bed in areas with more swift currents consists of some gravel substrate while the remainder of the channel bed is mixed sand and fine-grained material. Native forbs, wildflowers, and trees were planted along the banks and within 30-50 ft of the channel. Willows, many of which are now 10-12 ft tall, were one of the species planted along the length of the banks. The willows appear to be growing well, with the planted trees flourishing and beginning to provide shade. Reed canary grass and nettle appear to be taking over much of the area not containing willows.

As part of the restoration, the old channel was left largely untouched. At Stn 9000, the old channel was completely cut off and the inlet mostly filled in, and in outlet of the old channel at Stn 7000 was also mostly filled in. Between the inlet and outlet, however, the channel remains full of water, which spills into the channel downstream. The new bridge and road prism intercept cut off the old channel at ~Stn 8200-8700. This abandoned channel is partially supplied by cold-water seeps and is further shaded by a dense mat of duck weed. The water temperatures between Stn 7000 and 8200 in the abandoned channel ranged from 54-60°F, while the temperatures in the new channel between the same stations ranged from 74-84° F.

Upstream of Stn 8900, the newly restored channel has not been connected to the main channel at the upstream end, although this will likely happen once further development is completed. Currently, the main flows are through the original channel while the restored, sinuous channel provides cold-water habitat that is accessible from downstream. Water temperatures upstream of Stn 8900 are 5-10° F cooler in the restored channels that are not connected than in the main flows of the old channel.

A dirt farm road crossing at Stn 9500 constricts flow and presents a partial fish-passage barrier. It is also another location that prevents the restored channels from connecting to each other.

Figure C-6: North Creek, Reach 3; (top) Stn 28,250 looking upstream; (bottom) Stn 32,300 looking upstream at section with mowed lawn to the channel bank.

1.3 North Creek, Reach 3

Reach 3 of North Creek is 10,700ft long and extends from station 23,500 to station 34,200. This segment is a straightened ditch through residential neighborhoods and parks and acts as stormwater pipe to move water downstream through the reach as quickly as possible (Figure C-6). The channel is narrower than it would have been naturally, and the channel bed lies 6-10 ft below the surrounding land surfaces, on which the houses and parks are built. The channel width and depth vary throughout this reach from wide and shallow to narrow and slightly deeper, but the channel throughout is essentially a straightened ditch. While canopy cover exists in some areas, there is little effective riparian vegetation. Grass and shrub buffers have been provided in some locations, but these are too narrow to provide any stormwater attenuation. Elsewhere, residents and park maintenance personnel mow and maintain lawns to the channel edge. Bank erosion is often apparent in these locations. During the rainstorm on July 15, this ditch was completely flooded and the fields were flooded in some locations. While the large amount of park land is likely of great value, much of that area could be converted to provide wide floodplains and wetlands while still providing walking trails throughout.

1.4 North Creek, Reach 4

Figure C-7: North Creek, Reach 4; Stn 39,250 looking upstream at 2.5ft knickpoint.

Reach 4 of North Creek is 11,150ft from station 34,200 to station 45,350 and primarily consists of wide wetlands through which a narrow North Creek flows. North Creek was historically straightened through this reach, and the channel is actively adjusting to these changes through lateral migration and incision. Multiple 1 to 3-ft headcuts have formed through silt and clay till layers in the wetland channels resulting in steep banks and an incised channel downstream and a fairly stable channel upstream (Figure C-7). Small drainages and tributaries entering North Creek through the wetlands are incising to the new base level, and the incision can be traced upstream until the drainages blend in with the wetland surface and the channel can no longer be traced. While much of the channel contains good wetland habitat with no encroachment, incision and bank erosion is causing the downstream delivery of sediment. If the knickpoints migrate upstream to road crossings, culverts could be undermined and destabilized. With the overhanging grasses, undercut banks, and moderately deep pools and runs, this reach has decent aquatic habitat. Reach-wide restoration to eliminate the incision and utilize the functionality of the wetland could include creating a new, highly-sinuous channel that is only

1-2 ft below the wetland surface. This would increase the potential for flood waters to spread onto the wetlands and mitigate downstream flooding.

1.5 North Creek, Reach 5

Reach 5 of North Creek runs 1,550ft from station 45,350 to station 46,900. The reach has its headwater in a stormwater basin and consists of a narrow, straightened channel. It flows through residential neighborhoods. The narrow channel flows within a narrow alluvial valley with houses constructed on a terrace about 8 ft above the channel bed. Although riparian buffer is available, especially on the right side, there is little geomorphic and habitat complexity in the channel. Three 2-ft knickpoints are migrating upstream, and downstream bank erosion is resulting, particularly where adjacent landowners have removed the riparian vegetation and mowed to the channel edge (Figure C-8).

Figure C-8: North Creek, Reach 5; Stn 46,550 looking upstream at a 2ft knickpoint.

1.6 North Creek, Tributary 1

1.6a North Creek, Tributary 1, Reach 1

Reach 1 of North Creek Tributary 1 is 1,900ft long and consists of a narrow, straightened channel through a wide wetland on the left with an active farm within 50 ft of the right bank (Figure C-9). Water temperatures are warm (81° F during survey) as this channel is immediately downstream of Reach 2, which is essentially a series of in-stream stormwater basins for the adjacent developments. Because the channel was straightened into a deeper ditch, its interaction with the wetland is less frequent than it was in natural conditions. Restoration could include a more sinuous channel built just below the wetland surface, multiple side channels, and multiple channels that tap into cold groundwater would provide cold-water refugia and serve to cool down the main channels.

Figure C-9: North Creek, Tributary 1; Stn 250 looking upstream from within channel.

1.6b North Creek, Tributary 1, Reach 2

Reach 2 of North Creek Tributary 1 is 5,300ft long and consists of a series of in-stream stormwater basins built along with the residential developments that surround the current stream (Figure C-10). The river was straightened and over-widened, and multiple grade controls were built to hold back water. While stormwater retention is helpful in slowing the movement of stormwater into the river, the system of in-stream basins with little vegetation cover results in high water temperatures (exceeding 75°F and 80°F) and poor water quality. It may be more appropriate to retain a very narrow and sinuous channel through a narrow corridor bounded on both sides by elongated stormwater basins that only discharge to the river during large storm events. The majority of the stormwater basins in this area are too deep to sustain wetland vegetation and too shallow to eliminate the growth of aquatic vegetation and algae.

Figure C-10: North Creek, Tributary 2; (top) Stn 2,900 looking upstream from Dunbury Ave.

Figure C-11: North Creek, Tributary 2; Stn 2,200 looking downstream from railroad.

1.7 North Creek, Tributary 2

Where defined, North Creek Tributary 2 is a shallow swale through agriculture fields. In other areas, Tributary 2 is an undefined channel (Figure C-11). We could not find the outlet to North Creek. This swale drains ground water seeps and stormwater over fields. Water temperatures at the railroad bridge were below 60°F. No aquatic habitat or riparian habitat exists.

1.8 North Creek, Tributary 3

North Creek Tributary 3 is a wide wetland between agricultural fields and residential developments. There is no distinct channel through most of the tributary. The wetland contained about 1 ft of water through the entire width of the wetland during this assessment. Wetland vegetation included thick stands of cattails and, in some places, reed canary grass (Figure C-12). Also, large willow and cottonwood trees provided canopy cover in some areas. The thick wetland vegetation and diffuse nature of the water produced a wetland with copious aquatic and wetland habitat. In addition, seeps dispersing cold water into the channel cooled water temperatures in some locations.

1.9 North Creek, Tributary 4

North Creek Tributary 4 is a 4500 ft long stormwater drainage ditch from a stormwater basin through residential neighborhoods to North Creek (Figure C-13). It holds water during high flows that cause the basin to spill through its overflow pipe and into this ditch. This channel provides no aquatic or riparian habitat but is doing a good job of conveying stormwater between houses.

1.10 North Creek, Tributary 5

North Creek Tributary 5 is a small tributary flowing 5700 ft from its headwaters in residential neighborhoods to North Creek at Stn 37,000. While the entire tributary flows through wetlands, the wetland is somewhat confined by hillslopes and residential development upstream of Stn 1700 (Figure C-14). Downstream of Stn 1700, the wetland is unconfined, and the channel is undefined as it flows toward North Creek. This large wetland primarily consists of reed canary grass. As development is well removed from the channel and riparian corridor, the habitat within the riparian corridor is relatively good. Canopy cover provides shade and protection as does thick wetland vegetation. A few small knickpoints suggests incision is occurring, and these knickpoints also present fish passage barriers.

Figure C-12: North Creek, Tributary 3; (top) Stn 700 looking upstream in the wetland.

Figure C-13: North Creek, Tributary 4; (top) Stn 600 looking downstream.

Figure C-14: North Creek, Tributary 5; (top) Stn 3,900 looking downstream.

2.0 Middle Creek

The 9.5 miles of Middle Creek were divided into three reaches. The three reaches averaged 3.2 miles in length, but ranged from 1.9 to 5.7 miles. Middle Creek flows through a variety of landscapes that include thick wooded areas in the most downstream portions of the watershed. Reach 2 flows through straightened farm ditches, which are being degraded from overgrazing, then into a large wetland, which contains an abundance of flora. The upper most part of the watershed flows through farm fields and has experienced channel incision. There are nine main tributaries that flow into Middle Creek. In general, the landuse in the subwatershed is mostly agriculture with some residential houses.

2.1 Middle Creek, Reach 1

Reach 1 of Middle Creek extends 10,000 ft through wetlands to join North Creek at Stn 1700. Middle Creek in this reach is very sinuous and is actively migrating within a fairly wide wetland corridor (Figure C-15). The wetlands are dominated by reed canary grass, but in many places woody vegetation provides canopy cover. While residences are encroaching on the channel in the lower portions of this reach, there are generally wide buffers between houses or farm fields and the channel. The channel has not been straightened through much of the reach. Middle Creek, Reach 1 retains its sinuous planform and has been allowed to erode its banks and build point bars, displaying many geomorphic functions often lost in many of the over-managed streams. Because of this geomorphic complexity, habitat complexity and habitat potential is good.

Figure C-15: Middle Creek, Reach 1; (top) Stn 50 looking upstream; (bottom) Stn 7,150 looking upstream from Akin Road.

2.2 Middle Creek, Reach 2

Reach 2 of Middle Creek extends 9,850 ft through wetlands and active livestock grazing land from station 10,000 to 19,850 (Figure C-16). Middle Creek has been straightened and widened through much of this reach. In some locations, the channel was undefined as it became diffused in the wide wetland that is covered in cattails and other grasses. Much of this reach provides excellent wetland habitat that is well shaded and protected by the wetland grasses and occasional woody tree species. Where the channel is wide, willows along the banks overhang about 25% of the channel and provide some canopy cover. Livestock are actively grazed between Stn 16,700 and 19,800 and are able to walk through the channel. The channel banks in this portion of the reach have been eroded by trampling, which has likely resulted in a decrease in water quality.

Figure C-16: Middle Creek, Reach 2; (top) Stn 13,100 looking upstream at wetland from Pilot Knob Road; (bottom) Stn 19,850 looking downstream showing active grazing.

2.3 Middle Creek, Reach 3

Reach 3 of Middle Creek extends 30,500 ft from the headwaters to the downstream extent of a recent stream restoration effort. The channel through the entire reach was straightened historically and has undergone varying degrees of incision (3-4 ft at the downstream extent and less upstream). The channel primarily flows through agricultural fields with no, or little, riparian buffer (Figure C-17). The lack of geomorphic complexity results in a lack of habitat, and the lack of riparian buffer decreases the canopy cover and shading. Much of the upper sections of this reach may not have been a defined channel historically but rather a swale through the rolling hills. The historic swales in this reach were straightened and deepened as the land was cleared for agriculture and tilling, and residential development. These changes increased water volume in the channel. Today, flood flows spread out over the fields and transport fine-grained sediment into the stream increasing turbidity and decreasing water quality. Knickpoints have often been halted at road crossings with deeper channels downstream than upstream. While road crossings do provide good grade control, they should be monitored to ensure there are no effects on the infrastructure.

Figure C-17: Middle Creek, Reach 3; Stn 46,550 looking upstream from farm crossing.

2.4. Middle Creek, Tributary 1

2.4a Middle Creek, Tributary 1, Reach 1

Reach 1 of Middle Creek Tributary 1 extends 5700 ft from the outlet of a series of stormwater basins through agriculture fields to Middle Creek at Stn 2550. The channel was straightened historically into an over-deepened ditch. Though row crops are active on either side, a well-vegetated buffer of 25-40 ft bounds each side of the channel for much of this reach. In addition, earthen berms in some locations separate the fields from the channel and prevent runoff from flowing directly into the channel. Many additional farm ditches enter this tributary throughout reach 1. While the canopy cover and riparian vegetation generally provide good shelter and shade, good aquatic habitat was scarce due to the uniformity of the channel bed and lack of woody habitat. The water temperatures were relatively low, however, suggesting that this tributary could provide an opportunity for cold-water habitat for small fish and other aquatic organisms. The VRWJPO has classified this channel as a trout stream. Two passage barriers near the mouth of the channel would need to be modified to improve the habitat potential (Figure C-18).

Figure C-18: Middle Creek, Tributary 1; Stn 600 looking upstream at culverts.

2.4b Middle Creek, Tributary 1, Reach 2

Reach 2 of Middle Creek Tributary 1 consists of multiple stormwater basins within residential developments. The outlet is a vertical pipe with a trash grate, which is high enough to capture the water from most storm events and minimize the amount of water released downstream.

We do not recommend any restoration projects for this reach.

2.5 Middle Creek, Tributary 2

Middle Creek Tributary 2 extends 3100 ft from Easter Ave to Middle Creek at Stn 7550. This is a small tributary that is a straightened ditch through wetland and agriculture fields

Figure C-19: Middle Creek, Tributary 2; Stn 175 looking upstream from farm crossing.

(Figure C-19). While water temperatures are warm and overhanging grasses provide some cover, there is little substrate variability, canopy cover, in-stream habitat features, or variability in channel geometry or planform. Upstream of Stn 800, there may be an opportunity to restore the channel through the open fields and wetlands between the agriculture fields and the commercial complexes. Restoration could entail increasing the sinuosity, creating multiple side channels to tap into the groundwater seeps, installing large woody habitat features, creating backwater habitat and riffles and pools, and providing canopy cover.

2.6 Middle Creek, Tributary 3

Middle Creek Tributary 3 extends 2800 ft from a large wetland to Middle Creek at Stn 10,850. Between the large wetland upstream and the large wetland at the confluence with Middle Creek, a wide wetland channel was constructed between residential developments. The channel is filled with wetland vegetation, primarily cattails, and is separated from stormwater basins by earthen berms. While fish passage to the large wetland upstream may be difficult due to low water depths, the remainder of the reach provides excellent wetland habitat.

We do not recommend any restoration projects for this tributary.

2.7 Middle Creek, Tributary 4

A detailed field investigation was not completed for Middle Creek Tributary 4, which extends 5900 ft from a farm field near the junction of Lakeville Blvd and Pilot Knob Rd to Middle Creek at Stn 11,500. The channel through the entire reach has been straightened and ditched. Downstream of Stn 2500, the channel joins a wide wetland with Middle Creek, and it is difficult to find a defined channel in places. The Pilot Knob Rd prism blocks complete floodplain/wetland access and all flows appear to be forced to Middle Creek and under the four box culverts (Figure C-20). This wetland, although containing straightened channels, provides good wetland habitat with many grasses, sedges, cattails, willows, and plenty of cover for in-stream species. Upstream of Stn 2500, the channel is between farm fields but a 20-50-ft buffer on either side has been maintained. Between Stn 2500 and 4000, this buffer is mixed grasses and trees, and upstream of

Figure C-20: Middle Creek, Tributary 4; Stn 1750 looking upstream from Pilot Knob Rd.

Stn 4000, the buffer is primarily grasses. Upstream of Stn 4000, however, the channel is likely a shallow swale in the ground and does not contain water year round.

We do not recommend any restoration projects for this tributary.

2.8 Middle Creek, Tributary 5

Figure C-21: Middle Creek, Tributary 5; Stn 4425 looking downstream from on top of Flagstaff Rd.

Middle Creek Tributary 5 extends 5500 ft from a new stormwater basin near a new school to Middle Creek at Stn 16,100. The new stormwater basin prevents excessive stormwater from entering the stream channel. Downstream from Flagstaff Ave, Tributary 5 is primarily an undefined channel through a wide, well-vegetated wetland (Figure C-21). The channel becomes defined from the farm buildings at station 3500 to Flagstaff Ave at Stn 4400. In general, this tributary provides good wetland habitat and riparian habitat with a wide buffer from crops.

We do not recommend any restoration projects for this tributary.

2.9 Middle Creek, Tributary 6

Figure C-22: Middle Creek, Tributary 6; (top) Stn 1350 looking upstream at broken weir; (bottom) Stn 2425 looking upstream at knickpoint.

Middle Creek Tributary 6 extends 6800 ft from fields near the junction of Cedar Ave and 200th St W to Middle Creek at Stn 21,000. Tributary 6 is a channelized ditch through agricultural fields. While there is little quality habitat, year-round flows are low and may not sustain many aquatic species anyway. We did not observe ground water seeps were observed to be flowing overland into the stream, however, so some year-round flow is likely, and these seeps are able to provide cold water to the stream. Multiple knickpoints were observed upstream of the concrete dam at Stn 1400 (Figure C-22). These knickpoints were active but slowed at tree roots. The dam prevents further knickpoint migration but also prevents any fish passage. Unrestricted cattle grazing upstream of Stn 1400 results in some bank erosion and decreased water quality, but the bank erosion is not severe. Upstream of Stn 2800, little canopy and riparian buffer protect the stream from the row crops on either side. Historically, these streams were likely swales in the hillslopes that drained rainwater after storms.

2.10 Middle Creek, Tributary 7

2.10a Middle Creek, Tributary 7, Reach 1

Reach 1 of Middle Creek Tributary 7 extends 1550 ft from Flagstaff Ave to Middle Creek at Stn 22,650. This portion of Tributary 7 is a channelized ditch through agricultural fields (Figure C-23). While overhanging grasses and some undercut banks provide some in-stream cover and habitat, there is little geomorphic or habitat complexity. The channel dimensions are fairly consistent throughout with little change in bed substrate or channel type. This reach is primarily made up of runs/glides with few or no deep pools or riffles. There is no canopy cover, no woody habitat and few areas for fish and other aquatic organisms to find refuge during flood flows. The flood on July 15 resulted in water spreading out onto the fields in the lower half of this reach.

Figure C-23: Middle Creek, Tributary 7, Stn 1550 looking downstream.

2.10b Middle Creek, Tributary 7, Reach 2

Reach 2 of Middle Creek Tributary 7 extends 6200 ft from a 190th St W to Flagstaff Ave. This portion of Tributary 7 is relatively sinuous with variable channel dimensions throughout. While the channel is incised about 3 ft at the downstream end of the reach, the channel becomes less incised moving upstream until there is essentially no incision near the 190th St W crossing (Figure C-24). In this upstream area, the channel winds through a wide wetland valley with excellent buffer width from farms. Although the adjacent ground surface is 3-8 ft above the bed of the channel, this surface remains wet from ground water seeps. The habitat is decent through this section with a large percentage of canopy cover coming from overhanging grasses and some undercut banks. There are a few canopy species but more would improve canopy cover and large woody habitat recruitment. A few trees in the downstream end have fallen and their root balls

Figure C-24: Middle Creek, Tributary 7, Stn 7550 looking downstream at incision.

provide excellent shading and pool habitat. Upstream of 190th St W a good, grassy buffer also occurs, but the channel goes through an area of open grazing, which results in increased bank erosion and lower water quality. The channel through this area is a very shallow channel in the bottom of a wide valley so the bank erosion is not as dramatic. Upstream of Stn 6600, the channel is incised through forest. This portion of the river has good canopy cover and some good, variable instream habitat, but it is incised through fine silt and clay till, and the clay banks are eroding.

2.10c Middle Creek, Tributary 7, Reach 3

Reach 3 of Middle Creek Tributary 7 extends from close to Highview Ave to 190th St W. This portion of Tributary 7 is primarily a straightened ditch or swale in the valley bottom between fields. Much of the reach has cover from willow trees and good riparian buffer of grasses. Because the valley bottom is so flat and the farming continues into the valley bottom, however, the channel location in some places around Stn 11,000 has moved from within the vegetated wetland buffer to within the crop rows (Figure C-25). This alternative channel location is resulting in a slightly incised channel through the rows of corn. With re-grading, the channel could be encouraged to flow through the wetland again. The headwaters consist of multiple dams and small private ponds segmenting the channel.

Figure C-25: Middle Creek, Tributary 7; Stn 11,400 looking upstream at channel formed in corn field.

2.11 Middle Creek, Tributary 7A

2.11a Middle Creek, Tributary 7A, Reach 1

Reach 1 of Middle Creek Tributary 7A extends from Cedar Ave to Tributary 7 at Stn 1800. This portion of Tributary 7A was historically straightened and likely deepened to create the existing ditch (Figure C-26). The channel adjusted to its geometry over time to create a narrow channel between narrow floodplains within the walls of the ditch. Incision is continuing, however, resulting in excessive

Figure C-26: Middle Creek, Tributary 7A; Stn 5,300 looking downstream.

bank erosion and suspended sediment. Downstream of Stn 2100, trees provide canopy cover and some woody habitat within an approximately 50-ft riparian corridor. In this section, grasses provide an additional 50-100 ft of buffer between the riparian corridor and the farm fields. The opportunity exists in the lower portion of the reach to restore the channel with increased sinuosity, wider floodplains, and some grade control. Upstream of Stn 2100, the buffer width narrows, and the riparian vegetation is primarily grasses. The channel through this section is very narrow and entrenched within the straightened ditch with thick grass growth on the banks and slopes of the ditch. Between Stn 5750 and Cedar Ave, incision and bank erosion has resulted in 7-ft exposed clay banks and incision in small drainages entering the channel. The water is cool coming through the culvert as it is essentially ground water from tiling. This cool water (60° F) does present the opportunity to improve cool-water habitat in this reach.

2.11b Middle Creek, Tributary 7A, Reach 2

Reach 2 of Middle Creek Tributary 7A extends from farm fields to Cedar Ave. This portion of Tributary 7A is primarily a shallow swale between fields with no defined channel. There is little buffer, except for some grasses. This area presents a good opportunity to build a detention or retention basin as the surrounding hills and road prism provide good boundary conditions. This could slow the flow of water downstream that has been contributing to the incision and erosion in the rest of Tributary 7A and Tributary 7.

2.12 Middle Creek, Tributary 7B

Middle Creek Tributary 7B extends from agriculture fields to Stn 6100 of Tributary 7. Downstream of Cedar Ave, the channel is fairly intact with low floodplains and copious canopy cover and woody habitat (Figure C-27). Upstream of Cedar Ave, there is no discernable channel. Cold water emanates from under the field and through the culvert under Cedar Ave. This cold water provides an opportunity for good cold-water habitat. A 3.5-ft knickpoint suggests that incision remains an active force and will continue upstream leading to increased sediment loads downstream.

Figure C-27: Middle Creek, Tributary 7B; Stn 1,100 looking downstream.

2.13 Middle Creek, Tributary 8

Middle Creek Tributary 8 extends 6100 ft from stormwater basins north of Dodd Blvd through agriculture fields to Middle Creek Stn 38,100. This tributary is primarily an undefined channel or shallow swale between fields with no aquatic or riparian habitat. Downstream of Cedar Ave, between Stn 0 and 550, a small defined channel does exist providing a minor amount of habitat connected to Middle Creek. Middle Creek at this location is intermittent and provides minimal habitat itself.

We do not recommend any restoration projects for this tributary.

2.14 Middle Creek, Tributary 9

2.14a Middle Creek, Tributary 9, Reach 1

Reach 1 of Middle Creek Tributary 9 extends 2550 ft from Highview Ave to Middle Creek Stn 41,500. This tributary is primarily a deeply incised and actively widening channel within dense riparian forest (Figure C-28). The channel has incised about 4 ft. We observed the historic channel, likely a shallow channel with 1-ft banks, adjacent and perched 4 ft above the current channel. With the excessive erosion, gravel and cobbles have eroded out of the clay banks and are now creating gravel bars and riffles in the channel. This infusion of coarser-grained material increases the geomorphic and habitat complexity. Also due to the erosion, fallen trees provide woody habitat potential. With the wider riparian corridor and thick canopy cover, this reach could present an opportunity for restoration that raises the channel bed, creates and widens floodplains, provides grade control, and increases sinuosity.

Figure C-28: Middle Creek, Tributary 9; Stn 2450 looking upstream at incision.

2.14a Middle Creek, Tributary 9, Reach 2

Reach 2 of Middle Creek Tributary 9 extends through the corn field at Dodd Blvd to Highview Ave. This reach alternates between undefined swales through fields and channels undergoing active incision with defined channels and banks. The riparian buffer between the fields is fairly wide, and a portion of this reach is within a forested area with excellent habitat (Figure C-29). The active incision could threaten to cause instability in currently stable portions of this reach and could eventually impact farm fields. With the wide buffer and cold water from groundwater sources, this reach provides an opportunity for channel restoration with grade control, increasing channel sinuosity, and increasing channel and habitat complexity.

Figure C-29: Middle Creek, Tributary 9; Stn 5,700 looking upstream at active incision.

APPENDIX D: Channel reconnaissance forms

Channel Reconnaissance Form

Date	July 11, 2011
Stream/Drainage	North Creek
Stream Reach ID	Reach 1
Field Team	NN, DB

Station 0 **To** 3800

General Channel Conditions

Channel Shape (check)

☒Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	Sand
Bed	Sand and fines over fine gravel

Bar Types: ☐Alternate ☒Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Generally stable; lower portion below Chippendale Ave is likely influenced by the Vermillion River backwater; elsewhere, floodplains are generally low and still active				
Lateral stability *deposition, erosion*	Stable - typical erosion on the outside of bends and deposition on the inside of bends is occurring, but no excessive movement. This is a low-gradient reach does not migrate frequently				
Erosion (excessive/site specific)					
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks are nearly vertical in most locations and composed of fine-grained material, primarily silt and fine sandy loam. Bank material is dark and supports, alternately, dense reed canary grass and riparian forest				
Terrace/Valley	*Valley form* – wide and flat	*Land Use* – Mostly agriculture with some residential			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 1600: 2, 12x12-ft reinforced concrete box culverts under Chippendale Ave - middle pier slightly damaged by floods with some rebar showing, but generally in good condition; partially buried with 2-3 ft of silty material on the bottom Stn 1775: 2, 8x6.5-ft reinforced concrete box culverts; buried by 1.5 ft of riprap and natural substrate; water velocity is high as the slope is steep, but passage is likely ok due to the roughness providing shelter and low flow access always being available; good condition Stn 1825: wooden footbridge about 4 ft above channel bed; good condition Stn 2000: metal footbridge - broken and mangled in the channel; no longer usable and should be removed Stn 2325: 4.5-ft corrugated metal pipe under dirt road; concrete around pipe is separating from the banks due to scour and shear stresses during flooding; pipe is severely undersized and is perched about 1 ft on the downstream end; fish passage is poor and the road is likely flooded regularly Stn 3800: wooden railroad bridge; low chord is 4-6 ft above the channel bed; riprap channel bed; velocity is high and bed is steep, but ok for fish passage even at low flow; good condition				
Bankfull/Channel forming flow indication	Some undercut banks and tree roots on top of the banks				

Sediment Impacts

Riffle sediment type	Riprap under bridges	Pool sediment type	Fine sand and silt
Sorting / Imbrication	Sands accumulate on bars, fines accumulate in deep pools		

Bars / depositional features

Sediment type/size	Sand
Mid, alternate, braided	Small point bars
Bar Vegetation (type, age)	None
Floodplain soils	Silty loam
Overbank deposition	Fine sands and silts

Riparian Vegetation and Floodplain

Root coverage of banks (%)	75-100%
Width of veg. riparian corridor*	75-200 ft
Canopy coverage (%)	0-75%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	Reed canary grass
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	50
woody species	50
bare/other	
Exotic/invasive species	Reed canary grass, buckthorn

Woody Species present	% of total tree community
Box elder	70
Cottonwood	10
Willow	10
Silver Maple, Ash	10

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*
3100	cottonwood	~100 yrs	~6 inches above water surface on original floodplain; >3 ft DBH

Habitat

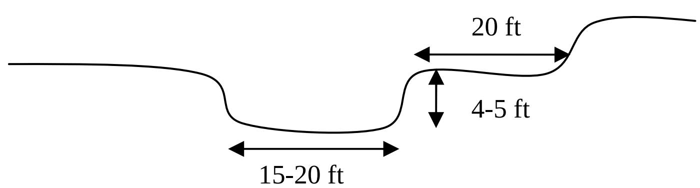
LWD density (pieces / 100 ft)	NA	General Habitat Notes: Deep pools and frequent undercut banks for shelter; for portions dominated by reed canary grass there is no canopy cover; low gradient reach with no true riffles - mostly long runs and pools; low substrate variability, but some gravels in the middle of the channel; reach is broken up by densely vegetated sections providing sufficient shade and cover.
Residual pool depth	1-3 ft	
Undercut bank frequency	High	
Riffle / Other frequency	Low	

Channel Stability Form

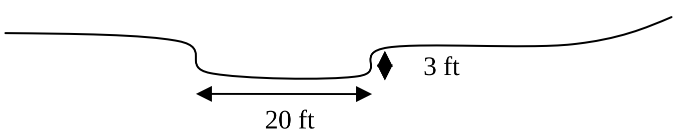
Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed	2	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 22/9 = 2.4**				

Representative cross-section sketch		
Bankfull width = 20/25 ft Bankfull depth = 4/3 ft	Floodplain width = 20-50/100 ft	Water depth (at survey) = 2-3 ft Water width (at survey) = 20-25 ft

Station: 1100



Station: 2800



GENERAL REACH NOTES

The channel in Reach 1 is moderately sinuous in some sections and relatively straight in others. The channel geometry is relatively consistent and the channel is stable with little noticeable bank erosion or incision. The channel bed is primarily composed of sand and silt, though the lower portions of the reach near the Vermillion River contains gravel in the main channel with the finer grained material on the edges. The channel banks are primarily composed of dark silty loam. Vegetation varies between long segments dominated by reed canary grass with no canopy cover and segments with large cottonwoods, willows, and other riparian trees that provide thick canopy cover and excellent shade and riparian habitat. In general, this reach is in relatively good condition although one culvert is undersized and presents a partial fish passage barrier.

POTENTIAL PROJECTS

Stn 1075-1200: mowed lawn to edge of right bank; plant riparian buffer

Stn 1300-1550: mowed to edge of left bank; some erosion and no root stability; cobbles have placed on the banks at Stn 1550 to slow the erosion, but this is only a temporary surficial fix; plant riparian buffer

Stn 2000: remove broken metal footbridge which is restricting flow and causing debris to pile up on the upstream side

Stn 2325: 4.5-ft corrugated metal pipe is undersized and perched 1 ft; concrete around pipe is separating from the banks due to scour and water pressure during flooding; presents a partial fish passage barrier and is resulting in a deep scour pool and bank erosion on the downstream end; dirt road is likely overtopped during flooding; if road is still needed, replace with larger culvert or, if used infrequently, remove and build a gravel/cobble ford

Stn 2500-2600: actually about 200ft of the left bank - mowed nearly to edge (has a 5ft reed canary grass buffer); minimal canopy cover provided by a few large trees; little bank protection; excessive erosion is not evident

Channel Reconnaissance Form

Date	July 11-12, 2011
Stream/Drainage	North Creek
Stream Reach ID	Reach 2
Field Team	NN, DB

Station 3800 **To** 23,500

General Channel Conditions

Channel Shape (check)
☒Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	None (except below undersized culverts - bars of sand)
Bed	Mostly fine sand and silt; small gravel and sand in faster areas

Bar Types: ☐Alternate ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Generally stable; this is a straightened ditch with no recent or ongoing incision apparent; road crossings at Stn 5350, 9500, and 22,000, former road detritus at Stn 14,350 and 16,500, the beaver dam at Stn 18,150, and the metal dam at Stn 20,100 all provide grade control (as well as fish passage problems).				
Lateral stability *deposition, erosion*	Stable - straightened ditch with little opportunity to migrate				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☐Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks are nearly vertical in most locations and composed of dark, fine-grained material, primarily silt and fine sandy loam.				
Terrace/Valley	*Valley form* – wide and flat	*Land Use* – Mostly agriculture adjacent to stream, but some residential developments have recently been built relatively close to the channel - stormwater basins have been built between developments and river.			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 3800: wooden railroad bridge (see Reach 1 description for details) Stn 5350: 3.5-ft corrugated metal pipe under farm road - undersized and very steep with >5-ft scour hole on downstream end; riprap on edges of culvert Stn 8400: 195th St bridge - 6 tall arch piers; new and does not impact channel or floodplain Stn 9500: 3, 3-ft corrugated metal pipes; some erosion of concrete and gullying around farm road Stn 14,350: 4, 18-inch metal pipes - failed culverts for abandoned farm road Stn 15,000: sanitary sewer manhole in channel Stn 16,500: abandoned bridge and earthen berm - 2 concrete abuttments and metal I-beams remain in channel Stn 20,100: 3.5-ft tall metal dam Stn 22,100-22,300: 3, 10x6-ft concrete box culverts under Pilot Knob Rd;				

Bankfull/Channel forming flow indication	Bankfull - edge of wetland surface and top of vertical bank; channel forming flow likely identified by undercut banks

Sediment Impacts

Riffle sediment type	Gravel	Pool sediment type	Fine sand and silt
Sorting / Imbrication	Gravel and sands found in faster thalwegs; fines accumulate on edges of channel and in deeper pools		

Bars / depositional features

Sediment type/size	Sand
Mid, alternate, braided	From recirculation eddies downstream of steep culverts
Bar Vegetation (type, age)	None
Floodplain soils	Silty loam
Overbank deposition	Fine sands and silts

Riparian Vegetation and Floodplain

Root coverage of banks (%)	90-100%
Width of veg. riparian corridor*	300-800 ft
Canopy coverage (%)	<5%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	Reed canary grass
low = single canopy layer	
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	98%
woody species	2%
bare/other	
Exotic/invasive species	Reed canary grass, Canada thistle, nettle (may be native variety, buckthorn

Woody Species present	% of total tree community
Ash	50
Willow	20
Buckthorn	20
Elm	10

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	A few where there is forest cover	General Habitat Notes: Little habitat complexity and little geomorphic complexity. Channels are straight with mostly sandy/silty beds, though the thalwegs in the swifter water may contain small gravel. Overhanging grasses and undercut banks provide some shade and cover near the edges of the channel.
Residual pool depth	2-4 ft	
Undercut bank frequency	High	
Riffle / Other frequency	Low	

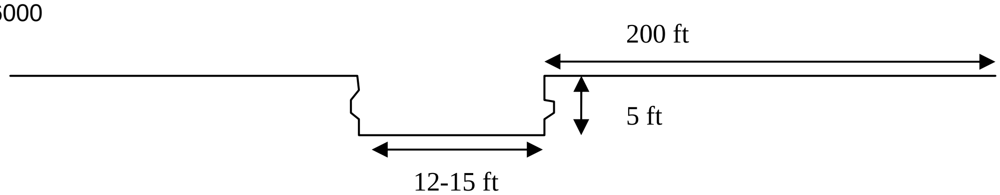
Channel Stability Form

Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 20/8 = 2.5**				

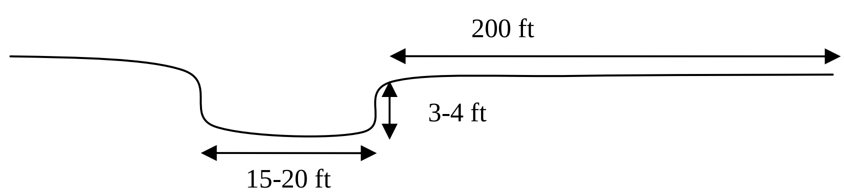
Representative cross-section sketch

Bankfull width = 15/20 ft Bankfull depth = 5/4 ft	Floodplain width = >200 ft	Water depth (at survey) = 3-4 ft Water width (at survey) = 15/20 ft

Station: 6000



Station: 16,000



GENERAL REACH NOTES

Reach 2 consists primarily of a straightened channel through wide, grassy wetlands. Upstream of Stn 16,500 the channel becomes slightly more sinuous, but the channel geometry is similar to elsewhere and the surrounding habitat is the same. The channel bed is primarily composed of fine sand and silt, though thalwegs with higher velocity to contain small gravel and coarse sand. The banks are nearly vertical and in many locations undercut with reed canary grass overhanging the channel. The channel banks are primarily composed of dark silty loam. The channel is in the middle of a wide (200-700 ft) wetland dominated by reed canary grass, Canada thistle, and nettle. Throughout the wetland, however, are patches of sedges and rushes and occasional willow shrubs, ash, and buckthorn. Portions of the wetland are spongy and small channels course through in some locations. In general, this reach provides a great deal of restoration potential. Reach 2A, between Stn 7000 and 10,150, is a recently restored section with portions that are still waiting to be completed. The width of this wetland provides an opportunity to increase the sinuosity, build small side channels and off-channel pools, and provide recreational opportunities through the Greenway Project. Cold groundwater seeps into the wetland and channel throughout. This is apparent in the restored section where the water in the abandoned channels was 10-15°F cooler than the main, restored channel. This indicates that cold groundwater is seeping into this reach, but is being diluted by the warmer water from upstream. The width of this wetland provides the opportunity to tap into this cold-water resource and provide habitat for all life cycles of cold-water species even when the main channel is warmer. Between Stn 4500 and 14,500, remnants of a ~2-ft tall earthen berm were identified 200-300 ft to the east of the channel. Pools of warm water with duckweed lay on the far side of these berms, which appeared to separate the grass-dominated wetland from the riparian forest that consisted of cottonwood, willow, and ash. The riparian forest was between the wetland and farm fields. Flood debris and flow paths indicated that flooding does go through gaps in the berm and overtops some of the farm roads. If flooding of farm fields is a concern, a berm could be constructed near the edges of the farm fields to allow the channel to migrate and wetland to be fully functional.

POTENTIAL PROJECTS

Stn 3800-7000, 10,150-16,500: channel is a straightened ditch - restore natural sinuosity, riparian vegetation, and wetland functionality.

Stn 5850: 3.5-ft corrugated metal pipe under dirt farm road is about 2 ft higher on upstream end and is undersized. Water velocity is very high through the pipe and is likely a complete fish passage barrier during most flows. A deep (5 ft) scour hole has been created on the downstream end with associated recirculation eddies and sand bars. If still necessary, replace with bottomless arch or partially buried box culvert.

Stn 14,400: 4, 18-inch metal pipes lie in channel - these had previously been culverts under a dirt farm road, but they have failed and the channel has moved around them. The road appears to be abandoned and these pipes and associated debris should be removed. This debris pile has created a steep, fast channel downstream. Channel should be restored to ensure fish passage.

