Lower Vermillion River Geomorphic Assessment

FINAL SUBMITTAL
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SUBMITTED TO
Vermillion River Watershed Joint Powers Organization
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1. Executive Summary

The Vermillion River Watershed Joint Powers Organization (VRWJPO) contracted with Inter-Fluve to conduct a fluvial geomorphic assessment of the Vermillion River from US Highway 52 (Hwy 52) to Vermillion Falls in the City of Hastings, referred to here as the Lower Vermillion River. The goals of this rapid geomorphic assessment were to:

1. Examine channel condition and stability
2. Assess riparian and aquatic habitats
3. Note infrastructure near, in, or crossing the Vermillion River and issues relating to the interactions between the river and infrastructure
4. Note past project conditions
5. Identify potential projects to improve water quality and aquatic and riparian ecosystems within the Vermillion River
6. Quantify pollutant reductions in select potential projects

The Lower Vermillion River flows approximately 13.5 miles from Hwy 52 to Vermillion Falls. The geomorphic assessment noted information on soils, stream bed grain size, infrastructure, land use and vegetation. Background research was also done on bedrock, surface geology, and historic conditions.

Inter-Fluve identified 34 potential projects (Appendices D-F), which were prioritized based on project metrics specifically designed for this project (Table 1). Projects primarily address one of 5 issues:

1) Localized bank erosion,

2) Early successional and sparsely vegetated riparian corridor,

3) Agricultural and urban encroachment,

4) Undersized and aging stream crossing infrastructure,

5) Lack of instream habitat complexity.

VRWJPO identified pollutant loading as a specific concern in the Lower Vermillion, specifically sediment, nitrogen and phosphorus. Our analysis of bank erosion sites and comparison to previously reported pollutant loading in the Vermillion River shows that nonpoint pollution and upstream sources are the primary cause of sediment pollution in the Lower Mainstem Vermillion River. We evaluated seven potential projects that had noticeable bank erosion and analyzed aerial photographs from the mid-1900s through 2016 to estimate the rate of erosion and volume of sediment entering the Vermillion River from these sites. Bank locations between 2010 and 2016 were quantified to estimate the volume of sediment eroded per year. Overall, based on bank erosion calculations and reported annual load estimates (Tetra-Tech, 2004; Dakota County Soil and Water Conservation District, 2017), these sites contribute approximately 3% of the annual sediment load to the Vermillion River, confirming our observations that this section of the Vermillion River is relatively stable with only minor bank erosion issues. Compared to some of the upstream and headwater tributaries in the watershed, the Lower Mainstem Vermillion River has abundant aquatic habitat features such as log jams, riffles and deep pools, overhanging banks, and canopy cover through most reaches. The primary issues of concern were areas of bank erosion, extensive mowing of the floodplain to the channel edge, and banks with less than 50 feet of perennial riparian buffer between agricultural fields and the river.

2. Introduction

In the summer of 2018, Inter-Fluve geomorphologists conducted a fluvial geomorphic assessment of the Lower Vermillion River. This reach begins just west of Vermillion, MN near Hwy 52 and ends at Vermillion Falls in Hastings, MN (Figure 1). The goals of this rapid assessment were to:

1. Examine channel condition and stability,
2. Assess riparian and aquatic habitats,
3. Note infrastructure near, in, or crossing the Vermillion River and issues relating to the interactions between the river and infrastructure,
4. Note past project conditions,
5. Identify potential projects to improve water quality, and aquatic and riparian ecosystems within the Vermillion River, and
6. Quantify pollutant reductions in select potential projects.

The report that follows is a summary of the data collected and the potential restoration and management projects identified along the Lower Vermillion River. Inter-Fluve completed similar geomorphic assessments along the Empire Drainages subwatershed of the mainstem Vermillion River (Inter-Fluve, 2013), South Creek (Inter-Fluve, 2010), North and Middle Creeks (Inter-Fluve, 2012), and the Etter Creek/Ravenna Coulee subwatersheds (Inter-Fluve, 2011) for the VRWJPO. Inter-Fluve project staff, while then working for the MNDNR, completed the original fluvial geomorphic assessment of the entire Vermillion system in 1997. This document follows a similar format to allow the VRWJPO to efficiently read through the results and analyses of this assessment. As in the prior reports, individual reach descriptions, channel reconnaissance forms, potential project forms, detailed scoring sheets for the potential projects, and potential project maps are in appendices:

- Appendix A: Historic maps and aerial photograph
- Appendix B: Channel Reconnaissance Forms
- Appendix C: Bank Erosion Analysis
- Appendix D: Potential Project Forms
- Appendix E: Potential Project Summary
- Appendix F: Reach Maps Showing Location of Potential Projects

Inter-Fluve conducted the fluvial geomorphic assessment in July 2018. During the assessment, we identified 34 potential restoration projects. In order to prioritize these projects for funding allocation, we developed a ranking system for the restoration projects. This ranking system scores potential restoration sites based on 13 metrics developed in coordination with the VRWJPO staff (Table 1). Each metric contributes a value of 1 through 7 for the site, and the total of all 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.

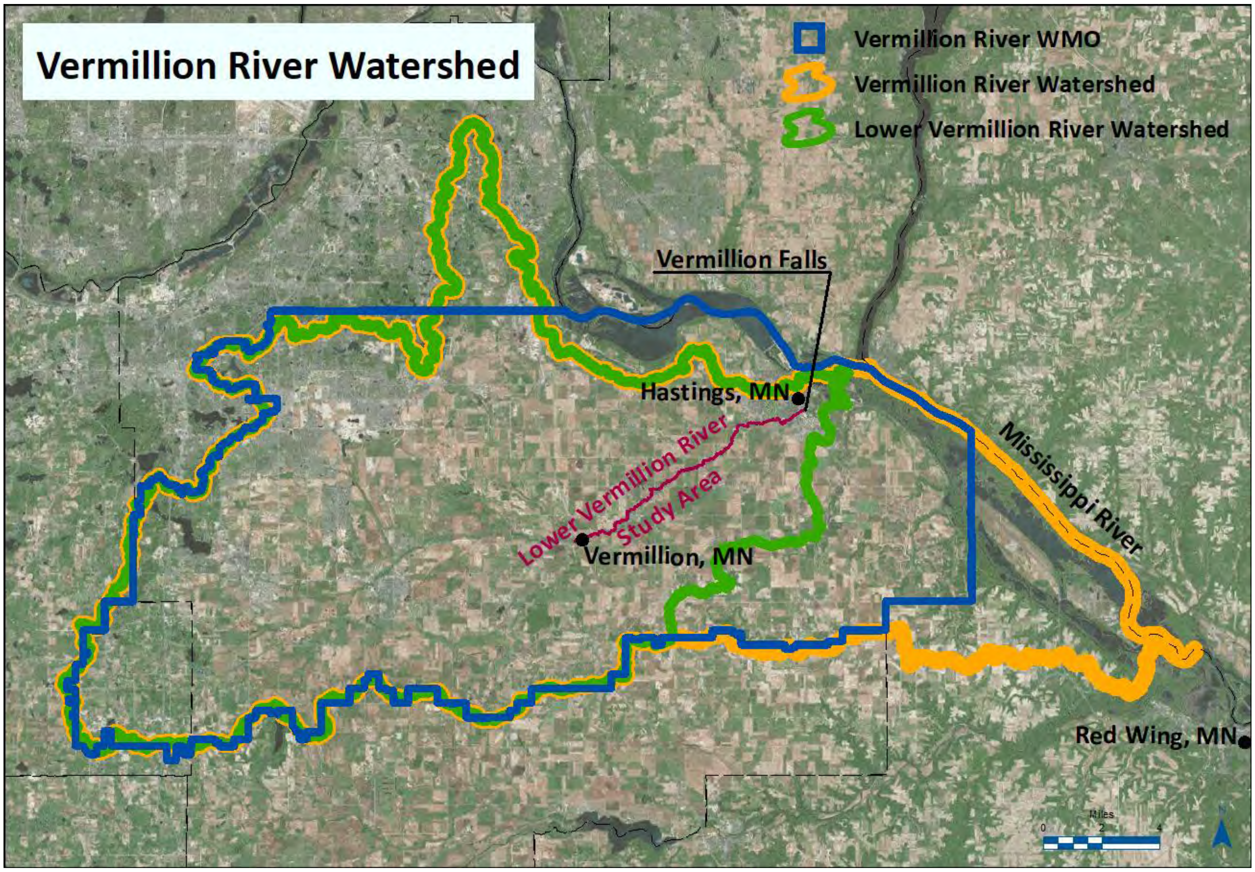

Figure 1: The Vermillion River Watershed located in Scott and Dakota Counties, MN. Vermillion River WMO from Dakota County GIS Database. Lower Vermillion River Watershed and Vermillion River Watershed based on National Hydrographic Dataset, 2018.

Table 1: Metrics for scoring potential projects

Metric Score:	*1*	*3*	*5*	*7*
Pollutant loading	No reduction in sediment/nutrient loading	Reduction in rate of bank erosion	Reduction in rate of bank erosion, establish buffer to reduce runoff	Reduction in bank erosion, establish buffer to reduce runoff, bank erosion poses infrastructure risk
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
Project cost	> $300K	$201 - $300K	$51 - 200K	$0 - $50K
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)
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
Infrastructure risk	No risk to infrastructure with no action, no infrastructure present, or no risk to public safety	Low to moderate infrastructure risk and minimal risk to public safety with no action, or inf. value <$50,000	Infrastructure at moderate but not immediate risk, moderate public safety risk, no potential injury, or infrastructure value <$500,000	Infrastructure at high, immanent risk of failure with no action, or potential loss of life. Public safety at risk or infrastructure value >$500,000
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
Aesthetic impact	No impact	Low impact	Moderate positive impact	High positive impact
Property Ownership	1: private property	3: NA	5: public property	7: NA
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

3. The Vermillion River Watershed

The mainstem of the Vermillion River is 60 miles in length, and meanders through Scott and Dakota Counties before flowing into the Mississippi River near Red Wing, MN. A small distributary also flows into the Mississippi River near Hastings. In total, the Vermillion River watershed area is 364 square miles, of which 273 square miles drains to and through the Lower Vermillion River (Figure 1). The VRWJPO administers 335 square miles. Primary land use within the Lower Vermillion River Watershed (Figure 2) is cropland (104,539 acres, 61.8%), urban (44,305 acres, 26.2%), forest (12,601 acres, 7.4%) and grassland (7,731 acres, 4.6%). Instantaneous discharges over the past 20 years just upstream of the study area near Empire, MN range from under 20 cfs to over 2000 cfs, with flows highest in spring and lowest in winter (Figure 3).

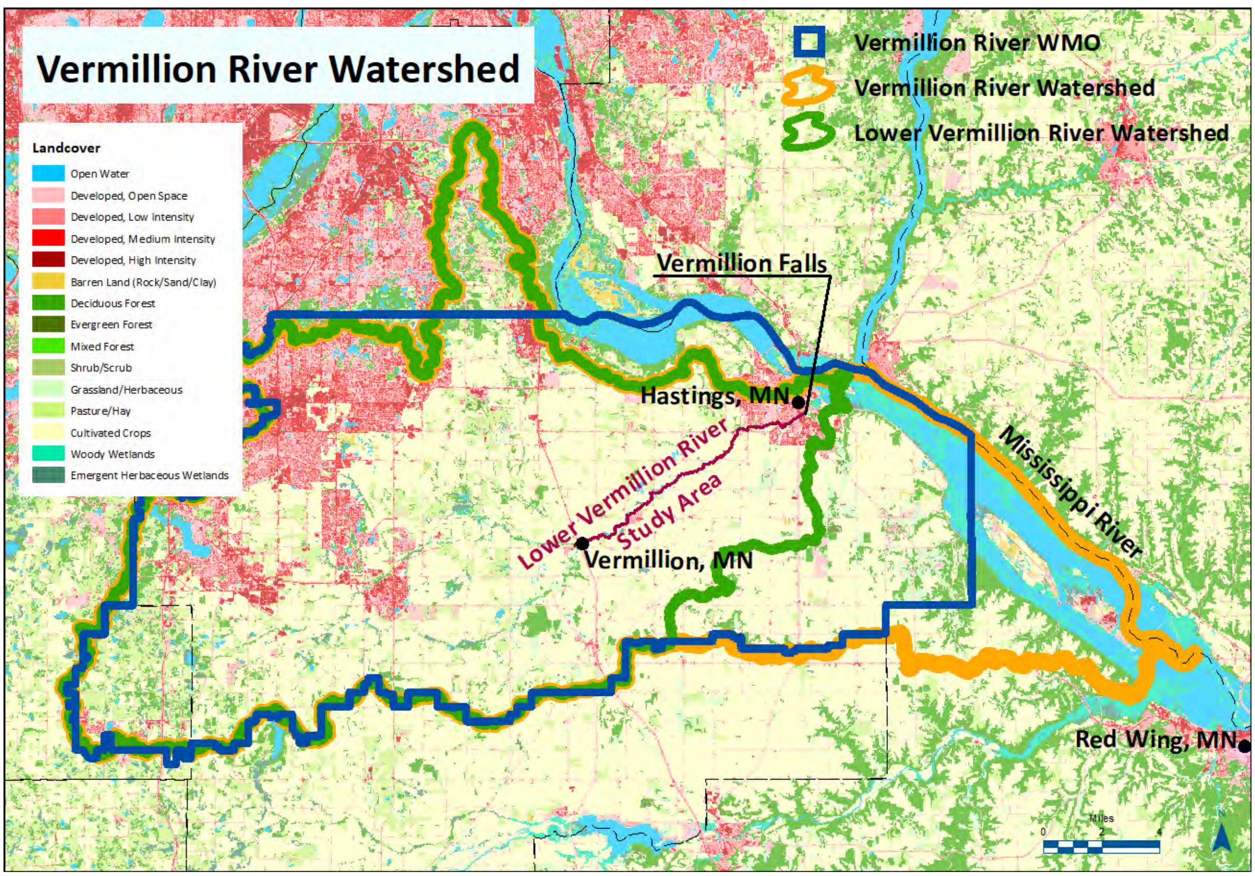

Figure 2: Landcover within the Vermillion River Watershed. Data from National Landcover Dataset 2011.

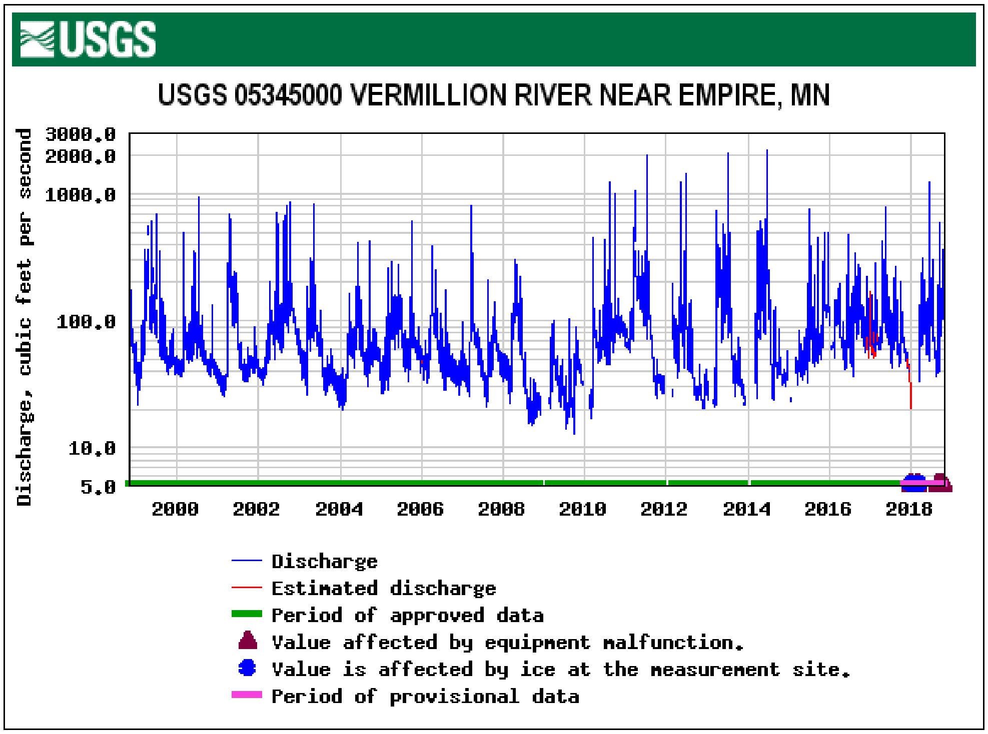

Figure 3: Instantaneous discharge USGS gage data upstream of the Vermillion River. Peaks are generally in the spring of each year while the low flow periods are typically in the winter.

3.1 GEOLOGIC HISTORY OF THE VERMILLION RIVER

Bedrock within the Vermillion watershed consists primarily of the Prairie du Chien Formation, St. Peter Sandstone, Jordan Sandstone, and Platteville Limestone (Balaban and Hobbs, 1990). Bedrock is best exposed at Vermillion Falls in Hastings, MN where the River flows over the Platteville Limestone. Bedrock throughout the studied reach forms a buried bedrock valley, with bedrock buried by up to 500 feet of glacial deposits on top of the pre-glacial drainage system (Figure 4). The deepest portions of the buried bedrock (shown in yellow on Figure 4) likely represents the pre-glacial (over 2.5 million years ago) drainage of the Mississippi River. Buried bedrock valleys commonly host productive groundwater resources (Bajc et al., 2018) and special care should be given to preserving these potential aquifers from surface water pollution.

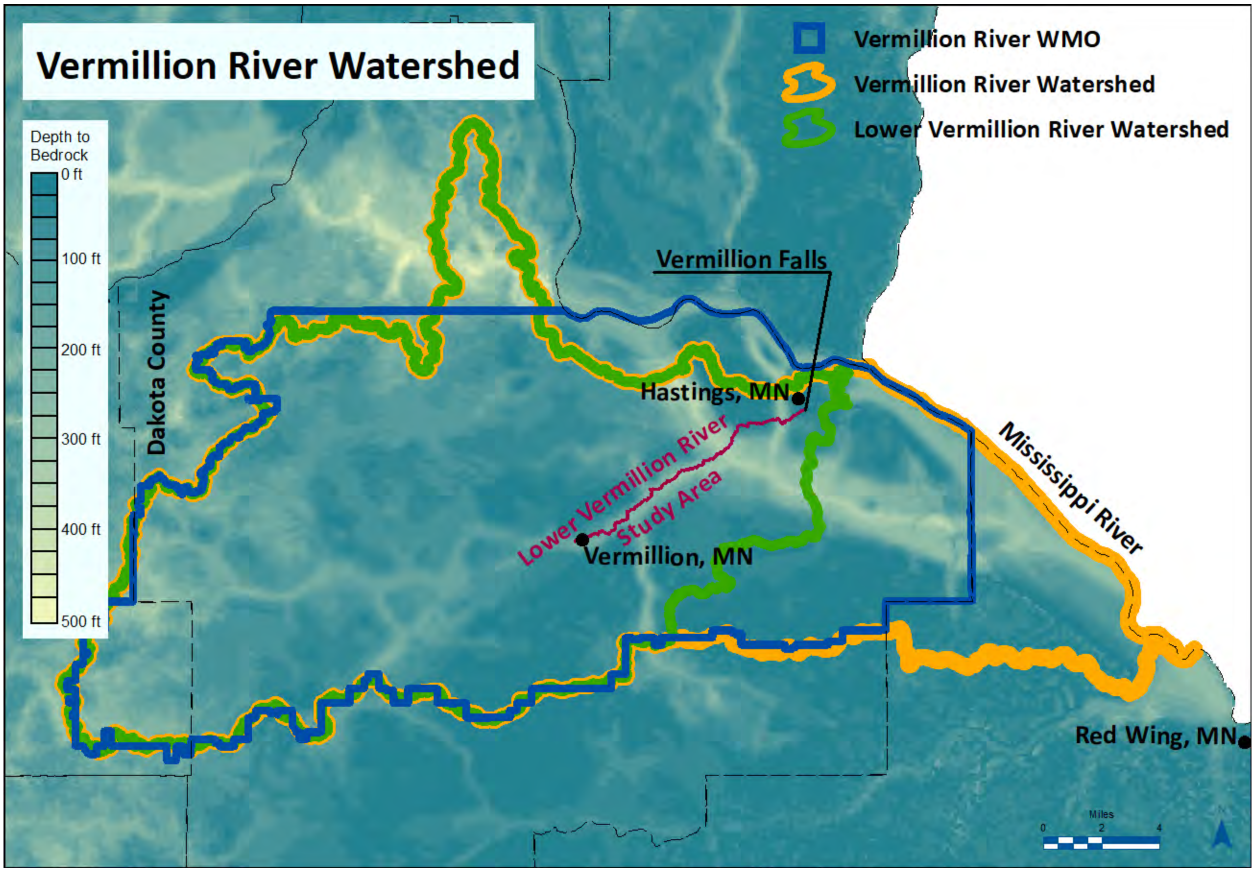

Figure 4: Depth to bedrock within the Vermillion River watershed. The deepest bedrock is shown in yellow and the shallowest bedrock is shown in dark teal. Data from Minnesota Geological Survey, 2016.

The earliest surficial geology consists of pre-Wisconsin moraines which form the southern edge of the watershed (Figure 5). Wisconsin-aged moraines form the western and northern edges of the watershed and were deposited by the Superior and Des Moines Glacial lobes (Balaban and Hobbs, 1990). The central and eastern portion of the watershed is occupied by a relatively flat glacial outwash plain (Figure 5).

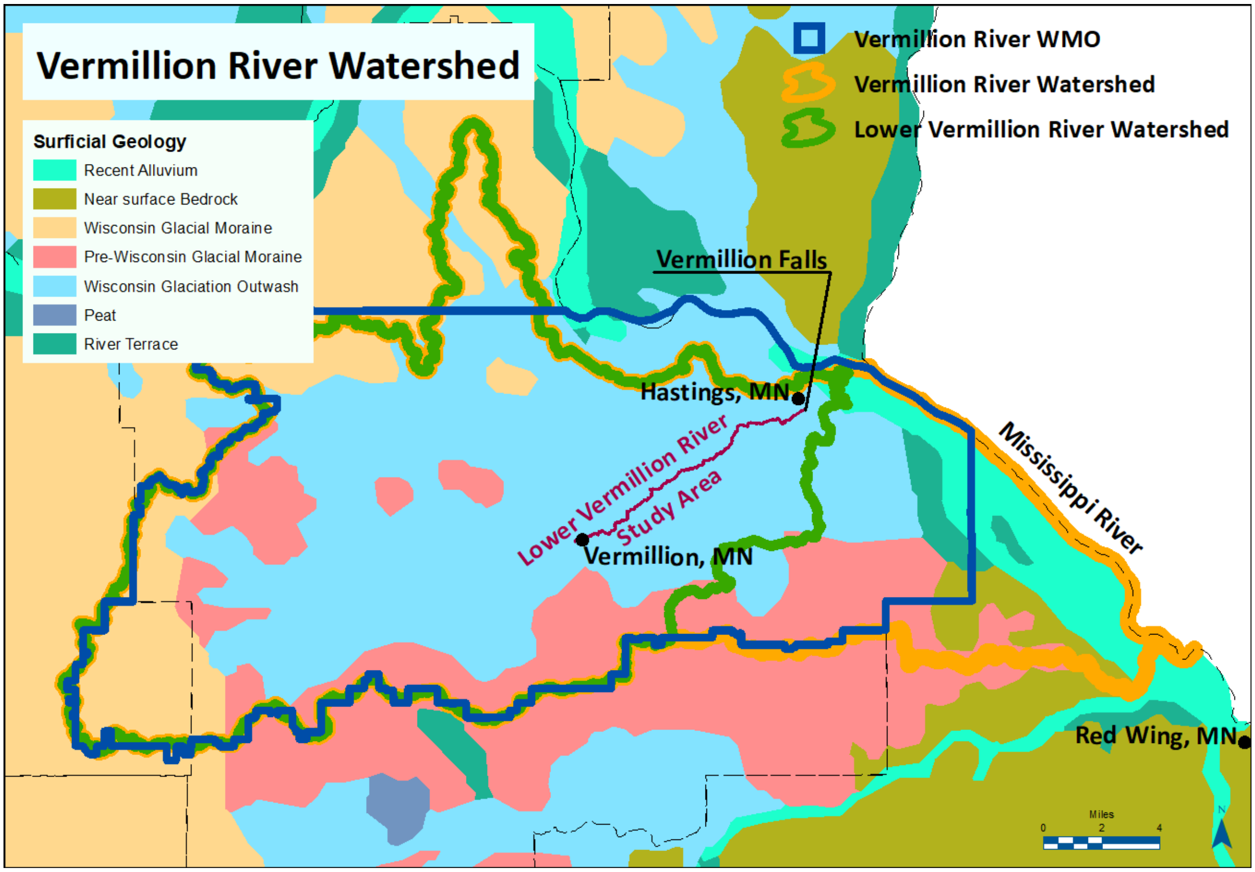

Figure 5: Surficial Geology within and surrounding the Vermillion River Watershed. Data from Balaban and Hobbs, 1990.

3.2 THE LOWER VERMILLION RIVER STUDY AREA

This geomorphic assessment examined the Lower Mainstem Vermillion River and two minor tributaries (Figure 6) which flow approximately 13.5 miles from Hwy 52 to Vermillion Falls. The Lower Mainstem Vermillion River typically meanders within a much larger alluvial valley. Similar to the Minnesota and Mississippi River Valleys, this oversized alluvial valley may have been formed by a glacial hydrologic regime which set and confined the course of the modern Vermillion River. Before the arrival of Europeans, the area surrounding the Lower Vermillion River was covered by prairies and likely grazed by herds of bison (Wendt and Coffin, 1988). A corridor of trees likely formed a floodplain forest in low areas where tree roots could reach the groundwater and stabilize the banks of the Vermillion River. After the arrival of Europeans, the land was cleared, plowed, and converted to agriculture. The modern Lower Vermillion River is almost entirely surrounded by agricultural cropland with some urban development near

Vermillion and Hastings, MN (Figure 2). In steeper headwater subwatersheds, land clearing likely resulted in loss of soil from the agricultural fields and deposition of this soil in the receiving water bodies, including the Vermillion River. Many of the tributary channels were straightened and adjacent wetlands ditched to maintain drier farming conditions and convey water downstream efficiently to reduce flooding. Through decreased infiltration in the farm fields and increased discharges due to ditching and straightening, the discharge in the receiving waters, such as the Vermillion River, likely increased in the decades following initiation of agriculture. These hydrologic changes typically result in adjustments to the channel slope and channel dimensions. The more recent increase in suburban and urban development throughout the Vermillion River watershed adds to the percent of impervious cover and increases in storm runoff, the effects of which can be observed along the Lower Mainstem Vermillion River.

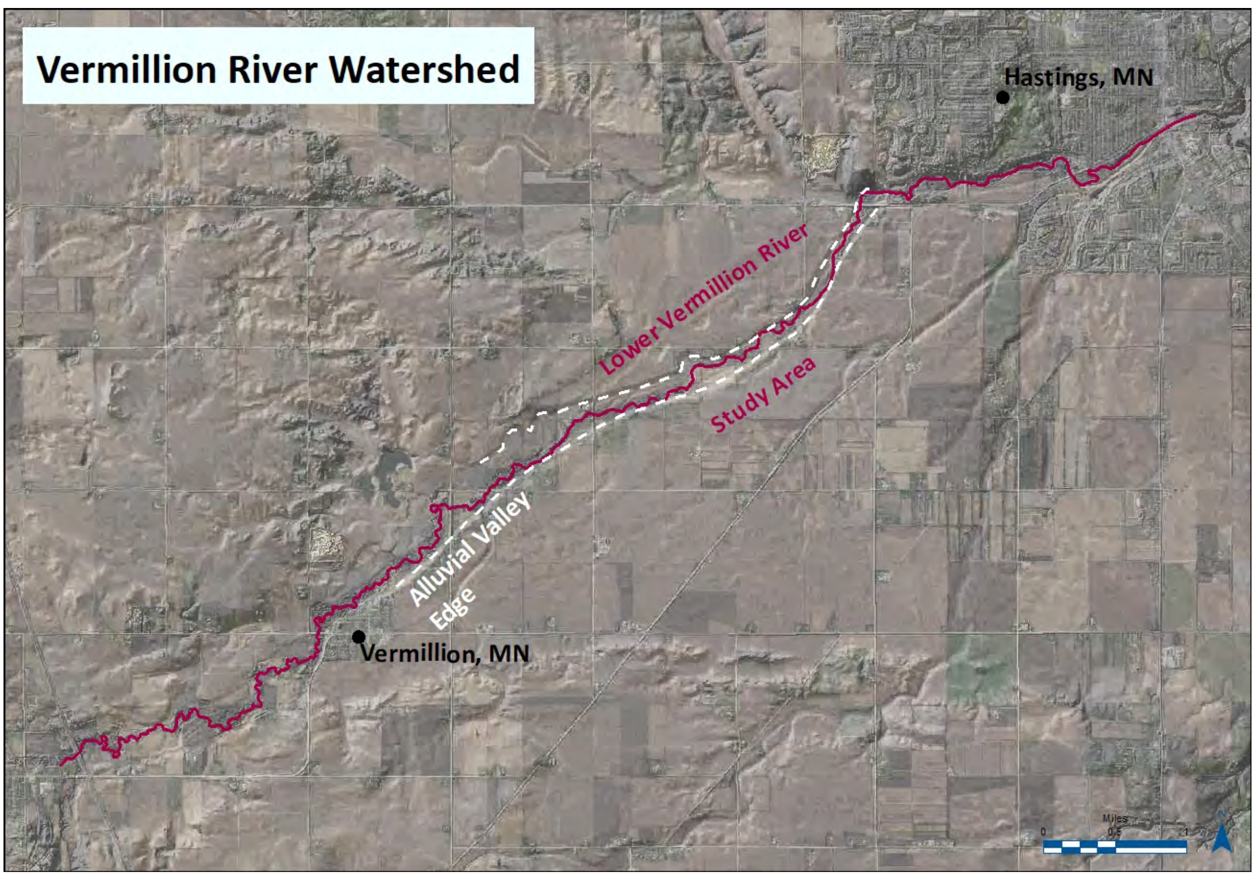

Figure 6: The study area of this geomorphic assessment including the Lower Vermillion River and select tributaries assessment

4. Data Collection Methods

To understand and compare the historic and modern Lower Vermillion River, Inter-Fluve geomorphologists collected and analyzed existing plat maps, aerial photographs, and land cover datasets. The first General Land Office (GLO) surveys in Dakota County were plat maps surveyed between 1852 and 1854. Later aerial photos (1937, 1964, 1991, 2003, 2010, 2016) show the landscape in more detail and also show the channel and land use changes that have occurred over the past 79 years. The changes observed in these maps and aerial photos are helpful in understanding land use change impacts to the river system, how the river has responded to these impacts, and how the river may continue to evolve. This gives context in assessing how certain restoration treatments may perform as the river continues to evolve.

4.1 CHANNEL AND LAND USE CHANGES

Direct comparison of plat maps and aerial photographs were made for the years 1852-1854, 1937, 1964, 1991, 2003, 2010, and 2016. Plat maps and the 1937 and 1964 aerial photographs were georeferenced by Inter-Fluve staff. The 1991, 2003, 2010, and 2016 aerial photographs were downloaded from the MnGeo WMS Service, georeferenced by others. All historic maps and aerial photo maps are shown in Appendix A.

The 1852-1854 Government Land Office (GLO) maps show a meandering river surrounded prairies. In later aerial photos, an increase in human influence is apparent. Field notes from the 1852-1854 maps describe mostly prairie vegetation, and list bur oak, black oak, and aspen as common tree types. The 1937 aerial photos show the Lower Vermillion River almost completely surrounded by cultivated crops with very little riparian tree cover. Comparison between the 1937 air photos and the 2016 air photos show numerous avulsions and meander cutoffs (Appendix A). Avulsions and cutoffs are natural processes (though sedimentation and increased flood flows due to land use changes may have impacted the timing or rate of these processes) and have created a variety of off-channel habitats such as oxbow lakes, side channels, and floodplain forest wetlands. The majority of observed avulsions and meander cutoffs occurred in the upstream portion of the Lower Vermillion River (upstream of river station

35000). The channel in the downstream portion of the Lower Vermillion River, where the river is confined by the alluvial valley, has remained relatively stable since 1937.Examining the additional air photos between 1937 and 2016 gives more detailed information on the timing of changes in land use, riparian vegetation, and river meander changes (Appendix A). The 1964 aerial photo shows urbanization near Hastings and Vermillion (River station 0 to 15000, and 45000 to 51000). Upstream of river station 35000, active river meandering is apparent in comparison of aerial photos. The 1991 aerial photo shows continued urban expansion. The Lower Vermillion River appears near its modern alignment, though localized bank erosion is apparent. A general increase in riparian tree cover occurs between 1964 and 1991, which may be related to the increased river meander stability. Between 1991 and 2016, a continued increase in riparian tree cover was identified, though this increase is coupled with an increase in farm field size and urbanization.

4.2 FLUVIAL GEOMORPHOLOGY

Inter-Fluve geomorphologists assessed the entire Lower Mainstem of the Vermillion River from canoe and on foot where appropriate. This reach of the Vermillion River is approximately 13.5 miles in length. Field forms were completed, digital photographs were collected at representative locations, geomorphic features were identified, land use influences on the river were noted, and sites were identified as potential projects.