Stn 16,500: 2 concrete abuttments and I-beams associated with an abandoned bridge remain in the channel. They are not creating a constriction or any other problems, though the earthen berm from the former bridge is cutting off floodplain and wetland connectivity. Remove structures and remove earthen berm.

Stn 20,100: 3.5-ft tall, 1-ft wide metal dam spans the channel creating a long impoundment that is about 40-50 ft wide and 3-5 ft deep. This dam creates a complete fish passage barrier. The purpose of the dam is unknown, but if unnecessary it could be removed and the channel restored.

Stn 22,200: 3, 10x6-ft concrete box culverts under Pilot Knob Rd - new culverts in good condition, but they appear to be placed high. Riprap on the upstream end creates a deep pool and small impoundment. On the downstream end, riprap prevents perching, but the gradient over the riprap is very steep and could present fish passage challenges. No natural habitat or low-flow channel has been provided within the culverts. During low flows, flow depth may not be great enough to provide fish passage. During high flows, velocity may be too high for passage. Installing cobbles, boulders and other natural-like substrate could provide better fish-passage opportunities.

Channel Reconnaissance Form

Date	July 11-12, 2011
Stream/Drainage	North Creek
Stream Reach ID	Reach 2A
Field Team	NN, DB

Station 7000 **To** 10,150

General Channel Conditions

Channel Shape (check)

☒Rectangular
☐Shallow Rectangular
☒Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	Sand (all submerged)
Bed	Mostly fine sand and silt with occasional placed gravel

Bar Types: ☐Alternate ☒Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: this is a recently restored reach with no evidence of vertical instability since restoration.				
Lateral stability *deposition, erosion*	Stable: fabric is still visible on banks, which do not show excessive erosion. Vegetation is maturing.				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks are steep and are composed of dark, silty loam enclosed in stabilizing fabric from the restoration efforts. Willow plugs and other plantings were completed to stability banks.				
Terrace/Valley	*Valley form* – wide and flat	*Land Use* – Mostly agriculture, though a new bridge was built in the last few years to access new developments nearby.			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Entire subreach has been recently restored from a straightened ditch to a channel with a more sinuous planform. The upper section of the newly built channel still needs to be reconnected to the restored section downstream. Stn 8400: 195th St bridge - 6 tall arch piers; new and does not impact channel or floodplain Stn 9500: 3, 3-ft corrugated metal pipes; some erosion of concrete and gullying around farm road				
Bankfull/Channel forming flow indication	Bankfull - edge of wetland surface and top of restored bank; has not had the opportunity to develop channel-forming indications.				

Sediment Impacts

Riffle sediment type	Gravel	Pool sediment type	Fine sand and silt
Sorting / Imbrication	Sorting has not fully developed		

Bars / depositional features

Sediment type/size	Sand
Mid, alternate, braided	Point bars on the inside of the restored bends.
Bar Vegetation (type, age)	All bars were submerged during survey and contained no vegetation.
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	90-100%
Width of veg. riparian corridor*	300-400 ft
Canopy coverage (%)	<5% (has not fully matured)

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	x
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	75%
woody species	25%
bare/other	
Exotic/invasive species	Reed canary grass, Canada thistle, nettle (may be native variety

Woody Species present	% of total tree community
Willow	85
Ash	5
Silver maple	5
Cottonwood	5

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*
	Willow	~3	Recent planting from restoration

Habitat

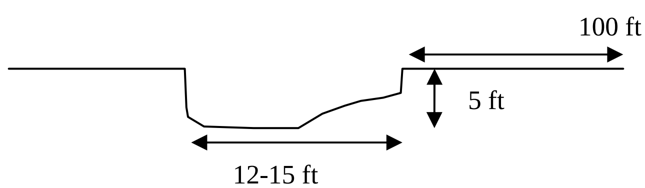
LWD density (pieces / 100 ft)	NA	General Habitat Notes: Restored sinuous planform provides deep pools on outer bends and shallow areas on the inside of bends; although still young, the planted vegetation will mature and the willows will provide good shading and canopy cover. The abandoned side channel in the downstream half, and the disconnected restored channel in the upstream half have excellent cold-water habitat as they collect cold groundwater and provide cover with duckweed, other aquatic vegetation, and bank vegetation.
Residual pool depth	2-4 ft	
Undercut bank frequency	Mod	
Riffle / Other frequency	Low	

Channel Stability Form

Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr	3	>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	3	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9		**= 26/9 = 2.9**				

Representative cross-section sketch		
Bankfull width = 15 ft Bankfull depth = 5 ft	Floodplain width = >100 ft	Water depth (at survey) = 3-4 ft Water width (at survey) = 12 ft

Station: 7500



Station:

GENERAL REACH NOTES

Reach 2A is the portion of Reach 2 that was restored since 2008. The restored channel planform is more sinuous and has a relatively consistent channel geometry of 12-15 ft wide and 4-5 ft deep. Deep scour pools were created on the outside of bends and sandy point bars were created or have developed on the inside of bends. The channel bed in the more swift currents consists of some gravel substrate while the remainder of the channel bed is mixed sand and fine-grained material. Native forbs, wildflowers, and trees were planted along the banks and within 30-50 ft of the channel. Willows were planted throughout and willow plugs were incorporated into the channel bank treatment. The willows appear to be growing well, with the planted trees flourishing and beginning to provide shade. Reed canarygrass and nettle appear to be taking over much of the area not containing willows.

As part of the restoration, the old channel was left largely untouched. At Stn 9000, the old channel was completely cut off and the inlet mostly filled in. The new bridge and road prism intercept and cut off the old channel at ~Stn 8200-8700. While the outlet of the old channel at Stn 7000 was mostly filled in, the old channel remains full of water and this water spills into the channel downstream. These abandoned channels are partially supplied by cold-water seeps and are further shaded by dense matting of duck weed. The water temperatures between Stn 7000 and 8200 in the abandoned channel ranged from 54-60°F, while the temperatures in the new channel between the same stations ranged from 74-74° F.

Upstream of Stn 8900, the newly restored channel has not been connected to the main channel at the upstream end, although this will likely happen once further development is completed. Currently, the main flows are through the original channel while the restore, sinuous channel provides cold-water habitat that is accessible from downstream. Water temperatures upstream of Stn 8900 are 5-10° F cooler in the restored channels that are not connected than in the main flows of the old channel.

A dirt farm road crossing at Stn 9500 is a constriction on flows and presents a partial fish-passage barrier. It is also another location that prevents the restored channels from connecting to each other.

POTENTIAL PROJECTS

Stn 9500: 3, 3-ft corrugated metal pipes under a dirt farm road are undersized; some erosion of the concrete on the downstream end is visible and gullying is occurring over the road due to flooding conditions. The left pipe is lower and most of the water flows through this pipe - this provides some low-water fish passage as well. High flow passage would be difficult, however, due to high flow velocities. Replace with larger culvert, or remove.

Channel Reconnaissance Form

Date	July 11-12, 2011
Stream/Drainage	North Creek
Stream Reach ID	Reach 3
Field Team	NN, DB

Station	23,500	**To**	34,200

General Channel Conditions

Channel Shape (check)

☐Rectangular
☒Shallow Rectangular
☐Irregular
☒Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty and clay
Bars	Sand
Bed	Fine gravel and sand

Bar Types: ☒Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	The channel is a man-made straightened ditch designed to remove water as quickly as possible. Evidence of incision is apparent in some locations, though the frequent culverts and grouted riprap at road crossings provide the grade control necessary to prevent incision from migrating.				
Lateral stability *deposition, erosion*	Fairly stable, so some minor bank erosion is occurring where riparian vegetation is lacking and no roots are available to stabilize the banks.				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: The banks through this reach vary in height but are generally composed of fine silt and clay. Although fairly cohesive and strong and steep angles, these banks fail when undercut.				
Terrace/Valley	*Valley form* – alluvial valley is narrow with rolling hills surrounding	*Land Use* – Residential with public parks			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Entire reach has been straightened into essentially and stormwater ditch with sewer pipes and manholes visible throughout. Stn 24,900: 3, 12x6-ft concrete box culverts under unused road; left culvert partially filled with sand Stn 26,600: 2, 12x7-ft concrete box culverts under Field Crest Ave Stn 28,150: 6-ft concrete pipe under Flagstaff Ave Stn 28,150-30,000: Dodd Trail Park Stn 29,950: 5-ft concrete pipe under Dodd Blvd Stn 30,550: 2-ft metal pipe (probably sewer) crosses channel ~2ft above bed Stn 30,550-31,200: Fairfield Park Stn 30,800: 10-ft wide wood plank and metal frame footbridge ~10 ft above channel bed Stn 31,950: 20x5-ft concrete bridge - Gannon Ave Stn 32,600: 2, 8x6-ft concrete box culverts under Gerdine Path; grouted riprap on edges Stn 33,150: 6-ft wood plank, metal frame footbridge				

	Stn 33,450: small foodbridge ~3 ft above bed Stn 34,100: 3, 5-ft concrete pipes with trash grates under Cedar Ave; right pipe is closed with concrete; 1-ft drop on upstream end to get into pipes
Bankfull/Channel forming flow indication	Bankfull - narrow floodplain surfaces within taller ditch

Sediment Impacts

Riffle sediment type	Gravel/cobble/riprap	Pool sediment type	Sand/fine gravel
Sorting / Imbrication	Fines are deposited on tops of bars; not much opportunity for sorting		

Bars / depositional features

Sediment type/size	Sand/fines
Mid, alternate, braided	Lateral below steep drops below road crossings; not many bars
Bar Vegetation (type, age)	Grasses, cattails
Floodplain soils	Silty loam
Overbank deposition	Silt

Riparian Vegetation and Floodplain

Root coverage of banks (%)	75%
Width of veg. riparian corridor*	20-50 ft
Canopy coverage (%)	30%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	50%
woody species	50%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Willow	80
Ash, silver maple, cottonwood, box elder	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	NA	General Habitat Notes: Very little habitat in this reach. There is moderate shade from overhanging grasses and canopy cover, but there are few pools and riffles as this reach is primarily a straight run. There
Residual pool depth	<1 ft	

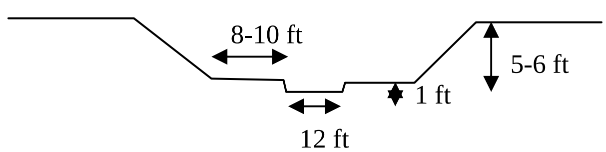
Undercut bank frequency	NA	are very few places to find shelter when flood waters flow through this ditch.
Riffle / Other frequency	Low	

Channel Stability Form

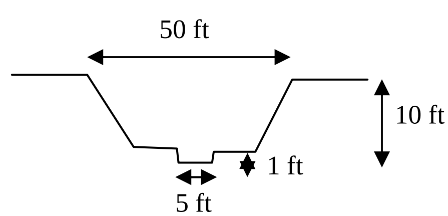
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels	3	Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed	1	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 21/9 = 2.3**				

Representative cross-section sketch		
Bankfull width = 12/5 ft Bankfull depth = 1 ft	Floodplain width = 5/10 ft	Water depth (at survey) = 0.5/1 ft Water width (at survey) = 12/5 ft

Station: 25,300



Station: 31,000



GENERAL REACH NOTES

Reach 3 of North Creek is a straightened ditch through residential neighborhoods and parks that acts as stormwater pipe to move water as quickly as possible through the reach and downstream. The channel is narrower than it would have been naturally and the channel bed lies 6-10 ft below the surrounding land surfaces where the houses and parks are built. The channel width and depth vary throughout this reach from wide and shallow to narrow and slightly deeper, but the channel throughout is essentially a straightened ditch. While canopy cover exists in some areas, there is little effective riparian vegetation. Grass and shrub buffers have been provided in some locations, but these are too narrow to provide any stormwater attenuation. Elsewhere, residents and park maintenance personnel mow and maintain lawns to the channel edge. Bank erosion is often apparent in these locations. During the rainstorm on July 15, this ditch was completely flooded and the fields were flooded in some locations. While the large amount of park space is likely of great value, much of that area could be converted to provide wide floodplains and wetlands while still providing walking trails throughout.

POTENTIAL PROJECTS

Stn 24,350-24,650 left bank: mowed and maintained to within about 10 ft of channel; little canopy cover or buffer; low priority

Stn 24,625: 1-ft concrete stormwater pipe outlets from left bank - perched 3 ft above channel bed and creating minor erosion around the pipe

Stn 24,900: 3, 12x6-ft concrete box culverts - flat bottoms may be hard for fish to pass during very low flows

Stn 25,100-26,600 right bank: mowed to top of benches with canopy trees on slopes to channel; the canopy cover is good, but there is little stormwater buffer or opportunity for water flowing off of maintained lawns (potentially with fertilizers, etc) to seep into the ground before entering the channel

Stn 25,850-26,150 left bank: minor bank erosion along lower 2 ft of bank - this slope only has wildflowers and grasses growing and no larger vegetation with stabilizing roots

Stn 26,400-26,500 left bank: 2 pipes (18-inch concrete and 4-ft concrete) drain stormwater from stormwater basin to channel; ~1 ft of incision and erosion is apparent at each even with grouted riprap; some riprap is falling into channel; something to monitor

Stn 27,200-27,400 left bank: mowed to edge or within 2 ft of edge of bank; minor bank erosion

Stn 28,050: 30-ft long riprap cascade was likely built to protect culvert at Flagstaff Ave from a migrating knickpoint; although there is always a low-flow channel, the gradient may present passage problems for some species at certain flows; the channel drops ~4 ft in elevation over the length of the cascade. There is room to length the cascade, or do a more gradual riffle/pool sequence

Stn 28,150: 6-ft concrete pipe under Flagstaff Ave is perched about 6 inches above the bed; backwater provides entrance into pipe, but low flows are shallow and all flows are very fast; likely a passage barrier at most flows

Stn 28,200-29,600 left bank: the slope from the edge of water to the top of the bench is vegetated with grasses and wildflowers that provide an 8-ft herbaceous buffer. Larger trees from right side of channel provide some canopy cover. Some shrubs or other woody vegetation would provide more year-round cover and protection; no significant erosion was observed

Stn 28,200-28,500; Stn 28,700-28, 900 right bank: mowed and maintained to edge of channel; gardens within 10 ft of channel; no buffer from fertilizers, watering, pesticides, etc.; there is no excessive bank erosion, but there is little substantial bank protection either

Stn 30,550: 2-ft metal sewer pipe with concrete abutments on either side of the stream; pipe is ~2 ft of the channel bed but traps debris on the upstream side and there is some scour occurring around the abutments; probably causes backwater during floods

Stn 30,975-31,000 right bank: minor erosion of the lower 3 ft of the bank

Stn 31,200-31,300 both banks; 31,500-31,600 right bank; 31,700-32,100 right bank; 32,000-32,100 left bank; 32,200-32,600 right bank; 33,350-33,450: all mowed/maintained to less than 10 ft of channel; <10 ft of buffer and most are mowed to the edge

Stn 34,000: 2.5-ft grouted riprap drop provides temporary grade control ~25 ft downstream of Cedar Ave; presents a fish passage barrier; some riprap and concrete are falling out as it is being undercut

Stn 34,100: 3, 5-ft concrete pipes with trash grates under Cedar Ave; right pipe is closed with concrete; on upstream end, pipes are designed with a 1-ft drop - this provides grade control and keeps water at certain level upstream, but it is also a complete fish passage barrier

Channel Reconnaissance Form

Date	July 16, 2011
Stream/Drainage	North Creek
Stream Reach ID	Reach 4
Field Team	NN, DB

Station 34,200 **To** 45,350

General Channel Conditions

Channel Shape (check)
☒Rectangular
☒Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Clay with silty loam on top
Bars	Gravel
Bed	Silt, clay

Bar Types: ☐Alternate lateral ☒Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Much of this channel was straightened into a narrow, deep ditch historically. As a result of this altered channel planform and geometry, portions of the channel are actively incising up to 3 ft. Multiple active knickpoints through silt and clay were observed, ranging from 1-3 ft in height. These will continue migrating upstream until road crossings are encountered.				
Lateral stability *deposition, erosion*	Because of the channel alterations mentioned above, the channel is also adjusting laterally with bank erosion along cutbanks. Some point bars are forming but none are mature.				
Erosion (excessive/site specific)	No specific large-scale erosion, though there are many areas of minor to moderate bank erosion between Stn 35,300 and 39,200				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: The banks through this reach vary in height but are generally composed of fine silt and clay layers overlain by 1-2 ft of silty loam. Gravel and cobbles and occasional boulders are dispersed and fall out of the banks where erosion is occuring.				
Terrace/Valley	*Valley form* – wide, flat wetlands	*Land Use* – parks and open wetlands; residential land use surrounding			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Entire reach has been straightened historically Stn 35,950: footbridge about 5 ft above channel bed Stn 35,350-36,950: public park Stn 39,900: 2, 4x3-ft corrugated metal pipes under bike path; riprap on downstream end and grouting at upstream end Stn 40,000: 6x3-ft concrete box culvert under Highview Ave; decent condition but fish passage barrier - steep and confined Stn 42,250: 3-ft concrete pipe under 172nd St W conveys water from stormwater basin to channel; recent damage from flooding Stn 42,350: 4.5x3-ft corrugated metal pipe under 172nd St W is perched 1 ft with a 3-ft scour hole; some bank erosion on upstream side; undersized - damage from flooding Stn 44,400: 5x3.5-ft concrete pipe with trash grate under 175th St W Stn 44,600: 6x4-ft concrete pipe under Iberia Ave				

Bankfull/Channel forming flow indication	Bankfull - vegetated wetland surface; channel forming - undercut banks, exposed roots in places

Sediment Impacts

Riffle sediment type	Gravel/cobble	Pool sediment type	Sand and silt
Sorting / Imbrication	Gravel on bars, finer material in pools		
Bars / depositional features			
Sediment type/size	Gravel and sand		
Mid, alternate, braided	Point bars		
Bar Vegetation (type, age)	Young grasses		
Floodplain soils	Silty loam		
Overbank deposition	Silt		

Riparian Vegetation and Floodplain

Root coverage of banks (%)	80%
Width of veg. riparian corridor*	50-1000 ft
Canopy coverage (%)	Mostly 0%; a few locations are 90%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	75%
woody species	25%
bare/other	
Exotic/invasive species	Reed canary grass, nettle, thistle

Woody Species present	% of total tree community
Willow	40
Cottonwood	40
Box elder	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

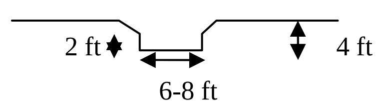
LWD density (pieces / 100 ft)	<1	General Habitat Notes: Decent wetland habitat with some deeper pools, undercut banks, and overhanging grasses. Grasses cover a high percentage of the channel in many places, but there is little other cover
Residual pool depth	1 ft	
Undercut bank frequency	high	
Riffle / Other frequency	Low	

Channel Stability Form

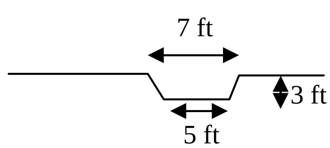
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed	1	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive	2	Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 17/9 = 1.9**				

Representative cross-section sketch		
Bankfull width = 10/7 ft Bankfull depth = 2/3 ft	Floodplain width = 0/300 ft	Water depth (at survey) = 1/1 ft Water width (at survey) = 8/5 ft

Station: 35,800



Station: 41,300



GENERAL REACH NOTES

Reach 4 of North Creek primarily consists of wide wetlands through which a narrow North Creek flows. North Creek was historically straightened through this reach and the channel is actively adjusting to these changes by incising and through lateral migration. Multiple 1 to 3-ft headcuts have formed through clay layers in the wetland channels resulting in steep banks and an incised channel downstream and a fairly stable channel upstream. Small drainages and tributaries entering North Creek through the wetlands are incising to the new base level and the incision can be traced back until the drainages blend in with the wetland surface and the channel can no longer be traced. While much of the channel is in good wetland habitat with no encroachment, incision and bank erosion is causing the downstream delivery of sediment. If the knickpoints migrate upstream to road crossings, culverts could be undermined and destabilized. With the overhanging grasses, undercut banks, and moderately deep pools and runs, this reach has decent aquatic habitat. Reach-wide restoration to eliminate the incision and utilize the functionality of the wetland could include creating a new, highly-sinuous channel that is only 1-2 ft below the wetland surface. This would increase the potential for flood waters to spread onto the wetlands and mitigate downstream flooding.

POTENTIAL PROJECTS

Stn 35,350-36,950: straightened channel through park; because of park, there may be some room to build small meanders and narrow floodplains along with riparian buffer

Stn 35,350-36,950 left bank and up to Stn 36,300 on right bank: less than 10 ft buffer with willows; the vegetation buffer through the entire section should be increased to provide stability rather than providing patchwork fixes; the following locations have no buffer and are experiencing some bank erosion:

- Stn 35,650-35,700 left bank: minor bank erosion through clay banks; mowed to within 2 ft of bank - no stabilizing vegetation
- Stn 35,800-35,900 left bank: mowed to within 2 ft of bank
- Stn 36,350-36,400 left bank: minor bank erosion through silt and clay with no vegetation cover
- Stn 36,800-36,950 left bank: bank erosion due to channel migration; no vegetation for bank stabilization

Stn 37,000-39,400: recent incision up to Stn 38,700 is causing bank erosion along nearly the entire length; between Stn 38,700 and 39,400, 4 knickpoints totaling ~4.5 ft are actively incising - this will in turn result in bank erosion as the channel adjusts; if this downstream release of turbidity and fine-grained sediment is acceptable, the channel can be allowed to adjust as there is no infrastructure of concern (until the knickpoints reach the bike path and road upstream); if that turbidity is a problem, build a new channel on top of the wetland that is very sinuous and drops grade more gradually to tie into the wetlands downstream.

Stn 37050-37,350 right bank: lawn is mowed to the edge of the bank and the banks are eroding

Stn 40,000: 6x3-ft concrete box culvert under Highview Ave is steep and plane bed - partial fish passage barrier at high flows (velocity) and at low flows (depth)

Stn 42,250: 3-ft concrete pipe - undersized pipe conveys flows from stormwater basin; recent flooding overwhelmed the pipe and eroded the road - all of this material washed into the channel downstream

Stn 42,350: 4.5x3-ft corrugated metal pipe under 172nd St W; undersized (see comments for other pipe above) and perched 1 ft on the downstream end with a 3-ft scour hole - fish passage barrier; in addition, a 1 ft^2 scour hole has developed under the pavement to the right of the pipe on the upstream side - this presents a safety risk due to potential road failure

Stn 42,750 - 1.5-ft knickpoint through clay in wetland; monitor this - could provide grade control but likely not worth the cost

Channel Reconnaissance Form

Date	July 16, 2011
Stream/Drainage	North Creek
Stream Reach ID	Reach 5
Field Team	NN

Station	45,350	**To**	46,900

General Channel Conditions

Channel Shape (check)

- ☐ Rectangular
- ☒ Shallow Rectangular
- ☐ Irregular
- ☒ Trapezoidal
- ☐ Parabolic
- ☐ Other _______________

Sediment Particle Size Estimate	
Banks	Silty and clay
Bars	Sand
Bed	Fine gravel and sand

Bar Types: ☐ Alternate lateral ☐ Point ☐ Mid-channel ☐ Transverse ☒ None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Actively incising with 3, 2-ft knickpoints				
Lateral stability *deposition, erosion*	Generally stable, though slight bank erosion is occurring where knickpoints have moved upstream				
Erosion (excessive/site specific)	No specific large-scale erosion, though there are many areas of minor				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒ Undercut / cantilever	☒ Selective erosion of noncohesive laters	☐ Dry flow	☐ Seepage
	Gravitational	☐ Rotational	☐ Planar	☐ Wedge	
Bank composition	*Notes (shape/character)*: Channel banks are approximately 1 ft high and steep. They are composed primarily of clay and fine silt overlain by silty loam.				
Terrace/Valley	*Valley form* – narrow, with rolling hills surrounding	*Land Use* – residential			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Entire reach has been straightened historically Stn 46,000 - 3.5-ft flared concrete pipe under Icon Trail perched 2 ft on downstream end; grouted riprap apron and banks have failed and are now broken in the channel Stn 46,700: 1-ft concrete pipe with trash grate conveys water from small stormwater basin to right bank Stn 46,850: 2-ft concrete pipe with trash grate conveys water to channel from stormwater basin that is the headwaters of the stream				
Bankfull/Channel forming flow indication	Bankfull - slope break and vegetation; channel forming flow - bankfull or undercut banks				

Sediment Impacts

Riffle sediment type	Gravel/cobble/riprap	Pool sediment type	Sand and silt/clay
Sorting / Imbrication	NA		

Bars / depositional features	
Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	Silt

Riparian Vegetation and Floodplain

Root coverage of banks (%)	75%
Width of veg. riparian corridor*	50ft
Canopy coverage (%)	60%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	
low = single canopy layer	x
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	50%
woody species	50%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Box elder	80
Other	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

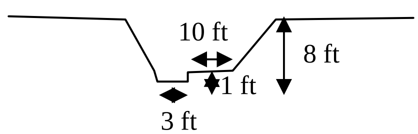
LWD density (pieces / 100 ft)	0	General Habitat Notes: Little habitat as this is a straightened reach with little complexity and fish passage barriers. Canopy is decent, however.
Residual pool depth	<1 ft	
Undercut bank frequency	Low	
Riffle / Other frequency	Low	

Channel Stability Form

Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed	1	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 20/9 = 2.2**				

Representative cross-section sketch		
Bankfull width = 5 ft Bankfull depth = 1 ft	Floodplain width = 10 ft	Water depth (at survey) = 0.5 ft Water width (at survey) = 3 ft

Station: 46,200



Station:

GENERAL REACH NOTES

Reach 5 of North Creek consists of a narrow, straightened channel with the headwaters in a stormwater basin and flowing through residential neighborhoods. The narrow channel flows with a narrow alluvial valley with houses on the surface about 8 ft above the channel bed. Although riparian buffer is available, especially on the right side, there is little geomorphic and habitat complexity in the channel. Three 2-ft knickpoints are migrating upstream and bank erosion is resulting downstream of these, particularly where adjacent landowners have removed the riparian vegetation and mowed to the channel edge.

POTENTIAL PROJECTS

Stn 45,500-46,000 left bank: mowed to edge of the bank or has less than 10-ft buffer; minor bank erosion throughout; provide at least 15-20ft buffer

Stn 46,000: 3.5-ft flared concrete pipe under Icon Trail is perched 2 ft on the downstream end. The grouted riprap apron and banks have failed and are now broken in the channel

Stn 46,600: 2-ft knickpoint - resulted in some erosion on left bank where there is little root stabilization; not much risk to infrastructure as this is the headwaters and houses are far from channel

Stn 46,700: 2-ft knickpoint - riprap cobbles may be slowing this, but much of the riprap has washed downstream; not much risk to infrastructure as this is the headwaters and houses are far from channel

Channel Reconnaissance Form

Date	July 12, 18, 2011
Stream/Drainage	North Creek, Tributary 1
Stream Reach ID	Reach 1
Field Team	NN, DB

Station	0	**To**	1900

General Channel Conditions

Channel Shape (check)
- ☐Rectangular
- ☒Shallow Rectangular
- ☐Irregular
- ☒Trapezoidal
- ☐Parabolic
- ☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty
Bars	NA
Bed	Fine sand and silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Historically straightened into a narrow ditch ~4 ft lower than its historic bed elevation; currently stable				
Lateral stability *deposition, erosion*	Currently stable with little erosion/deposition				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks are nearly vertical and are composed of silt and silty loam; supports reed canarygrass and other wetland vegetation				
Terrace/Valley	*Valley form* – flat and wide	*Land Use* – agriculture; residential upstream			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Entire reach has been straightened historically Stn 200: 24-inch half sphere concrete pipe with trash grate is either a release for field tiles or a stormwater pipe; perched 2 ft above the right bank				
Bankfull/Channel forming flow indication	Bankfull - slope break and vegetation; channel forming flow - undercut banks				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	Sand and silt
Sorting / Imbrication	NA		
Bars / depositional features			
Sediment type/size	NA		
Mid, alternate, braided	NA		

Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	>500ft
Canopy coverage (%)	5%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	
low = single canopy layer	x
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	95%
woody species	5%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Willow	100

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

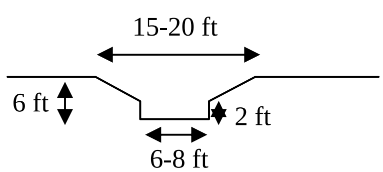
LWD density (pieces / 100 ft)	0	General Habitat Notes: Although there is little geomorph and habitat complexity, undercut banks and overhanging grasses do provide protection and some shade. However, there is little variability in channel depth, channel dimensions, substrate size, and there are no woody or other in-stream habitat features.
Residual pool depth	<1 ft	
Undercut bank frequency	High	
Riffle / Other frequency	NA	

Channel Stability Form

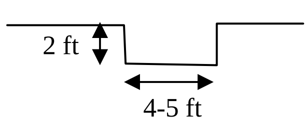
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed	1	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9		**= 22/9 = 2.4**				

Representative cross-section sketch		
Bankfull width = 8/5 ft Bankfull depth = 2 ft	Floodplain width = >500 ft	Water depth (at survey) = 0.5 ft Water width (at survey) = 6/4 ft

Station: 150



Station: 1600



GENERAL REACH NOTES

Reach 1 of North Creek Tributary 1 consists of a narrow, straightened channel through a wide wetland on the left with an active farm within 50 ft of the right bank. Water temperatures are warm (81° F during survey) as this channel is immediately downstream of Reach 2 which is essentially a series of in-stream stormwater basins for the adjacent developments. Because the channel was straightened into a deeper ditch, the interaction with the wetland is less frequent. Restoration could include a more sinuous channel built just below the wetland surface, multiple side channels, and multiple channels that tap into cold groundwater that would provide cold-water refugia and would also serve to cool down the main channels.

POTENTIAL PROJECTS

Stn 0-1500: straightened ditch that is not as connected to the adjacent wetland; in coordination with North Creek restoration, increase sinuosity and raise the channel bed to improve wetland reconnection

Channel Reconnaissance Form

Date	July 18, 2011
Stream/Drainage	North Creek, Tributary 1
Stream Reach ID	Reach 2
Field Team	NN

Station 1900 **To** 7200

General Channel Conditions

Channel Shape (check)
- ☐ Rectangular
- ☐ Shallow Rectangular
- ☐ Irregular
- ☒ Trapezoidal
- ☐ Parabolic
- ☐ Other _______________

Sediment Particle Size Estimate	
Banks	Silty
Bars	NA
Bed	Fine sand and silt

Bar Types: ☐ Alternate lateral ☐ Point ☐ Mid-channel ☐ Transverse ☒ None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Vertically stable as this is a series of in-stream stormwater basins for adjacent developments				
Lateral stability *deposition, erosion*	Stable				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐ Undercut / cantilever	☐ Selective erosion of noncohesive laters	☐ Dry flow	☐ Seepage
	Gravitational	☐ Rotational	☐ Planar	☐ Wedge	
Bank composition	*Notes (shape/character)*: Banks have been constructed to be gently sloping towards residential developments				
Terrace/Valley	*Valley form* – flat and wide	*Land Use* – residential - recent with lots of stormwater basins			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Entire reach has been converted to a series of in-stream stormwater basins Stn 2850: 12x5-ft concrete box culvert within bridge - Dunbury Ave; new Stn 4400: 12x5-ft concrete box culvert under Dylan Dr Stn 5050: 3-ft concrete pipe with trash grate under park path; vertical pipe on upstream end provides stormwater retention upstream - also a fish passage barrier Stn 6350: 3, 2.5-ft concrete pipes with trash grates under Embers Ave				
Bankfull/Channel forming flow indication	NA				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	Sand and silt
Sorting / Imbrication	NA		

Bars / depositional features	
Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	<100ft
Canopy coverage (%)	<5% (only the edges of the channel)

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	
low = single canopy layer	x
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	60%
woody species	40%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community
Willow	95

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

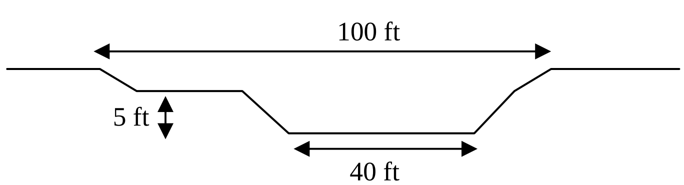
LWD density (pieces / 100 ft)	0	General Habitat Notes: No cold-water fluvial habitat, though there is warm-water lacustrine and fluvial habitat - deep pools with some shade near the banks
Residual pool depth	>5 ft	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	
Channel pattern	Single thread		Single thread		Multiple thread/braided	
Average bank slope	<3:1		>3:1			
Vegetative bank protection	Poor		Extensive		Poor	
Field stability rating (add all cells)/9		**= NA**				

Representative cross-section sketch		
Bankfull width = 45 ft Bankfull depth = 5 ft	Floodplain width = 25-50 ft	Water depth (at survey) = 2 ft Water width (at survey) = 40 ft

Station: 2700



Station:

GENERAL REACH NOTES

Reach 2 of North Creek Tributary 1 consists of a series of in-stream stormwater basins built along with the residential developments that surround the current stream. The river was straightened and over-widened and multiple grade controls were built to hold back water. While stormwater retention is helpful in slowing the movement of stormwater into the river, the system of in-stream basins with little vegetation cover results in high water temperatures (exceeding 75°F and 80°F) and poor water quality. It may have been more appropriate to retain a very narrow and sinuous channel through a narrow corridor bounded on both sides by elongated stormwater basins that only discharged to the river during large storm events. The majority of the stormwater basins in this area are too deep to sustain wetland vegetation and too shallow to eliminate the growth of aquatic vegetation and algae.

POTENTIAL PROJECTS

Stn 1900-7200 (entire reach): system of in-stream stormwater basins causes water to warm, providing a source of warm water to North Creek. Although changing conditions here is unlikely as this development is relatively new, the vertical pipe at Stn 5050 could be retained and everything upstream of that retained as a stormwater pond (could the pipe be raised so even more water could be stored?). Downstream of that vertical pipe, a narrow and more natural creek could be built between levees that contain the stormwater basins to either side of the stream. The stream would have riparian vegetation to provide cover.

Channel Reconnaissance Form

Date	July 18, 2011
Stream/Drainage	North Creek, Tributary 2
Stream Reach ID	Reach 1
Field Team	NN

Station | 0 | **To** 7100 |

General Channel Conditions

Channel Shape (check)
- ☐Rectangular
- ☐Shallow Rectangular
- ☐Irregular
- ☐Trapezoidal
- ☒Parabolic
- ☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty
Bars	NA
Bed	Fine sand and silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Vertically stable - swale through fields				
Lateral stability *deposition, erosion*	Stable				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☐Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: No distinct banks as the channel is either a shallow swale or is undefined				
Terrace/Valley	*Valley form* – flat and wide	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 2450: 3.5-ft concrete pipe under railroad tracks				
Bankfull/Channel forming flow indication	NA				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	NA
Sorting / Imbrication	NA		
Bars / depositional features			
Sediment type/size	NA		
Mid, alternate, braided	NA		

Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	30ft
Canopy coverage (%)	0%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	100%
woody species	
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

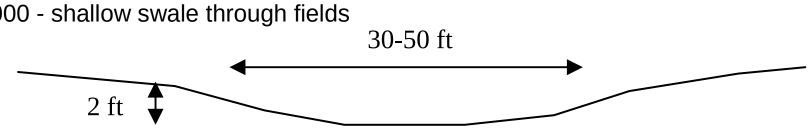
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No continuous habitat - channel outlet to North Creek could not be found and water in the channel (where defined) upstream is intermittent. Swale is between crops and in grazing land.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	
Channel pattern	Single thread		Single thread		Multiple thread/braided	
Average bank slope	<3:1		>3:1			
Vegetative bank protection	Poor		Extensive		Poor	
Field stability rating (add all cells)/9		**= NA**				

Representative cross-section sketch		
Bankfull width = NA Bankfull depth = NA	Floodplain width = NA	Water depth (at survey) = NA Water width (at survey) = NA

Station: 2000 - shallow swale through fields



Station:

GENERAL REACH NOTES

North Creek Tributary 2 is a shallow swale through agriculture fields or is an undefined channel. The outlet to North Creek was not found. This swale drains ground water seeps and stormwater over fields. Water temperatures at the railroad bridge were below 60°F. No aquatic habitat or riparian habitat exists.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	July 12, 18, 2011
Stream/Drainage	North Creek, Tributary 3
Stream Reach ID	Reach 1
Field Team	NN, DB

Station | 0 | **To** 3700 |

General Channel Conditions

Channel Shape (check)
- ☐Rectangular
- ☐Shallow Rectangular
- ☒Irregular
- ☐Trapezoidal
- ☐Parabolic
- ☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty
Bars	NA
Bed	Fine sand and silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Vertically stable - wide wetland through fields and through residential developments				
Lateral stability *deposition, erosion*	Stable				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☐Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: No distinct channel through this reach, so no distinct channel banks; Trib 3 is a wide wetland with water throughout				
Terrace/Valley	*Valley form* – flat and wide	*Land Use* – agriculture downstream of Stn 2300; residential upstream of Stn 2300			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 2200: 2, 5x3.5-ft concrete pipes under farm road Stn 2300: 2, 5x3.5-ft concrete pipes under 173rd St W Stn 3700: 2, 3-ft concrete pipes with trash grates under 170th St W; stormwater basin upstream				
Bankfull/Channel forming flow indication	NA				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	NA
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA

Bar Vegetation (type, age)	NA
Floodplain soils	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	150-300ft
Canopy coverage (%)	10%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	x
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	75%
woody species	25%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community
Willow	75
Cottonwood	25

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

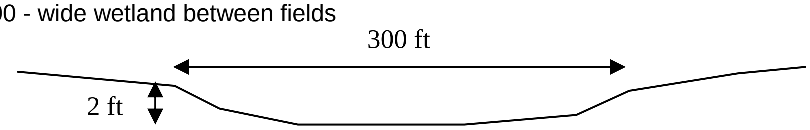
LWD density (pieces / 100 ft)	NA	General Habitat Notes: Good wetland habitat - though little canopy cover, the thick cattails and other vegetation provide protection and shade. Wide, wet areas with thick vegetation provides shelter and food sources. Pockets of cold water throughout suggest that seeps are releasing into this tributary - this can provide cold water refugia for cold water species.
Residual pool depth	1-2 ft	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	
Channel pattern	Single thread		Single thread		Multiple thread/braided	
Average bank slope	<3:1		>3:1			
Vegetative bank protection	Poor		Extensive		Poor	
Field stability rating (add all cells)/9		**= NA**				

Representative cross-section sketch		
Bankfull width = NA Bankfull depth = NA	Floodplain width = NA	Water depth (at survey) = NA Water width (at survey) = NA

Station: 500 - wide wetland between fields



Station:

GENERAL REACH NOTES

North Creek Tributary 3 is a wide wetland between agricultural fields and between residential developments. There is no distinct channel through most of the tributary. The wetland contained about 1 ft of water through the entire width of the wetland during this assessment. Wetland vegetation included thick stands of cattails and in some places reed canary grass. Also, large willow and cottonwood trees provided canopy cover in some areas. The thick wetland vegetation and diffuse nature of the water produced a wetland with copious aquatic and wetland habitat. In addition, seeps dispersing cold water into the channel cooled water temperatures in some locations.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	July 18, 2011
Stream/Drainage	North Creek, Tributary 4
Stream Reach ID	Reach 1
Field Team	NN

Station 0 **To** 4500

General Channel Conditions

Channel Shape (check)
- ☐Rectangular
- ☐Shallow Rectangular
- ☐Irregular
- ☒Trapezoidal
- ☐Parabolic
- ☐Other _______________

Sediment Particle Size Estimate	
Banks	NA
Bars	NA
Bed	Silty loam

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Vertically stable - this is a trapezoidal stormwater channel that conveys water from a stormwater basin to North Creek; only holds water after large storm events				
Lateral stability *deposition, erosion*	Stable				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☐Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Intermittent flows through what is essentially a trapezoidal canal to convey stormwater. The ditch is entirely silty loam.				
Terrace/Valley	*Valley form* – generally flat	*Land Use* – residential			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 500: 6x4-ft concrete pipe with stone masonry walls under Galena Ave W Stn 1500: 6x4-ft concrete pipe with stone masonry walls under 167th St W Stn 3000: 2, 3-ft concrete pipes in stone wall under Gerdine Path Stn 3400: 2, 3.5 ft concrete pipes in stone wall under 164th St W Stn 4450: 1.5-ft concrete pipe under path; drains stormwater basin Stn 3500-4500: park				
Bankfull/Channel forming flow indication	NA				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	NA
Sorting / Imbrication	NA		

Bars / depositional features	
Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100% (turf)
Width of veg. riparian corridor*	<50ft
Canopy coverage (%)	5%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	90%
woody species	10%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Spruce	
Planted trees	

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

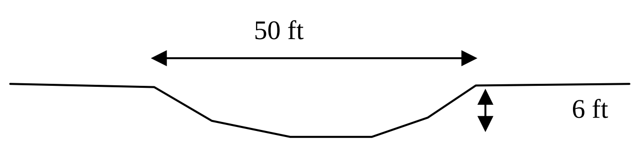
LWD density (pieces / 100 ft)	NA	General Habitat Notes: Stormwater ditch with no habitat
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	
Channel pattern	Single thread		Single thread		Multiple thread/braided	
Average bank slope	<3:1		>3:1			
Vegetative bank protection	Poor		Extensive		Poor	
Field stability rating (add all cells)/9		**= NA**				

Representative cross-section sketch		
Bankfull width = NA Bankfull depth = NA	Floodplain width = NA	Water depth (at survey) = NA Water width (at survey) = NA

Station: 3100 - stormwater ditch through residential neighborhood



Station:

GENERAL REACH NOTES

North Creek Tributary 4 is a stormwater drainage ditch 4500 ft long from a stormwater basin through residential neighborhoods to North Creek. It holds water during high flows that cause the basin to spill through its overflow pipe and into this ditch. This channel provides no aquatic or riparian habitat, but is doing a good job of conveying stormwater between houses.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	July 16, 2011
Stream/Drainage	North Creek, Tributary 5
Stream Reach ID	Reach 1
Field Team	NN

Station 0 **To** 5700

General Channel Conditions

Channel Shape (check)
☐Rectangular
☒Shallow Rectangular
☒Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silt/Clay
Bars	NA
Bed	Silt/Clay

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Slightly incising upstream of Stn 1700				
Lateral stability *deposition, erosion*	Stable with little erosion				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks are short, generally nearly vertical, and composed of silt, clay, and silty loam on top				
Terrace/Valley	*Valley form* – generally flat in alluvial valley and wetland though rolling hills nearby	*Land Use* – residential			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 1700: 4x3.2-ft concrete pipe under Hamilton Dr; riprap on upstream end creates steep 1-ft cascade Stn 3300: 3, 3-ft flared concrete pipes with trash grates under Griffon Trail; middle and left pipes have debris partially blocking upstream end Stn 4550: 5-ft flared concrete pipe under Highview Ave; riprap on downstream bed and bank generally in good condition though some erosion on the downstream end; 4-ft steep riprap cascade to pipe on upstream end				
Bankfull/Channel forming flow indication	Slope break and vegetation growth on floodplains and wetland				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	Silt/clay
Sorting / Imbrication	NA		

Bars / depositional features	
Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	100->500 ft
Canopy coverage (%)	75%; 0% downstream of Stn 1700

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	30%
woody species	70%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community
Willow	80
Cottonwood	15
Box elder	5

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	<1	General Habitat Notes: Decent wetland habitat throughout with thick stands of vegetation to provide cover; channel is small and narrow, but small fish were observed near the headwaters of this tributary
Residual pool depth	1 ft	
Undercut bank frequency	low	
Riffle / Other frequency	low	

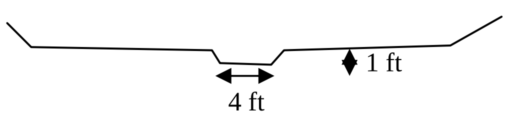
Channel Stability Form

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed	2	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9		**= 25/9 = 2.8**				

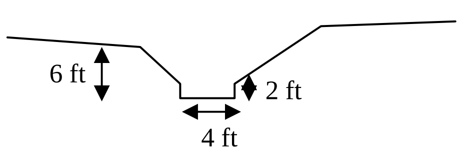
Representative cross-section sketch

Bankfull width = 6/6 ft Bankfull depth = 1/2 ft	Floodplain width = 100/0 ft	Water depth (at survey) = 0.5 ft Water width (at survey) = 4 ft

Station: 3000



Station: 4200



GENERAL REACH NOTES

North Creek Tributary 5 is a small tributary flowing 5700 ft from its headwaters in residential neighborhoods to North Creek at Stn 37,000. While the entire tributary flows through wetlands, the wetland is somewhat confined upstream of Stn 1700 by hillslopes and residential development. Downstream of Stn 1700, the wetland is unconfined and the channel is undefined as it flows toward North Creek. This large wetland primarily consists of reed canary grass. As development is well removed from the channel and riparian corridor, the habitat within the riparian corridor is relatively good. Canopy cover provides shade and protection as does thick wetland vegetation. A few small knickpoints suggests incision is occurring and these knickpoints also present fish passage barriers.

POTENTIAL PROJECTS

Stn 1800: multiple channels flow over 0.5-ft knickpoints as they enter the steep culvert; these knickpoints are not causing significant erosion or threat to infrastructure. These can be monitored and if action is necessary, stabilize the knickpoints or raise the culvert elevation

Stn 4000: 2 knickpoints - 2.5 knickpoint halted at root with a 1-ft knickpoint 10 ft upstream; these could continue to migrate upstream and impact the culvert under Highview Ave, only 500 ft upstream. These knickpoints also present fish passage barrier for small fish populations. The riprap below the culvert may prevent the culvert from being impacted, but this should be monitored

Channel Reconnaissance Form

Date	July 12, 13, 2011
Stream/Drainage	Middle Creek
Stream Reach ID	Reach 1
Field Team	NN, DB

Station | 0 | **To** 10,000 |

General Channel Conditions

Channel Shape (check)

- ☐Rectangular
- ☐Shallow Rectangular
- ☒Irregular
- ☐Trapezoidal
- ☒Parabolic
- ☐Other _______________

Sediment Particle Size Estimate	
Banks	Silt/Clay
Bars	Sand
Bed	Sand and fines with some gravel

Bar Types: ☐Alternate lateral ☒Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable - no active knickpoints or substantial deposition				
Lateral stability *deposition, erosion*	Bank erosion and point bar deposition typical of channel migration				
Erosion (excessive/site specific)	Many locations of outer bank erosion, but no excessive erosion				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Outside banks are nearly vertical, with inside banks being less steep with adjacent sand bars. Banks are typically composed of fine silt and clay with silty loam on top				
Terrace/Valley	*Valley form* – flat and wide	*Land Use* – Mostly agriculture but some residential			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 0: wooden bridge for bike path Stn 600: concrete farm crossing embedded in stream with 7, 14-inch holes in the concrete for low flows; crossing is concave so that high flows flow over the crossing Stn 2000: wooden railroad bridge; 3 piers with 12 pilings each; low chord is about 7 ft above the channel bed; riprap under the bridge; downstream piling of right pier is broken Stn 3500: log farm crossing about 4 ft above channel bed; 12-inch logs under with 10-12 inch planks on top; 12 ft wide Stn 5500: gravel and cobble farm ford Stn 7100: 3 concrete box culverts under Akin Rd; middle culvert is 8x6 ft for low flows and is partially buried; outer culverts are 10x5 ft for high flows Stn 10,000: 2, 5-ft corrugated metal pipes under farm road; pipes are compressed slightly and most flow is through the left pipe; concrete riprap not in great condition				
Bankfull/Channel forming flow indication	Bankfull: slope break and vegetation; channel forming: exposed roots and undercut banks				

Sediment Impacts

Riffle sediment type	Gravel, some cobble	Pool sediment type	Fine sand, silt, clay
Sorting / Imbrication	Sands on top of bars		

Bars / depositional features

Sediment type/size	Sand
Mid, alternate, braided	Point bars
Bar Vegetation (type, age)	Some grasses close to the channel banks
Floodplain soils	Silty loam
Overbank deposition	Sand and silt

Riparian Vegetation and Floodplain

Root coverage of banks (%)	90%
Width of veg. riparian corridor*	100-400 ft
Canopy coverage (%)	15%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	75%
woody species	25%
bare/other	
Exotic/invasive species	Reed canary grass, buckthorn

Woody Species present	% of total tree community
Willow	20
Cottonwood	10
Silver Maple	10
Ash	40
Buckthorn	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

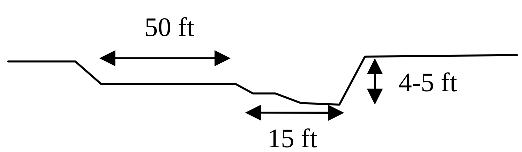
LWD density (pieces / 100 ft)	0-5	General Habitat Notes: Good in-stream and wetland habitat. Canopy cover from trees and cover from wetland grasses provide protection and shade. Undercut banks contribute to shelter. This reach has good geomorphic complexity with meander bends consisting of eroding outer banks with deep pools and sand bars on the aggrading inside of bends. Some substrate variability was also observed.
Residual pool depth	1-2 ft	
Undercut bank frequency	Mod	
Riffle / Other frequency	Mod	

Channel Stability Form

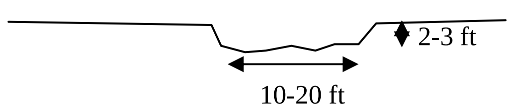
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	3	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9		**= 26/9 = 2.9**				

Representative cross-section sketch		
Bankfull width = 20/15-25 ft Bankfull depth = 4/3 ft	Floodplain width = 50/50-100 ft	Water depth (at survey) = 2 ft Water width (at survey) = 10/15-25 ft

Station: 1100



Station: 8300



GENERAL REACH NOTES

Reach 1 of Middle Creek extends 10,000 ft through wetlands to join North Creek at Stn 1700. Middle Creek in this reach is very sinuous and is actively migrating within a fairly wide wetland corridor. The wetlands are dominated by reed canary grass, but in many places woody vegetation provides canopy cover. While residences are encroaching on the channel in the lower portions of this reach, there are generally wide buffers between houses or farm fields and the channel. The channel has not been straightened through much of the reach as is common throughout MN. Middle Creek retains its sinuous planform and has been allowed to erode bank and build point bars, displaying many geomorphic functions often lost in many of the over-managed streams. Because of this geomorphic complexity, habitat complexity and habitat potential is good.

POTENTIAL PROJECTS

Stn 0-1900: many landowners have mowed lawns to the edge of the river or have very narrow buffers; increase the buffer width in these areas and plant native riparian vegetation that will stabilize channel banks

- Stn 50-150 left bank: mowed to edge
- Stn 1150-1250 right bank: mowed to edge with minor bank erosion
- Stn 1300 right bank: mowed to edge
- Stn 1425-1475 right bank: mowed to edge
- Stn 1500-1550 right bank: 10-ft buffer
- Stn 1600-1700 right bank: 10-15-ft buffer
- Stn 1750-1900 right bank: mowed to edge with little erosion

Stn 1200 right bank: utility pole is 4 ft from the channel and a support cable is in the water and is loose; potential infrastructure and health hazard

Stn 1500-1900: fences, pieces of metal, and other trash in channel

Stn 1950: downstream piling of right pier under railroad bridge is broken - monitor and evaluate remainder of bridge to ensure it is stable

Stn 8800: field runoff and flows resulting in 3-ft eroding bank; erosion is nearing fields; monitor and stabilize if necessary

Channel Reconnaissance Form

Date	July 13, 14, 2011
Stream/Drainage	Middle Creek
Stream Reach ID	Reach 2
Field Team	NN, DB

Station	10,000	**To**	19,850

General Channel Conditions

Channel Shape (check)
- ☐Rectangular
- ☐Shallow Rectangular
- ☒Irregular
- ☐Trapezoidal
- ☐Parabolic
- ☐Other _______________

Sediment Particle Size Estimate	
Banks	Silt/Clay
Bars	NA
Bed	Sand and fines with some gravel

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable - wide wetlands with no incision or excessive deposition observed				
Lateral stability *deposition, erosion*	Stable - wide, low gradient channel with little energy to erode banks				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks are gradual as they emerge from the wetland and blend with upland vegetation. Banks are mostly composed of silt and clay overlain by silty loam				
Terrace/Valley	*Valley form* – flat and wide	*Land Use* – Mostly agriculture but some residential			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 10,000: 2, 5-ft corrugated metal pipes under farm road; pipes are compressed slightly and most flow is through the left pipe; concrete riprap not in great condition Stn 13,050: 4, 12x5-ft concrete box culverts under Pilot Knob Rd; no low-flow channel with some accumulated fines Stn 16,700-19,800: active livestock grazing				
Bankfull/Channel forming flow indication	Edge of the wetland				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	Sand and fines
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	85%
Width of veg. riparian corridor*	Up to 500 ft
Canopy coverage (%)	10%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	90%
woody species	10%
bare/other	
Exotic/invasive species	Reed canary grass, buckthorn

Woody Species present	% of total tree community
Willow	20
Cottonwood	30
Elm	10
Ash	20
Buckthorn	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

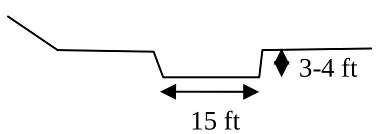
LWD density (pieces / 100 ft)	<1	General Habitat Notes: Although the channel through much of this reach has been straightened, the large wetland provides good buffer from agriculture and residential development. The tall grasses and the woody vegetation in a few places provides good shade and cover in the channel and throughout the wetland. Area of active grazing has reduced habitat potential due to decreased water quality.
Residual pool depth	1-2 ft	
Undercut bank frequency	Low	
Riffle / Other frequency	NA	

Channel Stability Form

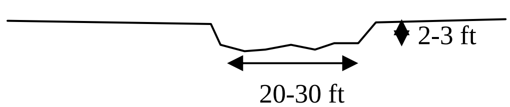
Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor		Extensive		Poor	4
Field stability rating (add all cells)/9		**= 24/8 = 3 - refers to the area of active livestock grazing**				

Representative cross-section sketch		
Bankfull width = 20/40 ft Bankfull depth = 4/3 ft	Floodplain width = <500/<300 ft	Water depth (at survey) = 3/2 ft Water width (at survey) = 18/25 ft

Station: 12,500



Station: 14,500



GENERAL REACH NOTES

Reach 2 of Middle Creek extends 9,850 ft through wetlands and active livestock grazing land. Middle Creek has been straightened and widened through much of this reach. In some locations, the channel was undefined as it became diffuse in the wide wetland covered in cattails and other grasses. Much of this reach provides excellent wetland habitat that is well shaded and protected by the wetland grasses and also by occasional woody tree species. Where the channel is wide, willows along the banks overhang about 25% of the channel and provide some canopy cover in these locations. Livestock are actively grazed between Stn 16,700 and 19,800 and are able to walk through the channel. The channel banks in this portion of the reach have been eroded by trampling and this has likely resulted in a decrease in water quality.

POTENTIAL PROJECTS

Stn 13,050: 4, 12x5-ft concrete box culverts under Pilot Knob Rd are in good condition but no low channels were provided. At very low flows, water depth may become a fish passage barrier

Stn 16,700-19,800: no restrictions on livestock grazing has resulted in eroding banks, which likely cause a decrease in water quality. Fencing could help keep livestock away from channel banks. Revegetation would help stabilize the banks and provide a buffer.

Channel Reconnaissance Form

Date	July 13-18, 2011
Stream/Drainage	Middle Creek
Stream Reach ID	Reach 3
Field Team	NN, DB

Station 19,850 **To** 50,200

General Channel Conditions

Channel Shape (check)
☐Rectangular
☐Shallow Rectangular
☐Irregular
☒Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silt and clay
Bars	NA
Bed	Sand and fines (silt and clay)

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Channel has incised historically and most of the knickpoints have reached grade controls at road crossings. If these migrate past these grade controls, or the grade controls are changed, incision will continue upstream				
Lateral stability *deposition, erosion*	Stable - straightened ditch; some local erosion in places				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Steep banks composed of silt and clay overlain by silty loam				
Terrace/Valley	*Valley form* – rolling hills	*Land Use* – Mostly agriculture but some residential			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 20,650: 3-ft corrugated metal pipe under dirt farm road; 1/2 of road was washed out and culvert was partially blocked Stn 22,550: 3 concrete box culverts under 195th St W - middle culvert is 8x8 ft and side culverts are 8x4 ft; middle culvert provides low flow Stn 32,500: 2, 10x4.5-ft concrete box culverts under Flagstaff Ave Stn 38,650: 3x1.8-ft flared concrete pipe under Cedar Ave Stn 44,150: 4x6-ft concrete culvert under Highview Ave; steep and fast Stn 45,300: 2, 4.5-ft corrugated metal pipes under Dodd Blvd Stn 48,100: 2, 4x3-ft concrete culverts under 183rd St W Stn 50,200: 2-ft concrete pipe under Ipava Ave; inlet is a vertical pipe where stormwater basin was built				
Bankfull/Channel forming flow indication	Top of bank or change in slope				

Sediment Impacts

Riffle sediment type	Gravel	Pool sediment type	Sand and fines
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	75%
Width of veg. riparian corridor*	Generally <30 ft
Canopy coverage (%)	10%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	80%
woody species	20%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community
Willow	25
Cottonwood	25
Box elder	50

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	<1
Residual pool depth	1 ft
Undercut bank frequency	Low
Riffle / Other frequency	Low

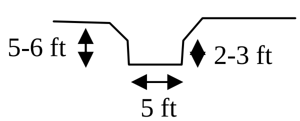
General Habitat Notes: In-stream and riparian habitat is poor in this reach. As this channel was straightened and deepened into a ditch, little geomorphic complexity is available. There is little variability in bed substrate and or channel dimensions. There is little buffer throughout this reach and livestock are permitted to graze through the channel in some locations.

Channel Stability Form

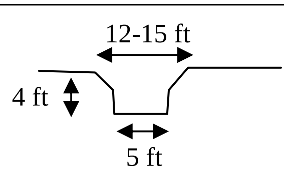
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed	2	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 21/9 = 2.3**				

Representative cross-section sketch		
Bankfull width = 5 ft Bankfull depth = 3/4 ft	Floodplain width = 0/50 ft	Water depth (at survey) = 1 ft Water width (at survey) = 5 ft

Station: 23,000



Station: 44,000



GENERAL REACH NOTES

Reach 3 of Middle Creek extends 30,500 ft from the headwaters to the downstream extent of a recent stream restoration effort. The channel through the entire reach was straightened historically and has undergone varying degrees of incision (3-4 ft at the downstream extent and getting less upstream). The channel primarily flows through agricultural fields with no, or little, riparian buffer. The lack of geomorphic complexity results in a lack of habitat and then lack of riparian buffer decreases the canopy cover and shading. Much of the upper sections of this reach may not have been a defined channel historically, but was a swale through the rolling hills instead. Upon clearing the land for agriculture and the increased water volumes due to tiling and residential development, these swales turned to channels, which were straightened and deepened to contain the flows. Today, flood flows spread out over the fields and transport fine-grained sediment into the stream increasing turbidity and decreasing water quality. Knickpoints have often been halted at road crossings with deeper channels downstream than upstream. While road crossings do provide good grade control, these should be monitored to ensure there are no effects on the infrastructure.

POTENTIAL PROJECTS

Stn 19,700 - 50,200 entire reach: entire reach has been straightened into a ditch with varying degrees of historic incision. This ditch generally provides little geomorphic or habitat complexity. Obtain easement on either side of channel to allow for construction of a sinuous, properly-sized channel throughout with a buffer between the agriculture fields and the channel

Stn 19,700 - 50,200 entire reach: much of this reach has little to no riparian buffer; increase buffer by planting native riparian shrubs and trees

Stn 19,700 - 22,500: unfinished restored channel - fix problem and make this functional

Stn 20,650: half of this dirt farm road is washed out on the upstream side with 4.5 ft of bank erosion. The culverts are partially or fully blocked with debris. Additional scour has occurred on the downstream side. Eliminate crossing if road is no longer necessary; replace culverts with larger culverts and rebuild road if the road is necessary

Stn 28,500-28,700 left bank: mowed to edge with minor erosion around trees; tiling from yard enters top of the bank

Stn 31,200-32,500: active livestock grazing throughout has resulted in some bank erosion and no vegetation cover over the channel

Channel Reconnaissance Form

Date	July 12, 17, 2011
Stream/Drainage	Middle Creek Tributary 1
Stream Reach ID	Reach 1
Field Team	NN, DB

Station 0 **To** 5700

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☐Irregular
☒Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	Small gravel
Bed	Sand with small gravel at edges

Bar Types: ☒Alternate lateral ☒Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Currently stable: channel was historically straightened into a deep ditch. Farm crossings within 1000 ft of the mouth provide grade control.				
Lateral stability *deposition, erosion*	Stable - straightened ditch - minor bank erosion where channel has begun to migrate				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks range from near vertical to a 1:1 slope and are composed primarily of dark silty loam. The banks are generally well-vegetated with grasses or woody vegetation or both.				
Terrace/Valley	*Valley form* – wide and flat	*Land Use* – Agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 600: 2, 14-inch concrete pipes under farm road. At low flows, water flows under pipes, not through. On upstream end, trees are growing directly on top of pipes and pipes are partially buried. On downstream end, pipes are perched about 1 ft. Stn 850: 2, 14-inch pipes under farm road that may not be used any more. Pipes are completely obscured by the growth of a large willow on the downstream end. Failing concrete slab on right bank. Stn 5700: 2-ft concrete pipe with trash grate under path to stormwater basin				
Bankfull/Channel forming flow indication	Bankfull: change in slope and vegetation growth; channel forming: vegetation growth, occasional undercut bank and exposed roots				

Sediment Impacts

Riffle sediment type	Fine gravel	Pool sediment type	Sand and fines
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	Fine gravel
Mid, alternate, braided	Point and lateral
Bar Vegetation (type, age)	Some grasses, but mostly bare
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	75%
Width of veg. riparian corridor*	60 ft
Canopy coverage (%)	60%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	25%
woody species	75%
bare/other	
Exotic/invasive species	Buckthorn

Woody Species present	% of total tree community
Box elder	80
Aspen	10
Other	10
Buckthorn understory	throughout

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*
650	Cottonwood	25-50 yrs	24-inch main trunk with 4 stems growing on top of pipes at farm crossing

Habitat

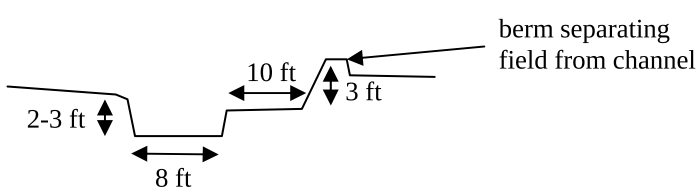
LWD density (pieces / 100 ft)	1	General Habitat Notes: During low flows, water depths are very low, limiting year-round aquatic habitat. However, the canopy cover is generally good and the water temperatures were low in places (56°F at Stn 400 and 53°F at Stn 1600). With additional woody habitat and improved riffle-pool sequences, this could be a good cold-water tributary providing refugia and habitat for smaller fish and other aquatic organisms.
Residual pool depth	<0.5 ft	
Undercut bank frequency	Low	
Riffle / Other frequency	Low	

Channel Stability Form

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels	3	Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	3	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	4
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9		**= 26/9 = 2.9**				

Representative cross-section sketch		
Bankfull width = 12 ft Bankfull depth = 2 ft	Floodplain width = 10 ft	Water depth (at survey) = 0.5 ft Water width (at survey) = 8 ft

Station: 1600



Station:

GENERAL REACH NOTES

Reach 1 of Middle Creek Tributary 1 extends 5700 ft from the outlet of a series of stormwater basins through agriculture fields to Middle Creek at Stn 2550. The channel was straightened historically into an over-deepened ditch. Though row crops are active on either side, a well-vegetated buffer of 25-40 ft bounds each side of the channel for much of this reach. In addition, earthen berms in some locations separate the fields from the channel and prevent runoff from flowing directly into the channel. Many additional farm ditches enter this tributary throughout this reach. While the canopy cover and riparian vegetation generally good shelter and shade, good aquatic habitat was scarce due to the uniformity of the channel bed and lack of woody habitat. The water temperatures were relatively low, however, suggesting that this tributary could provide an opportunity for cold-water habitat for small fish and other aquatic organisms. Two passage barriers near the mouth of the channel would need to be modified to improve the habitat potential.

POTENTIAL PROJECTS

Stn 600-4700: channel is straightened within a decent riparian corridor and there is little substrate variability, woody habitat, or channel dimension variability. The existing earthen berms could be extended on both sides of the channel to limit stormwater flow to the channel. Within the riparian corridor, the low-flow channel could be narrowed using large wood installations. This could be supplemented with construction of riffle-pool sequences to provide habitat variability.

Stn 600: 2, 14-inch concrete pipes under farm road are perched, undersized, and not fully functional as low flows go underneath the pipes. Culverts should be replaced with large culverts if the road is still necessary. A stabilized gravel/cobble ford could also replace the culverts.

Stn 850: 2, 14-inch pipes are not fully functional as they are undersized, partially buried, and trees are obscuring the outlet. This farm road does not appear active and may be redundant to the one at Stn 600. Remove pipes and crossing.

Channel Reconnaissance Form

Date	July 17, 2011
Stream/Drainage	Middle Creek Tributary 1
Stream Reach ID	Reach 2
Field Team	NN

Station	5700	**To**	7400

General Channel Conditions

Channel Shape (check)
- ☐Rectangular
- ☐Shallow Rectangular
- ☐Irregular
- ☐Trapezoidal
- ☐Parabolic
- ☒Other __stormwater basins_____________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	NA
Bed	Sand and silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: series of in-channel stormwater basins				
Lateral stability *deposition, erosion*	Stable - no active flow				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☐Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks slope gradually to houses and yards				
Terrace/Valley	*Valley form* – generally flat with some rolling hills	*Land Use* – Residential			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 5700: 2-ft concrete pipe with trash grate under path to stormwater basin Stn 6400: pipes under new development road connecting 2 stormwater basins				
Bankfull/Channel forming flow indication	NA				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	Sand and fines
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	Ponds are 200-300 ft wide
Canopy coverage (%)	<2%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	x
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	90%
woody species	10%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Willows on edges of pond	~100

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

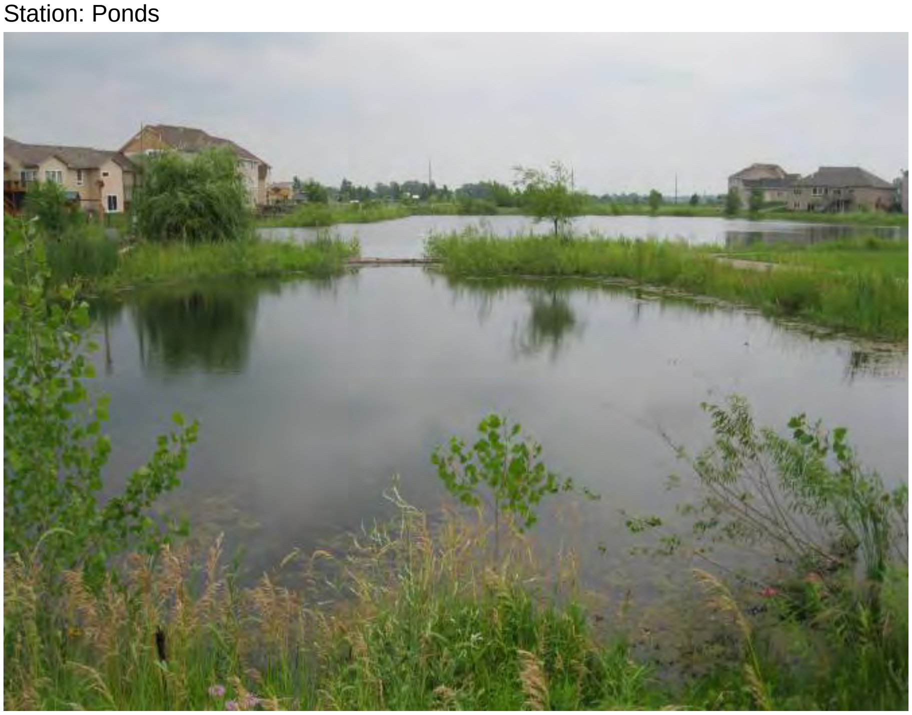
LWD density (pieces / 100 ft)	NA	General Habitat Notes: Good pond habitat with no downstream fish passage due to vertical pipe at outlet of basins.
Residual pool depth	Pond depth unknown	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	
Channel pattern	Single thread		Single thread		Multiple thread/braided	
Average bank slope	<3:1		>3:1			
Vegetative bank protection	Poor		Extensive		Poor	
Field stability rating (add all cells)/9		**= NA**				

Representative cross-section sketch		
Bankfull width = NA Bankfull depth = NA	Floodplain width = NA	Water depth (at survey) = NA Water width (at survey) = NA

Station: Ponds



GENERAL REACH NOTES

Reach 2 of Middle Creek Tributary 1 consists of multiple stormwater basins within residential developments. The outlet is a vertical pipe with a trash grate which is high enough to capture the water from most storm events and minimize the amount of water released downstream.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	July 13, 2011
Stream/Drainage	Middle Creek Tributary 2
Stream Reach ID	Reach 1
Field Team	NN, DB

Station 0 **To** 3100

General Channel Conditions

Channel Shape (check)
☒Rectangular
☐Shallow Rectangular
☐Irregular
☒Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	NA
Bed	Sand and silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Currently stable: channel was historically straightened into a deep ditch. No visible knickpoints.				
Lateral stability *deposition, erosion*	Stable - straightened ditch with no bank erosion				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks are nearly vertical and composed of silty loam with grasses growing on top				
Terrace/Valley	*Valley form* – wide and flat	*Land Use* – Agriculture with some industry in headwaters			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 150: 3-ft corrugated metal pipe under farm crossing				
Bankfull/Channel forming flow indication	Bankfull: change in slope and vegetation growth; channel forming: vegetation growth, occasional undercut banks				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	Sand and fines
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	<30 ft
Canopy coverage (%)	0%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	100%
woody species	0%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

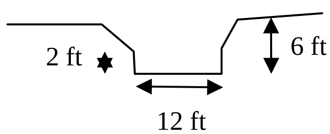
LWD density (pieces / 100 ft)	0	General Habitat Notes: Some undercut banks and overhanging grasses provide in-stream shelter. The water is cold suggesting it is receiving ground water through seeps. Aquatic vegetation is prevalent. Because of the cold water, this tributary could offer cold-water fisheries habitat with some restoration activities.
Residual pool depth	1-2 ft	
Undercut bank frequency	Low	
Riffle / Other frequency	0	

Channel Stability Form

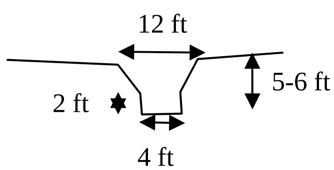
Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9		**= 22/8 = 2.8**				

Representative cross-section sketch		
Bankfull width = 12/4 ft Bankfull depth = 2 ft	Floodplain width = 0 ft	Water depth (at survey) = 1-2 ft Water width (at survey) = 12/4 ft

Station: 300



Station: 900



GENERAL REACH NOTES

Middle Creek Tributary 2 extends 3100 ft from Easter Ave to Middle Creek at Stn 7550. This is a small tributary that is a straightened ditch through wetland and agriculture fields. While water temperatures are warm and overhanging grasses provide some cover, there is little substrate variability, canopy cover, in-stream habitat features, or variability in channel geometry or planform. Upstream of Stn 800, there may be an opportunity to restore the channel through the open fields and wetlands between the agriculture fields and the commercial complexes. Restoration could entail increasing the sinuosity, creating multiple side channels to tap into the groundwater seeps, installing large woody habitat features, creating backwater habitat and riffles and pools, and providing canopy cover

POTENTIAL PROJECTS

Stn 0-3100 entire reach: straightened ditch through wetland and agriculture fields. Cold water presents the opportunity to restore this small tributary to provide cold-water fisheries habitat. Within the agriculture fields, an increased riparian buffer would provide some room to install large woody habitat features to initiate riffle-pool development and some variability in channel geometry. Upstream of Stn 800, the channel could be reconstructed into a sinuous wetland channel with multiple channels, woody habitat features, deep pools, undercut banks, and backwater habitat. Tapping into the cold groundwater would be very important.

Channel Reconnaissance Form

Date	July 17, 2011
Stream/Drainage	Middle Creek Tributary 3
Stream Reach ID	Reach 1
Field Team	NN

Station | 0 | **To** 2800 |

General Channel Conditions

Channel Shape (check)
☐Rectangular
☐Shallow Rectangular
☒Irregular
☒Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	NA
Bed	Sand and silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Currently stable: wetland channel between stormwater basins that outlets to a large wetland				
Lateral stability *deposition, erosion*	Stable - wetland channel with no erosion				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☐Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks within the residential neighborhood slope up to berms and yards at 1:1 or more gradual. Heavily vegetated with wetland grasses and forbs				
Terrace/Valley	*Valley form* – wide and flat	*Land Use* – Residential			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 850: 2-ft concrete pipe with trash grate under 206th St W; overflow pipe is 4 ft higher Stn 2850: pipe under 203rd St W between large wetland and the constructed channel downstream				
Bankfull/Channel forming flow indication	NA				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	Sand and fines
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	100-150 ft
Canopy coverage (%)	<5%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	x
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	98%
woody species	2%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Willow	100

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

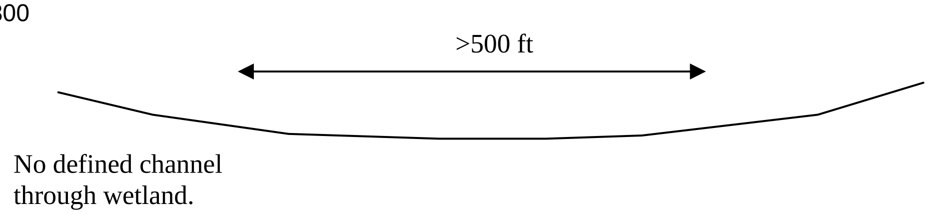
LWD density (pieces / 100 ft)	0	General Habitat Notes: Good wetland habitat with thick cover from cattails, other grasses, and duckweed. Rushes and sedges are also prevalent in some of the less saturated areas.
Residual pool depth	1-2 ft	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

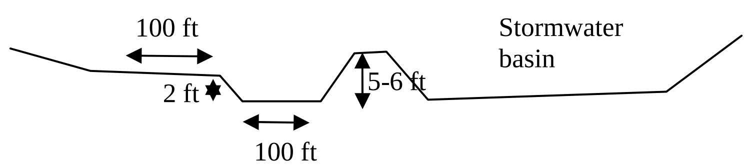
Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	4
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9		**= 24/8 = 3**				

Representative cross-section sketch		
Bankfull width = NA/>100 ft Bankfull depth = NA/2 ft	Floodplain width = NA/100 ft	Water depth (at survey) = 1-2 ft Water width (at survey) = NA/100 ft

Station: 300



Station: 1200



GENERAL REACH NOTES

Middle Creek Tributary 3 extends 2800 ft from a large wetland to Middle Creek at Stn 10,850. Between the large wetland upstream and the large wetland at the confluence with Middle Creek, a wide wetland channel was constructed between residential developments. The channel is filled with wetland vegetation, primarily cattails, and is separated from stormwater basins by earthen berms. While fish passage to the large wetland upstream may be difficult due to low water depths, the remainder of the reach provides excellent wetland habitat.