Inter-Fluve geomorphologists developed a reconnaissance form which 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 B provides a description of each reach based on these forms with maps displaying the reach locations in Appendix F. In general, the Lower Vermillion River is a low gradient, meandering stream with sand and gravel bed material and cohesive banks composed of silt and sand.

4.3 REACH SUMMARIES

Reach 1 is from river station 00000 to 16500, at the downstream end of the project reach in the city of Hastings, MN. The majority of the reach is in an urban setting with some agricultural fields. Some banks are almost fully naturalized but with manicured lawns mowed to the river edge on the opposite bank. The channel appears vertically and laterally stable with localized erosion occurring where the riparian is narrow to absent. The reach contains widely spaces (~500ft) riffles with gravels, cobbles and some boulders. Which is notably coarser than upstream reaches. There is large wood within the stream channel, but few channel spanning log jams. Largest source of pollutants is likely from lawn fertilizer and pesticide use.

Reach 2 is from station 16500 to 21000. Riparian corridor is narrow to non-existent with few riparian trees and no large wood in the channel. Land-use is agricultural fields and pastures. The channel is straight with a few small meanders at the north end of the reach (station 16500-17800). The channel appears straight in 1930s air photos and may represent the natural channel planform, or channel straightening prior to 1937. A few relict meanders are apparent in pastured land on river right (near station 18500 and 17100). Channel substrate consists of sand with sparse gravel. Channel type is predominately riffle-run. The largest source of pollution to river likely comes from adjacent farm fields.

Reach 3 is from station 21000 to 35000. Riparian corridor width varies between narrow (<20 ft) and wide (>100ft) with vegetations types ranging from prairie to forest. Adjacent to natural areas, land use is agricultural. In forested area large wood is abundant, but in all other areas large wood is nearly absent. Channel type is between riffle-run and riffle-pool, with at least one meander cut-off evident (station 33200). Channel substrate predominately consists of coarse sand with sparse gravels and cobbles. The largest source of pollution to river likely comes from adjacent farm fields.

Reach 4 is from station 35000 to 45500. The reach contains a relatively wide riparian buffer with floodplain forest and prairie vegetation. Large wood is present where there is surrounding floodplain forest. Some agricultural fields abut a narrow riparian zone (<20 ft). Cutoff meanders are present and abundant in backchannel areas. Channel pattern is meandering with run-pool channel type. Channel substrate is predominately coarse sand. Largest source of pollution to river is likely agricultural fields.

Reach 5 is from river station 45500 to 51000. The reach has a wide riparian corridor and is adjacent to the town of Vermillion on river right and farm fields on river left. Riparian vegetation is floodplain forest. Relict meander bends are abundant within the floodplain and were either dry or filled with water at the time of the survey. Channel pattern is meandering with a pool-run morphology. Channel substrate is coarse sand. Large wood and log jams are abundant in the channel. The largest source of pollution to river is likely from adjacent farm fields, though surrounding floodplain forest and riparian buffer likely mitigates pollutant inputs.

Reach 6 is from river station 51000 to 67500. The reach contains a relatively wide riparian buffer with floodplain forest and prairie vegetation. Some agricultural fields abut a narrow riparian zone (<20 ft). Cutoff meanders are present and abundant in backchannel areas. Channel pattern is meandering with run-pool channel type. Channel substrate is predominately coarse sand. The largest source of pollution to river is likely agricultural fields.

4.4 POLLUTION SOURCES

Historic changes in watershed land use have increased pollutant loading compared to assumed natural conditions. The estimated pollutant load in the Vermillion River at Hastings, MN is modeled to be 83,706 kg/yr of total phosphorus, 146,728 kg/yr of total Kjeldahl nitrogen, and 4,659,233 kg/yr total suspended sediment (Tetra-tech, 2004). Annual monitoring reports on state standard water quality show the Vermillion River to be within acceptable limits for Phosphorus and Total Suspended Solids during baseflow conditions. Nitrate shows greater concentrations under baseflow conditions as a result of shallow groundwater aquifers flowing directly to surface water. Phosphorus and total suspended solids spike under runoff events, but nitrates are diluted (Dakota County Soil and Water Conservation District, 2017). Erosion throughout the study site was identified and described, but seven specific bank erosion sites were investigated in more detail to quantify the contributions to the total annual sediment load of the Lower Vermillion River. These seven potential bank erosion projects displayed noticeable differences in bank location between the 2010 and 2016 aerial images. Volumes of sediment were calculated using the 2018 bank height observed in the field as the vertical dimension, and the aerial extent of erosion digitized from the 2010 and 2016 aerial photos (Table 2). The total estimated volume of eroded bank between all quantified sites was 7780 ft^3/yr (140,040 kg/yr assuming 18 kg/ ft^3), contributing roughly 3.0% of the total suspended sediment in the Vermillion River at Hastings. Maps associated with the bank erosion analysis are shown in Appendix C. We therefore conclude the majority of sediment pollutant loading to the Lower Vermillion River is from point and nonpoint upstream sources and nonpoint sources within the subwatershed primarily contributed during runoff events, and not from in-stream sources. Based on land use characteristics directly draining to the Vermillion River, the primary nonpoint pollution source is agricultural fields, which enter the river primarily through tile drains and surface runoff, though point and nonpoint sources originate in upstream subwatersheds. Potential projects are prioritized to mitigate the effect of nonpoint pollution sources.

Table 2: Results from bank erosion analysis.

Potential Project #	Area (ft^2)	Height (ft)	Volume (ft^3)	Years	Pollutant Loading (ft^3/year)
10	1505	7	10536	6	1756
17	1100	8	8802	6	1467
4	1266	6	7595	6	1266
23	1710	4	6840	6	1140
32	1111	5	5554	6	926
1	741	6	4445	6	741
2	581	5	2906	6	484

4.5 PROJECT IDENTIFICATION

Inter-Fluve staff identified potential projects during the field study and evaluated and ranked the projects based on 10 metrics (Table 1). In this system, the scoring refers mainly to the degree a completed project will affect each metric with a higher score indicating a larger impact on process and habitat, higher feasibility, and positive public impact. For example, an infrastructure risk score of 1 reflects that if nothing is done, no additional risk is expected 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. Other metrics gauge the effect of potential projects on channel stability, ecological benefit, and nutrient loading.

In this cost versus benefit evaluation tool, potentially complicated and expensive projects with fewer benefits score lower, while cheaper projects that are more easily implemented and offer more benefits score higher. Inter-Fluve recommends that the VRWJPO use this ranking as a guide to determine the projects that accomplish its goals and objectives and stay within the available budget. Appendix D 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.

5. Recommended Restoration Approaches

The Vermillion River watershed has been altered since agriculture and settlement began in the mid-1800s. Prairies and forestland were cleared, wetlands were ditched and drained to promote agriculture, river banks were stabilized to prevent erosion, and portions of farmland were later converted to residential development. Potential projects seek to address and mitigate past land use changes to improve the geomorphic and ecologic function of the Lower Vermillion River.

5.1 PROBLEM SUMMARY

Along the Lower Mainstem Vermillion River, we did not observe large, reach-scale erosion problems. Overall, the channel maintains greater physical habitat complexity than many of the headwater reaches and straightened tributaries, including a higher frequency of riffles and pools, higher frequency of large woody habitat, and more substrate variability (see past geomorphic assessments for details on headwater reaches). However, the response of channel and riparian environments to land-use changes have impacted the aquatic habitat in a number of ways. Warm-water surface runoff more rapidly enters the stream carrying fertilizers and pesticides widely 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 water retention, filtration capacity, and wetland habitat. Riparian vegetation is generally not well established, consists of young trees, or consists of the invasive reed canarygrass or buckthorn. Historic and current land use practices have resulted in few mature riparian trees in many of the study locations. Fewer mature trees results in poor canopy cover, reduced shading, and reduced woody recruitment in the channel and the subsequent loss of aquatic habitat. Past impacts have created a need for riparian habitat and function and increased wetland areas.

Other factors within the studied reach are positive and will support successful geomorphic and habitat restoration. Unlike many of the headwater tributaries that have been straightened and cleared of all wood in the channel, the Lower Mainstem Vermillion River maintains its sinuosity in most locations and has multiple reaches containing substantial large wood volumes and habitat complexity. Viable nearby habitat suggests that restoration actions will connect effectively with existing habitat to improve the overall opportunities for aquatic and terrestrial organisms along the Vermillion River.

5.2 POTENTIAL PROJECT SUMMARIES

Details on individual potential projects are listed in Appendix D. This section summarizes general observations and suggests general approaches to improve the Lower Vermillion River. Nearly all potential projects involve some form of bank erosion and the potential for bank stabilization; however, with the exception of PP04, the erosion appears minor and a result of natural river meander processes. The seven bank erosion projects examined using historic air photo analysis only contribute roughly 3.0% to the total Vermillion River sediment load. In order to minimize non-point pollution sources, landowners need to be educated on natural river processes and provide the river with enough space to naturally function. The planting and maintenance of a riparian buffer along the length of the Vermillion River promote wood recruitment, increase canopy cover, and limit bank erosion. Willow trees have been shown to effectively and naturally hold a bank in place up to four feet depth after five years of growth.

Wetland and riparian areas are effective at protecting water quality and reducing nonpoint source pollution entering the stream. When coupled with best management practices at the watershed scale, natural wetland and riparian areas can greatly reduce the effects of nonpoint source pollutants on surface waters while providing stream shading, flood attenuation, shoreline stabilization, ground water exchange, and habitat for aquatic, terrestrial, migratory, and rare species (USEPA, 2005). Wetlands and riparian prairie and forest have been shown to effectively remove, process, transform or store sediment, nitrogen, and phosphorus pollutants (Washington State Department of Ecology, 1996). Restoration of wetlands and the riparian corridor throughout the study area could reduce the inputs of pollutants into the Lower Vermillion River and help improve the water and aquatic habitat within the river. While major tributaries and headwater streams and wetlands were not part of this assessment, past evaluations have made similar recommendations in headwater subwatersheds. Actions taken in the headwater wetlands and tributaries and in the wetlands adjacent to the Vermillion River are all important in improving the water quality, stability, and habitat of the mainstem Vermillion River.

Past projects within the Lower Mainstem Vermillion River include in-channel work such as placement of rock vanes, large wood bank stabilization treatments, and prairie ecosystem restoration. Potential projects were identified where past projects were deemed ineffective and active erosion immediately upstream and downstream of the past project was observed. It is unknown when these restoration efforts were completed, what the goals were, or if monitoring has occurred. Riparian ecosystem restoration was also observed in the form of prairie vegetation. The addition of trees to these riparian prairie ecosystems would provide increased in-stream and riparian habitat complexity, improve bank stability, and provide large wood recruitment to the channel.

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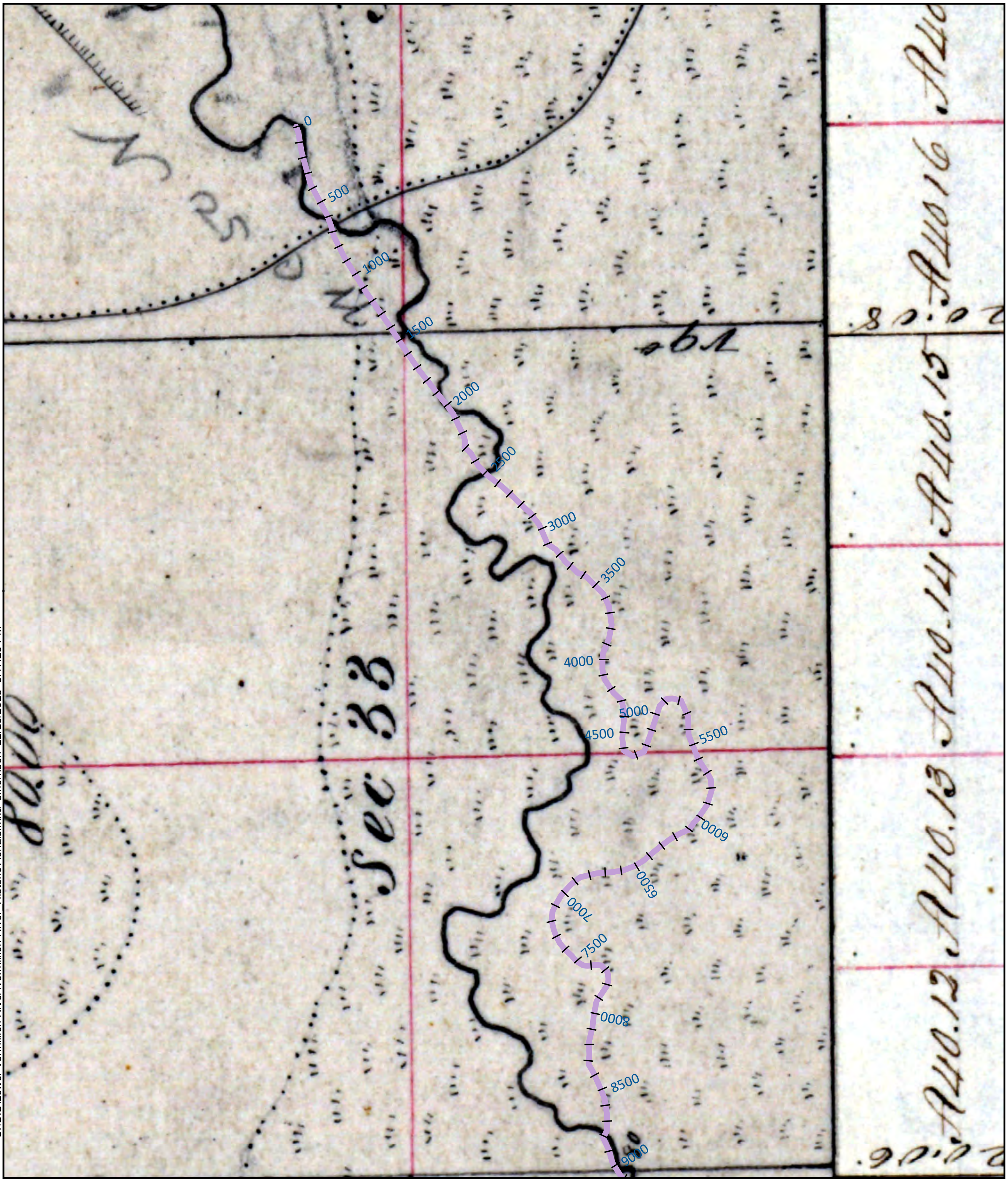
7. Appendix A

Historic Maps and Aerial Photographs



GLO Maps

Reaches
Reach Number
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Feet

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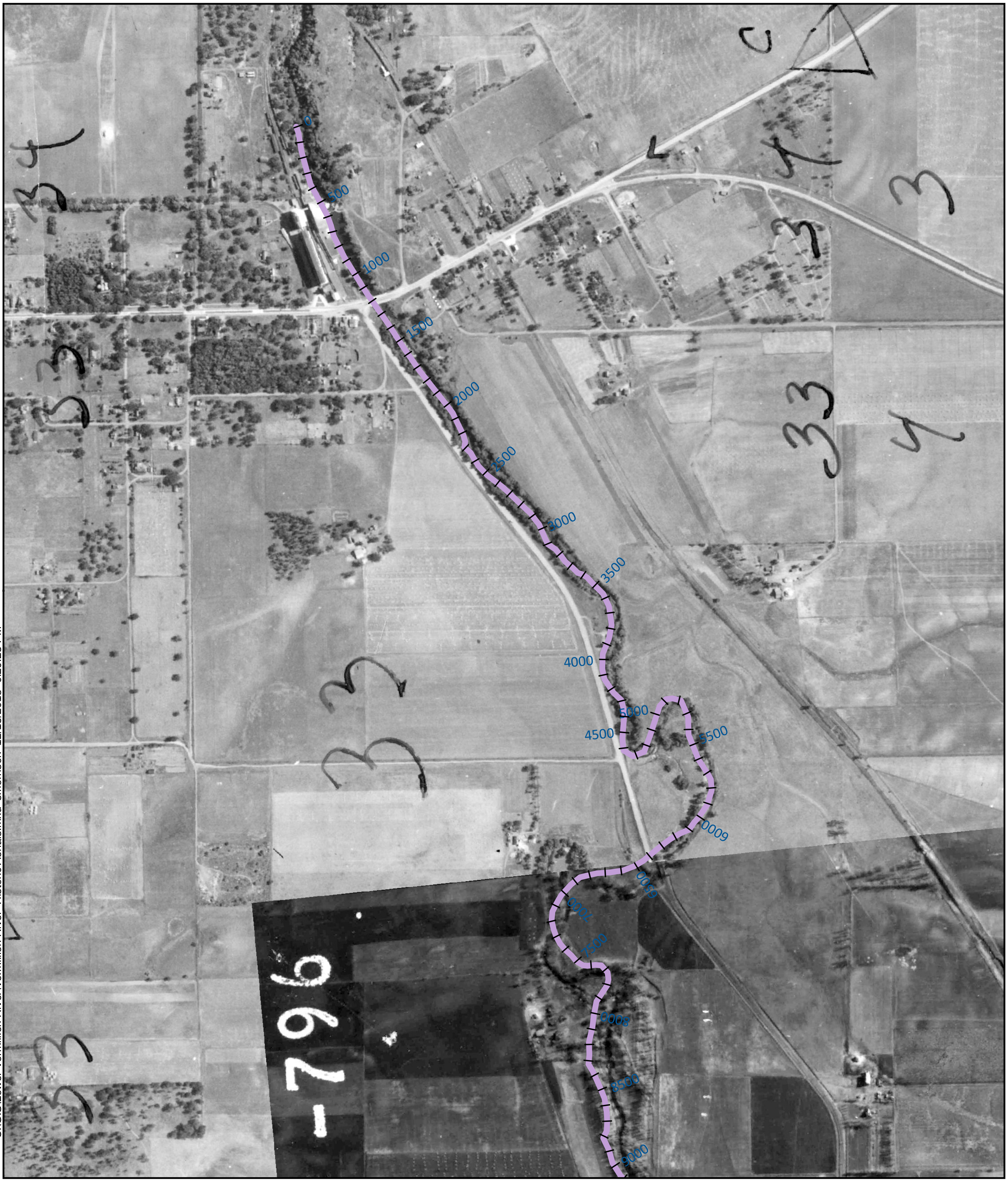