POTENTIAL PROJECTS

Middle Creek Tributary 4

GENERAL REACH NOTES

A detailed field investigation was not completed for Middle Creek Tributary 4, which extends 5900 ft from a farm field near the junction of Lakeville Blvd and Pilot Knob Rd to Middle Creek at Stn 11,500. The channel through the entire reach has been straightened and ditched. Downstream of Stn 2500, the channel joins a wide wetland with Middle Creek and it is difficult to find a defined channel in places. The Pilot Knob Rd prism blocks complete floodplain/wetland access and all flows appear to be forced to Middle Creek and under the four box culverts. This wetland, although containing straightened channels, provides good wetland habitat with many grasses, sedges, cattails, willows, and plenty of cover for in-stream species. Upstream of Stn 2500, the channel is between farm fields but a 20-50-ft buffer on either side has been maintained. Between Stn 2500 and 4000 this buffer is mixed grasses and trees and upstream of Stn 4000 the buffer is primarily grasses. Upstream of Stn 4000, however, the channel is likely a shallow swale in the ground and does not contain water year round.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	July 14, 2011
Stream/Drainage	Middle Creek Tributary 5
Stream Reach ID	Reach 1
Field Team	NN, DB

Station 0 **To** 5500

General Channel Conditions

Channel Shape (check)
☐Rectangular
☐Shallow Rectangular
☒Irregular
☒Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	NA
Bed	Sand and silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Currently stable: immediately downstream of Flagstaff Ave, the channel appears to have been historically incised or dug. Downstream of this point, there is no defined channel within a wide wetland. Upstream of Flagstaff Ave, stormwater basins capture flows and prevent vertical instability upstream of this point.				
Lateral stability *deposition, erosion*	Stable - wetland channel with no erosion				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks were only observed immediately downstream of Flagstaff Ave. These banks were nearly vertical and fine-grained and covered in grassy vegetation. Downstream of the farm buildings no channel or channel banks were visible.				
Terrace/Valley	*Valley form* – wide and rolling	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 4500: 2-ft flared concrete pipe under Flagstaff Ave Stn 4500-5500: stormwater basins for school and parking lots				
Bankfull/Channel forming flow indication	NA for much of the channel; vegetation immediately downstream of Flagstaff Ave				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	Sand and fines
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	200-700 ft
Canopy coverage (%)	30% of the wetland

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	x
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	60%
woody species	40%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community
Willow	80
Cottonwood	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

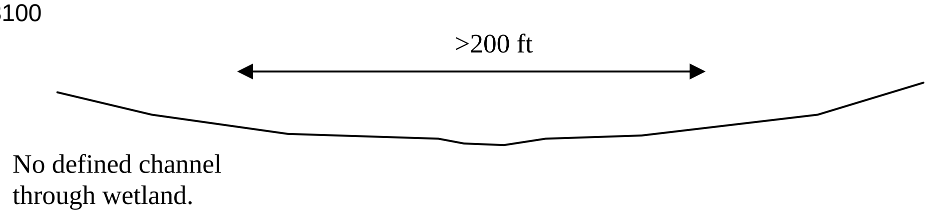
LWD density (pieces / 100 ft)	0	General Habitat Notes: Stream receives minimal water with the stormwater basins upstream. Habitat is in the form of wetland habitat and this is good - good cover and shelter and farms are not close to the stream.
Residual pool depth	<1 ft	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

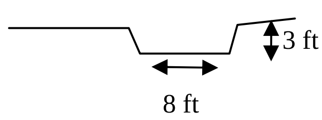
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	
Channel pattern	Single thread		Single thread		Multiple thread/braided	
Average bank slope	<3:1		>3:1			
Vegetative bank protection	Poor		Extensive		Poor	
Field stability rating (add all cells)/9		**= NA**				

Representative cross-section sketch		
Bankfull width = NA/>100 ft Bankfull depth = NA/2 ft	Floodplain width = NA/100 ft	Water depth (at survey) = 1-2 ft Water width (at survey) = NA/100 ft

Station: 3100



Station: 4300



GENERAL REACH NOTES

Middle Creek Tributary 5 extends 5500 ft from a new stormwater basin near a new school to Middle Creek at Stn 16,100. The new stormwater basin prevents excessive stormwater from entering the stream channel. Downstream from Flagstaff Ave, Tributary 5 is primarily an undefined channel through a wide, well-vegetated wetland. The channel becomes defined from the farm buildings at station 3500 to Flagstaff Ave at Stn 4400. In general, this tributary provides good wetland habitat and riparian habitat with a wide buffer from crops.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	July 14, 2011
Stream/Drainage	Middle Creek Tributary 6
Stream Reach ID	Reach 1
Field Team	NN, DB

Station | 0 | **To** 6800 |

General Channel Conditions

Channel Shape (check)
☒Rectangular
☐Shallow Rectangular
☐Irregular
☒Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	NA
Bed	Sand; some gravel and silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Multiple small knickpoints throughout. 3.2-ft concrete weir/dam at Stn 1400 prevents additional migration of knickpoint upstream. The knickpoints observed are active and generally slowed by tree roots in and adjacent to the channel.				
Lateral stability *deposition, erosion*	Generally stable, though some erosion throughout, particularly where cattle grazing is unrestricted in and around the channel between Stn 1400 and 2500.				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks are nearly vertical downstream of Stn 1300 and upstream of Stn 2500. Between these points, the banks are more gently sloped, likely due to cattle grazing throughout. Bank material is sily loam with mostly grassy vegetation on top.				
Terrace/Valley	*Valley form* – wide and rolling	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 1300: 6-ft flared concrete pipe under Flagstaff Ave with ~3 ft of debris blocking the pipe on the upstream end Stn 1400: 3.2-ft high concrete block weir/dam likely for grade control				
Bankfull/Channel forming flow indication	Vegetation, exposed roots				

Sediment Impacts

Riffle sediment type	Small gravel	Pool sediment type	Sand and fines
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	Fine silt/clay

Riparian Vegetation and Floodplain

Root coverage of banks (%)	80%
Width of veg. riparian corridor*	20-50 ft
Canopy coverage (%)	10%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	70%
woody species	30%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community
Willow	45
Cottonwood	45
Box elder	10

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*
~400	Cottonwood	~100	Huge cottonwoods up to 4 ft DBH are growing 3-4 ft above bed on narrow bench

Habitat

LWD density (pieces / 100 ft)	<1	General Habitat Notes: Likely not enough flow to provide substantial aquatic habitat. The channel has been straightened and generally there are severe impacts from grazing and agriculture. In parts, however, canopy cover and grass cover is substantial and in the lower section, some small riffles exist.
Residual pool depth	<1 ft	
Undercut bank frequency	Low	
Riffle / Other frequency	Low	

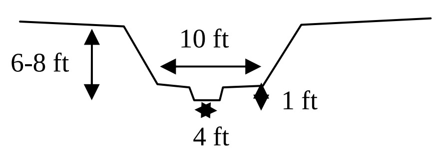
Channel Stability Form

Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed	2	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 22/9 = 2.4**				

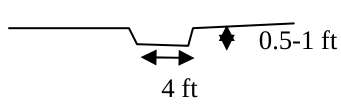
Representative cross-section sketch

Bankfull width = 6/>100 ft Bankfull depth = 1/2 ft	Floodplain width = 3/100 ft	Water depth (at survey) = <0.5 ft Water width (at survey) = 4/100 ft

Station: 150



Station: 1700



GENERAL REACH NOTES

Middle Creek Tributary 6 extends 6800 ft from a fields near the junction of Cedar Ave and 200th St W to Middle Creek at Stn 21,000. Tributary 6 is a channelized ditch through agricultural fields. While there is little quality habitat, year-round flows are low and may not sustain many aquatic species anyway. However, ground water seeps were observed to be flowing overland into the stream, so some year-round flow is likely and these seeps are able to provide cold water to the stream. Multiple knickpoints were observed upstream of the concrete dam at Stn 1400. These knickpoints were active but slowed at tree roots. The dam prevents further knickpoint migration, but also prevents any fish passage. Unrestricted cattle grazing upstream of Stn 1400 results in some bank erosion and decreased water quality, but the bank erosion is not severe. Upstream of Stn 2800, little canopy and little riparian buffer protect the stream from the row crops on either side. Historically, these streams were likely swales in the hillslopes that drained rainwater after storms.

POTENTIAL PROJECTS

Entire reach: has been straightened into a ditch historically - little opportunity for geomorphic or habitat complexity

Stn 500-1200 - little canopy cover, though grasses help to shade

Stn 1300: 6-ft flared concrete pipe with trash grates under Flagstaff Ave - fish passage barrier due to debris piled up multiple feet on both ends

Stn 1400: 3.2-ft high concrete dam/weir is about 12 ft long across the channel - part of this has broken and fallen into the stream. This likely was built to prevent further knickpoint migration, but it is also a fish passage barrier. Could replace with a series of steps-pool sequences.

Stn 1600: 2-knickpoint stopped at willow roots. Regrade and stabilize with riffles

Stn 2150, 2300, 2425: 0.5-ft knickpoints stopped at willow

Stn 2400: concrete steps in channel - remove from channel

Stn 1400-2500: unrestricted cattle grazing causing some bank erosion and poor water quality. Provide a buffer of 10-15 ft on either side of the channel with one or two crossings for the cattle.

Channel Reconnaissance Form

Date	July 17, 2011
Stream/Drainage	Middle Creek Tributary 7
Stream Reach ID	Reach 1
Field Team	NN

Station | 0 | **To** 1550

General Channel Conditions

Channel Shape (check)
☒Rectangular
☐Shallow Rectangular
☐Irregular
☒Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	NA
Bed	Sand and silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Channel was straightened and deepened into a ditch. It is incised 3-4 ft though no active knickpoints were observed.				
Lateral stability *deposition, erosion*	Generally stable.				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Banks are nearly vertical and heavily vegetated with grasses. Bank material is primarily silty loam.				
Terrace/Valley	*Valley form* – wide with rolling hills	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 1550: 2, 8x6-ft concrete box culverts under Flagstaff Ave. Good condition though flood on July 15 overtopped the culverts but not the road. Some riprap moved downstream				
Bankfull/Channel forming flow indication	Vegetation				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	NA
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	Fine silt/clay

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	20-30 ft
Canopy coverage (%)	0%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	100%
woody species	0%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

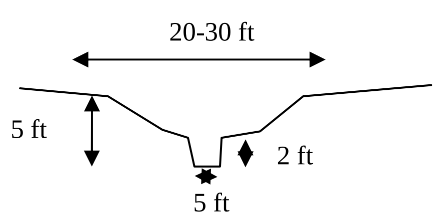
LWD density (pieces / 100 ft)	0	General Habitat Notes: With summer water temperatures at 66°F upstream of this reach, the water temperature can likely support cool water fish species if there are pockets of refugia supplied by cold ground water. However, little habitat exists in this reach as there is no canopy cover and little geomorphic complexity. Channel geometry is the same throughout with consistent runs/glides and no good riffles and pools. Some instream cover is provided by overhanging grasses and some undercut banks. Buffer is minimal.
Residual pool depth	NA	
Undercut bank frequency	Mod	
Riffle / Other frequency	Runs/glides	

Channel Stability Form

Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed	2	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 22/9 = 2.4**				

Representative cross-section sketch		
Bankfull width = 5 ft Bankfull depth = 2 ft	Floodplain width = 5 ft	Water depth (at survey) = 1 ft Water width (at survey) = 5 ft

Station: 1300



Station:

GENERAL REACH NOTES

Reach 1 of Middle Creek Tributary 7 extends 1550 ft from a Flagstaff Ave to Middle Creek at Stn 22,650. This portion of Tributary 7 is a channelized ditch through agricultural fields. While overhanging grasses and some undercut banks provide some in-stream cover and habitat, there is little geomorphic or habitat complexity. The channel dimensions are fairly consistent throughout with little change in bed substrate or channel type. This reach is primarily made up of runs/glides with few or no deep pools or riffles. There is no canopy cover, no woody habitat and few areas for fish and other aquatic organisms to find refuge during flood flows. The flood on July 15 resulted in water spreading out onto the fields in the lower half of this reach.

POTENTIAL PROJECTS

Entire reach: has been straightened into a ditch historically - little opportunity for geomorphic or habitat complexity. Increase riparian buffer, raise the channel bed and allow the channel to migrate and flood its floodplains. Plant native trees and shrubs.

Channel Reconnaissance Form

Date	July 17, 2011
Stream/Drainage	Middle Creek Tributary 7
Stream Reach ID	Reach 2
Field Team	NN

Station 1550 **To** 7750

General Channel Conditions

Channel Shape (check)
☒Rectangular
☐Shallow Rectangular
☐Irregular
☒Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam, clay
Bars	Fine sand
Bed	Sand and silt

Bar Types: ☒Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Portions of the channel in these reach are incised 3-4 ft, while other portions are not incised at all. Vertical incision through clay and fine silt is active downstream of the 190 St W bridge at ~Stn 7500				
Lateral stability *deposition, erosion*	Generally stable, though there is some lateral erosion where active incision is occurring.				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: The bank height and material vary considerable in this reach. Incised portions have steep, nearly vertical banks with fine silt and clay. Other portions have low, gradual banks leading to active floodplains. All are vegetated on top. Where the channel is incising through clay and fine silt near Stn 7500, cold ground water is seeping out of the banks.				
Terrace/Valley	*Valley form* – wide with rolling hills	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 1550: 2, 8x6-ft concrete box culverts under Flagstaff Ave. Good condition though flood on July 15 overtopped the culverts but not the road. Some riprap moved downstream Stn 4550: 6-ft corrugated pipe under 190th St W. Undersized with debris piled up following the high water on 7/15. The 7/15 flows overtopped the road with evidence of erosion on the downstream end Stn 7750: 6-ft concrete pipe under 190th St W. Good condition, but very steep. Lower half is backwatered by riprap knickpoint, but upstream half is fast - potential fish passage barrier.				
Bankfull/Channel forming flow indication	Vegetation, undercut banks, exposed roots				

Sediment Impacts

Riffle sediment type	Compacted clay; riprap; gravel	Pool sediment type	Silt, clay
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	Fine sand/silt
Mid, alternate, braided	Lateral
Bar Vegetation (type, age)	Young grasses
Floodplain soils	Silty loam underlain by clay
Overbank deposition	Fine silt/clay

Riparian Vegetation and Floodplain

Root coverage of banks (%)	85%
Width of veg. riparian corridor*	150-300 ft
Canopy coverage (%)	10%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	85%
woody species	15%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community
Box elder	80
Willow - large	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

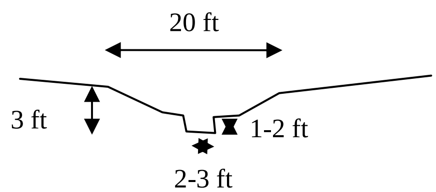
LWD density (pieces / 100 ft)	<1	General Habitat Notes: Relatively sinuous planform that has the ability to migrate and change channel dimensions. Overhanging grasses provide some in-channel cover, though there is minimal canopy cover or woody habitat in the channel. Cold water is emanating from the channel banks in some areas, providing good cool-water conditions. Slightly variable substrate and the pools and riffles provide decent habitat.
Residual pool depth	1 ft	
Undercut bank frequency	Mod	
Riffle / Other frequency	Mod	

Channel Stability Form

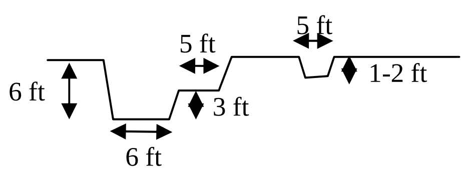
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed	2	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9	**= 20/9 = 2.2**					

Representative cross-section sketch		
Bankfull width = 5/8 ft Bankfull depth = 2/3 ft	Floodplain width = 10/5 ft	Water depth (at survey) = 1/1 ft Water width (at survey) = 3/6 ft

Station: 4300



Station: 7300



GENERAL REACH NOTES

Reach 2 of Middle Creek Tributary 7 extends 6200 ft from a 190th St W to Flagstaff Ave. This portion of Tributary 7 is relatively sinuous with variable channel dimensions throughout. While the channel is incision about 3 ft at the downstream end of the reach, the channel becomes less incised moving upstream, until there is essentially no incision near the 190th St W crossing. In this area, the channel winds through a wide wetland valley with excellent buffer width from farms. Although the adjacent ground surface is 3-8 ft above the bed of the channel, this surface remains wet from ground water seeps. The habitat is decent through this section with a large percentage of canopy cover coming from overhanging grasses and some undercut banks. There are a few canopy species, but more would improve canopy cover and large woody habitat recruitment. A few trees in the downstream end have fallen and their root balls provide excellent shading and pool habitat. Upstream of 190th St W continues to maintain a good grassy buffer, but the channel goes through an area of open grazing which results in increased bank erosion and lower water quality. The channel through this area is a very shallow channel in the bottom of a wide valley so the bank erosion is not as dramatic. Upstream of Stn 6600, the channel is incised through forest. This portion of the river has good canopy cover and some good, variable instream habitat, but it is incised through fine silt and clay and the clay banks are eroding.

POTENTIAL PROJECTS

Stn 1800-6600: Decent wetland habitat, but could be improved with the growth of trees and shrubs - this does not mean a dense forest, but scattered trees and shrubs would provide additional canopy cover for shade and shelter.

Stn 1800-4500: The channel is incised in the lower half of this section of river. This portion could be raised with grade control structures or the channel could be rebuilt as a very sinuous channel using more of the width that is available in this reach. This would allow for floodwaters to actively flood the floodplain and wetlands and would also provide grade control.

Stn 4550: 6-ft corrugate metal pipe is undersized and has resulted in overtopping the dirt road leading to rilling and erosion.

Stn 5500-6600: open grazing through channel and wetland decreases water quality and increases bank erosion. Develop buffer with fencing to keep cows out except at certain crossings.

Stn 6800-7600: excessive incision up to 5 ft has occurred. There is a 2-ft knickpoint at ~Stn 7600 about 100 ft downstream of the 190th St W crossing. This knickpoint is where grouted riprap failed and has piled up downstream from its intended location. Raise and widen the channel through this area to accommodate larger flows. Install grade controls to prevent further incision.

Stn 7750: 6-ft concrete pipe under 190th St W is steep on the upstream end of the culvert. This is likely a partial fish passage barrier.

Channel Reconnaissance Form

Date	July 16, 17, 2011
Stream/Drainage	Middle Creek Tributary 7
Stream Reach ID	Reach 3
Field Team	NN

Station 7750 **To** 14,700

General Channel Conditions

Channel Shape (check)
☒Rectangular
☐Shallow Rectangular
☒Irregular
☐Trapezoidal
☐Parabolic
☐Other ______________

Sediment Particle Size Estimate	
Banks	Silty loam, clay
Bars	NA
Bed	Sand and silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Generally stable though a few active knickpoints near road crossings indicates downcutting is till occurring and will increase if it moves through the crossing areas.				
Lateral stability *deposition, erosion*	Stable				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Portions of this reach have defined, steep banks, but much of this reach consists of a relatively undefined channel with minimal banks. The sediments in this region are generally fine silt and clay. Most of this reach has vegetation growing top of any existing banks or adjacent to the channel				
Terrace/Valley	*Valley form* – wide with rolling hills	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 7750: 6-ft concrete pipe under 190th St W. Good condition, but very steep. Lower half is backwatered by riprap knickpoint, but upstream half is fast - potential fish passage barrier. Stn 7850: 3-ft corrugated metal pipe under farm road with rounded cobbles and the downstream end Stn 8500: 2, 4-ft concrete pipes under Cedar Ave Stn 12,300, 12,600, 12,800, 13,000, and 13,600 are small private property crossings not evaluated				
Bankfull/Channel forming flow indication	Vegetation				

Sediment Impacts

Riffle sediment type	Sm gravel	Pool sediment type	Silt, clay
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam underlain by clay
Overbank deposition	Fine silt/clay

Riparian Vegetation and Floodplain

Root coverage of banks (%)	95%
Width of veg. riparian corridor*	30-100 ft
Canopy coverage (%)	15%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	x
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	85%
woody species	15%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community
Willows	~100%

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	0
Residual pool depth	<1 ft
Undercut bank frequency	Low
Riffle / Other frequency	Low

General Habitat Notes: There is little viable in-stream habitat in this reach due to the fragmentation and lack of canopy cover and large woody recruitment. The road crossings and diffuse channel across fields do not provide for adequate fish passage or in-stream habitat. However, through much of this reach, the buffer is of an acceptable width and thus provides some drainage and seepage opportunity for farm runoff.

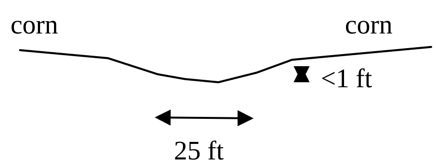
Channel Stability Form

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	4
Bar development	Poorly formed		Narrow, vegetated	3	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1		>3:1	3		
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 26/9 = 2.9**				

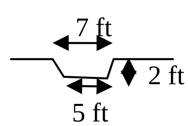
Representative cross-section sketch

Bankfull width = 7 ft Bankfull depth = 1/2 ft	Floodplain width = 40/10 ft	Water depth (at survey) = 1/1 ft Water width (at survey) = 20/5 ft

Station: 11,800



Station: 13,900



GENERAL REACH NOTES

Reach 3 of Middle Creek Tributary 7 extends from close to Highview Ave to 190th St W. This portion of Tributary 7 is Primarily a straightened ditch or swale in the valley bottom between fields. Much of the reach has cover from willow trees and good riparian buffer of grasses. However, because the valley bottom is so flat and the farming continues into the valley bottom, the channel location in some places around Stn 11,000 has moved from within the vegetated wetland buffer to the first couple rows of corn. This is resulting in a slightly incise channel through the rows of corn. With regrading, this could be remedied. The headwaters consists of multiple dams and small private ponds segmenting the channel.

POTENTIAL PROJECTS

Stn 8550: 2, 4-ft concrete pipes under Cedar Ave. A 2-ft knickpoint on the downstream end as water flows over riprap and a 2-ft knickpoint on the upstream end at the edge of the field suggest some vertical instability is active. Below the culvert the channel is deeply incised (4-5 ft). Because fish passage here would not open up a large amount of high quality habitat, the area between Stn 7750 and 8400 could be converted into a stormwater basin if the landowner is willing to part with their corn field. This would limit the impact of the downstream knickpoint and provide some storage. On the upstream end, regrading and the potential creation of an actual channel may improve conditions.

Stn 10,450-11,500: Channel has moved into the corn field and out of the wide riparian area. The channel is a trench between corn rows. Either increase buffer or redirect water back into channel and recreate channel to keep it in the preferred location. A small drainage from the south at Stn 11,550 has deposited a lobe of fines that has likely pushed the channel into the fields downstream. Could heavily vegetate that drainage so the soils are not as easily washed away.

Stn 13,950: 2-ft knickpoint over clay about 10 ft downstream of corrugated metal pipe under 190th St W. Has the potential to move upstream and impact the crossing.

Channel Reconnaissance Form

Date	July 17, 2011
Stream/Drainage	Middle Creek Tributary 7A
Stream Reach ID	Reach 1
Field Team	NN

Station 0 **To** 6050

General Channel Conditions

Channel Shape (check)
☒Rectangular
☐Shallow Rectangular
☐Irregular
☒Trapezoidal
☒Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Silty loam, clay
Bars	silt
Bed	Silt/clay; occasional sand and gravel

Bar Types: ☒Alternate lateral ☒Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Likely historically straightened and deepened, this channel is continuing to actively incise with multiple knickpoints observed in the channel and on some adjacent drainages. The channel is likely about 6 ft lower than historical levels.				
Lateral stability *deposition, erosion*	Actively eroding banks and slope failures due to incision and channel migration.				
Erosion (excessive/site specific)	Stn 850, 1150: outer bank erosion Stn 5750-5950: recently incised with active bank erosion - bare banks and cloudy water downstream				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: channel banks are generally steep and composed of consolidated fine silt and clay. The channel has adjusted to historic deepening or incision to form 1-2-ft banks in some places; elsewhere, incision continues and the banks are 3-4 ft; elsewhere, lower banks have not formed and 6-ft banks are eroding. The bank tops are generally well-vegetated.				
Terrace/Valley	*Valley form* – wide and flat	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 6050: 6.5-ft concrete pipe under Cedar Ave; riprap grade control downstream of culvert				
Bankfull/Channel forming flow indication	Vegetation, undercut banks				

Sediment Impacts

Riffle sediment type	Sm gravel	Pool sediment type	Silt, clay
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	Silt
Mid, alternate, braided	Alternate, point
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam underlain by clay
Overbank deposition	Fine silt/clay

Riparian Vegetation and Floodplain

Root coverage of banks (%)	85%
Width of veg. riparian corridor*	30-50 ft
Canopy coverage (%)	0% between Stn 2100 and 5750; 85% elsewhere

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	60%
woody species	40%
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community
Willows	40
Cottonwood	40
Box Elder	15
Ash	5

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

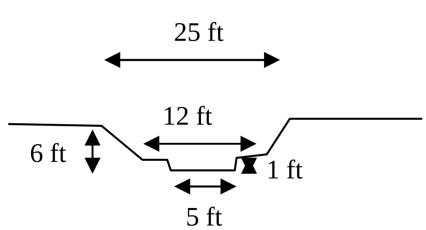
LWD density (pieces / 100 ft)	<1	General Habitat Notes: This is a very small channel with little high-quality habitat. Incision and bank erosion through fine silts and clays results in large volumes of suspended sediment in the water. The portions with trees in the riparian zone have good canopy cover and a wide buffer. These areas do have some geomorphic complexity with eroding outer banks and depositional bars, low floodplains, and some woody debris in the channel for habitat potential. Elsewhere, the channel winds within an incised ditch with only grasses for cover.
Residual pool depth	<1 ft	
Undercut bank frequency	Low	
Riffle / Other frequency	Low	

Channel Stability Form

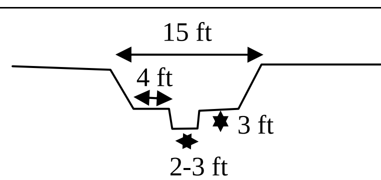
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed	2	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive	2	Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9	**= 19/9 = 2.1**					

Representative cross-section sketch		
Bankfull width = 7/4 ft Bankfull depth = 1-4/3 ft	Floodplain width = 5/4 ft	Water depth (at survey) = <1/1 ft Water width (at survey) = 5/3 ft

Station: 1200



Station: 5300



GENERAL REACH NOTES

Reach 1 of Middle Creek Tributary 7A extends from Cedar Ave to Tributary 7 at Stn 1800. This portion of Tributary 7A was historically straightened and likely deepened to create the existing ditch. The channel adjusted to its geometry over time to create a narrow channel between narrow floodplains within the walls of the ditch. Incision is continuing, however, resulting in excessive bank erosion and suspended sediment. Downstream of Stn 2100, trees provide canopy cover and some woody habitat within an approximately 50-ft riparian corridor. In this section, grasses provide an additional 50-100 ft of buffer between the riparian corridor and the farm fields. As this tributary continues to contribute excessive suspended sediment downstream, the lower portion may provide an opportunity to restore the channel with increased sinuosity, wider floodplains, and some grade control. Upstream of Stn 2100, the buffer width narrows and the riparian vegetation is primarily grasses. The channel through this section is very narrow and entrenched within the straightened ditch with thick grass growth on the banks and slopes of the ditch. Between Stn 5750 and Cedar Ave, incision and bank erosion has resulted in 7-ft exposed clay banks and incision in small drainages entering the channel. The water is cool coming through the culvert as it is essentially ground water from tiling. This cool water (60° F) does present the opportunity to improve cool-water habitat in this reach.

POTENTIAL PROJECTS

Stn 50: 2, 6-inch knickpoints near the confluence are evidence of active incision. These will migrate upstream resulting in continued instability in this reach.

Stn 0-2100: historically straightened and deepened channel is now a ditch. The historic and ongoing incision results in excessive bank erosion through much of this section. The cool water, canopy cover, and wide buffer from the fields presents an opportunity to complete full channel restoration with grade controls, riffles and pools, wider floodplains, and increased sinuosity.

Stn 2100-5750: historically straightened and deepened channel is now a ditch. There is little channel or habitat complexity and no canopy cover, though grasses do provide some cover. The buffer is narrow - about 5-15 ft. For full restoration, increase the riparian buffer, widen the floodplains and raise the channel bed, increase the sinuosity, and plant native riparian tree and shrub species.

Stn 5750-5900: incision has resulted in bank erosion and channel widening. Incision is continuing in drainages from fields and may impact field conditions in the future. Provide toe stabilization and grade control where necessary.

Channel Reconnaissance Form

Date	July 17, 2011
Stream/Drainage	Middle Creek Tributary 7A
Stream Reach ID	Reach 2
Field Team	NN

Station	6050	**To**	11,300

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☒Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	NA
Bars	NA
Bed	Silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable swale between fields				
Lateral stability *deposition, erosion*	Stable swale between fields				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☐Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: No channel banks as this reach is a shallow swale between fields				
Terrace/Valley	*Valley form* – wide and rolling	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 6050: 6.5-ft concrete pipe under Cedar Ave; riprap grade control downstream of culvert				
Bankfull/Channel forming flow indication	NA				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	NA
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	Fine silt

Riparian Vegetation and Floodplain

Root coverage of banks (%)	NA
Width of veg. riparian corridor*	0-30 ft
Canopy coverage (%)	0%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	100%
woody species	
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

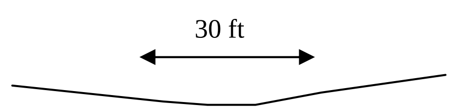
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No habitat as this is a shallow swale between fields.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	
Channel pattern	Single thread		Single thread		Multiple thread/braided	
Average bank slope	<3:1		>3:1			
Vegetative bank protection	Poor		Extensive		Poor	
Field stability rating (add all cells)/9		**= NA**				

Representative cross-section sketch		
Bankfull width = NA Bankfull depth = NA	Floodplain width = NA	Water depth (at survey) = <0.5 Water width (at survey) = 20 ft

Station: 6400



Station:

GENERAL REACH NOTES

Reach 2 of Middle Creek Tributary 7A extends from farm fields to Cedar Ave. This portion of Tributary 7A is primarily a shallow swale between fields with no defined channel. There is little buffer, but for some grasses. This area presents a good opportunity to build a detention or retention basin as the surrounding hills and road prism provide good boundary conditions. This could slow the flow of water downstream that has been contributing to the incision and erosion in the rest of Tributary 7A and Tributary 7.

POTENTIAL PROJECTS

Stn 6200: Upstream of Cedar Ave, Tributary 7A presents no opportunity for in-stream aquatic habitat, yet the watershed upstream of the road delivers volumes of water at rates that result in excessive incision and bank erosion downstream of Cedar Ave. While a loss of agriculture land would be necessary, the area upstream of Cedar Ave could be a good location for a stormwater basin to slow the flow of overland flow to the downstream reaches. The culvert could be retro-fitted with a vertical pipe that would result in a retention or detention pond.

Channel Reconnaissance Form

Date	July 17, 2011
Stream/Drainage	Middle Creek Tributary 7B
Stream Reach ID	Reach 1
Field Team	NN

Station 0 **To** 8000

General Channel Conditions

Channel Shape (check)
☐Rectangular
☐Shallow Rectangular
☒Irregular
☒Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	silt
Bars	silt
Bed	Silt/sand

Bar Types: ☐Alternate lateral ☒Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Generally stable, though 1, 3.5-ft knickpoint indicates active incision.				
Lateral stability *deposition, erosion*	Stable, though near the knickpoint some bank erosion is occurring.				
Erosion (excessive/site specific)	Stn 1350: 3.5-ft knickpoint halted at tree roots				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Generally the banks are low and composed of fine silt.				
Terrace/Valley	*Valley form* – wide and rolling	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 2600: 2-ft concrete pipe under Cedar Ave, partially buried on the downstream side				
Bankfull/Channel forming flow indication	Undercut roots, vegetation				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	Silt
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	Fine sand and silt
Mid, alternate, braided	Alternate point
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	Silt

Riparian Vegetation and Floodplain

Root coverage of banks (%)	95%
Width of veg. riparian corridor*	~150 ft downstream of Cedar Ave
Canopy coverage (%)	90% downstream of Cedar Ave

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	
high = multiple canopy layers	x

Primary veg forms present: (%)

grasses/forbs	80%
woody species	20%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Box elder	80
Willow	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	3
Residual pool depth	<0.5 ft
Undercut bank frequency	Low
Riffle / Other frequency	Low

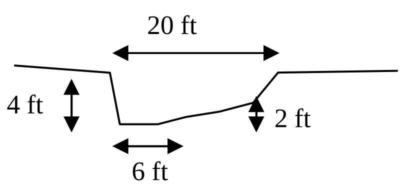
General Habitat Notes: Good canopy cover and cold-water habitat. The knickpoint presents a passage barrier and the open grazing degrades channel habitat and water quality. The area within the forest is relatively healthy for small aquatic organisms.

Channel Stability Form

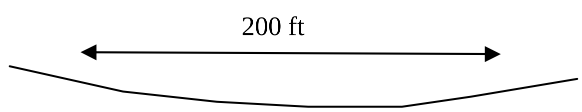
Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed	2	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1		>3:1	3		
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9	**= 24/9 = 2.7**					

Representative cross-section sketch		
Bankfull width = 20/NA ft Bankfull depth = 4/NA ft	Floodplain width = NA/200	Water depth (at survey) = <0.5 ft Water width (at survey) = 6/NA ft

Station: 900



Station: 1800



GENERAL REACH NOTES

Middle Creek Tributary 7B extends from agriculture fields to Stn 6100 of Tributary 7. Downstream of Cedar Ave, the channel is fairly intact with low floodplains and copious canopy cover and woody habitat. Upstream of Cedar Ave, there is no discernable channel. Cold water emanates from under the field and through the culvert under Cedar Ave. This cold water provides an opportunity for good cold-water habitat. A 3.5-ft knickpoint suggests that incision remains an active force and that incision will continue upstream leading to increase sediment loads downstream.

POTENTIAL PROJECTS

Stn 0-700: open grazing through channel with no canopy cover and barely a channel. Prevent livestock from grazing within a specific buffer width.

Stn 1350: 3.5-ft knickpoint is currently stopped at tree roots, but is likely to continue if it works through the roots. If allowed to continue, this migrating knickpoint will continue to increase sediment loads downstream and could eventually impact the Cedar Ave crossing.

Channel Reconnaissance Form

Date	July 14, 16, 2011
Stream/Drainage	Middle Creek Tributary 8
Stream Reach ID	Reach 1
Field Team	NN, DB

Station	0	**To**	6100

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☒Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	NA
Bars	NA
Bed	Silt

Bar Types: ☐Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☒None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: undefined channel or shallow swale between fields				
Lateral stability *deposition, erosion*	Stable: undefined channel or shallow swale between fields				
Erosion (excessive/site specific)	NA				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☐Undercut / cantilever	☐Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: No channel banks as the channel is either undefined or is a shallow swale between fields.				
Terrace/Valley	*Valley form* – wide and rolling	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 500: 3-ft corrugated metal pipe under farm road Stn 650: 2, 4-ft flared concrete pipes under Cedar Ave with grouted riprap on banks and riprap at the mouth Stn 4825: 2-ft corrugated metal pipe under farm road - new and may have replaced old pipe/road that blew out Stn 4900: 2, 2-ft corrugated metal pipe under Dodd Blvd Stn 5000: 2-ft concrete pipe with trash grate is the outlet pipe from stormwater basin Stn 5000-5500: stormwater basin				
Bankfull/Channel forming flow indication	NA				

Sediment Impacts

Riffle sediment type	NA	Pool sediment type	NA
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	NA
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	Fine silt

Riparian Vegetation and Floodplain

Root coverage of banks (%)	NA
Width of veg. riparian corridor*	0-30 ft
Canopy coverage (%)	0%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	100%
woody species	
bare/other	
Exotic/invasive species	Reed canary grass

Woody Species present	% of total tree community

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

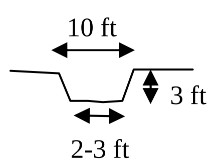
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No habitat as this is primarily an undefined channel or shallow swale between fields.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

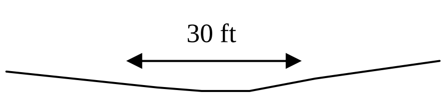
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	
Channel pattern	Single thread		Single thread		Multiple thread/braided	
Average bank slope	<3:1		>3:1			
Vegetative bank protection	Poor		Extensive		Poor	
Field stability rating (add all cells)/9	**= NA**					

Representative cross-section sketch		
Bankfull width = 10 ft Bankfull depth = 3 ft	Floodplain width = 15-30 ft	Water depth (at survey) = <0.5 ft/0 ft Water width (at survey) = 3/0 ft

Station: 400



Station: 1500



GENERAL REACH NOTES

Middle Creek Tributary 8 extends 6100 ft from stormwater basins north of Dodd Blvd through agriculture fields to Middle Creek Stn 38,100. This tributary is primarily an undefined channel or shallow swale between fields with no aquatic or riparian habitat. Downstream of Cedar Ave, between Stn 0 and 550, a small defined channel does exist providing minor amounts of habitat connected to Middle Creek. Middle Creek at this location is intermittent and provides minimal habitat itself.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	July 16, 18, 2011
Stream/Drainage	Middle Creek Tributary 9
Stream Reach ID	Reach 1
Field Team	NN

Station	0	To	2550

General Channel Conditions

Channel Shape (check)
☒Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

Sediment Particle Size Estimate	
Banks	Clay/silt
Bars	gravel
Bed	Gravel/cobble over clay

Bar Types: ☒Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Incised about 4 ft - may not be currently actively incising, but the channel is now eroding laterally.				
Lateral stability *deposition, erosion*	Bank erosion occurring as the channel is widening in response to the incision				
Erosion (excessive/site specific)	Entire reach is widening				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Steep, tall banks devoid of vegetation as the channel widening is actively occurring following incision. The banks are primarily composed of clay with about 1 ft of silt loam on top.				
Terrace/Valley	*Valley form* – wide and rolling	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 2550: 4x6-ft concrete culvert with rounded top. Riprap along bed and banks on both ends				
Bankfull/Channel forming flow indication	Undercut banks and roots				

Sediment Impacts

Riffle sediment type	Gravel/cobble	Pool sediment type	Silt/clay
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	Small to medium gravel
Mid, alternate, braided	Lateral and mid
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	50%
Width of veg. riparian corridor*	75-175 ft
Canopy coverage (%)	80%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	
low = single canopy layer	
medium = at least two canopy layers	
high = multiple canopy layers	x

Primary veg forms present: (%)

grasses/forbs	10%
woody species	90%
bare/other	
Exotic/invasive species	Buckthorn

Woody Species present	% of total tree community
Cottonwood	40
Box elder	40
Elm	5
Willow	5

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	5
Residual pool depth	<0.5 ft
Undercut bank frequency	Low
Riffle / Other frequency	mod

General Habitat Notes: Decent habitat for small aquatic organisms as the canopy cover is thick and varied and the channel bed is variable with riffles and pools, gravel beds, glides, and other features. Because of the incision and bank erosion, the trees falling in have provid in-stream habitat.

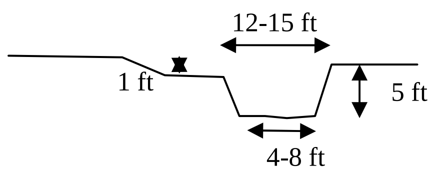
Channel Stability Form

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels	3	Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed	2	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive	2	Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor	1	Extensive		Poor	
Field stability rating (add all cells)/9	**= 18/9 = 2**					

Representative cross-section sketch

Bankfull width = 15 ft Bankfull depth = 4 ft	Floodplain width = NA	Water depth (at survey) = <0.5 ft Water width (at survey) = 8 ft

Station: 2200



Station:

GENERAL REACH NOTES

Reach 1 of Middle Creek Tributary 9 extends 2550 ft from Highview Ave to Middle Creek Stn 41,500. This tributary is primarily a deeply incised and actively widening channel within dense riparian forest. The channel has incised about 4 ft and the historic channel, likely a shallow channel with 1-ft banks, was observed adjacent to the current channel and perched 4 ft above the existing channel. With the excessive erosion, gravel and cobbles have eroded out of the clay banks and are now created gravel bars and riffles in the channel. This infusion of coarser-grained material increases the geomorphic and habitat complexity. Also due to the erosion, the fallen trees provide woody habitat potential. With the wider riparian corridor and thick canopy cover, this reach could present an opportunity for restoration to raise the channel bed, create and widen floodplains, provide grade control, and increase sinuosity.

POTENTIAL PROJECTS

Stn 0-2500: channel is incised about 4 ft and is actively widening with excessive erosion and supply of suspended sediment. Restore channel by raising the channel bed, widening the floodplains, increasing sinuosity, increasing riffle/pool frequency.

Stn 2500: 4x6-ft concrete pipe under Highview Ave is perched 8 inches on the downstream end and the riprap at the mouth has been displaced by large flows with riprap on the banks sliding into the channel. With channel restoration in this reach, this culvert could be protected by the raised bed or by improved grade control downstream of the culvert. This culvert is also long and has a flat bottom, both factors that would create challenges for fish passage.