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1937 Aerials

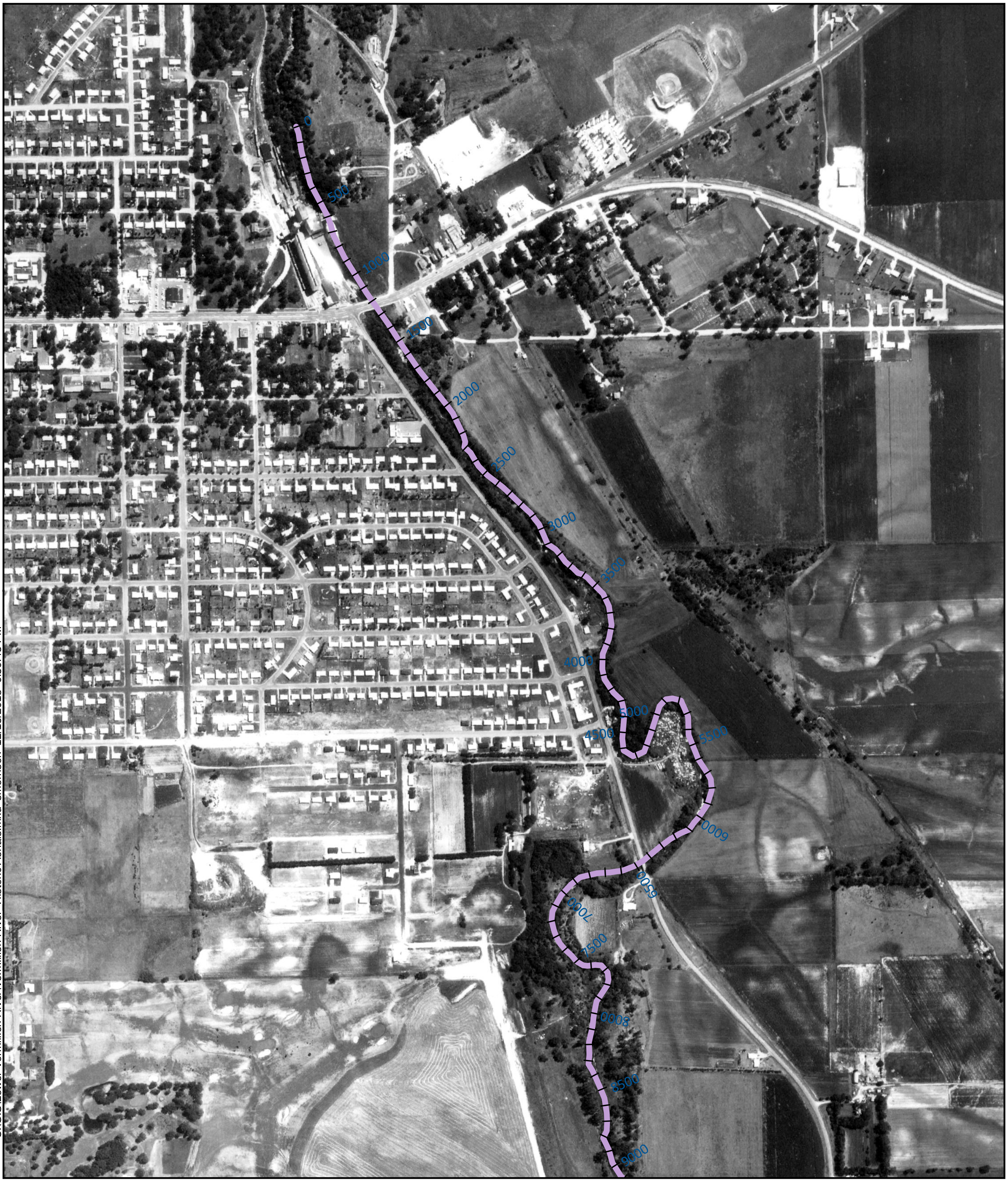
0 1,000 Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



1964 Aerials

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

0 1,000 Feet

N

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:30:43 PM

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:32:26 PM

1991 Aerials

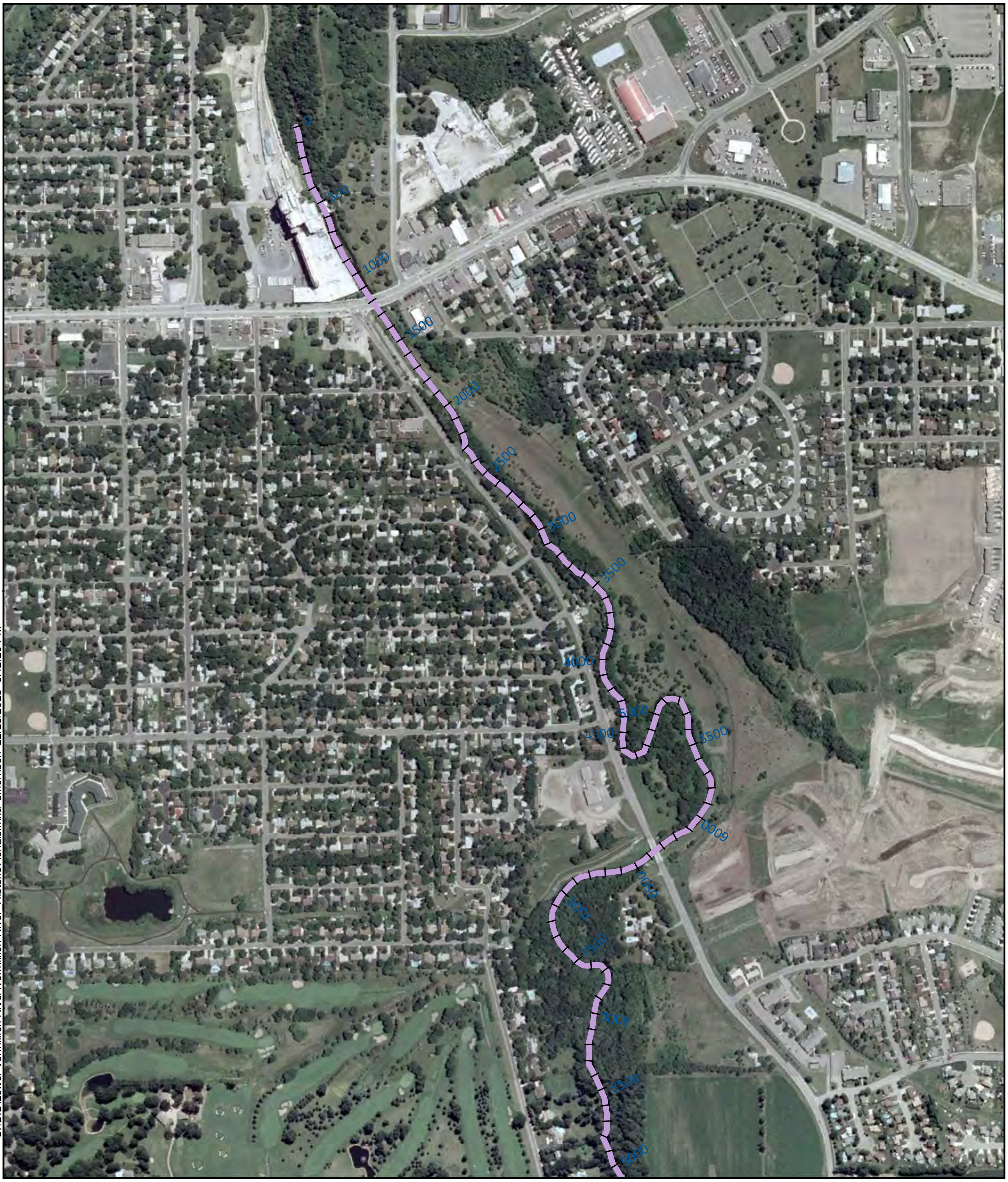
0 1,000
Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



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2003 Aerials

0 1,000 Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

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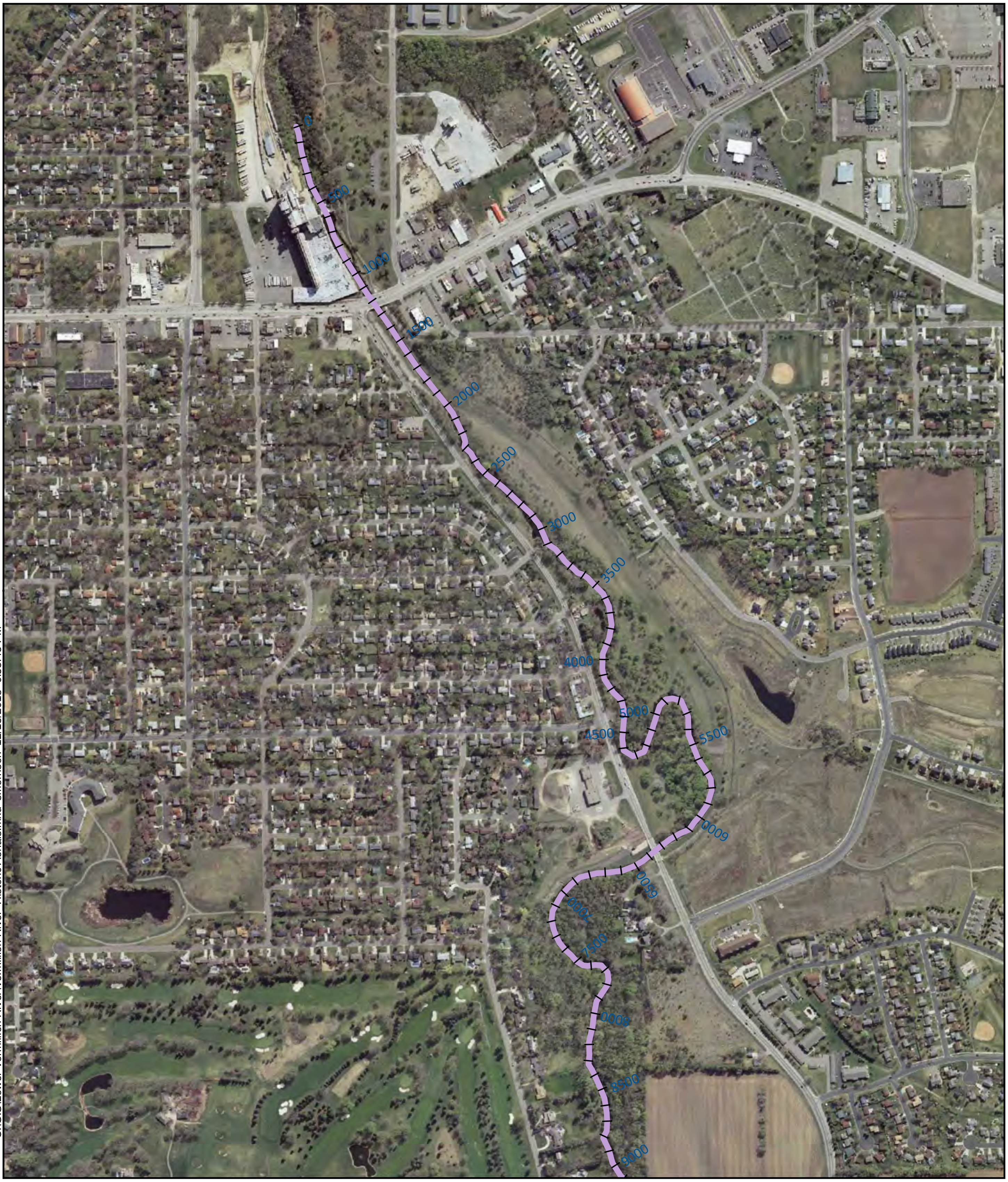


2010 Aerials

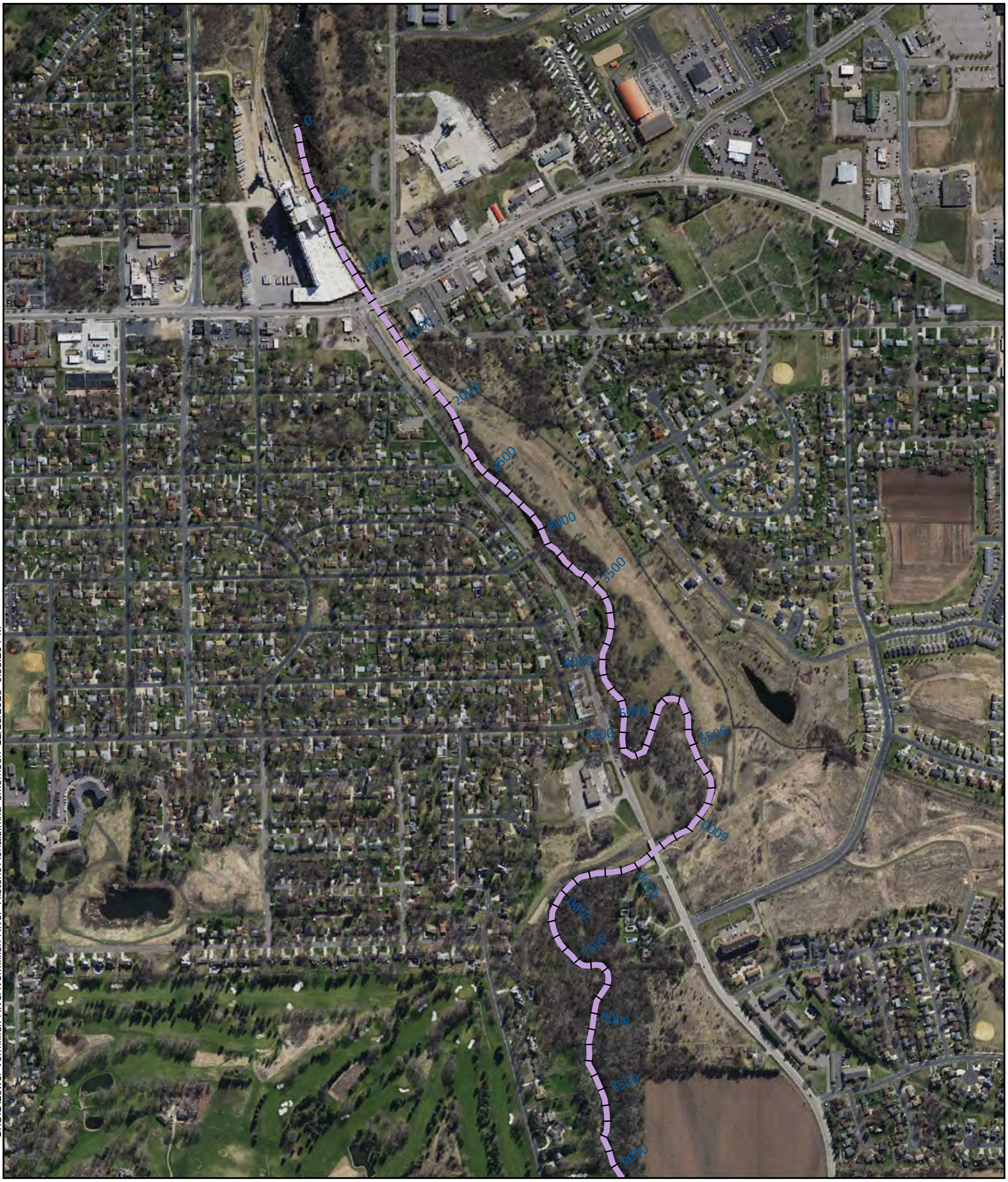
0 1,000
Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:58:20 PM

2016 Aerials

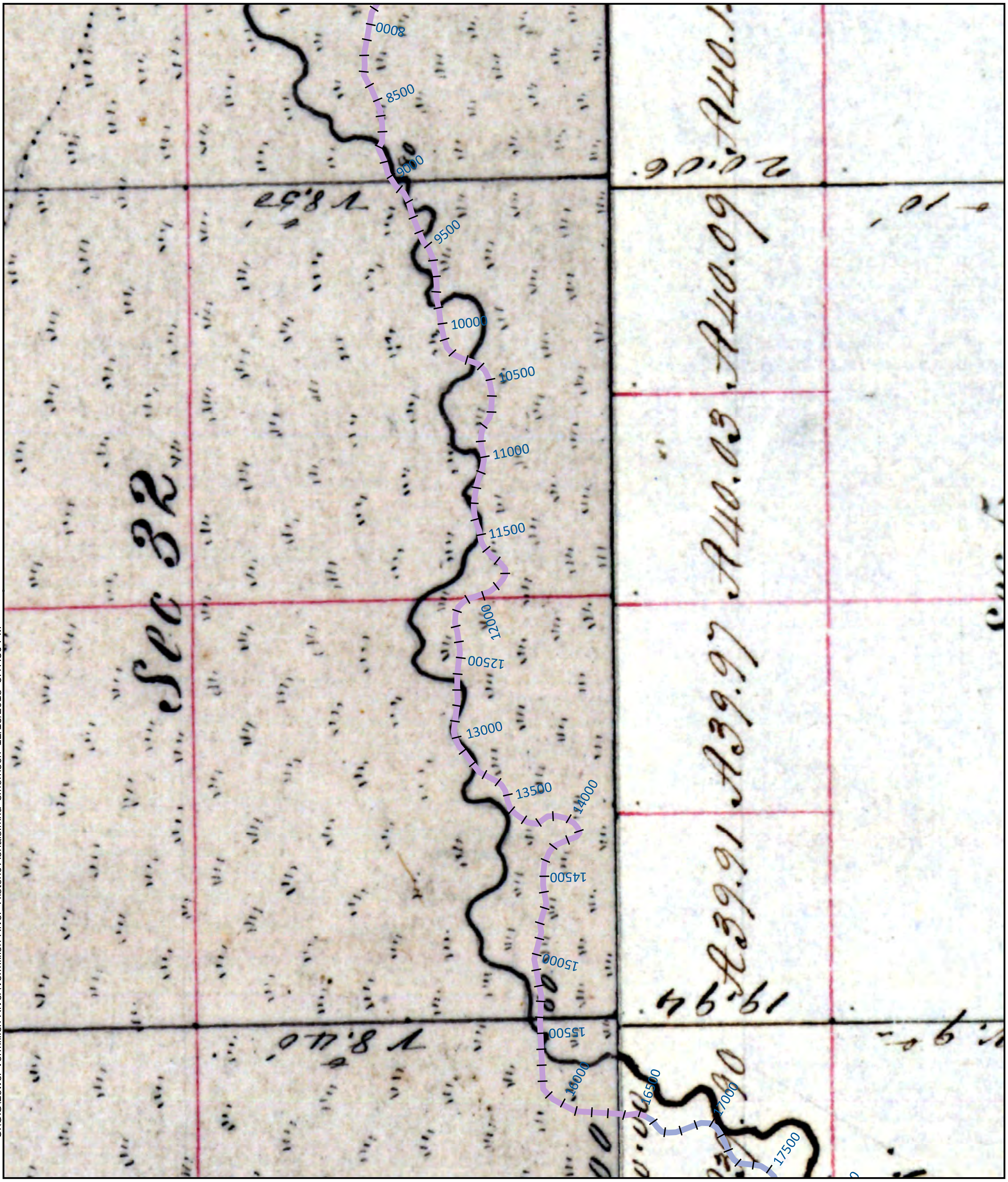
0 1,000
Feet

N

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 5:47:30 PM



GLO Maps

0 1,000
Feet

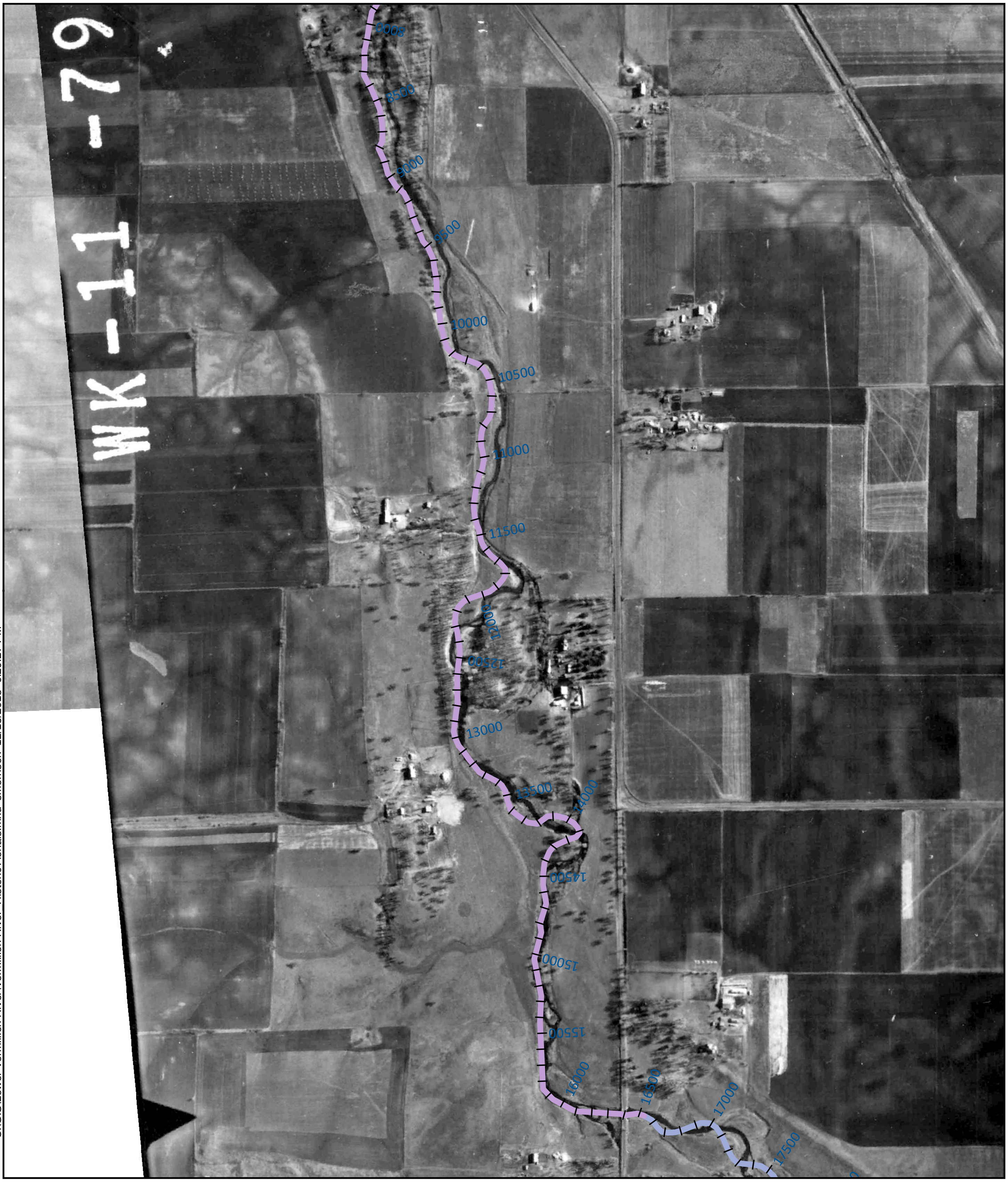
N

Reaches

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



1937 Aerials

0 1,000
Feet
N

Reach Number
1
2
3
4
5
6

inter·fluve

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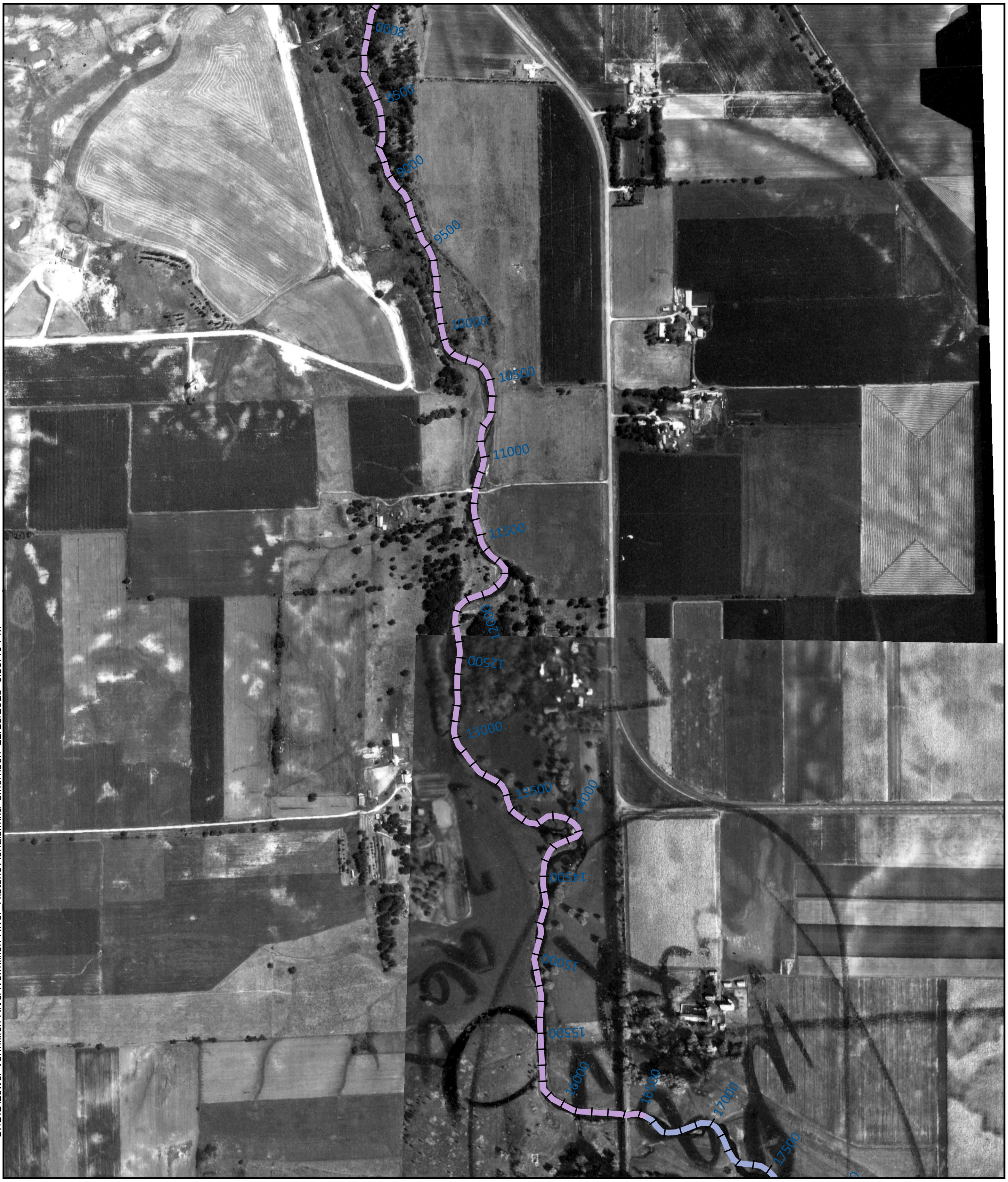