Channel Reconnaissance Form

Date	July 16, 18, 2011
Stream/Drainage	Middle Creek Tributary 9
Stream Reach ID	Reach 2
Field Team	NN

Station 2550 **To** 7400

General Channel Conditions

Channel Shape (check)

- ☐Rectangular
- ☐Shallow Rectangular
- ☒Irregular
- ☒Trapezoidal
- ☐Parabolic
- ☐Other _______________

Sediment Particle Size Estimate	
Banks	Clay/silt
Bars	sand
Bed	Silt/clay

Bar Types: ☒Alternate lateral ☐Point ☐Mid-channel ☐Transverse ☐None

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Much of this reach is stable - ill-defined swale between fields. However, a 3-ft knickpoint upstream of Highview Ave and a 4.5-ft knickpoint at Stn 5850 indicate that incision is actively occurring.				
Lateral stability *deposition, erosion*	Most of the reach is stable, though in areas of incision, bank failure is also occurring.				
Erosion (excessive/site specific)	Stn 270: 3-ft knickpoint through clay Stn 5850: 4.5 ft knickpoint through clay; associated bank erosion				
Dominant bank erosion types (circle any that apply)	*Fluvial*	☒Undercut / cantilever	☒Selective erosion of noncohesive laters	☐Dry flow	☐Seepage
	Gravitational	☐Rotational	☐Planar	☐Wedge	
Bank composition	*Notes (shape/character)*: Where there is a defined channel, the banks are steep and primarily composed of consolidated whitish clays overlain by silty loam.				
Terrace/Valley	*Valley form* – wide and rolling	*Land Use* – agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 2550: 4x6-ft concrete culvert with rounded top. Riprap along bed and banks on both ends Stn 6050: 8-inch corrugated metal pipe tiling from fields Stn 6100: 1-ft corrugated metal pipe from under fields Stn 7400: 1.5-ft concrete pipe under Dodd Blvd				
Bankfull/Channel forming flow indication	Undercut roots, vegetation				

Sediment Impacts

Riffle sediment type	Sm gravel	Pool sediment type	Silt/clay
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	Sand
Mid, alternate, braided	Lateral
Bar Vegetation (type, age)	NA
Floodplain soils	Silty loam
Overbank deposition	Silt/clays

Riparian Vegetation and Floodplain

Root coverage of banks (%)	95%
Width of veg. riparian corridor*	60-150 ft
Canopy coverage (%)	40%

** Verify with orthoquad data*

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	x
low = single canopy layer	
medium = at least two canopy layers	
high = multiple canopy layers	x

Primary veg forms present: (%)

grasses/forbs	50%
woody species	50%
bare/other	
Exotic/invasive species	Buckthorn

Woody Species present	% of total tree community
Cottonwood	10
Box elder	50
Elm	10
Willow	10
Ash	10

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	5
Residual pool depth	<0.5 ft
Undercut bank frequency	Low
Riffle / Other frequency	mod

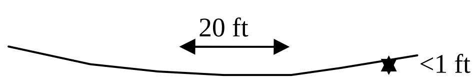
General Habitat Notes: Because portions of this reach do not contain a defined channel, there is no continuous aquatic habitat. However, the water is cool and there are portions with copious canopy cover, good woody habitat, channel sinuosity, and riffles and pools.

Channel Stability Form

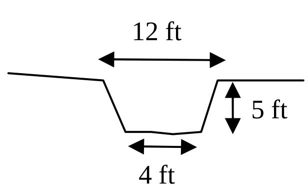
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed	2	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	3	High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1		>3:1	3		
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9		**= 24/9 = 2.7**				

Representative cross-section sketch		
Bankfull width = 20/12 ft Bankfull depth = NA/5 ft	Floodplain width = NA	Water depth (at survey) = <0.5 ft Water width (at survey) = 20/4 ft

Station: 3500



Station: 5600



GENERAL REACH NOTES

Reach 2 of Middle Creek Tributary 9 extends the corn field at Dodd Blvd to Highview Ave. This reach alternates between undefined swales between fields and channels undergoing active incision with defined channels and banks. The riparian buffer between the fields is fairly wide and a portion of this reach is within a forested area with excellent habitat. The active incision could threaten to cause instability in currently stable portions of this reach and could eventually impact farm fields. With the wide buffer and cold water from groundwater sources, this reach provides an opportunity for channel restoration with grade control, increasing channel sinuosity, and increasing channel and habitat complexity.

POTENTIAL PROJECTS

Stn 2700: 3-ft knickpoint through clay will continue to migrate upstream, potentially destabilizing the channel throughout this reach.

Stn 5550: 4-ft knickpoint in drainage from drain tile about 100 ft from the channel and close to the fields. This knickpoint could undermine the tiling and eventually impact the fields.

Stn 5850: 4.5-ft knickpoint over ~30-ft series of drops through clay could continue to migrate, thus destabilizing an intact channel and floodplain complex and potentially impact fields in the future.

APPENDIX E: Potential project forms

Potential Project PP 01

Stream: North Creek, Reach 1	Problem description: Riparian vegetation has been cleared and a mowed lawn is maintained up to, or within 5 ft of, the channel bank. There is no root stabilization of the banks, although bank erosion was not significant. With no riparian buffer, pesticides, herbicides, or fertilizers applied to the lawn may enter the stream, thus degrading water quality.
Station: 1075-1200, right bank	
Solution: Increase riparian buffer by planting native riparian trees, shrubs, and forbs. Native riparian vegetation helps stabilize channel banks and provides canopy cover and in-stream habitat.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	Can use volunteer labor
Location	1	
Sediment/nutrient loading	3	
Project cost	7	Can use volunteer labor
Aesthetic impact	3	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	Near occupied house - likely no opportunity for trail

Project Area Photo/Map Location

(Left to right): Stn 1100 looking upstream; Stn 1100 looking across channel from right bank

Potential Project PP 02

Stream: North Creek, Reach 1	Problem description: Riparian vegetation has been cleared and a mowed lawn is maintained up to the channel bank. There is no root stabilization of the banks and some minor bank erosion was observed. With no riparian buffer, pesticides, herbicides, or fertilizers applied to the lawn may enter the stream, thus degrading water quality. Canopy cover is provided by a few large trees and vegetation on the opposite bank.
Station: 1300-1550, left bank	

Solution: Increase riparian buffer by planting native riparian trees, shrubs, and forbs. Native riparian vegetation helps stabilize channel banks and provides canopy cover and in-stream habitat.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	Can use volunteer labor
Location	1	
Sediment/nutrient loading	3	
Project cost	7	Can use volunteer labor
Aesthetic impact	3	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	5	Just off Chippendale Ave
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	Near occupied house - likely no opportunity for trail

Project Area Photo/Map Location

(Left to right): Stn 1400 looking downstream; Stn 1400 looking upstream

Potential Project **PP 03**

Stream: North Creek, Reach 1	Problem description: Metal foot bridge is structurally insufficient and fallen apart. All the wood planks have washed away and debris has piled on upstream side of bridge. It now presents a barrier to flow and is not aesthetically pleasing.
Station: 2000	
Solution: Remove	

	Score	***Notes***
Infrastructure risk	1	Already failed and no longer being used
Erosion/channel stability	1	
Project complexity	7	Can use volunteer labor
Location	1	
Sediment/nutrient loading	1	
Project cost	7	Can use volunteer labor
Aesthetic impact	3	This is an eyesore, but it is small.
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	1	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	Along potential trail location, but an isolated and small project

Project Area Photo/Map Location

(Below): Stn 1950 looking upstream

Potential Project **PP 04**

Stream: North Creek, Reach 1	Problem description: 4.5-ft corrugated metal pipe is undersized and perched about 1 ft on the downstream end. During moderate and high flows, the velocity is too high for passage and during moderate and low flows the 1-ft drop is too high for fish to jump and water depths in the culvert would be too low. Overtopping of road crossing has caused erosion on the downstream side of road. Debris has become wedged on upstream side of culvert.
Station: 2325	

Solution: Determine the necessity of this crossing and either remove or replace crossing with a more suitable culvert or bridge. If the crossing is necessary, replace existing culvert with much larger bottomless arch culvert or multiple box culverts so that the width is greater than the bankfull width of the stream.

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	1	
Project complexity	5	
Location	1	
Sediment/nutrient loading	1	
Project cost	5	Less expensive to remove than to replace
Aesthetic impact	3	
Fish passage	7	The culvert is acting like a dam for fish and, being close to the mouth, is preventing all passage of fish to upstream waters.
Property Ownership	0	Unknown, possibly a private drive, but active use is unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	3	

Project Area Photo/Map Location

(Left to right): Stn 2300 looking upstream; Stn 2325 looking at erosion on downstream side of crossing; Stn 2350 looking downstream at culvert inlet

Potential Project **PP 05**

Stream: North Creek, Reach 1 Station: 2500-2600, left bank	Problem description: Riparian vegetation has been cleared and a mowed lawn is maintained up to, or within 5 ft of, the channel bank. There is no root stabilization of the banks, although bank erosion was not significant. With no riparian buffer, pesticides, herbicides, or fertilizers applied to the lawn may enter the stream, thus degrading water quality.
Solution: Increase riparian buffer by planting native riparian trees, shrubs, and forbs. Native riparian vegetation helps stabilize channel banks and provides canopy cover and in-stream habitat.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	Can use volunteer labor
Location	1	
Sediment/nutrient loading	3	
Project cost	7	Can use volunteer labor
Aesthetic impact	3	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	Near occupied house - likely no opportunity for trail

Project Area Photo/Map Location

(Left to right): Stn 2600 looking downstream

Potential Project PP 06

Stream: North Creek, Reach 2	Problem description: The channel has been straightened into a ditch with minimal geomorphic complexity (sinuosity, riffles and pools, variable substrate, gravel bars and cut banks, alcoves, backwater channels). While water depth and undercut banks provide the bare essentials for fish to survive, the habitat and water quality are not great. There is little to no canopy cover and with no trees or shrubs near the channel there is no large wood habitat in the channel.
Station: 3,800-7,000, 10,150-16,500	

Solution: The existing wide riparian buffer provides an opportunity to restore natural sinuosity, riparian vegetation, and wetland functionality. A similar solution was recently completed between Stns 7000 and 10,150. Restoring the natural channel planform and functionality upstream and downstream of this restored section would provide expansive in-channel, wetland, and riparian habitat. The cold water documented in the abandoned channels of the restored section should be considered - cold groundwater should be taken advantage of throughout this restoration project by building side channels, alcoves, and backwaters that tap into that cold water. Revegetate with natural riparian trees, shrubs, and forbs.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	7	Improves the functionality of a long section of river; decreases channel slope and reduces energy
Project complexity	1	
Location	3	
Sediment/nutrient loading	7	Sediment and nutrients could be stored on re-activated floodplains following floods
Project cost	1	
Aesthetic impact	7	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	7	
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	7	
Greenway Benefit	7	

Project Area Photo/Map Location

(Left to right): Stn 4400 looking downstream at silt-curtains in channel, Stn 6000 looking downstream at the straight channel


Potential Project PP 07

Stream: North Creek, Reach 2	Problem description: 3.5-ft corrugated metal pipe under dirt farm road is about 2 ft higher on upstream end and is undersized. Water velocity is very high through the pipe and is likely a complete fish passage barrier during most flows. A deep (5 ft) scour hole has been created on the downstream end with associated recirculation eddies and sand bars.
Station: 5375	

Solution: Replace or if still necessary, replace with bottomless arch or partially buried box culvert. Culvert should be sized so that the width is greater than the bankfull width of the channel.

	Score	*Notes*
Infrastructure risk	3	
Erosion/channel stability	1	
Project complexity	5	
Location	1	
Sediment/nutrient loading	1	
Project cost	5	Less expensive to remove than to replace
Aesthetic impact	3	
Fish passage	7	The culvert is acting like a dam for fish
Property Ownership	0	Willingness to participate unknown, private property farm crossing
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	3	

Project Area Photo/Map Location

(Left to right): Stn 5300 looking upstream at culvert; Stn 5380 looking downstream at culvert inlet

Potential Project PP 08

Stream: North Creek, Reach 2A Station: 9500	Problem description: 3, 3-ft corrugated metal pipes under dirt farm road are inadequate during high flows; some erosion of the concrete on the downstream end is visible and gullying is occurring over the road due to flooding conditions. The left pipe is lower and most of the water flows through this pipe - this provides some low-water fish passage as well. High flow passage would be difficult, however, due to high flow velocities.

Solution: If road is still needed, replace with larger culvert or if used infrequently, remove. This crossing intersects the recently restored channel, but the restored channel has not been connected on either side of this crossing. Once the restored channel is ready to be finalized, this crossing can be updated or removed at the same time. A replaced culvert width should be greater than the width of the bankfull channel.

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	3	
Project complexity	5	
Location	1	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	3	
Fish passage	3	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	3	

Project Area Photo/Map Location

(Left to right): Stn 9500 looking at erosion on downstream side of road crossing; Stn 9525 looking downstream at 3 CM culverts

Potential Project PP 9

Stream: North Creek, Reach 2	Problem description: Four undersized metal culverts failed due to debris blocking the inlets. Flows washed out around pipes and on the right bank. The road appears to be abandoned. The pipes now obstruct flows and alter the channel conditions.
Station: 14,400	

Solution: The pipes and associated debris should be removed. This debris pile has created a steep, fast channel downstream. Channel should be restored to ensure fish passage.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	Could use volunteer labor
Location	3	
Sediment/nutrient loading	1	
Project cost	7	Could use volunteer labor
Aesthetic impact	1	Not a very visible location
Fish passage	3	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	3	

Project Area Photo/Map Location

(Left to right): Stn 14350 looking upstream at failed culverts; Stn 14400 looking downstream at debris and culverts

Potential Project **PP 10**

Stream: North Creek, Reach 2	Problem description: An old bridge that consists of 2 abutments and two I-beams remain in the channel. One of the I-beams has fallen and now lies submerged in the water. The earthen berm from the former bridge is cutting off floodplain and wetland connectivity. One I-beam crossing the channel may cause debris to accumulate.
Station: 16500	
Solution: Remove I-beams, concrete abutments and earthen berm.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	5	
Location	3	
Sediment/nutrient loading	1	
Project cost	5	Removing the earthen berm increases the cost
Aesthetic impact	3	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	5	
Greenway Benefit	3	

Project Area Photo/Map Location

(Left to right): Stn 16525 looking downstream at abutments; Stn 16500 looking across channel at submerged I-beam

Potential Project PP 11

Stream: North Creek, Reach 2	Problem description: 3.5-ft tall, 1-ft wide, 40-ft long metal dam spans the channel creating a long impoundment that is about 40-50 ft wide and 3-5 ft deep. This dam creates a complete fish passage barrier and reduces the transport of sediment downstream.
Station: 20100	

Solution: The purpose of the dam is unknown, but if unnecessary it could be removed. Although active channel restoration could be completed upstream of the dam, the less costly option would be to allow the channel to self-restored. Active wetland planting would help prevent the immediate colonization by reed canary grass and other invasives.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	5	
Location	3	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	5	
Fish passage	7	
Property Ownership	7	City of Lakeville owns the land around the dam and most of the land adjacent to the impoundment
Public Education	5	About 2000 ft downstream of Pilot Knob Rd.
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	3	
Greenway Benefit	5	Within the 1st priority project area and close to an access point

Project Area Photo/Map Location

(Left to right): Stn 20075 looking upstream at weir; Stn 20100 looking at weir from left bank

Potential Project PP 12

Stream: North Creek, Reach 2	Problem description: 3, 10x6-ft concrete box culverts under Pilot Knob Rd - new culverts in good condition, but the gradient over the riprap is very steep and could present fish passage challenges. No natural habitat or low-flow channel has been provided within the culverts. During low flows, flow depth may not be great enough to provide fish passage. During high flows, velocity may be too high for passage.
Station: 22,200	
Solution: Installing cobbles, boulders and other natural-like substrate could provide better fish-passage opportunities.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	3	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	Within a culvert
Fish passage	5	
Property Ownership	7	City of Lakeville, though downstream is a private landowner
Public Education	5	Good access and demonstration value
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	3	Within 1st priority project area

Project Area Photo/Map Location

(Left to right): Stn 22,050 looking upstream at box culverts; Stn 22,300 looking downstream at box culverts

Potential Project PP 13

Stream: North Creek, Reach 3	Problem description: 1-ft concrete stormwater pipe outlet from left bank - perched 3 ft above channel bed and creating minor erosion around the pipe
Station: 24,625, left bank	
Solution: Add stone below culvert to dissipate the energy.	

	Score	***Notes***
Infrastructure risk	3	Yards could begin eroding
Erosion/channel stability	3	
Project complexity	7	
Location	5	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	1	
Fish passage	1	
Property Ownership	7	City of Lakeville owns the riparian corridor
Public Education	1	
In-stream Ecological Benefit	1	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 24,625 looking at the left bank

Potential Project PP 14

Stream: North Creek, Reach 3	Problem description: 3, 12x6-ft concrete box culverts - flat bottoms may be hard for fish to pass during very low flows
Station: 24,900	

Solution: Creating a low-flow channel by installing cobbles, boulders and other natural-like substrate could provide better fish-passage opportunities at all flow levels.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	5	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	Within a culvert
Fish passage	3	
Property Ownership	7	City of Lakeville
Public Education	5	Easy access and near residential neighborhood
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	3	Could be near Greenway if it expanded along North Creek to the west

Project Area Photo/Map Location

(Left to right): Stn 24,900 looking upstream at culverts; Stn 24,950 looking downstream at culverts

Potential Project **PP 15**

Stream: North Creek, Reach 3	Problem description: mowed to top of bench on left bank. In some locations, saplings on the left slope provide canopy cover and trees on the right floodplain provide additional cover. However, there is little stormwater buffer or opportunity for water flowing off of maintained lawns (potentially with fertilizers, etc) to seep into the ground before entering the channel
Station: 25,100-26,600, mostly left bank	
Solution: Increase buffer by limiting the width of mowed area and planting native riparian vegetation.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	5	
Sediment/nutrient loading	5	
Project cost	7	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	7	City of Lakeville
Public Education	5	Residential with adjacent path
In-stream Ecological Benefit	1	
Riparian Ecological Benefit	5	
Greenway Benefit	5	Along bikepath if Greenway expands to this part of the watershed

Project Area Photo/Map Location

(Left to right): Stn 25,300 looking downstream at the buffer: Stn 25,300 looking upstream at the buffer and prox. of mowing

Potential Project PP 16

Stream: North Creek, Reach 3	Problem description: Minor bank erosion along lower 2 ft of bank - this slope only has wildflowers and grasses growing and no larger vegetation with stabilizing roots
Station: 25,850-26,150, left bank	
Solution: Plant riparian trees and shrubs with stabilizing roots.	

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	3	
Project complexity	7	
Location	5	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	7	City of Lakeville
Public Education	3	Bike path and residential neighborhood
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	3	Near bike path that could be included in expanded Greenway

Project Area Photo/Map Location

(Left to right): Stn 25,900 looking upstream at left bank erosion

Potential Project **PP 17**

Stream: North Creek, Reach 3	Problem description: 2 pipes (18-inch concrete and 4-ft concrete) drain stormwater from stormwater basin to channel; ~1 ft of incision and erosion is apparent at each even with grouted riprap. Some riprap is falling into channel
Station: 26,400-26,450, left bank	
Solution: Monitor the erosion. If progressing rapidly, replace riprap and concrete with larger stone or lower the pipe elevation to the channel bed elevation.	

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	3	
Project complexity	7	
Location	5	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	7	City of Lakeville
Public Education	3	Residential area
In-stream Ecological Benefit	1	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 26,400 looking at left bank; Stn 26,450 looking at left bank

Potential Project

PP 18

Stream: North Creek, Reach 3 Station: 27,200-27,400, left bank	Problem description: Mowed to the edge or within 2 ft of the edge of bank. The lack of root stabilization has resulted in minor bank erosion and the lack of a riparian buffer could result in fertilizers and other contaminants from washing off the lawn and into the channel.
Solution: Plant riparian buffer with native trees, shrubs, and forbs.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	5	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	7	City of Lakeville owns a corridor surrounding the channel
Public Education	3	Near bike path and within residential neighborhood
In-stream Ecological Benefit	1	
Riparian Ecological Benefit	3	
Greenway Benefit	3	Near bike path that could be included in expanded Greenway

Project Area Photo/Map Location

(Left to right): Stn 27,200 looking upstream; Stn 27,200 looking upstream

Potential Project PP 19

Stream: North Creek, Reach 3	Problem description: 30-ft long riprap cascade was likely built to protect culvert at Flagstaff Ave from a migrating knickpoint. Although there is always a low-flow channel, the gradient may present passage problems (velocity) for some species at certain flows. The channel drops ~4 ft in elevation over the length of the cascade.
Station: Stn 28,050	
Solution: There is room to lengthen the cascade, or build a more gradual riffle/pool sequence	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	5	
Location	5	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	3	
Fish passage	5	
Property Ownership	7	City of Lakeville
Public Education	5	Near paths, parks, and residential areas
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	1	
Greenway Benefit	3	Near bike path that could be included in expanded Greenway

Project Area Photo/Map Location

(Left to right): Stn 28,000 looking upstream at the cascades; Stn 28,050 looking downstream at the cascades


Potential Project PP 20

Stream: North Creek, Reach 3	Problem description: 6-ft concrete pipe under Flagstaff Ave is perched about 6 inches above the bed; backwater provides entrance into pipe, but low flows are shallow and all flows are very fast; likely a passage barrier at most flows.
Station: Stn 28,150	

Solution: Increase tailwater elevation to provide backwater through the culvert. When in need of replacement, replace culvert with larger culvert at lower elevation. *None of this is necessary unless downstream cascade is shown to pass fish.*

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	3	
Location	5	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	1	
Fish passage	5	
Property Ownership	7	City of Lakeville
Public Education	5	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 28,050

Potential Project PP 21

Stream: North Creek, Reach 3	Problem description: The left slope from the edge of water to the top of the bench is vegetated with grasses and wildflowers that provide an 8-ft herbaceous buffer, but there is buffer on the flat bench. Floods do inundate these fields and stormwater does flow off the fields into the channel carrying any pesticides, fertilizers and other chemicals that may have been applied. Larger trees from right side of channel provide some canopy cover; no significant erosion was observed.
Station: 28,200-29,600, left bank	
Solution: Expand riparian buffer onto the flat bench surface and include trees and shrubs in the planting plan to provide more year-round cover and protection.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	Can use volunteers
Location	5	
Sediment/nutrient loading	5	
Project cost	7	Can use volunteers
Aesthetic impact	5	
Fish passage	1	
Property Ownership	7	City of Lakeville
Public Education	7	Public park and easy to use volunteers
In-stream Ecological Benefit	1	
Riparian Ecological Benefit	5	
Greenway Benefit	3	Along paths and in park if Greenway is expanded

Project Area Photo/Map Location

(Left to right): Stn 28,250 looking upstream - park is in right side of picture; Stn 29,300 looking upstream

Potential Project **PP 22**

Stream: North Creek, Reach 3	Problem description: Right bank: mowed and maintained to edge of channel. Gardens are within 10 ft of channel and there is no buffer from fertilizers, watering, pesticides, etc. There is no excessive bank erosion, but there is little substantial bank protection either.
Station: 28,200-28,500; 28,700-28, 900	
Solution: Plant riparian buffer that includes native trees, shrubs, and forbs.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	5	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	7	Some may be within the City of Lakeville property, but definitely maintained by private landowners
Public Education	5	Near park and residential neighborhood
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	5	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 28,500 looking upstream; Stn 28,900 looking downstream

Potential Project PP 23

Stream: North Creek, Reach 3	Problem description: 2-ft metal high pressure gas main crosses the channel with concrete abutments on either side of the stream. The pipe is ~2 ft above the channel bed but traps debris on the upstream side and there is some scour occurring around the abutments. The pipe probably causes backwater during floods
Station: 30,550	
Solution: Bury the pipe well under the stream.	

	Score	*Notes*
Infrastructure risk	3	
Erosion/channel stability	3	
Project complexity	3	
Location	5	
Sediment/nutrient loading	3	
Project cost	5	
Aesthetic impact	7	
Fish passage	1	
Property Ownership	7	City of Lakeville
Public Education	3	Near parks and paths
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	3	If Greenway is expanded to this area, removal would improve aesthetics

Project Area Photo/Map Location

(Left to right): Stn 30,550 looking upstream at the sewer pipe

Potential Project PP 24

Stream: North Creek, Reach 3	Problem description: Minor erosion of the lower 3 ft of the right bank
Station: 30,975-31,000, right bank	
Solution: Stabilize the toe of the banks, re-grade the bank, and plant native riparian shrubs and trees.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	5	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	7	City of Lakeville
Public Education	5	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 30,800 looking upstream from footbridge; Stn 31,000 looking at right bank erosion

Potential Project PP 25

Stream: North Creek, Reach 3	Problem description: Lawn has been mowed to the edge of the channel or to within 10 ft of channel. Fertilizers and other contaminants could be washed into the channel during floods or rain events. A lack of a riparian buffer also reduces the canopy cover, instream habitat, as well as bank stabilization.
Station: 31,200-31,300 both banks; 31,500-31,600 right bank; 31,700-32,100 right bank; 32,000-32,100 left bank; 32,200-32,600 right bank; 33,350-33,450:	
Solution: Increase riparian buffer by planting native riparian trees, shrubs, and forbs.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	Could use volunteer labor
Location	5	
Sediment/nutrient loading	5	
Project cost	7	Could use volunteer labor
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	Residential
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	5	
Greenway Benefit	1	

Project Area Photo/Map Location

See photos on next page.

A) Stn 31,200 looking upstream; B) Stn 31,700 looking upstream; C) Stn 32,300 looking upstream; D) Stn 33,400 looking upstream

Potential Project **PP 26**

Stream: North Creek, Reach 3	Problem description: 2.5-ft grouted riprap drop provides temporary grade control ~25 ft downstream of Cedar Ave. The drop is a fish passage barrier and some riprap and concrete are falling out as it is being undercut. If the grade control fails, the culvert under Cedar Ave could be compromised.
Station: 34,000	

Solution: Remove grouted riprap and re-grade the channel bed into a series of grade controlling steps and energy-diffusing pools. Only a fish passage problem if downstream barriers are removed and the 1-ft drop in the culvert at the upstream end of Cedar Ave is removed.

	Score	*Notes*
Infrastructure risk	3	The Cedar Ave culvert is 25 ft upstream and could be impacted if remainder of grade control fails
Erosion/channel stability	3	
Project complexity	5	
Location	5	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	1	Not very visible from road
Fish passage	5	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 34,000 looking upstream at the drop; Stn 34,000 looking downstream

Potential Project **PP 27**

Stream: North Creek, Reach 3	Problem description: 3, 5-ft concrete pipes with trash grates under Cedar Ave. Right pipe is closed with concrete allowing no flow. On upstream end, pipes are designed with a 1-ft drop - this provides grade control and keeps water at certain level upstream, but it is also a complete fish passage barrier
Station: 34,100	

Solution: If fish passage is important at this location, remove the drop (only if downstream barriers are removed); if fish passage is not important, there is no need to change anything. If fish passage and maintaining upstream water levels is important, either 1) remove the drop and build a riffle-pool complex upstream of the road to maintain grade while providing passage or 2) replace culverts and downstream grade control with much wider culverts within which natural substrate provides passage and grade control at the upstream end. With potentially much greater wetland habitat available further upstream, we recommend removing the passage barrier while maintaining the grade control. Because the road surface was recently repaired, the probability of replacing the culvert in the near future is low. Therefore, building a riffle (or step)-pool complex upstream of the culvert to provide passage and grade control is the best option. The scores below reflect this option.

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	3	
Location	5	
Sediment/nutrient loading	3	
Project cost	5	
Aesthetic impact	1	
Fish passage	7	
Property Ownership	7	City of Lakeville
Public Education	5	Easy to access and near a park
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 34,000 looking upstream; Stn 34,250 looking downstream at pipes with debris piled up

Potential Project **PP 28**

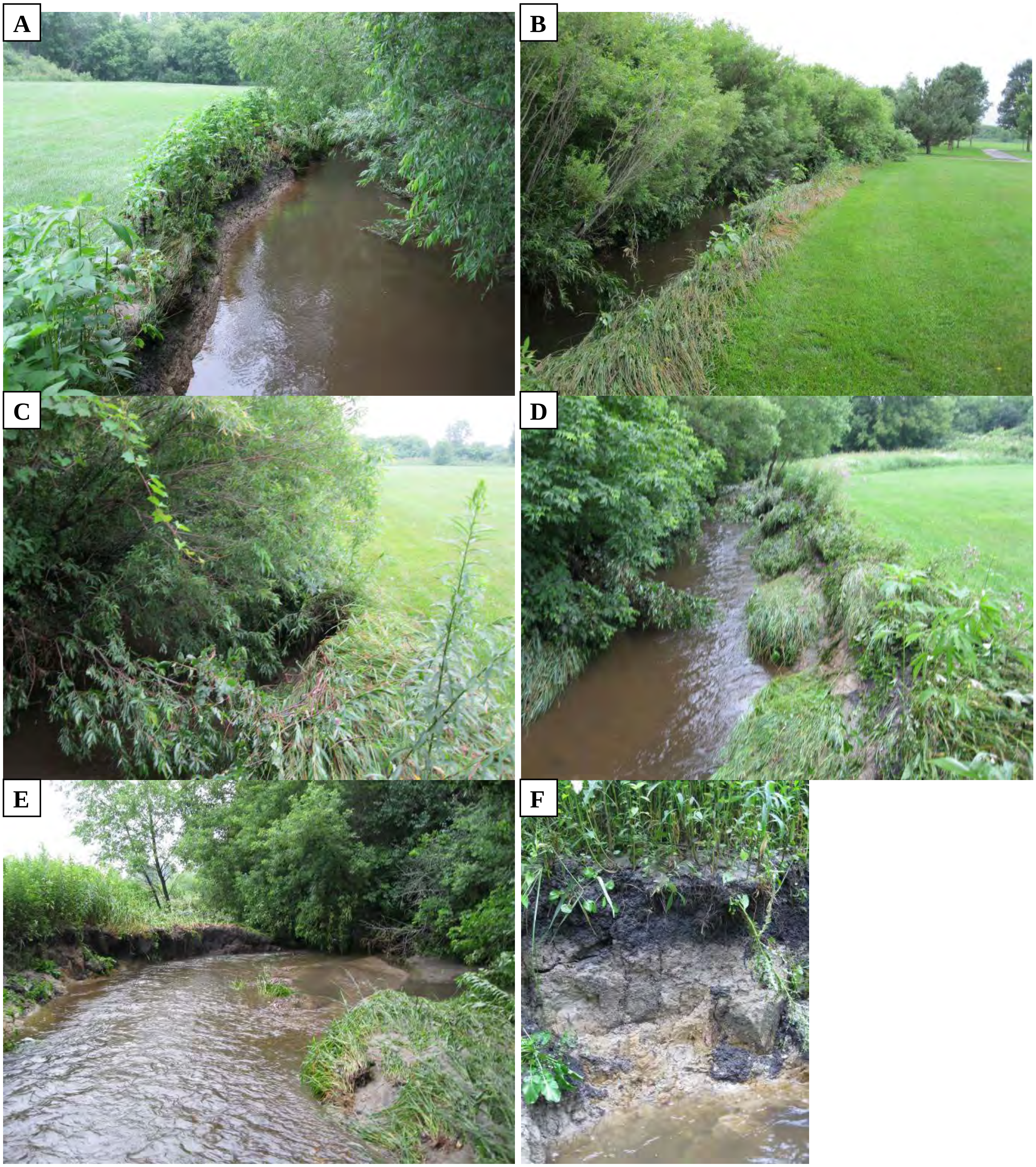
Stream: North Creek, Reach 4	Problem description: The left bank and up to Stn 36,300 on the right bank have less than 10 ft of buffer with willows. Straightened channel through park provides little geomorphic or habitat complexity. The following locations have no buffer and are experiencing some bank erosion: • Stn 35,650-35,700 left bank: minor bank erosion through clay banks; mowed to within 2 ft of bank - no stabilizing vegetation • Stn 35,800-35,900 left bank: mowed to within 2 ft of bank • Stn 36,350-36,400 left bank: minor bank erosion through silt and clay with no vegetation cover • Stn 36,800-36,950 left bank: bank erosion due to channel migration; no vegetation for bank stabilization
Station: 35,350-36,950	

Solution: The riparian corridor through this section should be increased. The public park provides some opportunity to widen the meander beltwidth and increase the riparian buffer. Through most of the park, a riparian corridor of >75 ft is feasible; this includes a 25-ft meander beltwidth and 25-ft riparian buffer zones on each side. This would provide geomorphic and habitat complexity as well as riparian habitat and infiltration. This park floods currently during high flows and an expanded floodplain would help limit the amount of park land flooded. Trails and access points could be provided as desired.

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	5	
Project complexity	3	
Location	7	
Sediment/nutrient loading	5	
Project cost	3	
Aesthetic impact	7	
Fish passage	1	
Property Ownership	7	City of Lakeville
Public Education	7	Within city park
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	5	
Greenway Benefit	5	Good opportunity if Greenway were to expand into this area

Project Area Photo/Map Location

See photos on next page.



A) Stn 35,700 DS at mowed left edge with some erosion; B) Stn 35,800 looking upstream at mowed left edge; C) Stn 36,350 looking upstream at mowed left edge; D) Stn 36,850 looking upstream at mowed left edge and straight channel; E) Stn 36,950 looking downstream at eroding left bank; F) Stn 36,950 erosion of silt/clay on left bank

Potential Project **PP 29**

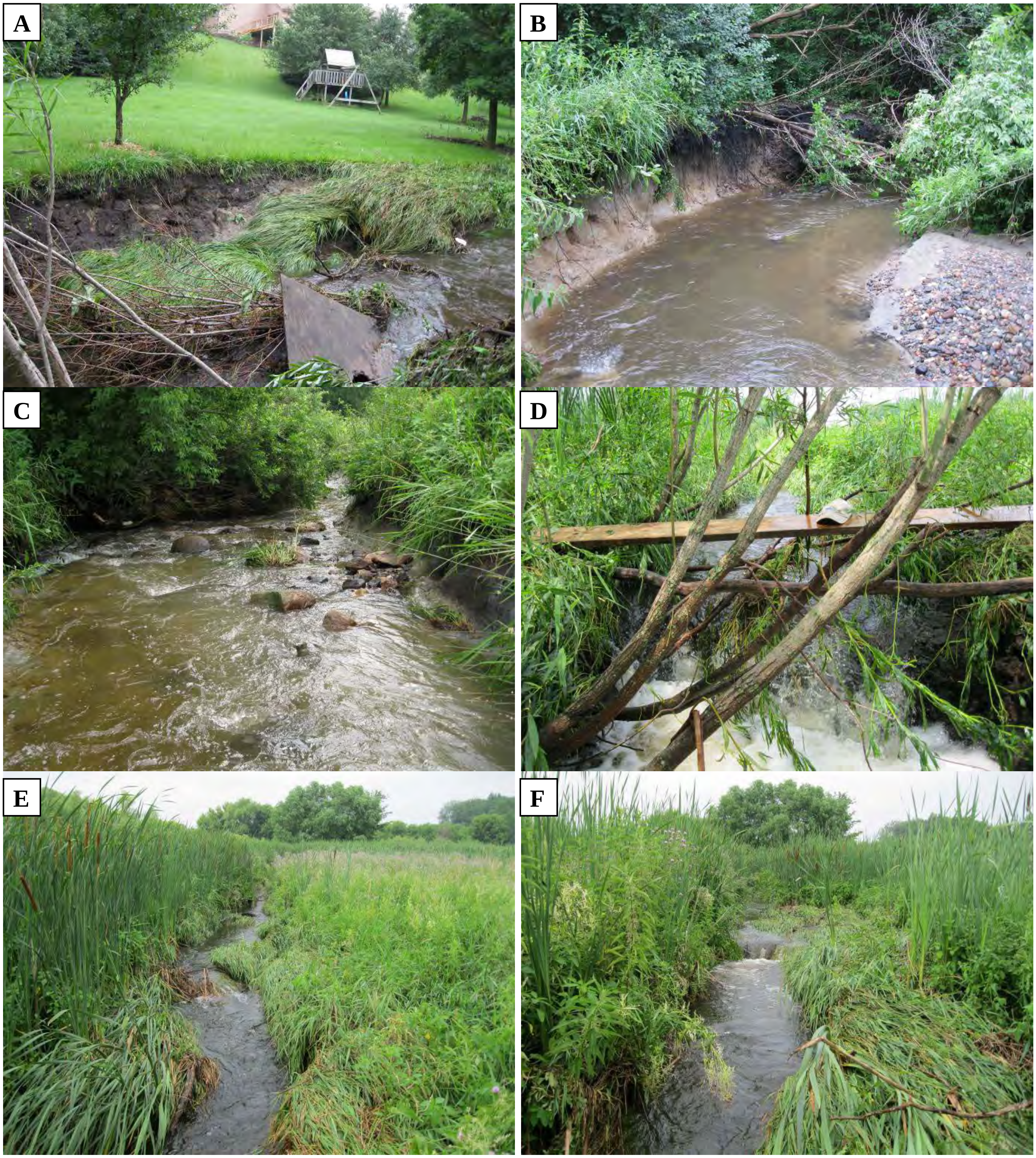
Stream: North Creek, Reach 4	Problem description: Recent incision up to Stn 38,700 is causing bank erosion along nearly the entire length. Between Stn 38,700 and 39,400, 4 knickpoints totaling ~4.5 ft are actively incising - this will in turn result in bank erosion as the channel adjusts. Incision and bank erosion cause excessive sedimentation of the channel and decreased water quality.
Station: 37,000-39,400	

Solution: If this downstream release of turbidity and fine-grained sediment is acceptable, the channel can be allowed to adjust as there is no infrastructure of concern (until the knickpoints reach the bike path and road upstream). However, we believe the turbidity substantially degrades water quality and habitat downstream. To decrease the channel instability and increase wetland functionality and flood storage, we recommend channel reconstruction. The wide wetland complex is owned by the City of Lakeville and there is no infrastructure near the channel. Small drainages and side channels on the wetland surface suggest that the historic channel was not entrenched as it is today. A riffle- or step-pool channel complex could be built at the transition between the downstream park and the wetland. This could be built to bring the channel grade up to less than 2 ft below the wetland surface. A new channel, with channel dimensions to fit the new hydrology, would then be built at a higher elevation and with a more sinuous planform. Side channels, secondary channels, alcoves, off-channel pools could be built to encourage the spread of floodwaters and to provide additional habitat. Flood waters would easily overtop the channel banks and dissipate across the wetland, thus slowing the discharge of water downstream.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	7	
Project complexity	1	
Location	7	
Sediment/nutrient loading	7	
Project cost	1	
Aesthetic impact	5	
Fish passage	5	
Property Ownership	7	City of Lakeville
Public Education	7	Near park and residential areas
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	7	
Greenway Benefit	5	Near parks and would be a great opportunity for Greenway to expand

Project Area Photo/Map Location

See photos on next page.



A) Stn 37,100 Right bank erosion and mowed to edge; B) Stn 37,425 DS at incision and woody debris; C) Stn 38,800 looking downstream; D) Stn 39,250 looking upstream at 2.5-ft knickpoint; E) Stn 39,300 looking upstream; F) Stn 39,400 looking upstream at 0.5-ft knickpoint

Potential Project PP 30

Stream: North Creek, Reach 4	Problem description: Right bank: lawn is mowed to the edge of the bank and the banks are eroding. There is no buffer to provide infiltration or prevent fertilizers or other contaminants from entering the stream.
Station: 37,050-37,350	
Solution: Plant riparian buffer of native trees, shrubs, and forbs.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	7	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	7	County property lines identify it as City of Lakeville, but it is clearly maintained by the private landowner
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 37,100 right bank erosion and mowed to edge; Stn 37,300 downstream at mowed left edge with some erosion

Potential Project PP 31

Stream: North Creek, Reach 4	Problem description: 6x3-ft concrete box culvert under Highview Ave is steep and plane bed - partial fish passage barrier at high flows (velocity) and at low flows (depth).
Station: 40,000	
Solution: Replace with larger culvert that allows fish passage during low flows and high flows.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	5	
Location	7	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	1	
Fish passage	5	
Property Ownership	7	City of Lakeville
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 39,925 looking upstream from bike path at 3x6-ft concrete box culvert under Highview Ave; Stn 40,000 looking downstream at Highview Ave culvert

Potential Project PP 32

Stream: North Creek, Reach 4	Problem description: 3-ft concrete pipe - undersized pipe conveys flows from stormwater basin; recent flooding overwhelmed the pipe and eroded the road - all of this material washed into the channel downstream.
Station: 42,250	
Solution: Combine with the solution for project 33: Replace culvert with larger box culverts or a bridge. This would provide passage during high and low flows and would allow the channel to adjust.	

	Score	***Notes***
Infrastructure risk	5	Immediate risk, but low cost
Erosion/channel stability	3	
Project complexity	3	
Location	7	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	3	
Fish passage	5	
Property Ownership	7	City of Lakeville
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 42,250 US at outlet of drainage from stormwater basin as it flows under dirt road through 3-ft concrete pipe; Stn 42,250 looking upstream

Potential Project **PP 33**

Stream: North Creek, Reach 4	Problem description: 4.5x3-ft corrugated metal pipe under 172nd St W. This is an undersized culvert that is perched 1 ft on the downstream end with a 3-ft scour hole. This presents a fish and aquatic organism passage barrier. In addition, a 1-ft^2 scour hole has developed under the pavement to the right of the pipe on the upstream side - this presents a safety risk due to potential road failure. The road did partially fail recently as repairs were observed and gravel deposits from the road were observed in the channel downstream.
Station: 42,350	

Solution: Replace culvert (and the culvert to the east from the stormwater basin) with larger box culverts or a bridge. This would provide passage during high and low flows and would allow the channel to adjust.

	Score	***Notes***
Infrastructure risk	5	Immediate risk, but low cost
Erosion/channel stability	3	
Project complexity	3	
Location	7	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	3	
Fish passage	5	
Property Ownership	7	City of Lakeville
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 42,350 looking west along bike path and dirt road where road was recently patched after overtopping and flooding; Stn 42,350 looking upstream at 3x4.5-ft corrugated metal pipe perched 1 ft with 3-ft scour hole

Potential Project PP 34

Stream: North Creek, Reach 4	Problem description: 1.5-ft knickpoint through clay in wetland.
Station: 42,750	

Solution: Monitor knickpoint - could provide grade control but likely not worth the cost. Could tie into holistic wetland restoration downstream of culverts if desired. Scores are based on monitoring.

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	7	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Fish passage	1	
Property Ownership	7	City of Lakeville
Public Education	3	
In-stream Ecological Benefit	1	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 42,750 looking upstream at 1.5-ft knickpoint

Potential Project PP 35

Stream: North Creek, Reach 5	Problem description: Left bank: mowed to edge of the bank or has less than 10-ft buffer; minor bank erosion throughout.
Station: 45,500-46,000	
Solution: Provide riparian buffer that is at least 15-20ft. Plant native trees, shrubs, and forbs.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	7	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	7	City of Lakeville should own the riparian corridor, but private landowners maintain the lawns
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 45,850 looking downstream at mowed left edge; Stn 45,900 looking downstream at mowed left edge

Potential Project **PP 36**

Stream: North Creek, Reach 5	Problem description: 3.5-ft flared concrete pipe under Icon Trail is perched 2 ft on the downstream end. The grouted riprap apron and banks have failed and are now broken in the channel
Station: 46,000	

Solution: Place rock at mouth to protect culvert. No habitat is available upstream, so fish passage is not a concern.

	Score	*Notes*
Infrastructure risk	3	
Erosion/channel stability	3	
Project complexity	7	
Location	7	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Fish passage	1	
Property Ownership	7	City of Lakeville
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 45,900 looking upstream at 3.5-ft concrete pipe perched 2 ft under Icon Trail; Stn 46,000 looking downstream at 3.5-ft concrete pipe under Icon Trail

Potential Project **PP 37**

Stream: North Creek, Reach 5	Problem description: 2-ft knickpoint - resulted in some erosion on left bank where there is little root stabilization; not much risk to infrastructure as this is the headwaters and houses are far from channel
Station: 46,600	
Solution: Monitor knickpoint and plant riparian buffer to stabilize left bank.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	7	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	7	City of Lakeville should own the riparian corridor, though private landowners maintain the lawns
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 46,550 looking upstream at 2-ft knickpoint

Potential Project **PP 38**

Stream: North Creek, Reach 5	Problem description: 2-ft knickpoint - riprap cobbles may be slowing this, but much of the riprap has washed downstream; not much risk to infrastructure as this is the headwaters and houses are far from channel
Station: 46,700	

Solution: Monitor the knickpoint and if it is causing major instability, regrade, widen channel, and plant riparian vegetation. Scores are based on monitoring.

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	7	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Fish passage	1	
Property Ownership	7	City of Lakeville should own the riparian corridor
Public Education	1	
In-stream Ecological Benefit	1	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 46,700 looking upstream at 2-ft knickpoint

Potential Project **PP 39**

Stream: North Creek Trib 1, Reach 1	Problem description: Straightened ditch that is not connected to the adjacent wetland. The straightened ditch does not provide adequate habitat complexity and because of the disconnection with the wetland, flood storage is not provided.
Station: 0-1500	
Solution: Increase sinuosity and raise the channel bed to improve wetland reconnection. Plant native trees, shrubs and forbs. Tap into the cold groundwater through the construction of side channels, alcoves, and backwaters.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	3	
Location	1	
Sediment/nutrient loading	5	
Project cost	5	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	5	
Greenway Benefit	7	Within 1st priority project area and near residential areas

Project Area Photo/Map Location

(Left to right): Stn 200 looking downstream; Stn 250 looking upstream

Potential Project **PP 40**

Stream: North Creek Trib 1, Reach 2	Problem description: System of in-stream stormwater basins causes water to warm to more than 80°F in the summer, providing a source of warm water to North Creek. Maintaining stormwater basins is beneficial in reducing the volume of water entering the channels downstream, but the over-heated water does not help the water quality.
Station: 1900-7200 (entire reach)	

Solution: Although changing conditions here is unlikely as this development is relatively new, the vertical pipe at Stn 5050 could be retained and everything upstream of that retained as a stormwater pond (could the pipe be raised so water only discharges downstream during large rain events?). Downstream of that vertical pipe, a narrow and more natural creek with floodplain could be built between levees that contain stormwater basins to either side of the stream. The stream would have riparian vegetation to provide cover.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	3	
Location	1	
Sediment/nutrient loading	5	
Project cost	3	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	7	City of Farmington
Public Education	5	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	3	
Greenway Benefit	5	Near 1st priority project area and in residential area

Project Area Photo/Map Location

(Left to right): Stn 4450 downstream from Dylan Drive; Stn 5050 looking down at debris on top of vertical storm water pipe inlet

Potential Project **PP 41**

Stream: North Creek Trib 5, Reach 1 Station: 1800	Problem description: Multiple channels flow over 0.5-ft knickpoints as they enter the steep culvert; these knickpoints are not currently causing significant erosion or threat to infrastructure.
Solution: These can be monitored and if action is necessary, the knickpoints can be stabilized. This is not a fish passage problem as there are likely no fish entering this channel downstream.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	7	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Fish passage	1	
Property Ownership	7	City of Lakeville
Public Education	3	
In-stream Ecological Benefit	1	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 1800 looking upstream at multiple channels with 0.5-ft knickpoints through clay; Stn 1750 looking downstream at 3.2x4-ft concrete pipe under Hamilton Dr.

Potential Project PP 42

Stream: North Creek Trib 5, Reach 1	Problem description: 2 knickpoints - 2.5-ft knickpoint halted at root with a 1-ft knickpoint 10 ft upstream; these could continue to migrate upstream and impact the culvert under Highview Ave, only 500 ft upstream. These knickpoints also present fish passage barrier for small fish populations, though the fish habitat is minimal in this tributary.
Station: 4000	
Solution: The riprap below the culvert may prevent the culvert from being impacted, but the knickpoint migration should be monitored.	

	Score	*Notes*
Infrastructure risk	3	
Erosion/channel stability	1	
Project complexity	7	
Location	7	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Fish passage	3	
Property Ownership	7	City of Lakeville
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 4000 looking upstream at 2.5-ft knickpoint halted at tree root; Stn 4500 looking upstream at cascade into 5-ft concrete pipe under Highview Ave


Potential Project **PP 01**

Stream: Middle Creek, Reach 1	Problem description: Many landowners have mowed lawns to the edge of the river or have very narrow buffers: • Stn 50-150 left bank: mowed to edge • Stn 1150-1250 right bank: mowed to edge with minor bank erosion • Stn 1300 right bank: mowed to edge • Stn 1425-1475 right bank: mowed to edge • Stn 1500-1550 right bank: 10-ft buffer • Stn 1600-1700 right bank: 10-15-ft buffer • Stn 1750-1900 right bank: mowed to edge with little erosion
Station: 0-1900	
Solution: Increase the buffer width in these areas and plant native riparian vegetation that will stabilize channel banks	

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	3	
Project complexity	7	Good volunteer project
Location	1	
Sediment/nutrient loading	5	
Project cost	7	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	5	
Greenway Benefit	1	

Project Area Photo/Map Location

See photos on next page.

A) Stn 100 looking upstream; B) Stn 1150 looking upstream; C) Stn 1300 looking upstream; D) Stn 1400 looking upstream; E) Stn 1700 looking upstream; F) Stn 1850 looking upstream

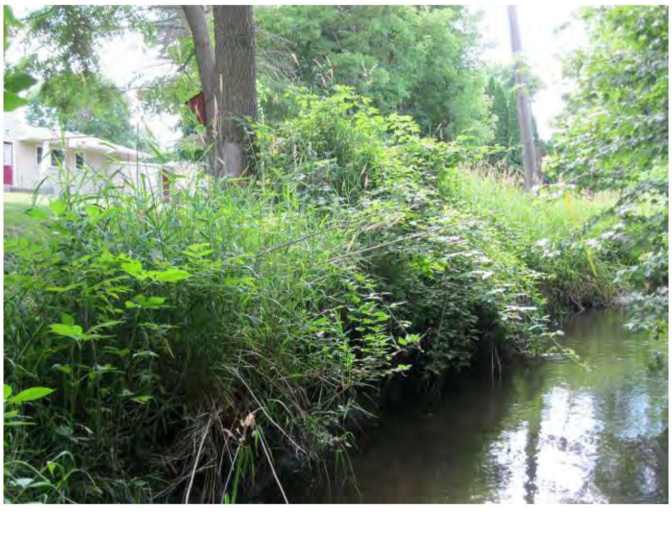
Potential Project **PP 02**

Stream: Middle Creek, Reach 1	Problem description: right bank: utility pole is 4 ft from the channel and a support cable is in the water and is loose; potential infrastructure and health hazard.
Station: 1200	
Solution: Move pole and cable away from bank and future bank erosion.	

	Score	*Notes*
Infrastructure risk	7	Utility pole and cable
Erosion/channel stability	3	
Project complexity	5	
Location	1	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown, though electrical company would have access
Public Education	1	
In-stream Ecological Benefit	1	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 1150 looking upstream at the telephone pole; Stn 1200 looking at the telephone pole support cable in the water



Potential Project PP 03

Stream: Middle Creek, Reach 1	Problem description: Fences, pieces of metal, and other trash in channel. This degrades water quality and habitat, may increase bank erosion, and is not aesthetically pleasing.
Station: 1500-1900; 3100-3600	
Solution: Remove trash from channel.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	Volunteer project
Location	1	
Sediment/nutrient loading	1	
Project cost	7	Volunteer project
Aesthetic impact	7	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	Volunteer project
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

See photos on next page.

A) Stn 1550 looking upstream at exposed culvert & broken fence; B) Stn 1650 looking upstream at chain link fence and debris in water C) Stn 1850 looking downstream at fence and car hood in water, erosion under wood fence, and unprotected bank with lawn cut to edge further downstream; D) Stn 3100 looking upstream at garbage in water and much more exists on right bank; E) Stn 3600 looking downstream at garbage in the channel

Potential Project PP 04

Stream: Middle Creek, Reach 1	Problem description: Downstream piling of right pier under railroad bridge is broken.
Station: 1950	
Solution: Monitor and evaluate remainder of bridge to ensure it is stable.	

	Score	***Notes***
Infrastructure risk	5	
Erosion/channel stability	1	
Project complexity	7	
Location	1	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Fish passage	1	
Property Ownership	7	Railroad company
Public Education	1	
In-stream Ecological Benefit	1	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 1900 looking upstream at the RR bridge; Stn 1950 view of failed RR bridge support.

Potential Project PP 05

Stream: Middle Creek, Reach 1	Problem description: Field runoff and flows resulting in 3-ft eroding bank; erosion is nearing fields.
Station: 8800	
Solution: Monitor and stabilize if necessary	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	1	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	1	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	1	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 8800 erosion from field runoff on right bank; Stn 8800 erosion from field runoff on right bank

Potential Project PP 06

Stream: Middle Creek, Reach 1	Problem description: Two corrugated metal culverts under what appears to be an infrequently used road crossing are slightly compressed and there is some erosion of the surrounding riprap.
Station: 10,000	

Solution: Monitor or if the crossing is no longer needed, remove and re-grade banks to maintain backwater for the upstream wetland.

	Score	*Notes*
Infrastructure risk	3	
Erosion/channel stability	1	
Project complexity	5	
Location	1	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 10,050 looking downstream at the two culverts, the right culvert is hidden by significant vegetation; Stn 10,050 looking upstream at the wetland

Potential Project **PP 07**

Stream: Middle Creek, Reach 2	Problem description: 4, 12x5-ft concrete box culverts under Pilot Knob Rd are in good condition but no low channels were provided. At very low flows, water depth may become a fish passage barrier.
Station: 13,050	

Solution: Study hydrology - if water depths remain sufficient throughout the year, do nothing. If depths decrease substantially during portions of the year, block low flows with stone in all but one culvert; in remaining culvert, build low flow channel with stone throughout culvert. Scores assume hydrology is sufficient, and only monitoring is necessary.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	3	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Fish passage	3	
Property Ownership	7	City of Farmington
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 12,925 looking upstream at 4 box culverts under Pilot Knob Rd; Stn 13,200 looking downstream at 4 box culverts under Pilot Knob Rd.

Potential Project **PP 08**

Stream: Middle Creek, Reach 2	Problem description: No restrictions on livestock grazing has resulted in eroding banks, which likely cause a decrease in water quality.
Station: 16,700-19,800	

Solution: Fencing could help keep livestock away from channel banks. A riparian buffer within the fencing would help stabilize the banks, provide infiltration for livestock waste, and provide instream cover and habitat.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	7	
Project complexity	7	
Location	3	
Sediment/nutrient loading	7	
Project cost	7	
Aesthetic impact	7	
Fish passage	1	
Property Ownership	-7	Not excited about the project.
Public Education	5	Near school
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	7	
Greenway Benefit	5	Would be a good opportunity if Greenway were expanded and if landowner permission could be obtained

Project Area Photo/Map Location

(Left to right): Stn 19,000 looking at flooding from Flagstaff Ave; Bob Donnelly's property; closeup of cows; Stn 19,850 looking downstream at right bank erosion due to open grazing

Potential Project **PP 09**

Stream: Middle Creek, Reach 3	Problem description: Entire reach has been straightened into a ditch with varying degrees of historic incision. This is an agricultural ditch that generally provides little geomorphic or habitat complexity. Historically, portions of this reach were either wetland or a shallow drainage swale through rolling hills. Following land clearing, ditch construction, and suburban development in the watershed, the hydrology has increased and the channels are perennially filled.
Station: 19,700-50,200	

Solution: While reach-wide landowner cooperation will be extremely difficult to obtain, easements on either side of the channel would allow for construction of a sinuous, properly-sized channel throughout with a buffer between the agriculture fields and the channel. Small levees could separate the fields from this easement and prevent large volumes of runoff from entering the streams. Where appropriate, portions of the reach could be converted to wider wetlands providing stormwater retention.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	7	
Project complexity	3	
Location	7	
Sediment/nutrient loading	7	
Project cost	1	
Aesthetic impact	7	
Fish passage	3	
Property Ownership	-7	Some not excited about the project.
Public Education	7	
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	7	
Greenway Benefit	7	

Project Area Photo/Map Location

(Left to right): Stn 22,600 looking upstream at straightened channel; Stn 47,900 looking downstream at straightened channel

Potential Project **PP 10**

Stream: Middle Creek, Reach 3	Problem description: Entire reach: much of this reach has little to no riparian buffer between the row crops and the channel.
Station: 19,700-50,200	

Solution: If natural channel reconstruction is unlikely (PP09), increasing the riparian buffer by planting native riparian shrubs, trees, and forbs may be more possible. Many portions of the crops near the channel were flooded following a rain event during the survey. With a 30-50-ft heavily vegetated riparian buffer on either side of the channel, fewer crops would be impacted and large volumes of sediment, pesticides, herbicides, and fertilizers would not be as likely to be washed into the channel.

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	7	
Project complexity	5	
Location	7	
Sediment/nutrient loading	7	
Project cost	5	Excludes easement costs
Aesthetic impact	7	
Fish passage	1	
Property Ownership	-7	Some not excited about the project.
Public Education	7	
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	7	
Greenway Benefit	7	

Project Area Photo/Map Location

(Left to right): Stn 22,500 looking downstream during flood, the left stretch is the main channel; Stn 22,600 looking upstream during flood

Potential Project PP 11

Stream: Middle Creek, Reach 3	Problem description: A restored section of channel was built but never connected with Middle Creek. There may be some engineering and hydraulic problems that need to be resolved.
Station: 19,700-22,500	
Solution: Identify and fix problems and activate restored channel.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	5	
Project complexity	7	
Location	3	
Sediment/nutrient loading	5	
Project cost	7	
Aesthetic impact	5	
Fish passage	3	
Property Ownership	7	Independent School District 192, Meadowview Elementary School
Public Education	7	Meadowview Elementary School is adjacent
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	5	
Greenway Benefit	3	

Project Area Photo/Map Location

(Left to right): Stn 20,600 looking upstream straight channel; Stn 19,950 looking downstream sinous side channel; See next page for aerial view of two separate channels


037-146575000034
22000
037-146575000010
21500
500
MC-70
21000
0
037-146575000033
037-146575000040
20500
MIDDLE CREEK
MCreek_reaches
Roads
OK
Call and meet
REACH 2
0
200
400
800
Feet
N

Potential Project **PP 12**

Stream: Middle Creek, Reach 3	Problem description: Half of this dirt farm road is washed out on the upstream side with 4.5 ft of bank erosion. The culverts are partially or fully blocked with debris. Additional scour has occurred on the downstream side.
Station: 20,650	
Solution: Eliminate crossing if road is no longer necessary; replace culverts with larger culverts and rebuild road if the road is necessary. If restored channel is connected, new culverts will need to be built under the road anyway.	

	Score	*Notes*
Infrastructure risk	3	
Erosion/channel stability	5	
Project complexity	5	
Location	3	
Sediment/nutrient loading	5	
Project cost	7	
Aesthetic impact	3	
Fish passage	5	
Property Ownership	7	Independent School District 192; Meadowview Elementary School
Public Education	5	Meadowview Elementary School is nearby
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

See photos on next page.

A) Stn 20,650 looking downstream at road crossing; B) Stn 20,650 looking across channel showing severity of erosion to farm road; C) Stn 20650 looking across channel; D) Stn 20675 looking upstream at culvert outlet.

Potential Project PP 13

Stream: Middle Creek, Reach 3	Problem description: Left bank: mowed to edge with minor erosion around trees; tiling from yard enters top of the bank. No riparian buffer to slow the flow of water, nutrients, or fertilizers and other contaminants.
Station: 28,500-28,700	

Solution: Plant native riparian vegetation.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	5	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	1	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 28,550 looking downstream; Stn 28,550 looking upstream

Potential Project **PP 14**

Stream: Middle Creek, Reach 3	Problem description: Active livestock grazing throughout has resulted in some bank erosion and no vegetation cover over the channel. The lack of riparian buffer minimizes the canopy and in-stream cover and minimizes the in-stream aquatic habitat.
Station: 31,200-32,500	
Solution: Build fence to prevent livestock from directly entering the channel. Plant native vegetation within the fencing buffer to restore banks, provide shade and reduce impacts of high floods.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	5	
Project complexity	7	
Location	5	
Sediment/nutrient loading	5	
Project cost	7	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	-7	Potentially unwilling landowner
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	5	
Greenway Benefit	3	

Project Area Photo/Map Location

(Left to right): Stn 32,100 looking downstream at cow pasture; Stn 32,500 looking downstream from Flagstaff Ave


Potential Project PP 15

Stream: Middle Creek Trib 1, Reach 1	Problem description: Channel is straightened within a decent riparian corridor and there is little substrate variability, woody habitat, or channel dimension variability.
Station: 600-4700	
Solution: The existing earthen berms could be extended on both sides of the channel to limit stormwater flow to the channel from row crops. Within the riparian corridor, the low-flow channel could be narrowed using large wood installations. This could be supplemented with construction of riffle-pool sequences to provide habitat variability.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	3	
Location	1	
Sediment/nutrient loading	5	
Project cost	3	
Aesthetic impact	5	
Fish passage	3	
Property Ownership	0	Willingness to participate unknown
Public Education	3	Private land, but good demonstration project and downstream of residential area
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	7	
Greenway Benefit	5	While outside of the North Creek Greenway, this could be an opportunity to link residential areas with other paths

Project Area Photo/Map Location

(Left to right): Stn 1600 looking downstream; Stn 1600 looking upstream

Potential Project **PP 16**

Stream: Middle Creek Trib 1, Reach 1	Problem description: 2, 14-inch concrete pipes under farm road are perched, undersized, and not fully functional as low flows go underneath the pipes.
Station: 600	
Solution: Culverts should be replaced with large culverts if the road is still necessary. A stabilized gravel/cobble ford or bridge could also replace the culverts. Scores reflect replacing with a stabilized gravel/cobble ford.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	1	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	3	
Fish passage	5	
Property Ownership	0	Willingness to participate unknown
Public Education	1	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 600 looking upstream at culverts; Stn 600 looking downstream at culverts

Potential Project PP 17

Stream: Middle Creek Trib 1, Reach 1	Problem description: 2, 14-inch pipes are not fully functional as they are undersized, partially buried, and trees are obscuring the outlet. This farm road does not appear active and may be redundant to the one at Stn 600.
Station: 850	
Solution: Remove pipes and crossing.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	1	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	3	
Fish passage	5	
Property Ownership	0	Willingness to participate unknown
Public Education	1	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 850 looking downstream at culverts

Potential Project **PP 18**

Stream: Middle Creek Trib 2, Reach 1 Station: 0-3100	Problem description: Entire reach is a straightened ditch through wetland and agriculture fields. There is little habitat variability, but cold water presents the opportunity to restore this small tributary to provide cold-water fisheries habitat.
Solution: Within the agriculture fields, an increased riparian buffer would provide some room to install large woody habitat features to initiate habitat complexity and some variability in channel geometry. Upstream of Stn 800, the channel could be reconstructed into a sinuous wetland channel with multiple channels, woody habitat features, deep pools, undercut banks, and backwater habitat. Tapping into the cold groundwater would be very important.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	3	
Location	1	
Sediment/nutrient loading	3	
Project cost	5	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown; upstream portion owned by natural gas company
Public Education	3	
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	7	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 175 looking upstream from farm crossing; Stn 775 looking upstream.


Potential Project PP 19

Stream: Middle Creek Trib 6, Reach 1	Problem description: Portions of this reach have little canopy cover, though grasses provide some in-channel shade. Trees planted on small benches between the channel and the ditch walls would provide stability, canopy cover, and geomorphic/habitat complexity as is found in a few locations with trees in this reach.
Station: 500-1200	
Solution: Plant native riparian trees and shrubs both within the ditch and between the row crops and the ditch.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	3	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	0	half owned by Independent School District 192 - Meadowview Elementary School
Public Education	3	Close to a school
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 1250 looking downstream from Flagstaff Ave; Stn 700 looking upstream

Potential Project **PP 20**

Stream: Middle Creek Trib 6, Reach 1 Station: 1300	Problem description: 6-ft flared concrete pipe with trash grates under Flagstaff Ave is a fish passage barrier due to debris piled up multiple feet on both ends.
Solution: Clean trash grates regularly, especially after flood events. *Only complete if downstream passage barriers are removed and habitat upstream is improved and found to be viable for fish species.*	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	Volunteer labor
Location	3	
Sediment/nutrient loading	1	
Project cost	7	Volunteer labor
Aesthetic impact	3	
Fish passage	5	
Property Ownership	7	Culvert likely owned and maintained by City of Farmington
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 1400 looking downstream at culvert below Flagstaff Rd; Stn 1250 looking upstream through culvert

Potential Project **PP 21**

Stream: Middle Creek Trib 6, Reach 1	Problem description: Multiple knickpoints, a dam, and trash suggest active channel incision and all present fish passage barriers: • Stn 1400: 3.2-ft high concrete dam/weir is about 12 ft long across the channel. Part of the dam has broken and fallen into the stream. The dam provides grade control to prevent further knickpoint migration, but it is also a fish passage barrier. • Stn 1600: 2-knickpoint stopped at willow roots • Stns 2150, 2300, 2425: 0.5-ft knickpoints stopped at willows • Stn 2400: Concrete steps in channel block flows
Station: 1400-2500	
Solution: If fish passage becomes important in this tributary, the dam and the concrete steps should be removed and the channel rebuilt with a riffle-pool structure that provides grade control and habitat. If fish passage is not a concern, monitor the knickpoints - if incision and downstream sediment release becomes a problem, rebuild channel to fit new hydrology and provide grade control. Scores reflect monitoring.	

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	3	
Project complexity	7	
Location	3	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	7	
Property Ownership	0	Willingness to participate unknown
Public Education	3	Easy access and near a school
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

See photos on next page.

A) Stn 1350 looking upstream at concrete weir; B) Stn 1550 looking upstream at knickpoint; C) Stn 2300 looking upstream at knickpoint; D) Stn 2400 looking upstream at concrete steps

Potential Project **PP 22**

Stream: Middle Creek Trib 6, Reach 1 Station: 1400-2500	Problem description: Unrestricted cattle grazing causing some bank erosion and poor water quality.
Solution: Cold water was observed emerging from seeps near the channel, suggesting that this tributary could be a good source of cold, clean water to downstream reaches with better habitat. Provide a buffer of at least15 ft on either side of the channel with one or two stabilized crossings for the cattle. Plant native understory species within these fences to provide a buffer between waste runoff and the channel.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	Volunteer labor
Location	3	
Sediment/nutrient loading	5	
Project cost	7	Volunteer labor
Aesthetic impact	3	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	Near school
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	5	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 1550 looking upstream at open grazing; Stn 2450 looking upstream at open grazing

Potential Project **PP 23**

Stream: Middle Creek Trib 7, Reach 1	Problem description: Entire reach has been straightened into a ditch historically - little opportunity for geomorphic or habitat complexity. During large rain events, portions of the fields flood, introducing sediment and any chemicals and fertilizers applied on the fields to the channel. Excessive suspended sediment and introduced chemicals and fertilizers can degrade water quality and in-stream habitat.
Station: 0-1500	
Solution: Increase riparian buffer to encompass the extent of overbank flooding. With riparian buffer, build more sinuous channel with wider floodplains. Plant native riparian trees, shrubs and forbs throughout.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	3	
Location	3	
Sediment/nutrient loading	5	
Project cost	5	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	-7	Potentially unwilling landowner
Public Education	5	Near school and good demonstration project to go along with existing restored channel downstream
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	5	
Greenway Benefit	3	

Project Area Photo/Map Location

(Left to right): Stn 50 looking upstream; Stn 50 looking upstream during flood.

Potential Project PP 24

Stream: Middle Creek Trib 7, Reach 2	Problem description: Decent wetland habitat, but no canopy cover to provide shade, habitat, or wood recruitment for in-channel habitat.
Station: 1800-6600	
Solution: Plant trees and shrubs periodically along channel and throughout wetland.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	3	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	5	
Greenway Benefit	3	

Project Area Photo/Map Location

(Left to right): Stn 2700 looking upstream; Stn 4550 looking downstream from 190th St. W

Potential Project **PP 25**

Stream: Middle Creek Trib 7, Reach 2	Problem description: The channel has been straightened historically and is incised in the lower half of this section of river. While there is good wetland buffer, the in-channel habitat is limited by the lack of habitat complexity.
Station: 1800-4500	
Solution: Take advantage of the wide wetland/riparian buffer and rebuild channel as a sinuous channel. Grade-controlling riffles at the downstream end could be built to stabilize the channel and raise the channel elevation to the wetland surface. This would allow for floodwaters to actively flood the floodplain and wetlands and would also provide grade control. Plant with native riparian trees, shrubs, and forbs (PP 24).	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	5	
Project complexity	3	
Location	3	
Sediment/nutrient loading	5	
Project cost	3	
Aesthetic impact	5	
Fish passage	3	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	7	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 1800 looking upstream at incised channel and flood debris; Stn 2700 looking downstream

Potential Project PP 26

Stream: Middle Creek Trib 7, Reach 2	Problem description: 6-ft corrugated metal pipe is undersized and has resulted in overtopping the dirt road leading to rilling and erosion.
Station: 4550	
Solution: Replace culvert with a larger bottomless arch or box culvert and re-grade to allow appropriate fish passage.	

	Score	*Notes*
Infrastructure risk	5	
Erosion/channel stability	3	
Project complexity	5	
Location	3	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	1	
Fish passage	3	
Property Ownership	7	County or town road
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 4600 at corrugated metal pipe; Stn 4550 looking east along 190th St. W showing evidence of recent overtopping of road

Potential Project PP 27

Stream: Middle Creek Trib 7, Reach 2	Problem description: Open grazing through channel and wetland decreases water quality and increases bank erosion.
Station: 5500-6600	
Solution: Develop buffer with fencing to keep cows out except at certain crossings. Plant native riparian vegetation within fencing to help infiltrate waste runoff before it reaches the channel.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	3	
Sediment/nutrient loading	5	
Project cost	7	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	5	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 6400 looking upstream; Stn 6550 looking downstream at pasture

Potential Project **PP 28**

Stream: Middle Creek Trib 7, Reach 2	Problem description: Excessive incision up to 5 ft has occurred. There is a 2-ft knickpoint at ~Stn 7600 about 100 ft downstream of the 190th St W crossing. This knickpoint is where grouted riprap failed and has piled up downstream from its intended location.
Station: 6800-7600	
Solution: Raise and widen the channel through this area to accommodate larger flows. Install grade controls to prevent further incision.	

	Score	*Notes*
Infrastructure risk	3	
Erosion/channel stability	5	
Project complexity	3	
Location	3	
Sediment/nutrient loading	5	
Project cost	3	
Aesthetic impact	3	
Fish passage	5	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 7550 looking downstream at incision; Stn 7650 looking downstream at incision

Potential Project PP 29

Stream: Middle Creek Trib 7, Reach 2	Problem description: 6-ft concrete pipe under 190th St W is steep on the upstream end of the culvert. This is likely a partial fish passage barrier.
Station: 7750	
Solution: If culvert is not being replaced in near future, install natural bed material on base of culvert to provide refuge and resting places as fish navigate the culvert. Fish were observed at the downstream end of the culvert.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	3	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Fish passage	3	
Property Ownership	7	Probably county or city road and culvert
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 7700 looking upstream inside culvert; Stn 7650 looking upstream at outlet of culvert

Potential Project **PP 30**

Stream: Middle Creek Trib 7, Reach 3	Problem description: 2, 4-ft concrete pipes under Cedar Ave. A 2-ft knickpoint on the downstream end as water flows over riprap and a 2-ft knickpoint on the upstream end at the edge of the field suggest some active vertical instability. Below the culvert the channel is deeply incised (4-5 ft).
Station: 8550	

Solution: Because fish passage here would not open up a large amount of high quality habitat, the area between Stn 7750 and 8400 could be converted into a stormwater basin if the landowner is willing. This would limit the impact of the downstream knickpoint and provide some storage. On the upstream end, regrading and the potential creation of an actual channel may improve conditions.

	Score	*Notes*
Infrastructure risk	3	
Erosion/channel stability	3	
Project complexity	5	
Location	3	
Sediment/nutrient loading	5	
Project cost	5	
Aesthetic impact	3	
Fish passage	3	
Property Ownership	0	Willingness to participate unknown, but roads are likely county or city-owned
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 8300 looking upstream at 2-ft knickpoint over riprap; Stn 8400 looking downstream from Cedar Ave.

Potential Project **PP 31**

Stream: Middle Creek Trib 7, Reach 3 Station: 10,450-11,500	Problem description: Channel has moved into the corn field and out of the wide riparian area. The channel is a trench between corn rows negatively impacting crops and introducing excessive quantities of sediment and contaminants to the channel downstream.

Solution: Either increase buffer or redirect water back into channel and recreate channel to keep it in the preferred location. A small drainage from the south at Stn 11,550 has deposited a lobe of fines that has likely pushed the channel into the fields downstream. Could heavily vegetate that drainage so the soils are not as easily washed away.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	5	
Project complexity	7	
Location	3	
Sediment/nutrient loading	5	
Project cost	7	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 11,400 looking upstream at channel formed in cornfield; Stn 11,550 looking South across channel at deposition from drainage off of fields


Potential Project PP 32

Stream: Middle Creek Trib 7, Reach 3	Problem description: 2-ft knickpoint over clay about 10 ft downstream of corrugated metal pipe under 190th St W. Has the potential to move upstream and impact the crossing.
Station: 13,950	
Solution: Build grade control below the culvert.	

	Score	*Notes*
Infrastructure risk	3	
Erosion/channel stability	3	
Project complexity	5	
Location	3	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Fish passage	1	No quality habitat upstream
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 13,950 looking upstream at 2-ft knickpoint

Potential Project PP 33

Stream: Middle Creek Trib 7A, Reach 1	Problem description: 2, 6-inch knickpoints near the confluence are evidence of active incision. These will migrate upstream resulting in continued instability in this reach.
Station: 50	
Solution: Stabilize knickpoints with grade-controlling riffles.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	5	
Location	3	
Sediment/nutrient loading	3	
Project cost	5	
Aesthetic impact	1	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 0 looking upstream from confluence at small knickpoint

Potential Project PP 34

Stream: Middle Creek Trib 7A, Reach 1	Problem description: Historically straightened and deepened channel is now a ditch. The historic and ongoing incision results in excessive bank erosion through much of this section.
Station: 0-2100	

Solution: The cool water, canopy cover, and wide buffer from the fields presents an opportunity to complete full channel restoration with grade controls, riffles and pools, wider floodplains, and increased sinuosity.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	5	
Project complexity	3	
Location	3	
Sediment/nutrient loading	3	
Project cost	5	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	5	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 650 looking upstream at incised channel; Stn 1100 looking upstream at eroded bank

Potential Project **PP 35**

Stream: Middle Creek Trib 7A, Reach 1 Station: 2100-5750	Problem description: Historically straightened and deepened channel is now a ditch. There is little channel or habitat complexity and no canopy cover, though grasses do provide some cover near the banks. The buffer is narrow, about 5-15 ft, and consists of grass.
Solution: For full restoration, increase the riparian buffer similar to that in the section downstream, widen the floodplains and raise the channel bed, increase the sinuosity, and plant native riparian tree and shrub species.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	5	
Project complexity	3	
Location	3	
Sediment/nutrient loading	5	
Project cost	5	
Aesthetic impact	7	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	5	
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	7	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 5300 looking downstream at straightened ditch; Stn 5300 looking upstream at incised ditch

Potential Project **PP 36**

Stream: Middle Creek Trib 7A, Reach 1 Station: 5750-5900	Problem description: Incision has resulted in bank erosion and channel widening. Incision is continuing in drainages from fields and may impact field conditions in the future.
Solution: Provide toe stabilization and grade control where necessary. Could be incorporated into downstream restoration. Monitor the incision near the fields.	

	Score	*Notes*
Infrastructure risk	3	Fields
Erosion/channel stability	3	
Project complexity	5	
Location	3	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 5800 looking upstream at incision and pile of riprap below culvert; Stn 5950 looking downstream at incision

Potential Project **PP 37**

Stream: Middle Creek Trib 7A, Reach 2	Problem description: Upstream of Cedar Ave, Tributary 7A presents no opportunity for in-stream aquatic habitat, yet the watershed upstream of the road delivers volumes of water at rates that result in excessive incision and bank erosion downstream of Cedar Ave.
Station: 6200	

Solution: While a loss of agriculture land would be necessary, the area upstream of Cedar Ave could be a good location for a stormwater basin to slow the flow of overland flow to the downstream reaches. The culvert could be retro-fitted with a vertical pipe that would result in a retention or detention pond.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	5	Stability downstream will be improved
Project complexity	3	
Location	3	
Sediment/nutrient loading	7	
Project cost	7	Does not include any land purchase that may be necessary
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	5	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 6150 looking upstream at swale between corn fields; Stn 6200 looking downstream at 6.5-ft concrete pipe under Cedar Ave

Potential Project **PP 38**

Stream: Middle Creek Trib 7B, Reach 1	Problem description: Open grazing through channel with no canopy cover. Grazing has resulted in bank erosion and a diffuse channel as well as decreased water quality.
Station: 0-700	
Solution: Prevent livestock from grazing within a specific buffer width. Plant native riparian trees, shrubs, and forbs within fence to provide shading and improve infiltration of waste from livestock before it enters the channel. High-quality, cold-water aquatic habitat with wide riparian buffer is upstream of this section.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	3	
Sediment/nutrient loading	5	
Project cost	7	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	5	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 650 looking downstream at pasture

Potential Project **PP 39**

Stream: Middle Creek Trib 7B, Reach 1	Problem description: 3.5-ft knickpoint is currently stopped at tree roots, but is likely to continue if it works through the roots. If allowed to continue, this migrating knickpoint will continue to increase sediment loads downstream and could eventually impact the Cedar Ave crossing.
Station: 1350	
Solution: Build grade-controlling riffle.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	5	
Location	3	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	1	
Fish passage	5	
Property Ownership	0	Willingness to participate unknown
Public Education	1	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 1300 looking upstream at willow halting 3.5-ft knickpoint; Stn 1350 looking towards left bank at top of 3.5-ft knickpoint


Potential Project PP 40

Stream: Middle Creek Trib 9, Reach 1	Problem description: Channel is incised about 4 ft and is actively widening with excessive erosion and supply of suspended sediment.
Station: 0-2500	
Solution: Restore channel by raising the channel bed, widening the floodplains, increasing sinuosity, increasing riffle/pool frequency. Moderate riparian buffer width provides an opportunity to restore this channel.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	7	
Project complexity	3	
Location	7	
Sediment/nutrient loading	5	
Project cost	5	
Aesthetic impact	5	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	5	
In-stream Ecological Benefit	7	
Riparian Ecological Benefit	5	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 2350 looking downstream at incision and erosion; Stn 2450 looking downstream at incision

Potential Project **PP 41**

Stream: Middle Creek Trib 9, Reach 1 Station: 2500	Problem description: 4x6-ft concrete pipe under Highview Ave is perched 8 inches on the downstream end and the riprap at the mouth has been displaced by large flows with riprap on the banks sliding into the channel.