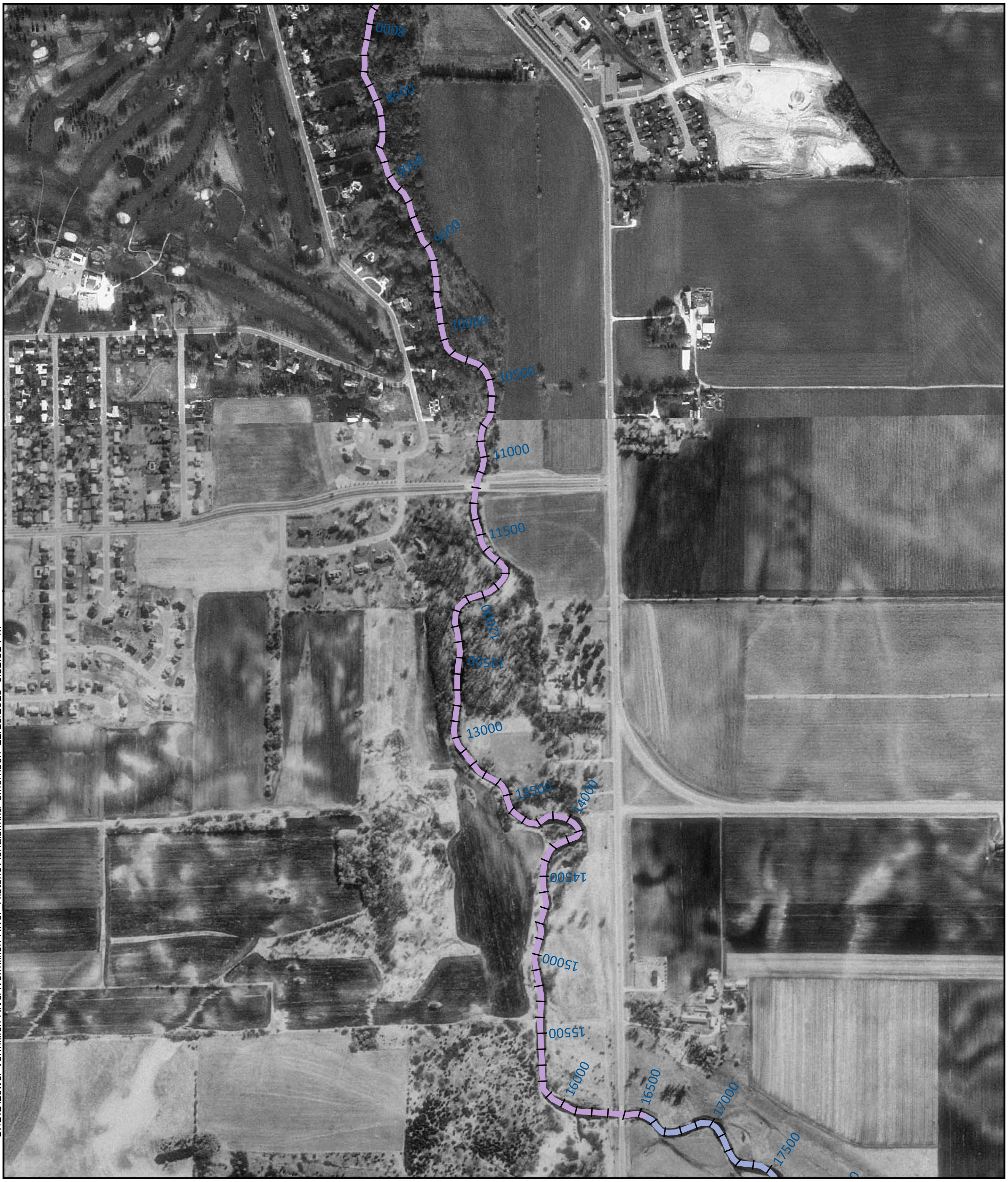
1964 Aerials

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

0 1,000
Feet

N



1991 Aerials

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

0 1,000 Feet

N

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:42:30 PM

2003 Aerials

0 1,000 Feet

N

Reach Number

1
2
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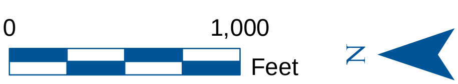
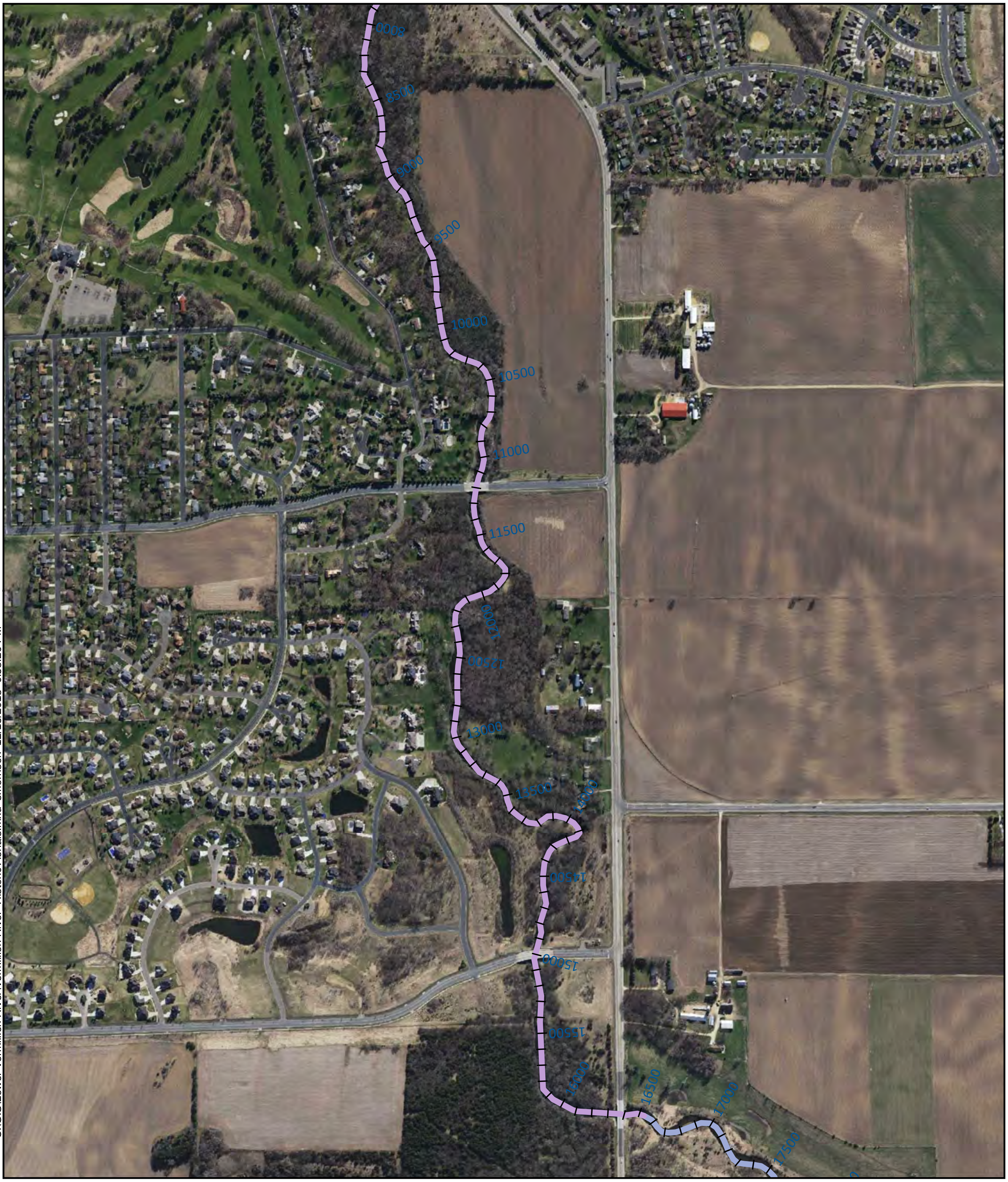
4
5
6

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:55:49 PM

2010 Aerials



inter·fluve



C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:58:26 PM

2016 Aerials

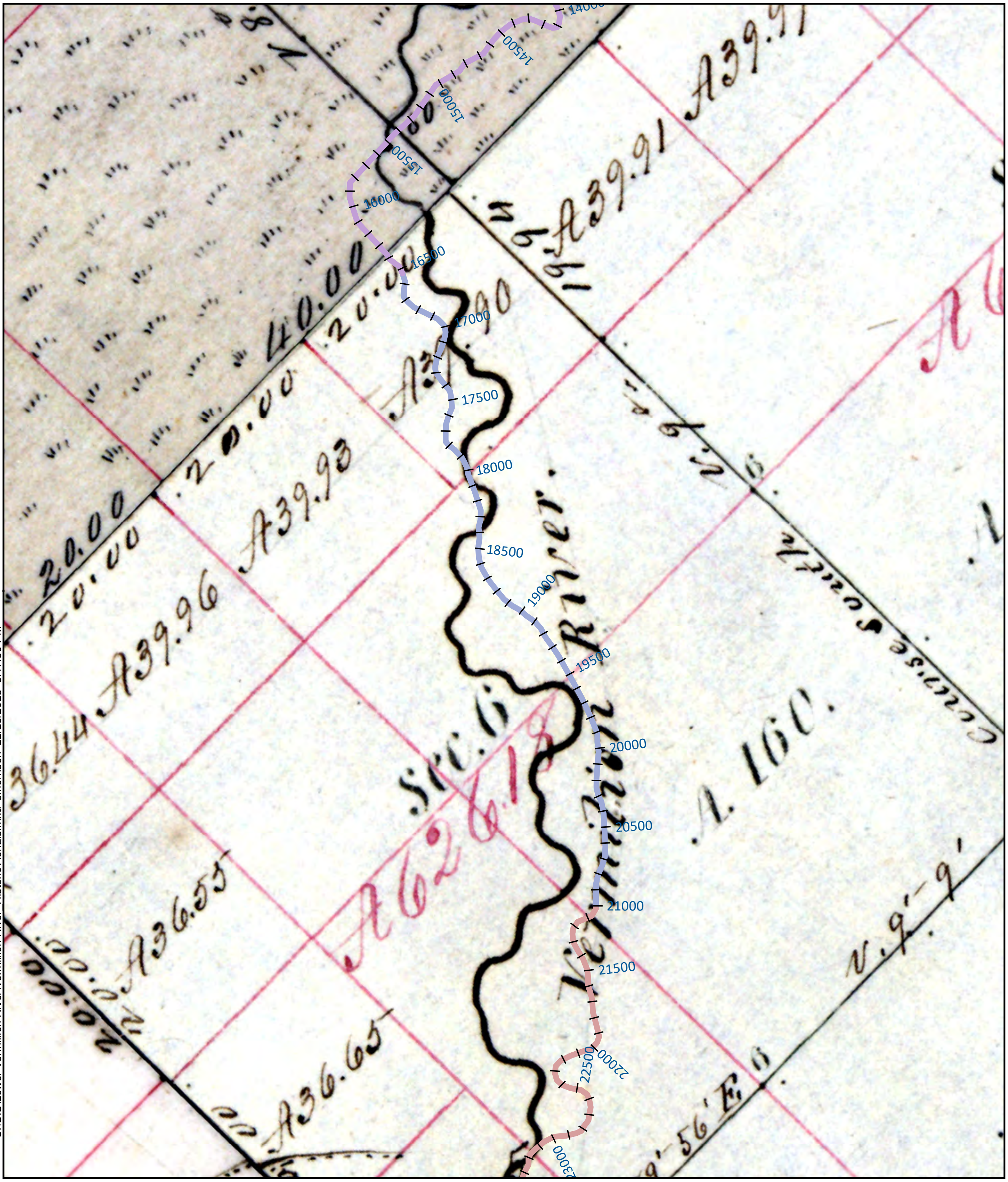
0 1,000 Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



GLO Maps

0 1,000
Feet

N

Reaches
Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

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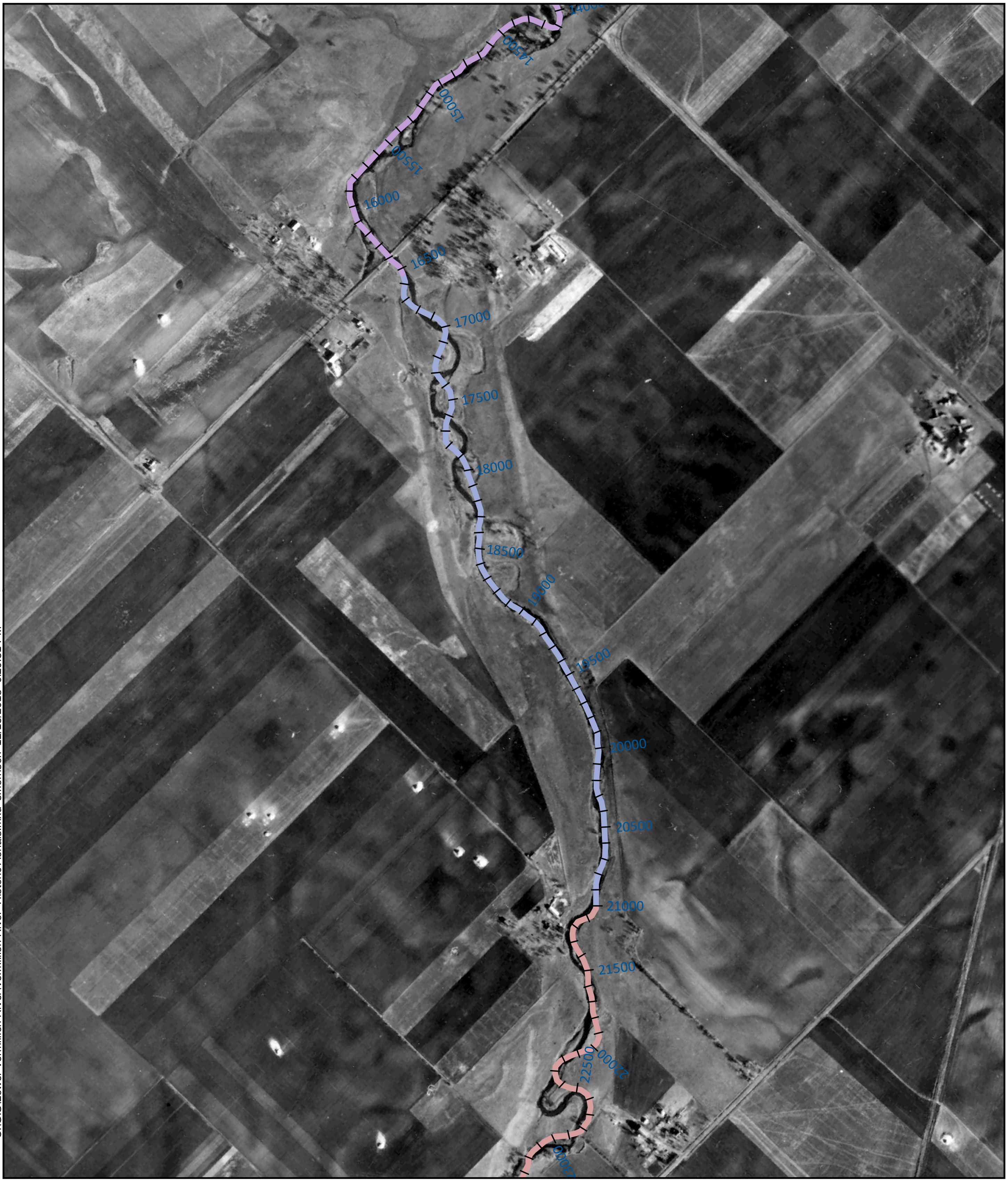
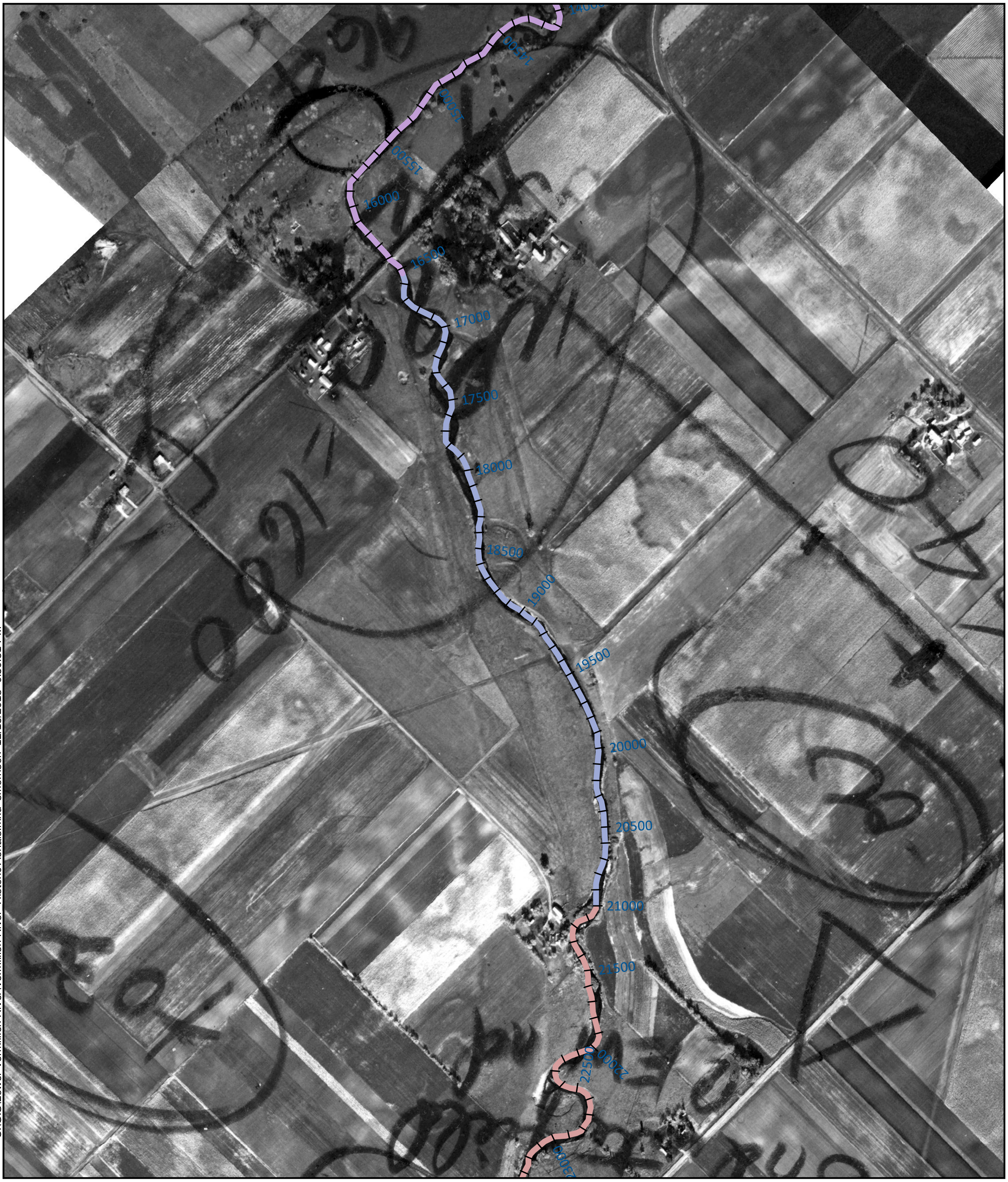


1937 Aerials



1964 Aerials

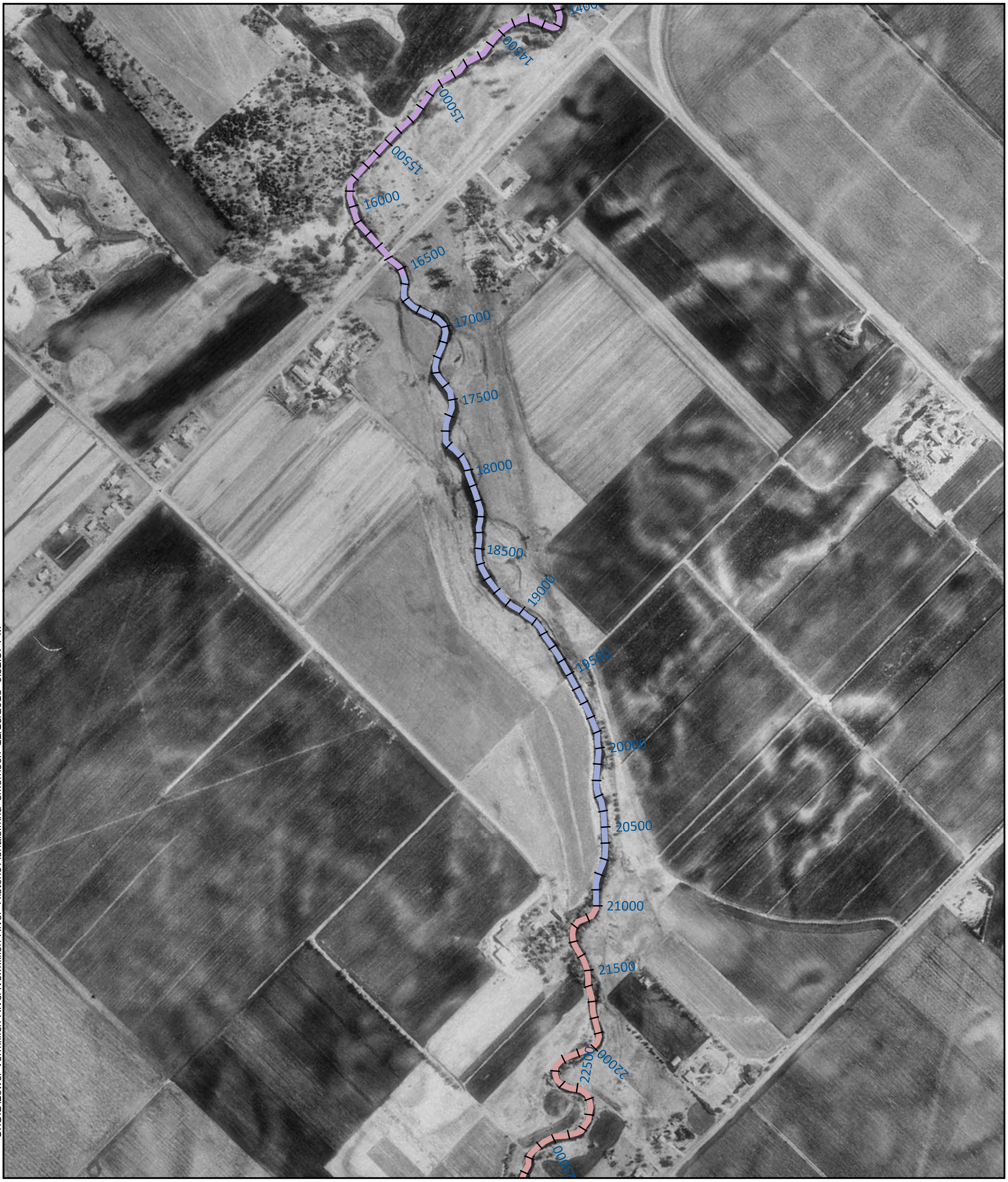
0 1,000 Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



1991 Aerials

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

0 1,000

Feet

N

inter·fluve

2003 Aerials

0 1,000
Feet

N

Reach Number
1
2
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5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:42:36 PM

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:55:52 PM

2010 Aerials

0 1,000
Feet

N

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:58:32 PM

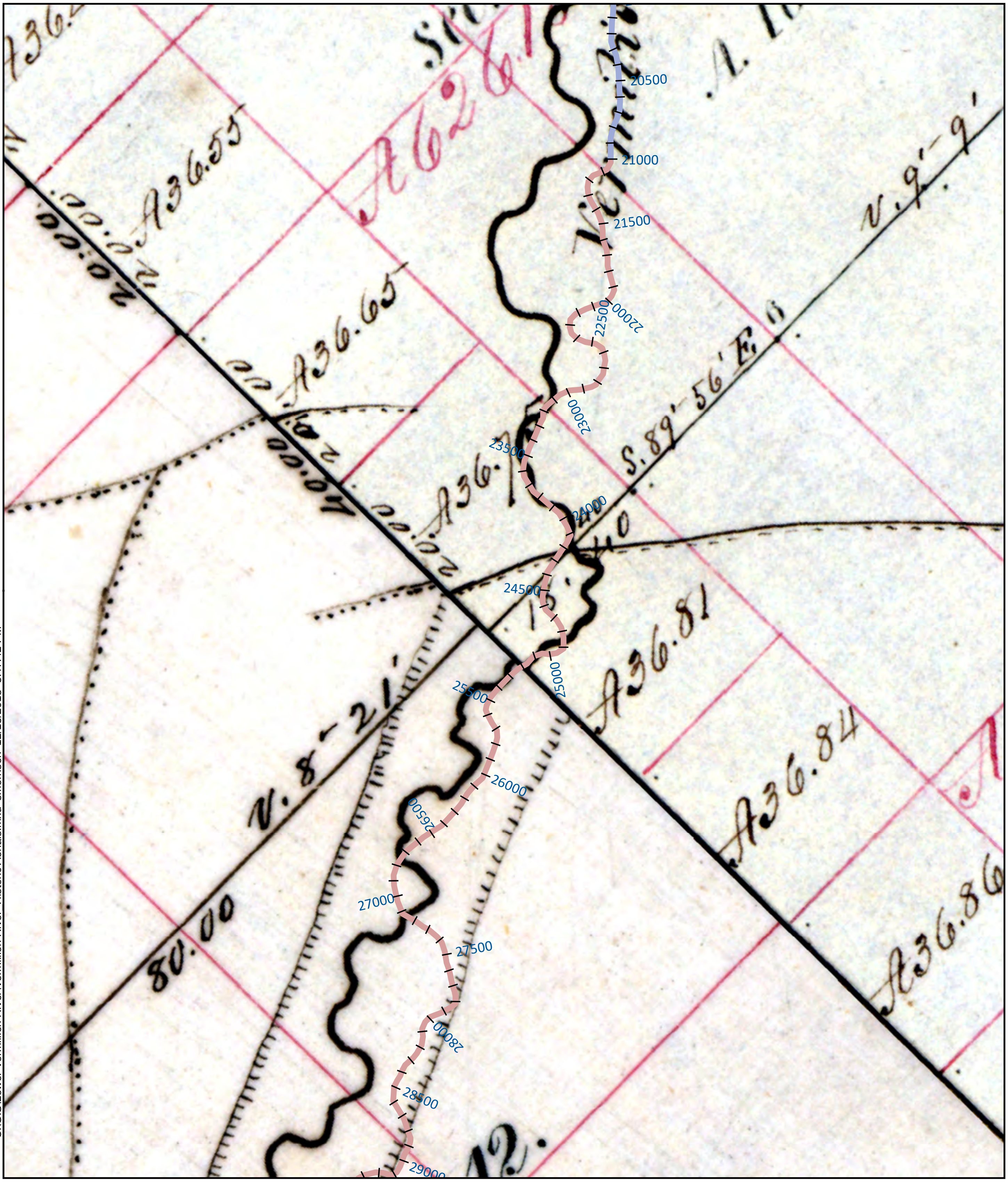
2016 Aerials

0 1,000 Feet

N

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



GLO Maps

0 1,000
Feet

N

Reaches

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

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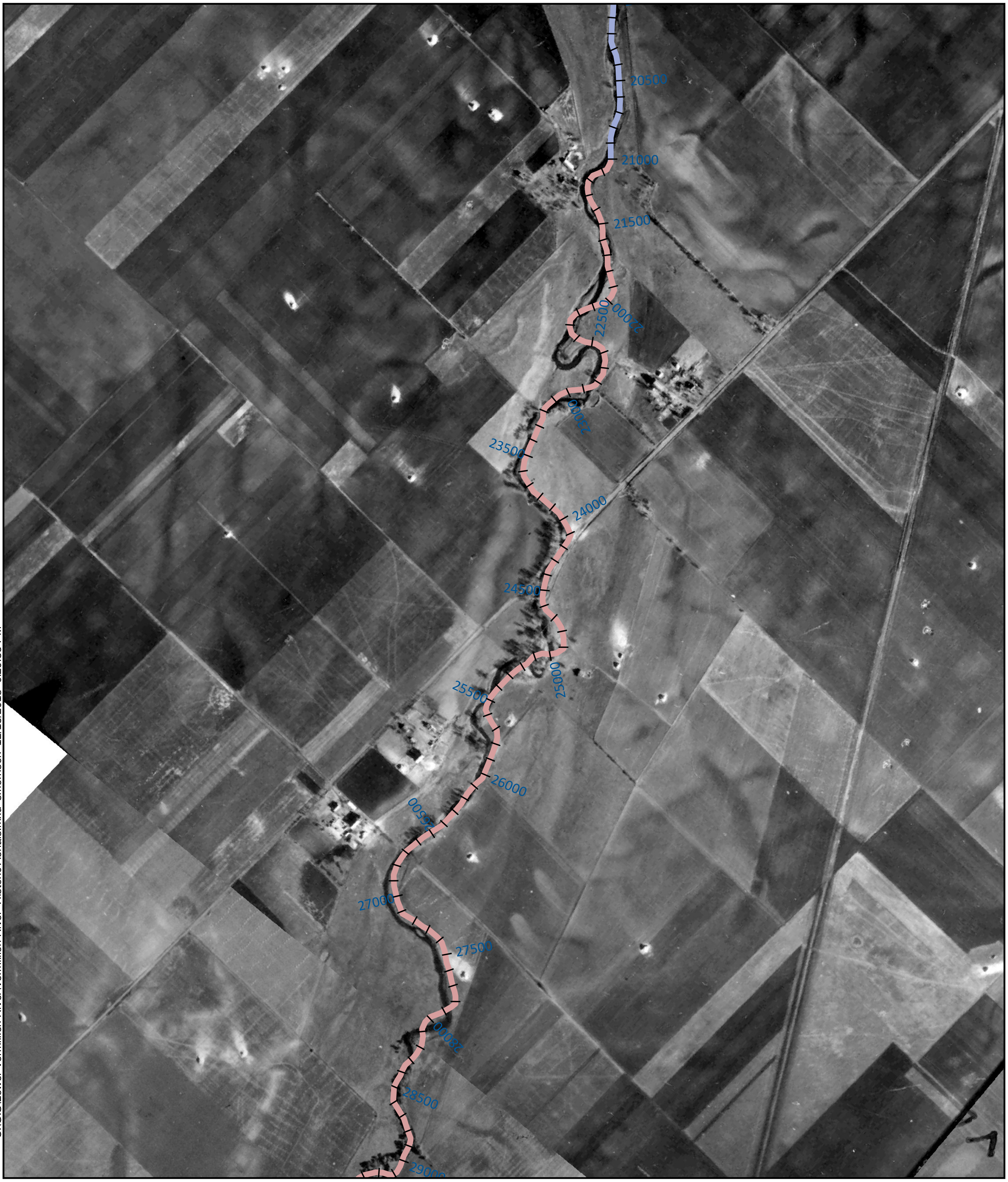

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1937 Aerials

0 1,000 Feet

N

Reach Number
- 1
- 2
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- 4
- 5
- 6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:30:54 PM

1964 Aerials

0 1,000
Feet

N

Reach Number
1
2
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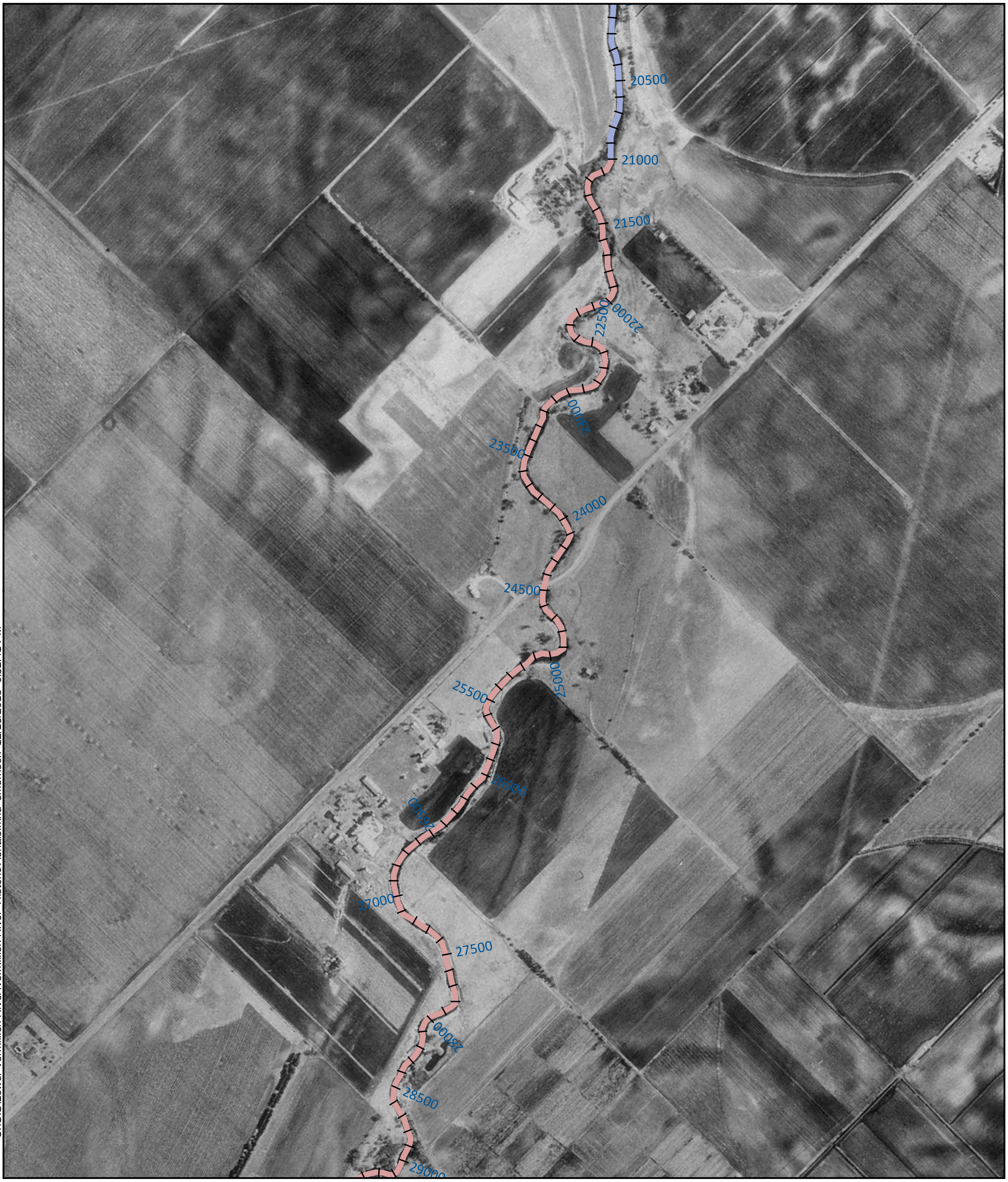
4
5
6

inter·fluve



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1991 Aerials

0 1,000
Feet

N

Reach Number

1
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5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:42:41 PM

2003 Aerials

0 1,000
Feet

N

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:55:56 PM

2010 Aerials

0 1,000 Feet

N

Reach Number

1
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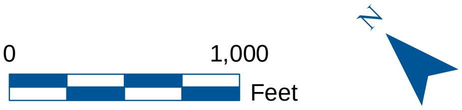
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:58:41 PM