Solution: With channel restoration in this reach, this culvert could be protected by the raised bed or by improved grade control downstream of the culvert. This culvert is also long and has a flat bottom, both factors that would create challenges for fish passage. Replacing the existing riprap with a larger-rock riffle could create a backwater in the culvert, improving passage and stability.

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	3	
Project complexity	7	
Location	7	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	3	
Fish passage	5	
Property Ownership	7	County/city road
Public Education	3	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 2500 looking upstream at slightly perched culvert under Highview Ave; Stn 2600 looking downstream at 6X4 culvert under Highview Ave

Potential Project **PP 42**

Stream: Middle Creek Trib 9, Reach 2	Problem description: 3-ft knickpoint through clay will continue to migrate upstream, potentially destabilizing the channel throughout this reach
Station: 2700	
Solution: Stabilize with grade-controlling riffle. Cold-water, high-quality habitat is available further upstream	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	5	
Location	7	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Fish passage	5	
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 2700 looking upstream at 3-ft knickpoint through clay

Potential Project PP 43

Stream: Middle Creek Trib 9, Reach 2	Problem description: 4-ft knickpoint in drainage from drain tile about 100 ft from the channel and close to the fields. This knickpoint could undermine the tiling and eventually impact the fields. It also supplies excessive sediment loads to the channel.
Station: 5550	
Solution: Extend tiling to main channel and lower the outlet to the channel bed. Install stone at outlet to prevent bank erosion.	

	Score	*Notes*
Infrastructure risk	1	Though fields are fairly close
Erosion/channel stability	3	
Project complexity	7	
Location	7	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	1	
Fish passage	1	
Property Ownership	0	Willingness to participate unknown
Public Education	1	
In-stream Ecological Benefit	3	
Riparian Ecological Benefit	1	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 5550 looking South at 6-in tiling draining from field about 100-ft south of Tributary 9; Stn 5550 looking South at incision due to tiling

Potential Project **PP 44**

Stream: Middle Creek Trib 9, Reach 2	Problem description: 4.5-ft knickpoint over ~30-ft series of drops through clay. This knickpoint could continue to migrate upstream, thus destabilizing an intact channel and floodplain complex and potentially impacting fields in the future.
Station: 5850	
Solution: Re-grade and stabilize channel with grade-controlling riffle/pool sequence.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	5	
Project complexity	5	
Location	7	
Sediment/nutrient loading	3	
Project cost	5	
Aesthetic impact	1	
Fish passage	1	Not much habitat upstream
Property Ownership	0	Willingness to participate unknown
Public Education	3	
In-stream Ecological Benefit	5	
Riparian Ecological Benefit	3	
Greenway Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 5825 looking upstream at a knickpoint; Stn 5850 looking upstream at knickpoint

APPENDIX F: Detailed scoring sheet for all potential projects

Stream: North Creek
Location: Dakota County, MN
Client: Vermillion River Watershed Joint Powers Organization

Potential Project - Priority Ranking List

Project Number	Station Number	Primary Project	Secondary Project	*Inf. Risk*	*Channel stability*	*Project Complexity*	*Location*	*Sed/Nutrient Loading*	*Cost*	*Aesthetic impact*	*Fish Passage*	*Property Ownership*	*Public Education*	*In-stream Ecological*	*Riparian Ecological*	*Greenway Benefit*	*Total Score*
Banks Stabilization																	
PP16	25,850-26,150	B	R	3	3	7	5	3	7	3	1	7	3	3	3	3	**51**
PP24	30,975-31,000	B		1	1	7	5	3	7	3	1	7	5	3	3	1	**47**
Crossings																	
PP11	20,100	C		1	1	5	3	1	7	5	7	7	5	5	3	5	**55**
PP32	42,250	C		5	3	3	7	1	5	3	5	7	3	3	1	1	**47**
PP33	42,350	C		5	3	3	7	1	5	3	5	7	3	3	1	1	**47**
PP12	22,200	C		1	1	7	3	1	7	1	5	7	5	3	1	3	**45**
PP14	24,900	C		1	1	7	5	1	7	1	3	7	5	3	1	3	**45**
PP36	46,000	C		3	3	7	7	1	7	1	1	7	3	3	1	1	**45**
PP27	34,100	C	F	1	1	3	5	3	5	1	7	7	5	3	1	1	**43**
PP31	40,000	C		1	1	5	7	1	5	1	5	7	3	3	1	1	**41**
PP20	28,150	C		1	1	3	5	1	5	1	5	7	5	3	1	1	**39**
PP04	2,325	C		3	1	5	1	1	5	3	7	0	3	3	1	3	**36**
PP07	5,375	C		3	1	5	1	1	5	3	7	0	3	3	1	3	**36**
PP08	9,500	C		3	3	5	1	1	5	3	3	0	3	3	1	3	**34**
PP09	14,400	C		1	1	7	3	1	7	1	3	0	3	3	1	3	**34**
PP10	16,500	C	F	1	1	5	3	1	5	3	1	0	3	3	5	3	**34**
Grade Control																	
PP37	46,600	G	B	1	3	7	7	3	7	3	1	7	3	3	3	1	**49**
PP19	28,050	G	N	1	1	5	5	1	5	3	5	7	5	5	1	3	**47**
PP34	42,750	G	F	1	1	7	7	1	7	1	1	7	3	1	1	1	**39**
PP38	46,700	G		1	1	7	7	1	7	1	1	7	1	1	1	1	**37**
PP26	34,000	G	C	3	3	5	5	1	5	1	5	0	3	3	1	1	**36**
Infrastructure																	
PP17	26,400-26,450	I	B	3	3	7	5	3	7	3	1	7	3	1	3	1	**47**
PP23	30,550	I		3	3	3	5	3	5	7	1	7	3	3	1	3	**47**
PP13	24,625	I	B	3	3	7	5	3	7	1	1	7	1	1	1	1	**41**
PP03	2,000	I		1	1	7	1	1	7	3	1	0	1	3	1	1	**28**
Natural Channel Restoration																	
PP29	37,000-39,400	N	F	1	7	1	7	7	1	5	5	7	7	7	7	5	**67**
PP28	35,350-36,950	N	R	3	5	3	7	5	3	7	1	7	7	7	5	5	**65**
PP06	3,800-7,000; 10,150-16,500	N	R	1	7	1	3	7	1	7	1	0	7	7	7	7	**56**
Riparian Management																	
PP15	25,100-26,600	R	F	1	3	7	5	5	7	5	1	7	5	1	5	5	**57**
PP21	28,200-29,600	R		1	1	7	5	5	7	5	1	7	7	1	5	3	**55**

PP22	28,200-28,500; 28,700-28, 900	R		1	3	7	5	3	7	5	1	7	5	3	5	1	**53**
PP30	37,050-37,350	R	B	1	3	7	7	3	7	3	1	7	3	3	3	1	**49**
PP35	45,500-46,000	R	B	1	3	7	7	3	7	3	1	7	3	3	3	1	**49**
PP18	27,200-27,400	R	F	1	3	7	5	3	7	3	1	7	3	1	3	3	**47**
PP25	31,200-31,300 both banks; 31,500-31,600 right bank; 31,700-32,100 right bank; 32,000-32,100 left bank; 32,200-32,600 right bank; 33,350-33,450	R		1	3	7	5	5	7	5	1	0	3	3	5	1	**46**
PP02	1,300-1,550	R		1	3	7	1	3	7	3	1	0	5	3	3	1	**38**
PP01	1,075-1,200	R		1	1	7	1	3	7	3	1	0	3	3	3	1	**34**
PP05	2,500-2,600	R		1	1	7	1	3	7	3	1	0	3	3	3	1	**34**

Project type

B	Bank stabilization
C	Culvert or other crossing
F	Floodplain management
G	Grade control
I	Infrastructure (outfalls, buildings etc.)
N	Natural channel restoration/relocation
R	Riparian management

Stream: North Creek Tributaries
Location: Dakota County, MN
Client: Vermillion River Watershed Joint Powers Organization

Potential Project - Priority Ranking List

Project Number	Station Number	Primary Project	Secondary Project	*Inf. Risk*	*Channel stability*	*Project Complexity*	*Location*	*Sed/Nutrient Loading*	*Cost*	*Aesthetic impact*	*Fish Passage*	*Property Ownership*	*Public Education*	*In-stream Ecological*	*Riparian Ecological*	*Green way*	*Total Score*
Floodplain Management																	
PP40-Trib 1	1,900-7,200	F	N	1	1	3	1	5	3	5	1	7	5	5	3	5	**45**
Grade Control																	
PP42-Trib 5	4,000	G	C	3	1	7	7	1	7	1	3	7	3	3	1	1	**45**
PP41-Trib 5	1,800	G		1	1	7	7	1	7	1	1	7	3	1	1	1	**39**
Natural Channel Restoration																	
PP39-Trib 1	0-1,500	N	F	1	3	3	1	5	5	5	1	0	3	5	5	7	**44**

Project type

B	Bank stabilization
C	Culvert or other crossing
F	Floodplain management
G	Grade control
I	Infrastructure (outfalls, buildings etc.)
N	Natural channel restoration/relocation
R	Riparian management

Stream: Middle Creek
Location: Dakota County, MN
Client: Vermillion River Watershed Joint Powers Organization

Potential Project - Priority Ranking List

Project Number	Station Number	Primary Project	Secondary Project	*Inf. Risk*	*Channel stability*	*Project Complexity*	*Location*	*Sed/Nutrient Loading*	*Cost*	*Aesthetic impact*	*Fish Passage*	*Property Ownership*	*Public Education*	*In-stream Ecological*	*Riparian Ecological*	*Green way*	*Total Score*
Bank Stabilization																	
PP08	16,700-19,800	B	R	1	7	7	3	7	7	7	1	-7	5	7	7	5	**57**
PP05	8800	B		1	1	7	1	3	7	1	1	0	1	3	3	1	**30**
Crossings																	
PP12	20,650	C		3	5	5	3	5	7	3	5	7	5	5	1	1	**55**
PP07	13,050	C		1	1	7	3	1	7	1	3	7	3	3	1	1	**39**
PP04	1950	C		5	1	7	1	1	7	1	1	7	1	1	1	1	**35**
PP06	10000	C		3	1	5	1	1	7	5	1	0	3	3	1	1	**32**
Infrastructure																	
PP03	3,100-3,600	I		1	3	7	1	1	7	7	1	0	3	3	1	1	**36**
PP02	1200	I		7	3	5	1	1	7	1	1	0	1	1	1	1	**30**
Natural Channel Restoration																	
PP11	19,700-22,500	N		1	5	7	3	5	7	5	3	7	7	5	5	3	**63**
PP09	19,700-50,200	N	F	1	7	3	7	7	1	7	3	-7	7	7	7	7	**57**
Riparian Management																	
PP10	19,700-50,200	R	F	1	7	5	7	7	5	7	1	-7	7	7	7	7	**61**
PP01	0-1,900	R	B	3	3	7	1	5	7	5	1	0	3	5	5	1	**46**
PP14	31,200-32,500	R	F	1	5	7	5	5	7	5	1	-7	3	3	5	3	**43**
PP13	28,500-28,700	R		1	3	7	5	3	7	5	1	0	1	3	3	1	**40**

Project type

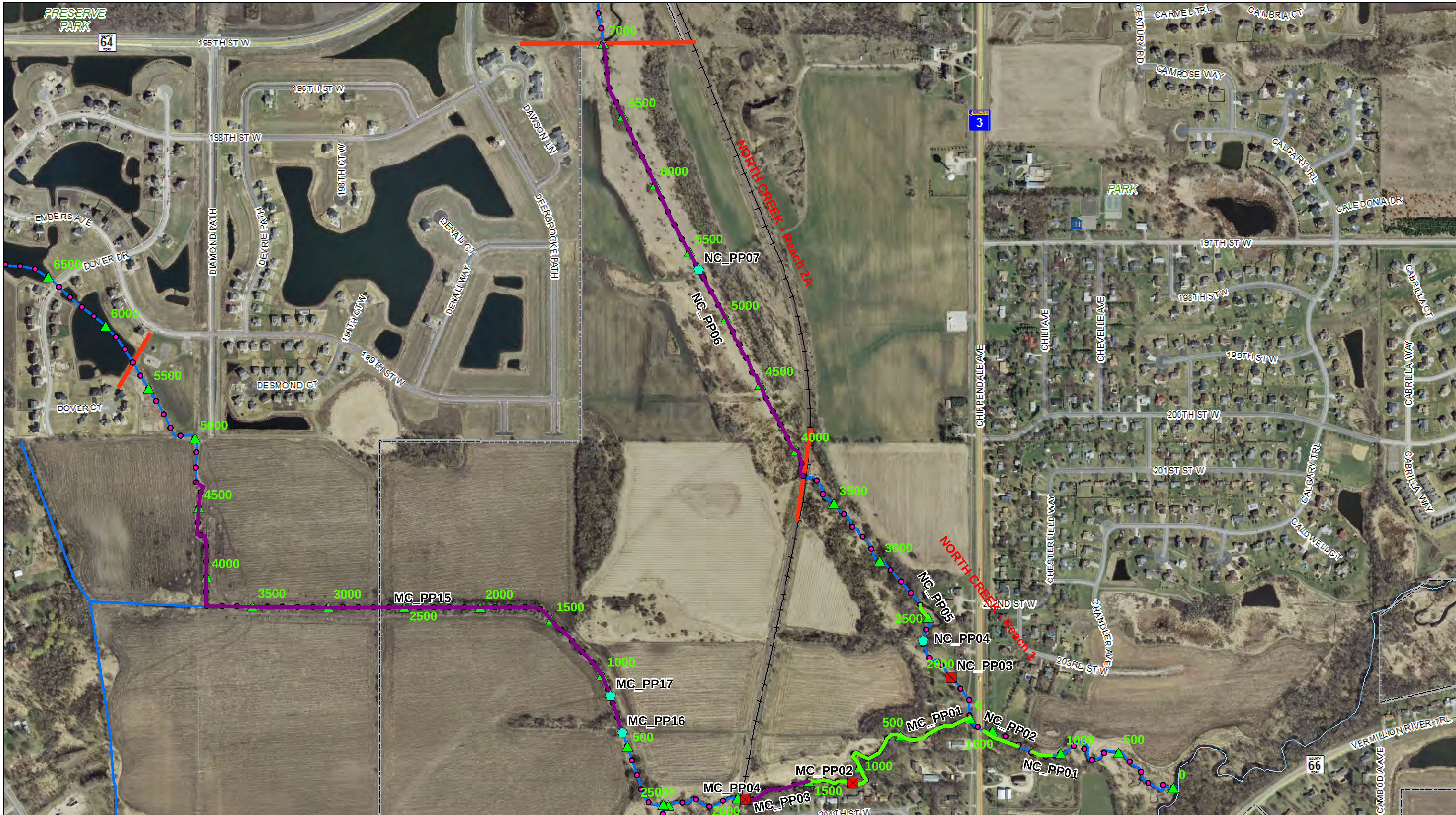
B	Bank stabilization
C	Culvert or other crossing
F	Floodplain management
G	Grade control
I	Infrastructure (outfalls, buildings etc.)
N	Natural channel restoration/relocation
R	Riparian management

Stream: Middle Creek Tributaries
Location: Dakota County, MN
Client: Vermillion River Watershed Joint Powers Organization

Potential Project - Priority Ranking List

Project Number	Station Number	Primary Project	Secondary Project	*Inf. Risk*	*Channel stability*	*Project Complexity*	*Location*	*Sed/Nutrient Loading*	*Cost*	*Aesthetic impact*	*Fish Passage*	*Property Ownership*	*Public Education*	*In-stream Ecological*	*Riparian Ecological*	*Green way*	*Total Score*
Bank Stabilization																	
PP36-Trib 7A	5,750-5,900	B	G	3	3	5	3	3	7	3	1	0	3	3	1	1	**36**
Crossings																	
PP41-Trib 7B	2,500	C	G	3	3	7	7	1	7	3	5	7	3	3	1	1	**51**
PP20-Trib 6	1,300	C		1	1	7	3	1	7	3	5	7	3	3	1	1	**43**
PP26-Trib 7	4,550	C		5	3	5	3	1	5	1	3	7	3	3	1	1	**41**
PP30-Trib 7	8,550	C	F	3	3	5	3	5	5	3	3	0	3	3	3	1	**40**
PP29-Trib 7	7,750	C		1	1	7	3	1	7	1	3	7	3	3	1	1	**39**
PP16-Trib 1	600	C		1	1	7	1	1	7	3	5	0	1	5	1	1	**34**
PP17-Trib 1	850	C		1	1	7	1	1	7	3	5	0	1	5	1	1	**34**
Floodplain Management																	
PP27-Trib 7	5,500-6,600	F	R	1	3	7	3	5	7	5	1	0	3	5	5	1	**46**
PP37-Trib 7A	6,200	F		1	5	3	3	7	7	5	1	0	5	5	3	1	**46**
PP38-Trib 7A	0-700	F	R	1	3	7	3	5	7	5	1	0	3	5	5	1	**46**
PP31-Trib 7	10,450-11,500	F	N	1	5	7	3	5	7	3	1	0	3	5	3	1	**44**
PP22-Trib 6	1,400-2,500	F	R	1	3	7	3	5	7	3	1	0	3	3	5	1	**42**
PP43-Trib 9	5,550	F	G	1	3	7	7	3	7	1	1	0	1	3	1	1	**36**
Grade Control																	
PP21-Trib 6	1,400-2,500	G	I	3	3	7	3	3	7	3	7	0	3	5	1	1	**46**
PP42-Trib 9	2,700	G		1	3	5	7	3	7	3	5	0	3	5	1	1	**44**
PP44-Trib 9	5,850	G		1	5	5	7	3	5	1	1	0	3	5	3	1	**40**
PP39-Trib 7A	1,350	G		1	3	5	3	3	7	1	5	0	1	3	1	1	**34**
PP32-Trib 7	13,950	G	C	3	3	5	3	1	7	1	1	0	3	3	1	1	**32**
PP33-Trib 7	50	G		1	3	5	3	3	5	1	1	0	3	3	1	1	**30**
Natural Channel Restoration																	
PP40-Trib 7B	0-2,500	N	R	1	7	3	7	5	5	5	1	0	5	7	5	1	**52**
PP35-Trib 7A	2,100-5,750	N	R	1	5	3	3	5	5	7	1	0	5	7	7	1	**50**
PP25-Trib 7	1,800-4,500	N	R	1	5	3	3	5	3	5	3	0	3	7	7	1	**46**
PP15-Trib 1	600-4,700	N	R	1	1	3	1	5	3	5	3	0	3	7	7	5	**44**
PP28-Trib 7	6,800-7,600	N	G	3	5	3	3	5	3	3	5	0	3	5	3	1	**42**
PP34-Trib 7	0-2,100	N	R	1	5	3	3	3	5	5	1	0	5	5	3	1	**40**
PP23-Trib 6	0-1,500	N	R	1	3	3	3	5	5	5	1	-7	5	5	5	3	**37**
PP18-Trib 2	0-3,100	N	R	1	1	3	1	3	5	3	1	0	3	7	7	1	**36**
Riparian Management																	
PP24-Trib 6	1,800-6,600	R		1	3	7	3	3	7	5	1	0	3	3	5	3	**44**
PP19-Trib 6	500-1,200	R		1	3	7	3	3	7	3	1	0	3	3	3	1	**38**

APPENDIX G: Detailed maps of all streams and subwatersheds with potential projects identified. Green numbers are 500ft stationing along the channel centerline; black numbers within the white halo are the number of the potential project.



N

0 0.1 Miles

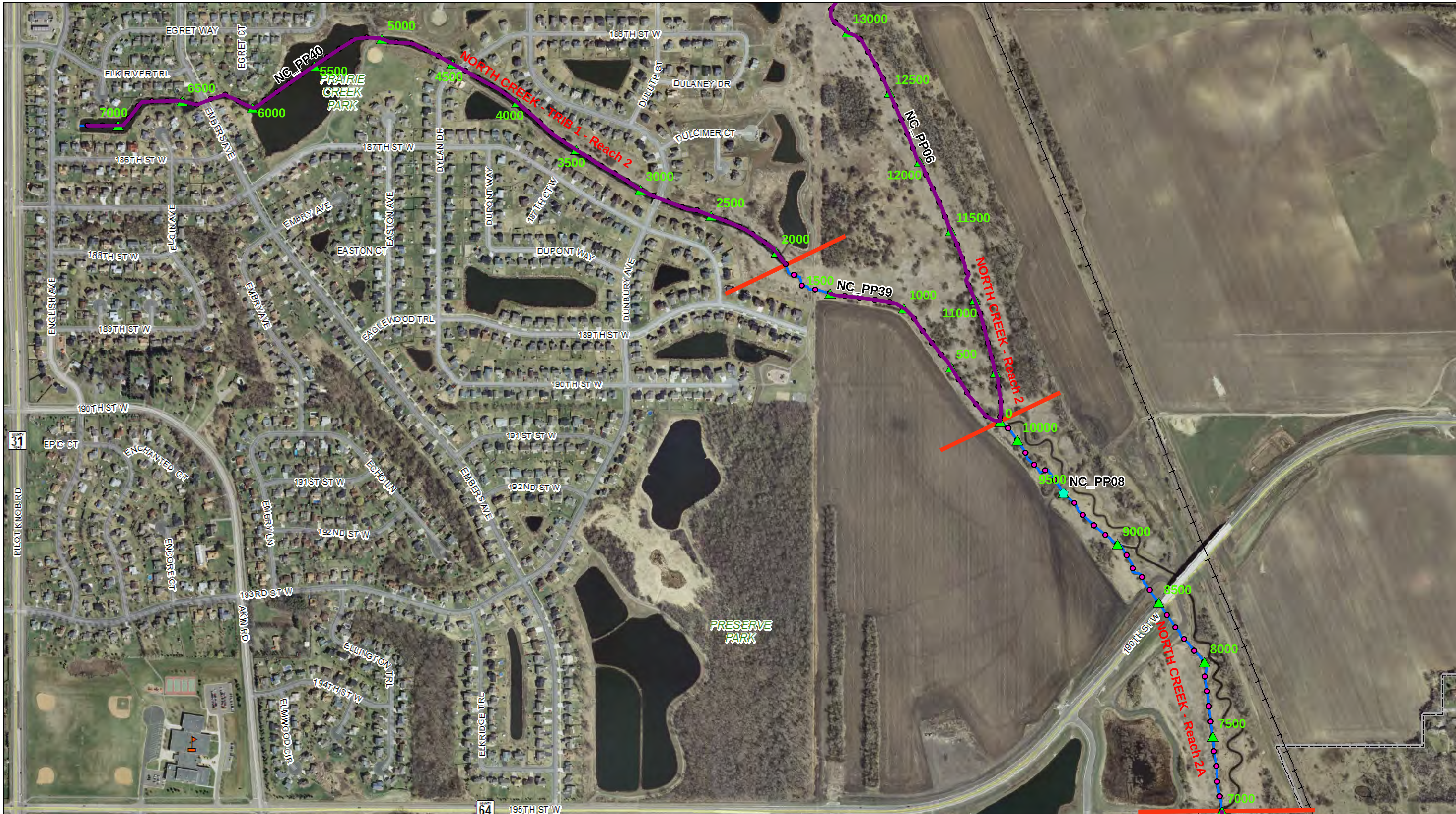
- Streams
- 500ft Stations
- 100ft Stations
- Reach Break

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment
Potential Projects
North Creek
Sheet 01 of 18

inter·fluve
Inter-Fluve, Inc.
3602 Atwood Ave., Suite #3
Madison, WI 53714
www.interfluve.com
608-441-0342



N	0 — 0.1 Miles

Legend

- Streams
- 500ft Stations
- 100ft Stations
- Reach Break

Project Type

Points		Lines	
Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment
Potential Projects
North Creek
Sheet 02 of 18

Inter-Fluve, Inc.
3602 Atwood Ave., Suite #3
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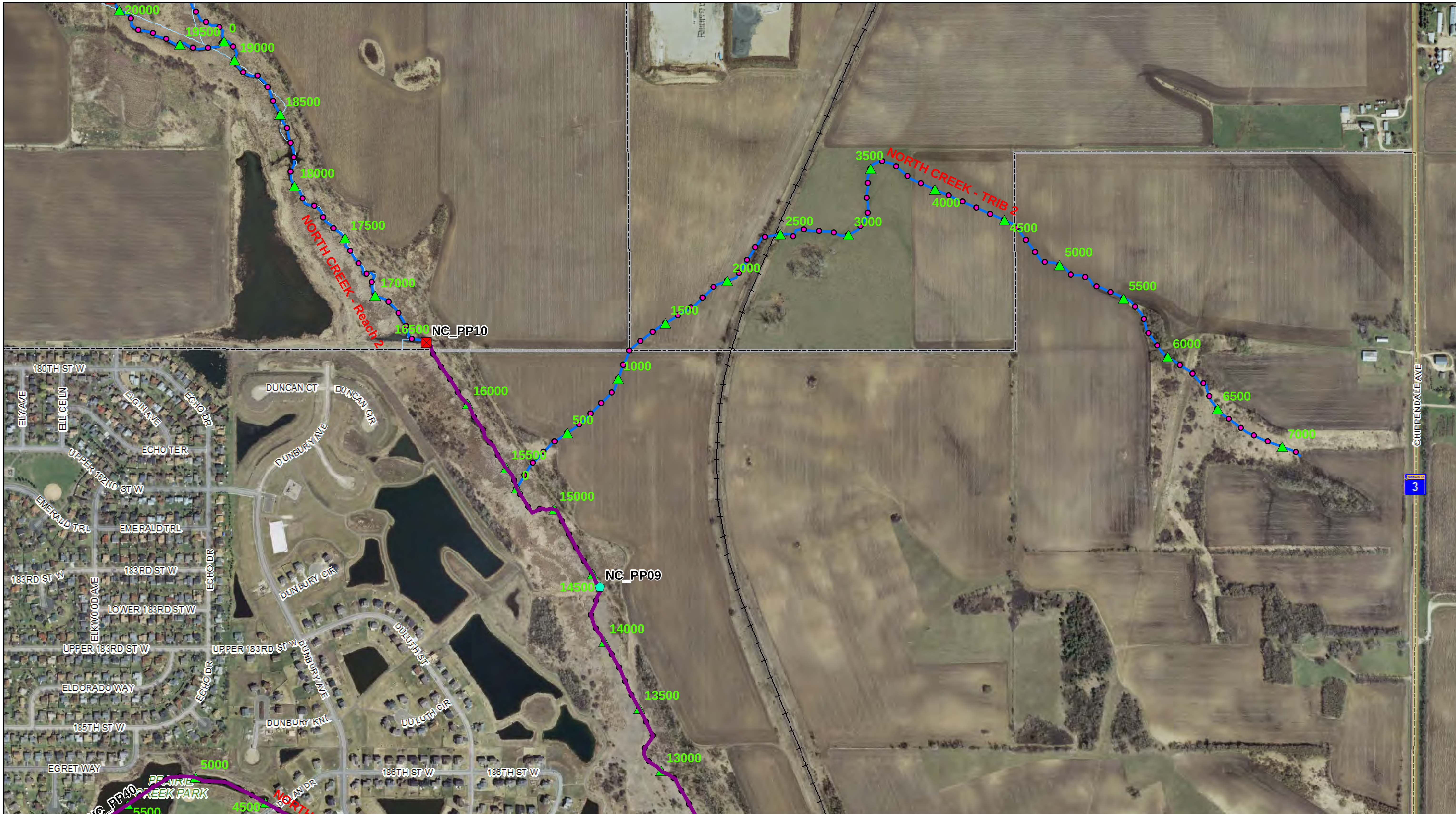

N

0 0.1 Miles

- Streams
- 500ft Stations
- 100ft Stations
- Reach Break

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment
Potential Projects
North Creek
Sheet 03 of 18

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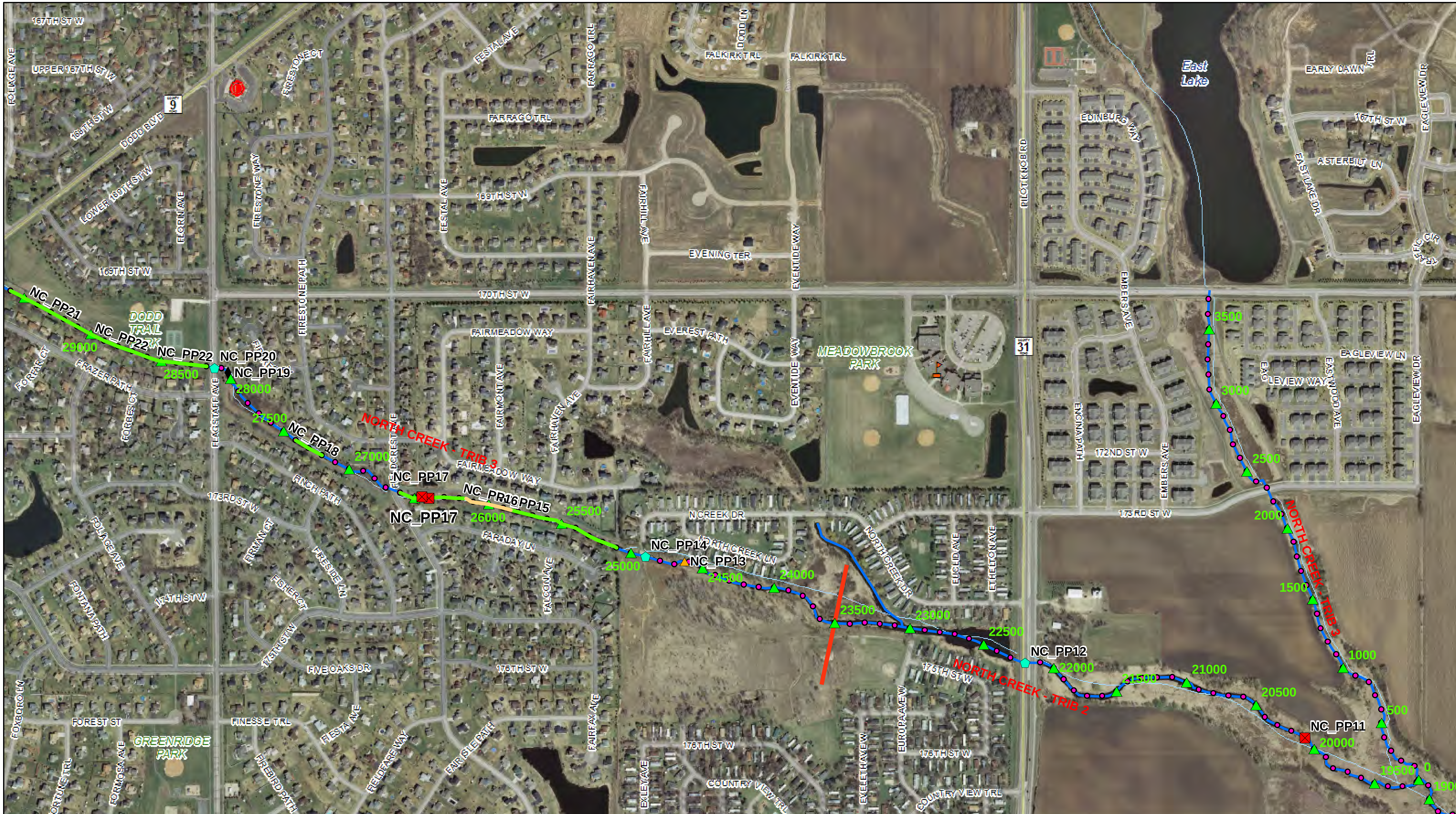

N

0 0.1 Miles

- Streams
- 500ft Stations
- 100ft Stations
- Reach Break

Project Type

- Bank
- Crossing
- Floodplain
- Grade
- Infrastructure
- Riparian
- Bank
- Floodplain
- Grade
- Infrastructure
- Natural Channel
- Riparian

Geomorphic Assessment Potential Projects
North Creek
Sheet 04 of 18

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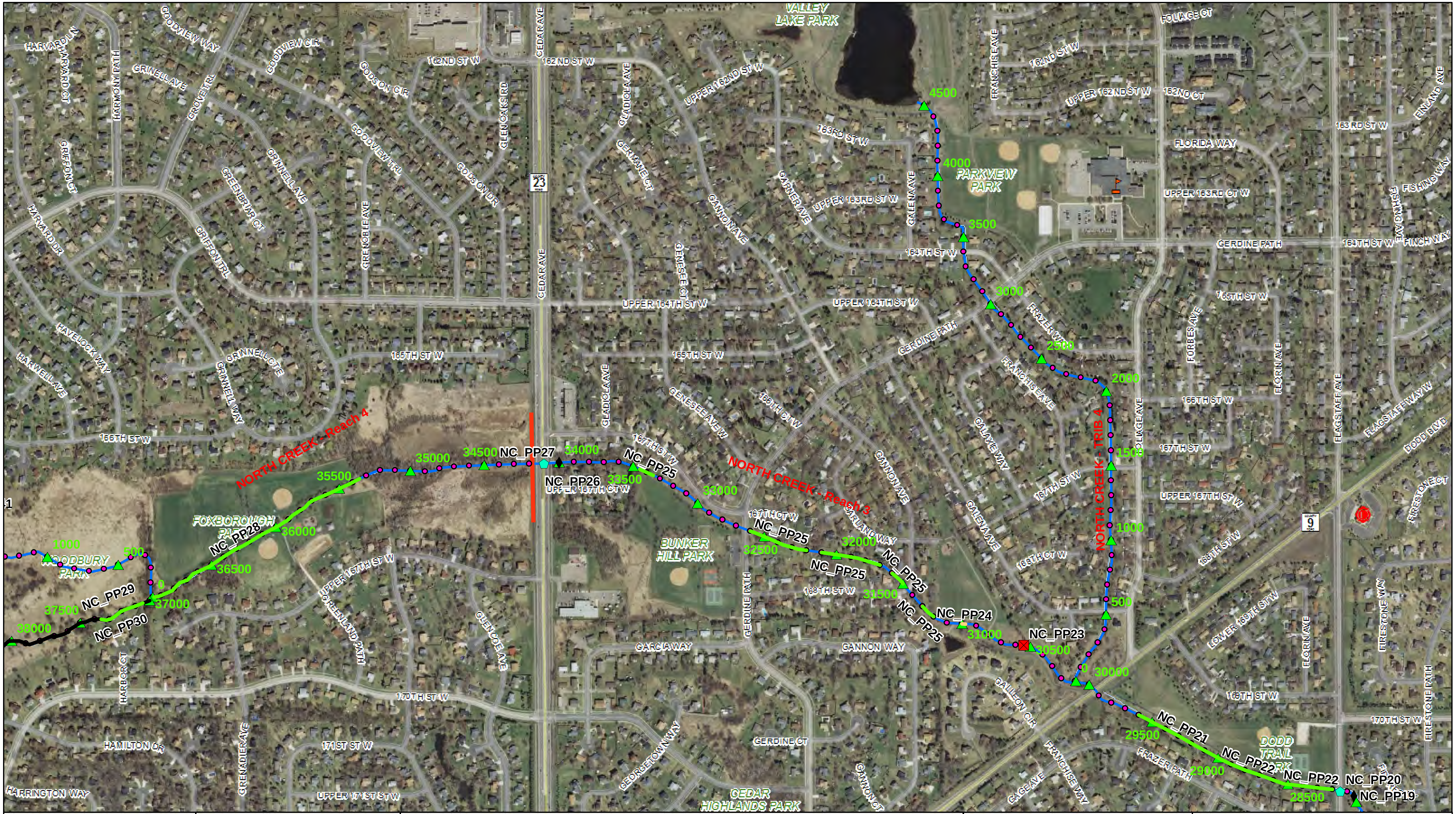
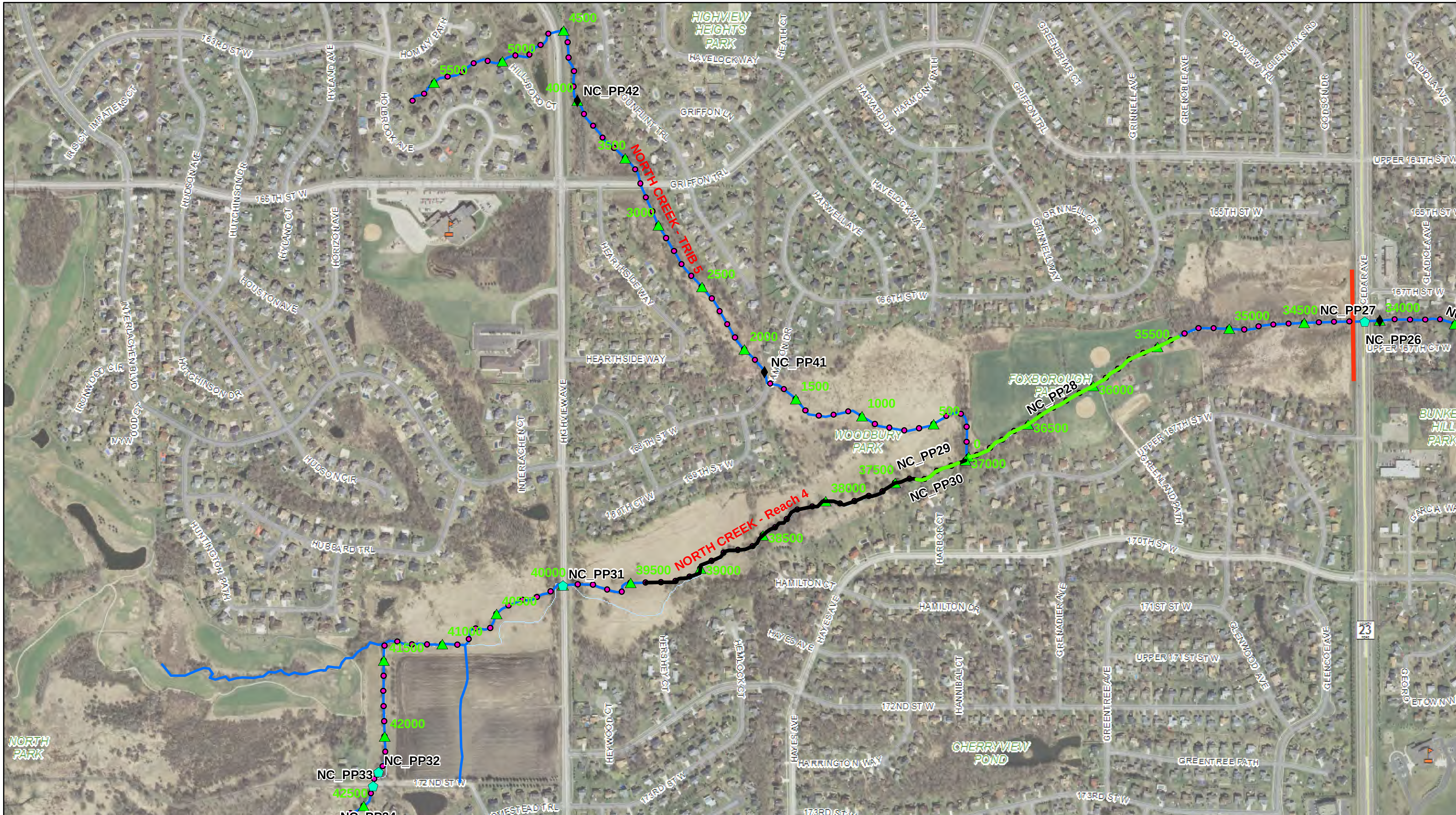


Streams	**Project Type**						**Geomorphic Assessment Potential Projects**	Inter-Fluve, Inc.
500ft Stations	Bank	Grade	Bank	Infrastructure			**North Creek**	3602 Atwood Ave., Suite #3
100ft Stations	Crossing	Infrastructure	Floodplain	Natural Channel			**Sheet 05 of 18**	Madison, WI 53714
Reach Break	Floodplain	Riparian	Grade	Riparian				www.interfluve.com
0 0.1 Miles								608-441-0342



N

0 0.1 Miles

- Streams
- 500ft Stations
- 100ft Stations
- Reach Break

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment Potential Projects
North Creek
Sheet 06 of 18

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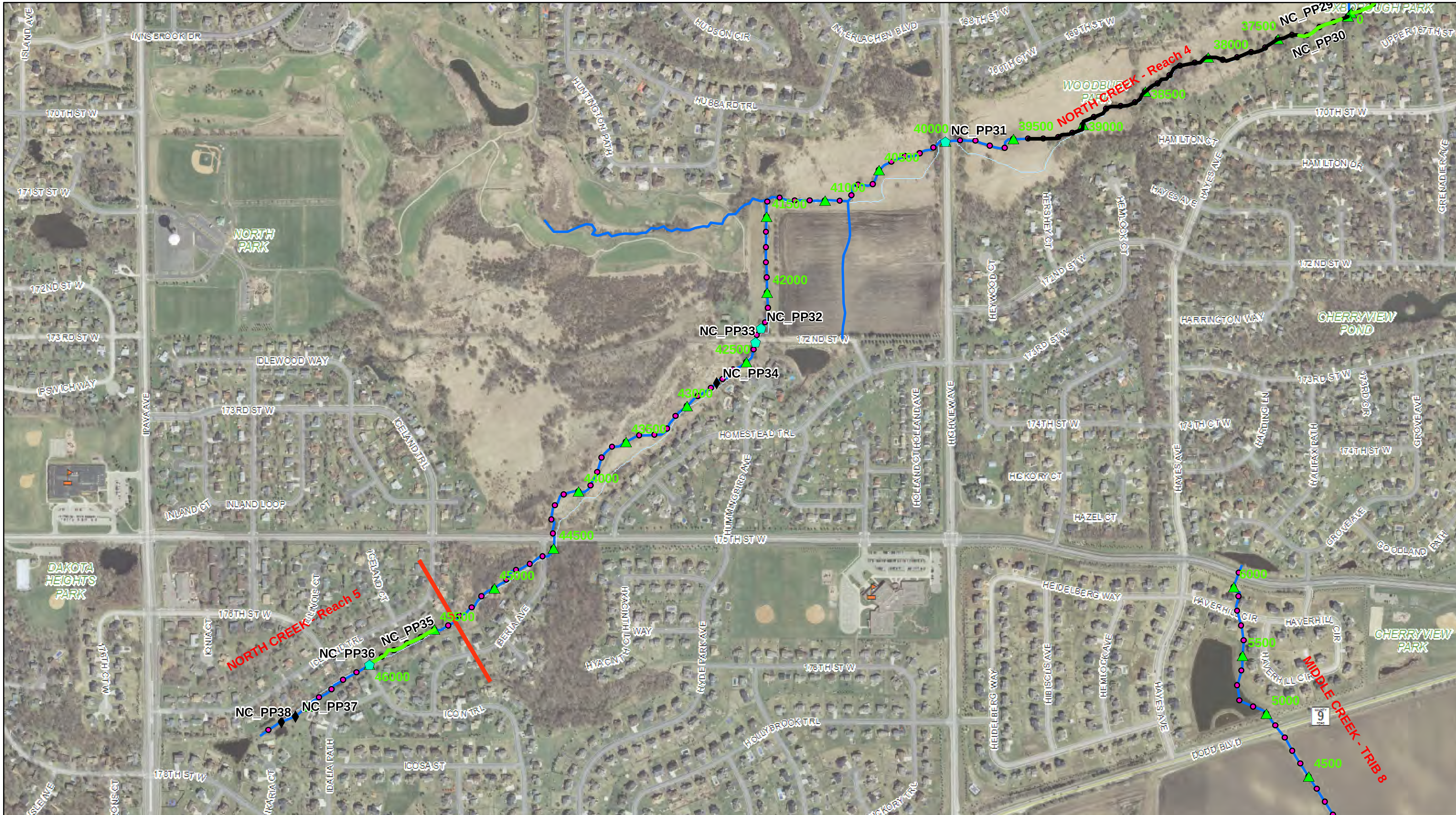

N	Streams	**Project Type**				
0 0.1 Miles	500ft Stations	Bank (point)	Grade (point)	Bank (line)	Infrastructure (line)	
	100ft Stations	Crossing	Infrastructure (point)	Floodplain (line)	Natural Channel (line)	
	Reach Break	Floodplain (point)	Riparian (point)	Grade (line)	Riparian (line)	

Geomorphic Assessment Potential Projects North Creek

Sheet 07 of 18

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Streams		
500ft Stations		
100ft Stations		
Reach Break		

0 0.1 Miles

Project Type

Points		Lines	
Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment Potential Projects
Middle Creek
Sheet 08 of 18

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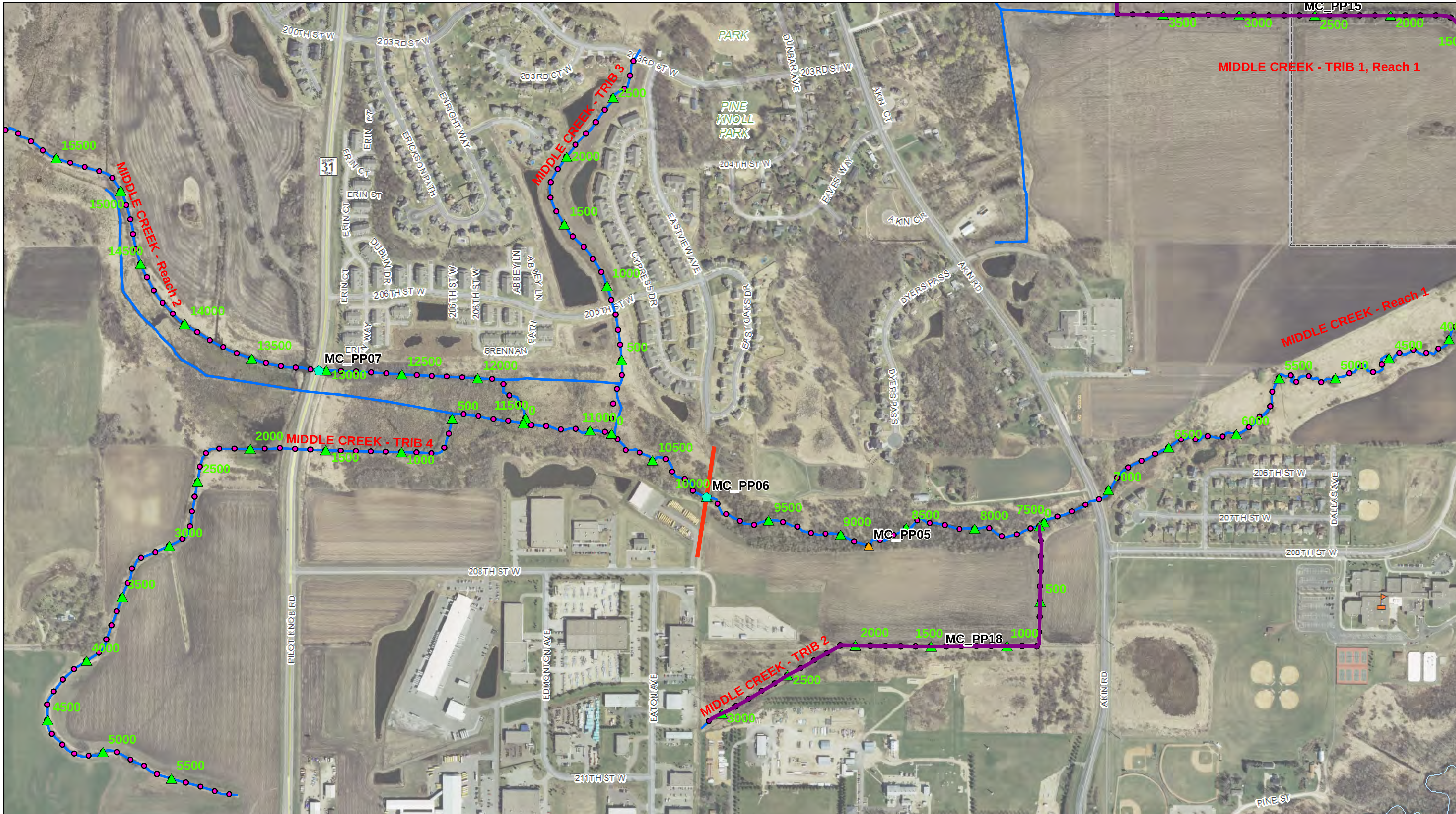

N

0 0.1 Miles

- Streams
- 500ft Stations
- 100ft Stations
- Reach Break

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment Potential Projects
Middle Creek
Sheet 09 of 18

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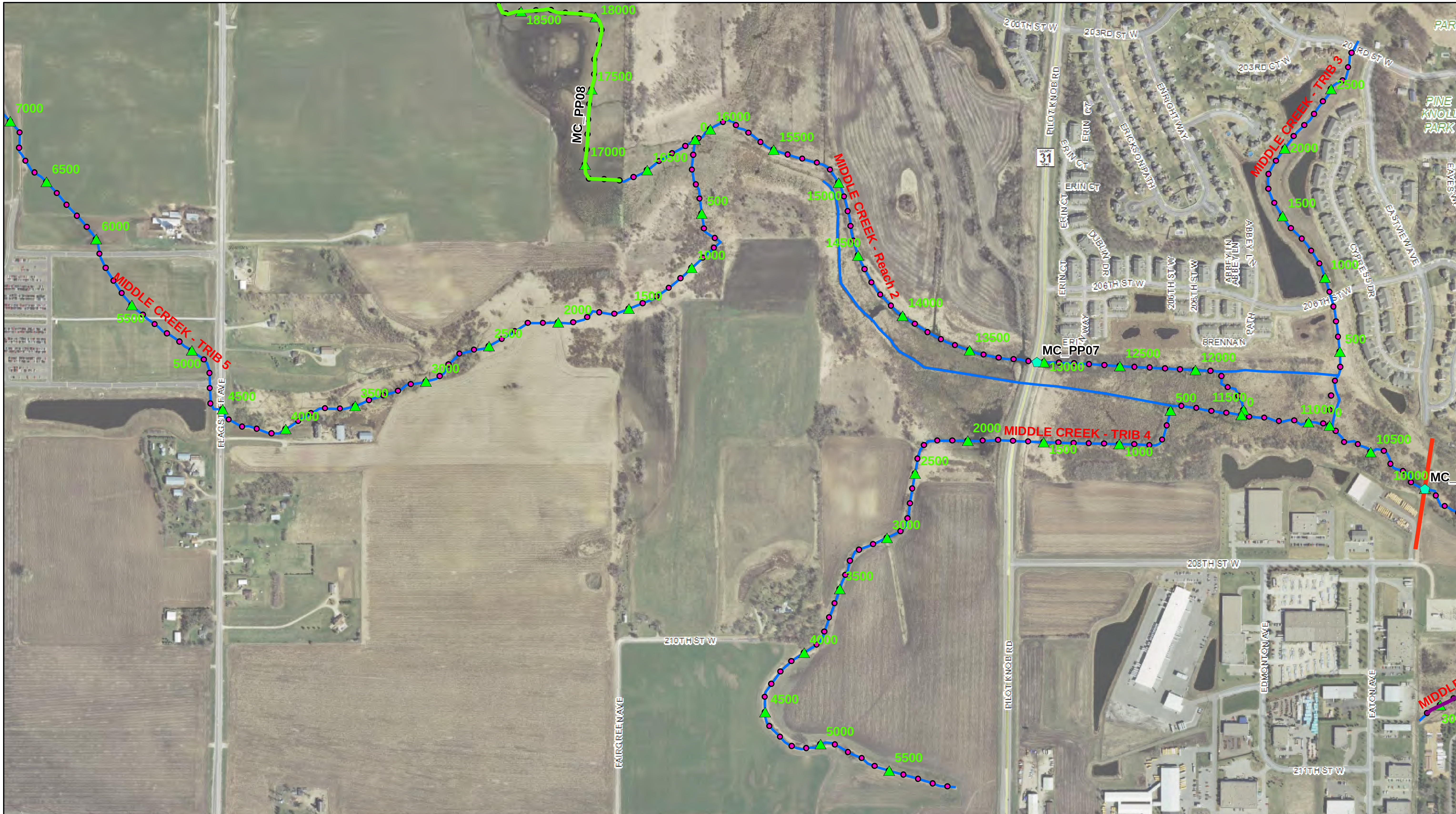

Streams			
500ft Stations			
100ft Stations			
Reach Break			

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

N

0 0.1 Miles

Geomorphic Assessment
Potential Projects
Middle Creek
Sheet 10 of 18

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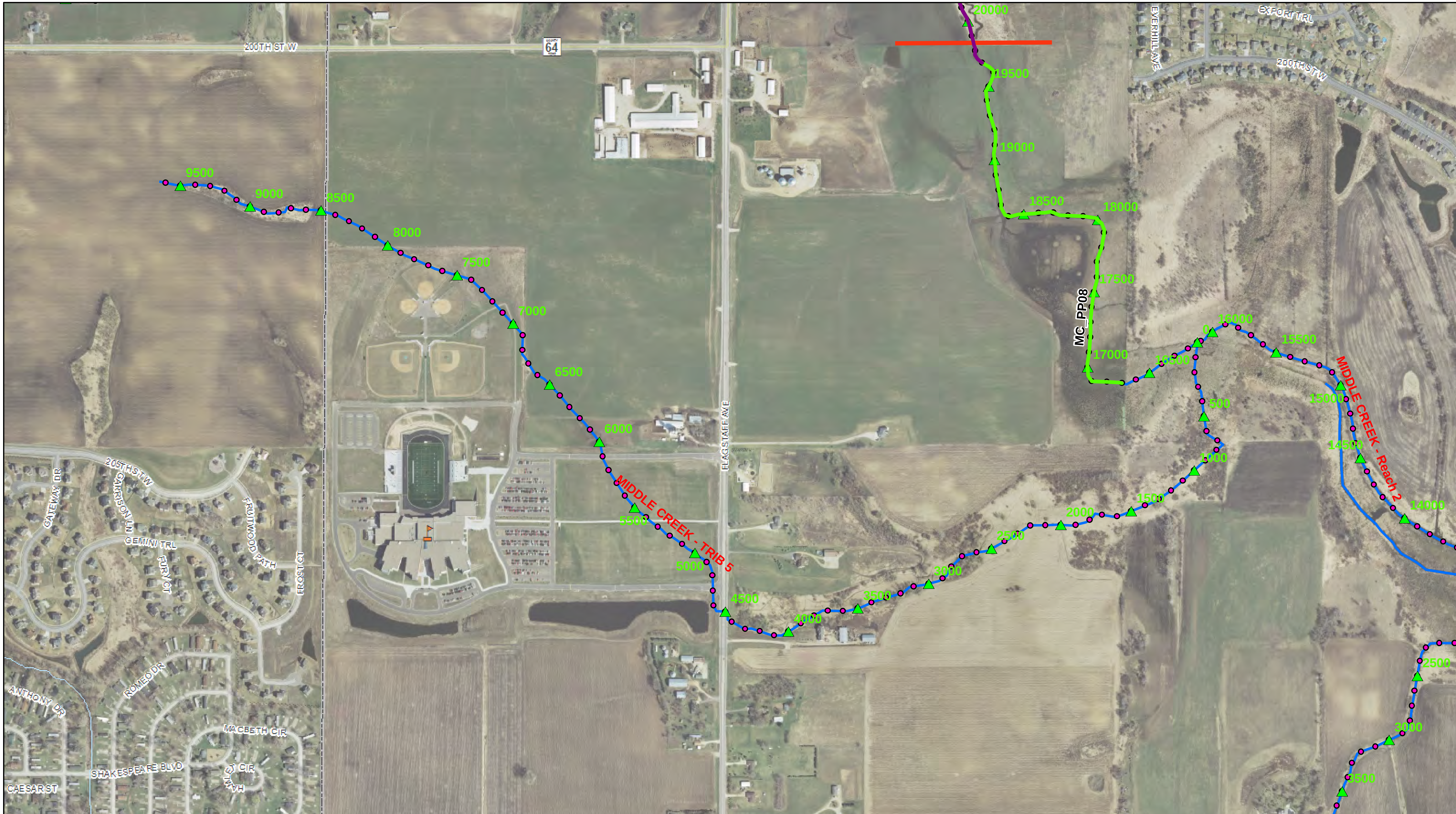

N

0 0.1 Miles

- Streams
- 500ft Stations
- 100ft Stations
- Reach Break

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment Potential Projects
Middle Creek
Sheet 11 of 18

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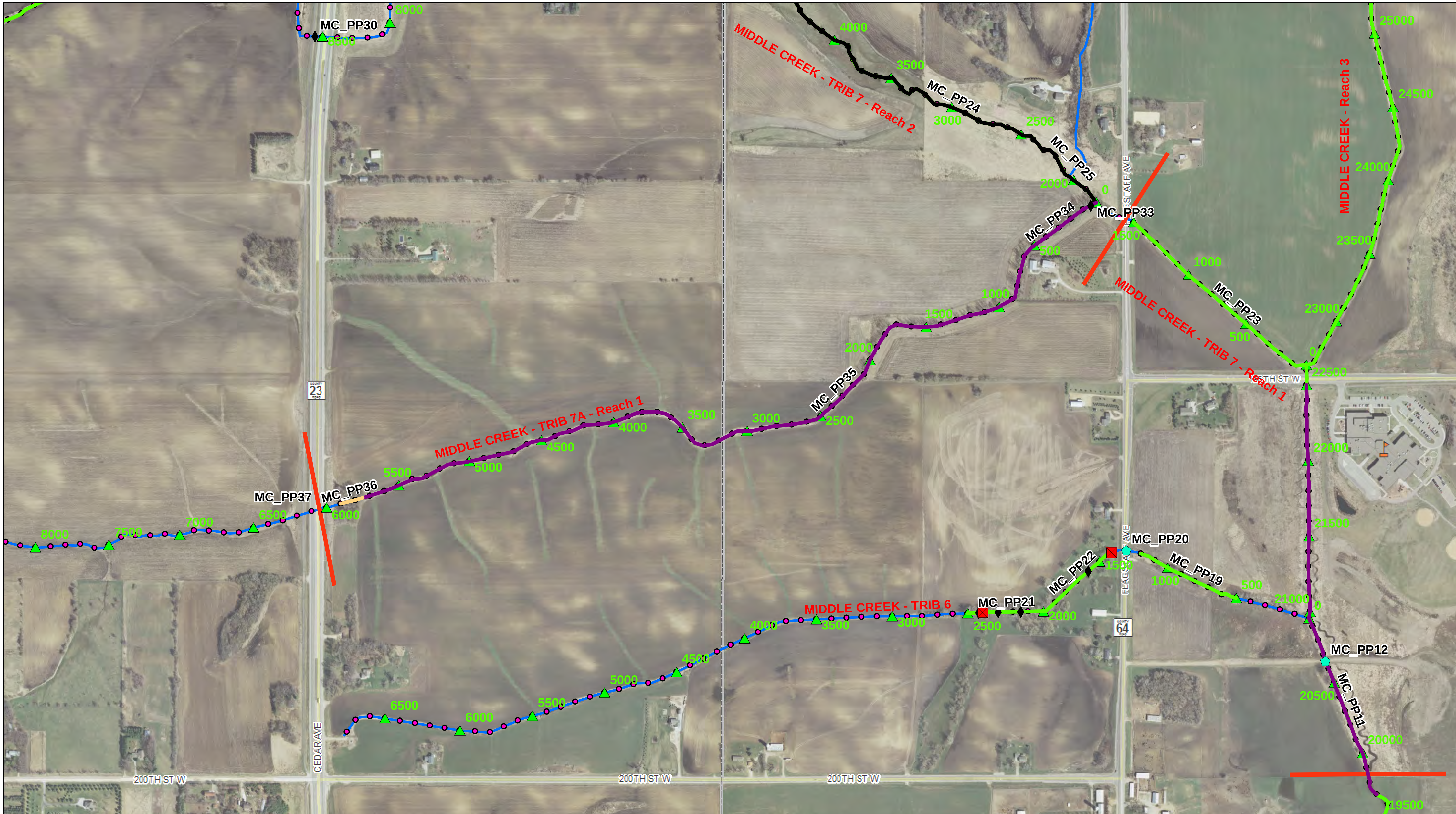

Streams	Project Type			
500ft Stations	Bank	Grade	Bank	Infrastructure
100ft Stations	Crossing	Infrastructure	Floodplain	Natural Channel
Reach Break	Floodplain	Riparian	Grade	Riparian

N

0 0.1 Miles

Geomorphic Assessment Potential Projects
Middle Creek
Sheet 12 of 18

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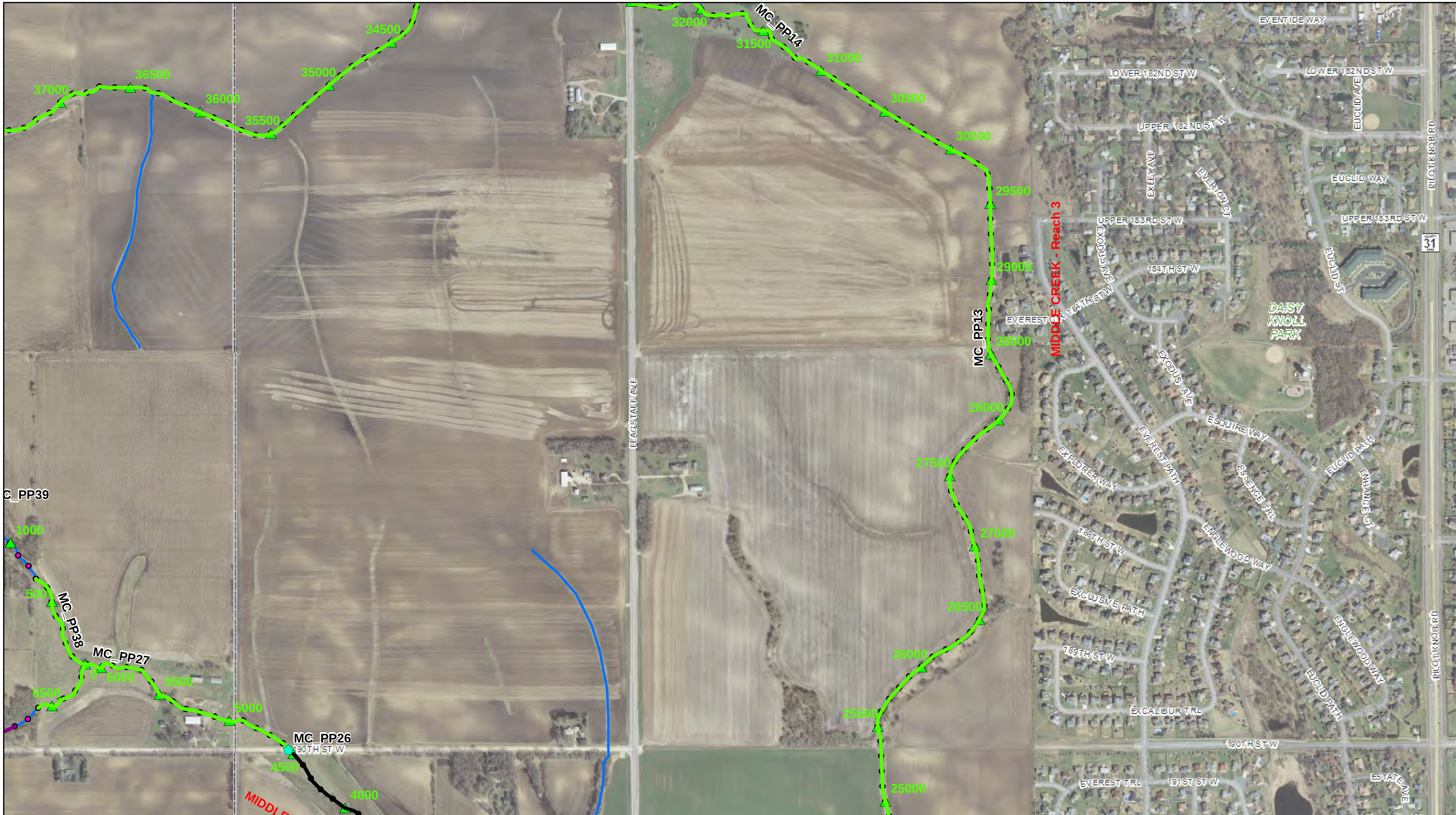

N

0 0.1 Miles

- Streams
- 500ft Stations
- 100ft Stations
- Reach Break

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment Potential Projects
Middle Creek
Sheet 13 of 18

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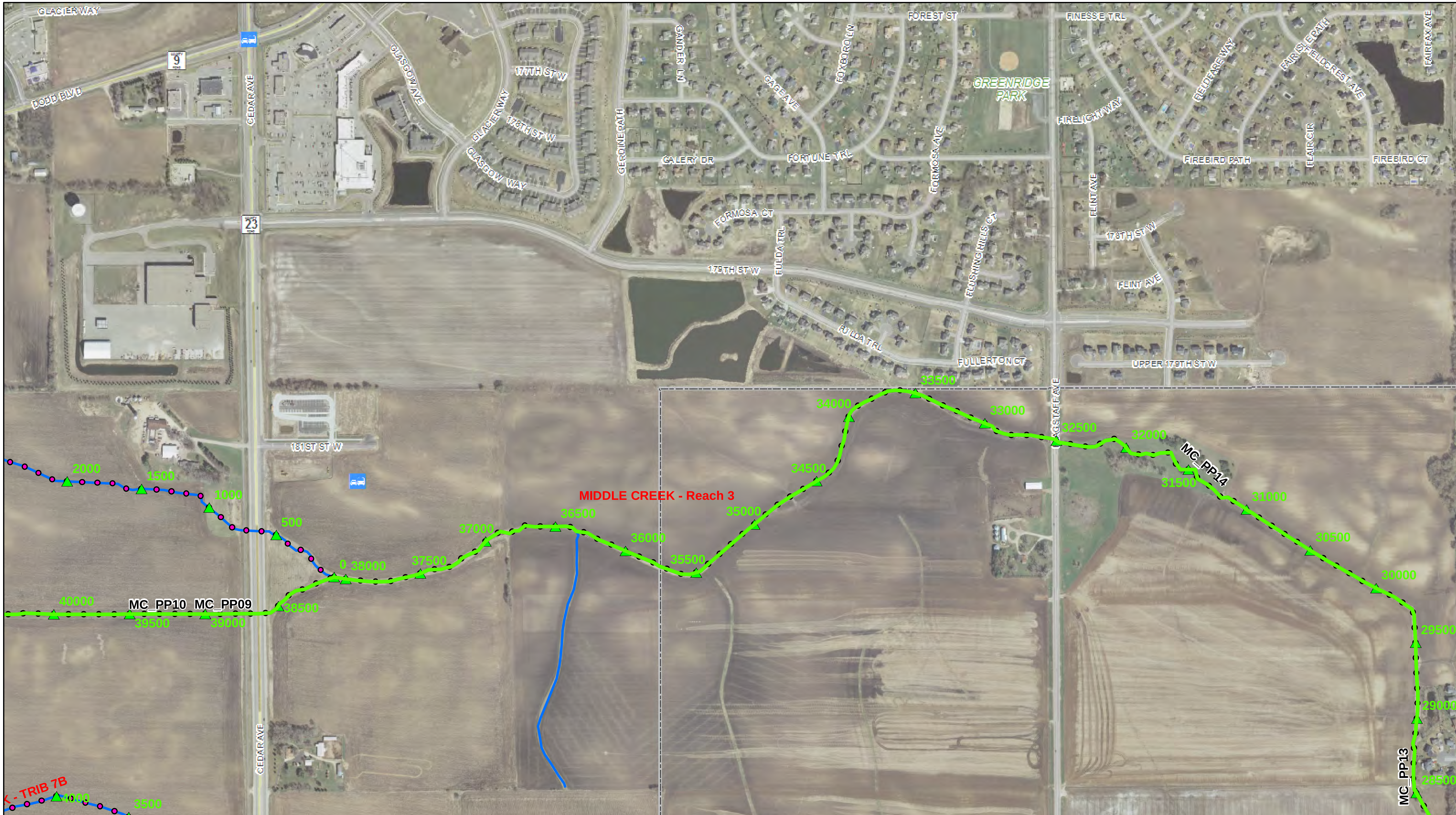

N

0 0.1 Miles

Streams
500ft Stations
100ft Stations
Reach Break

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment
Potential Projects
Middle Creek
Sheet 14 of 18

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N	Streams	
0 0.1 Miles	500ft Stations	
	100ft Stations	
	Reach Break	

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment Potential Projects
Middle Creek
Sheet 15 of 18

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0 0.1 Miles		

Streams
500ft Stations
100ft Stations
Reach Break

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment
Potential Projects
Middle Creek
Sheet 16 of 18

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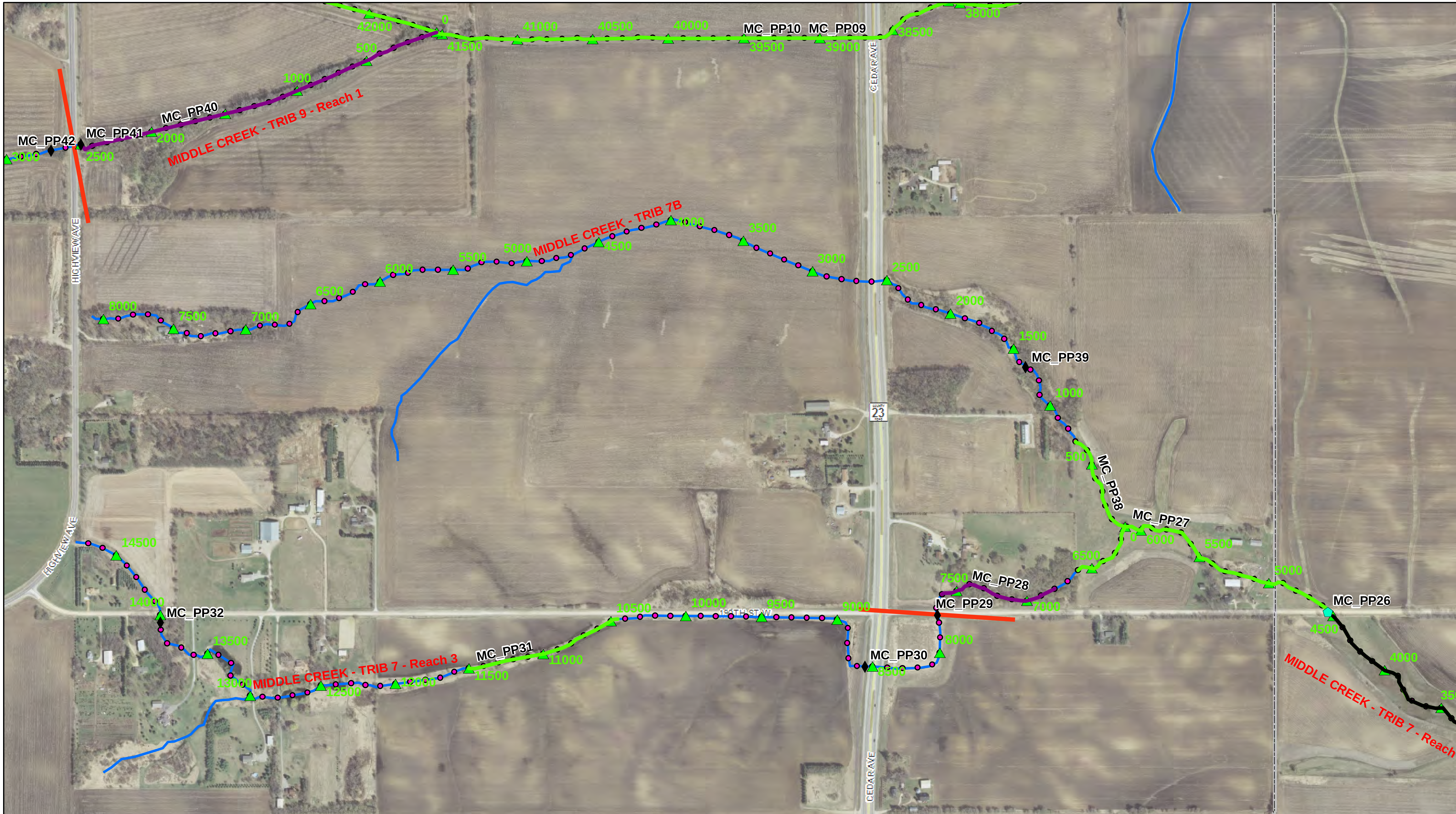

N

0 0.1 Miles

Legend	
Streams	
500ft Stations	
100ft Stations	
Reach Break	

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment
Potential Projects
Middle Creek
Sheet 17 of 18

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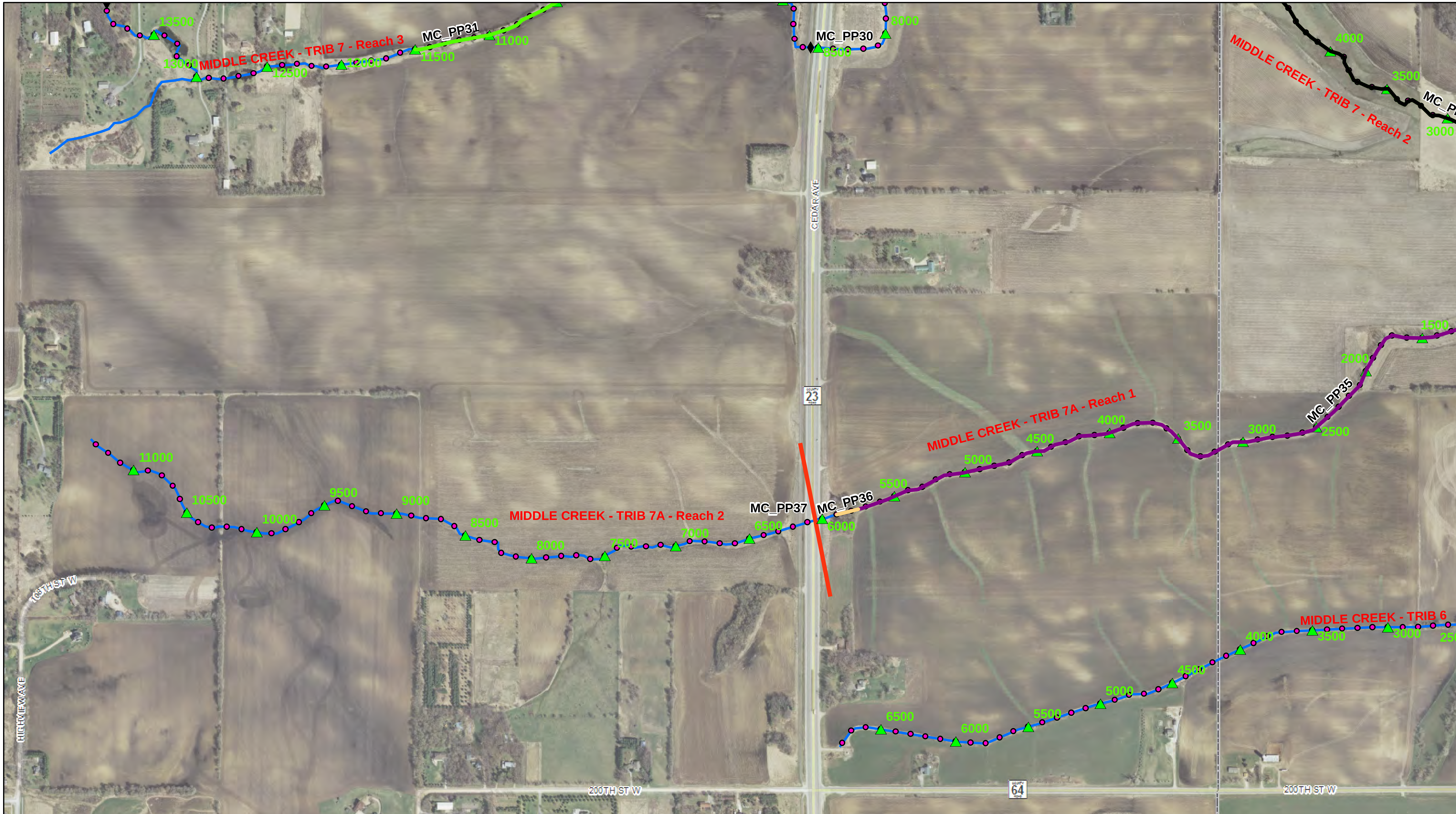

N

0 0.1 Miles

- Streams
- 500ft Stations
- 100ft Stations
- Reach Break

Project Type

Bank	Grade	Bank	Infrastructure
Crossing	Infrastructure	Floodplain	Natural Channel
Floodplain	Riparian	Grade	Riparian

Geomorphic Assessment
Potential Projects
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Sheet 18 of 18

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