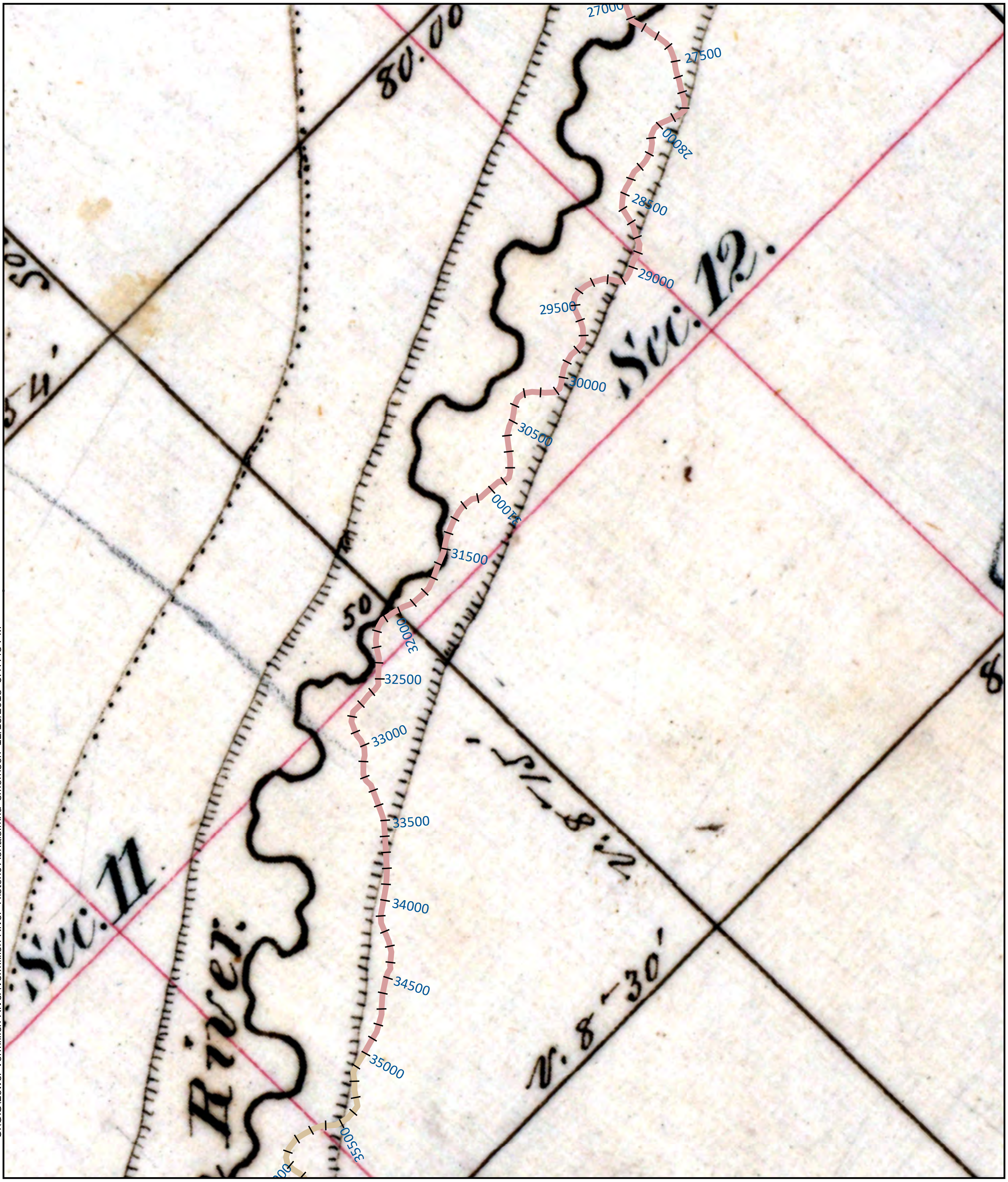
2016 Aerials



Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



GLO Maps

0 1,000 Feet

N

Reaches

Reach Number

1
2
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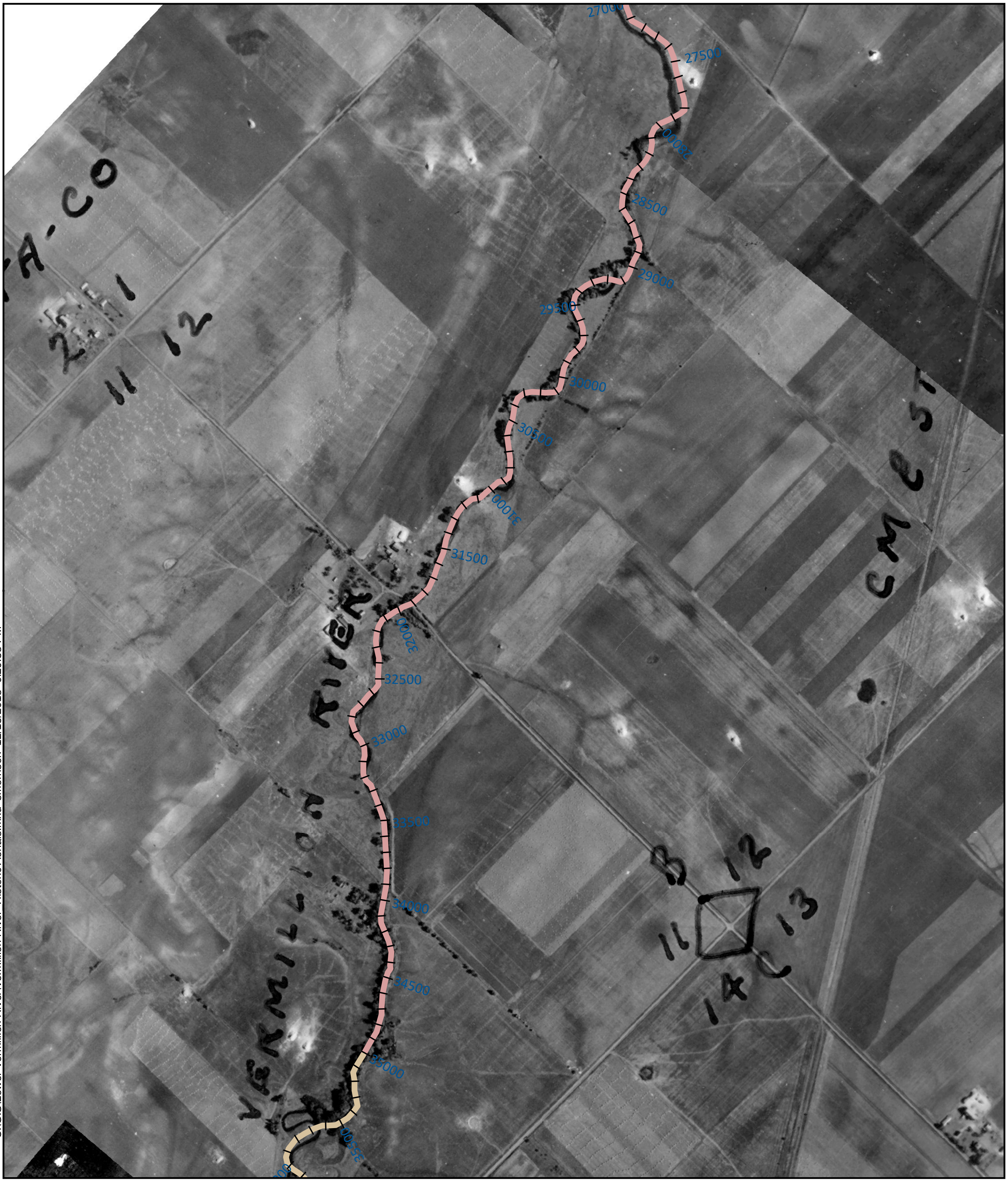
4
5
6



C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:29:38 PM

1937 Aerials

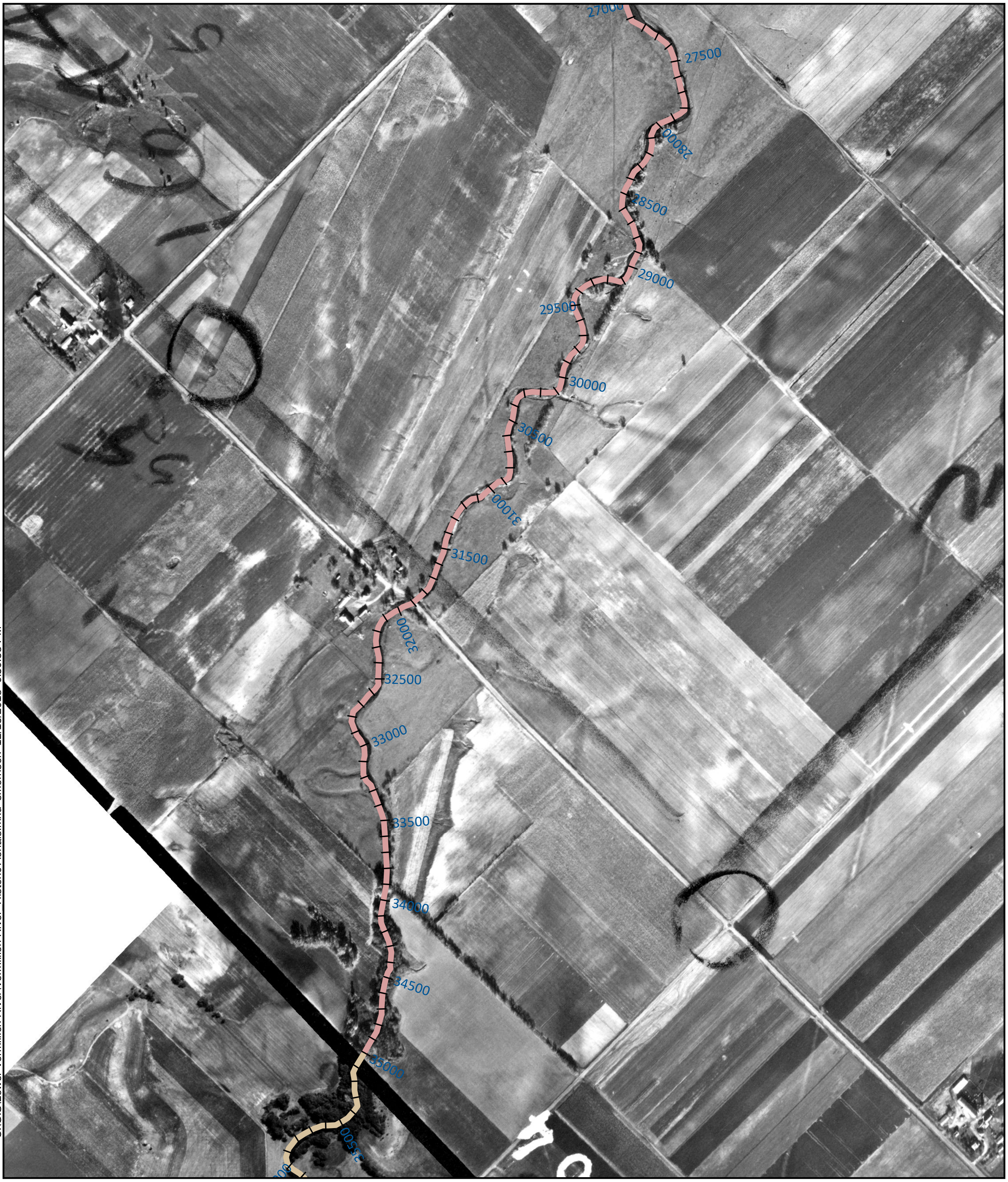
0 1,000
Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



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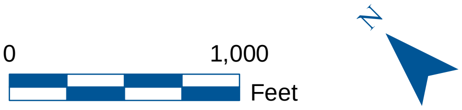
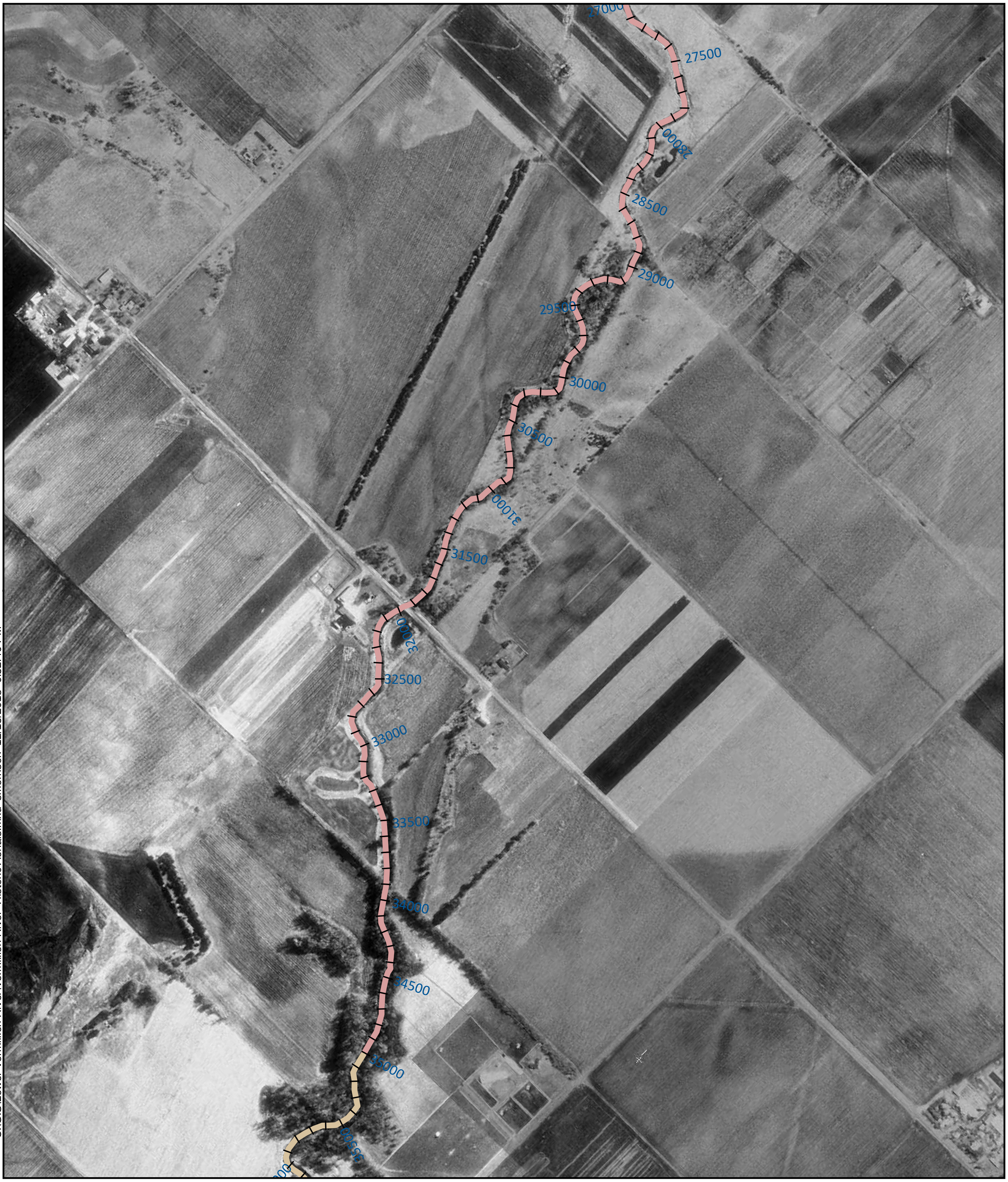
1964 Aerials



Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



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1991 Aerials

0 1,000 Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:42:46 PM

2003 Aerials

0 1,000 Feet

N

Reach Number
1
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3
4
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:55:59 PM

2010 Aerials

0 1,000 Feet

N

Reach Number

1
2
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4
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:58:47 PM

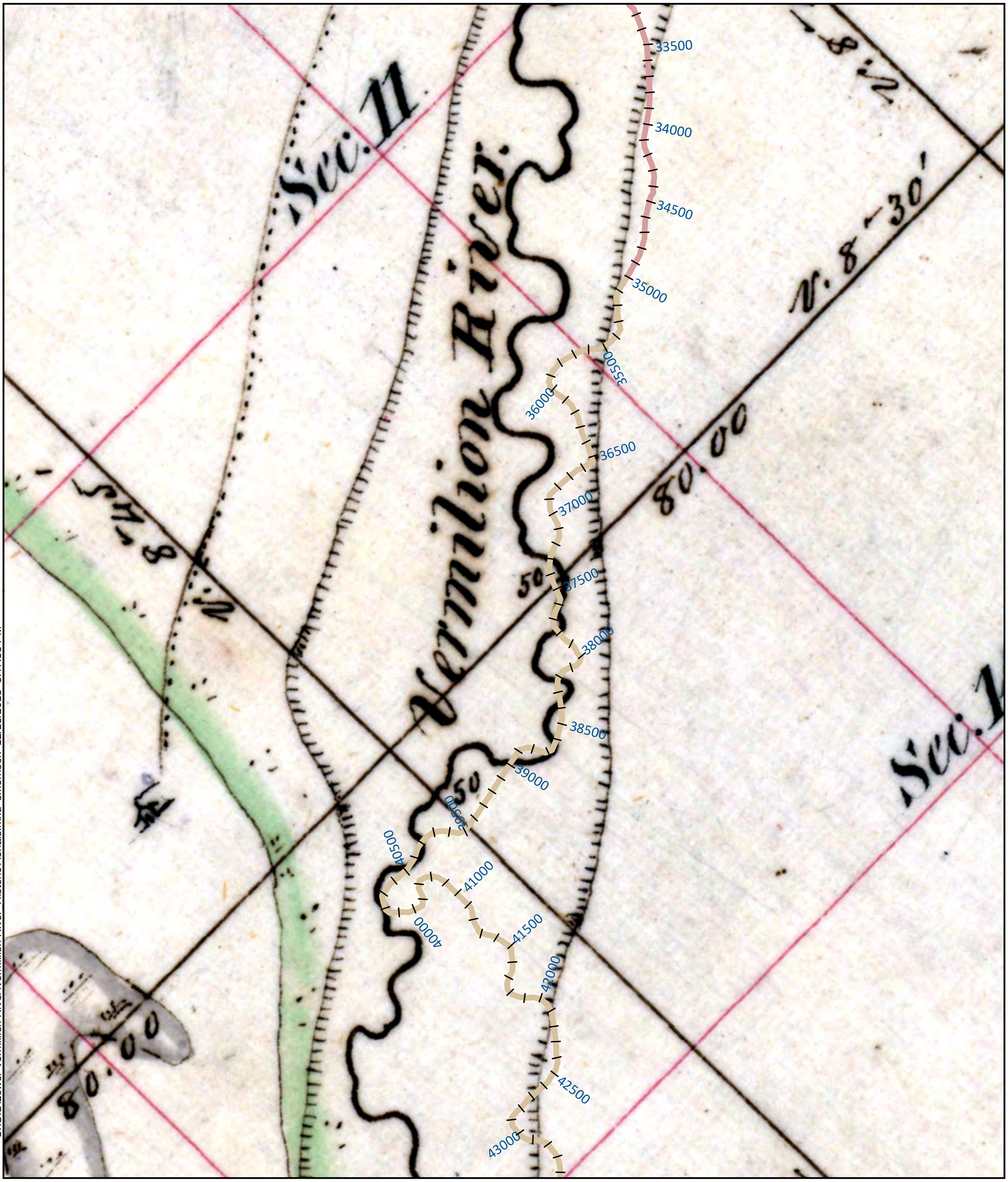
2016 Aerials

0 1,000 Feet

N

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 5:47:53 PM

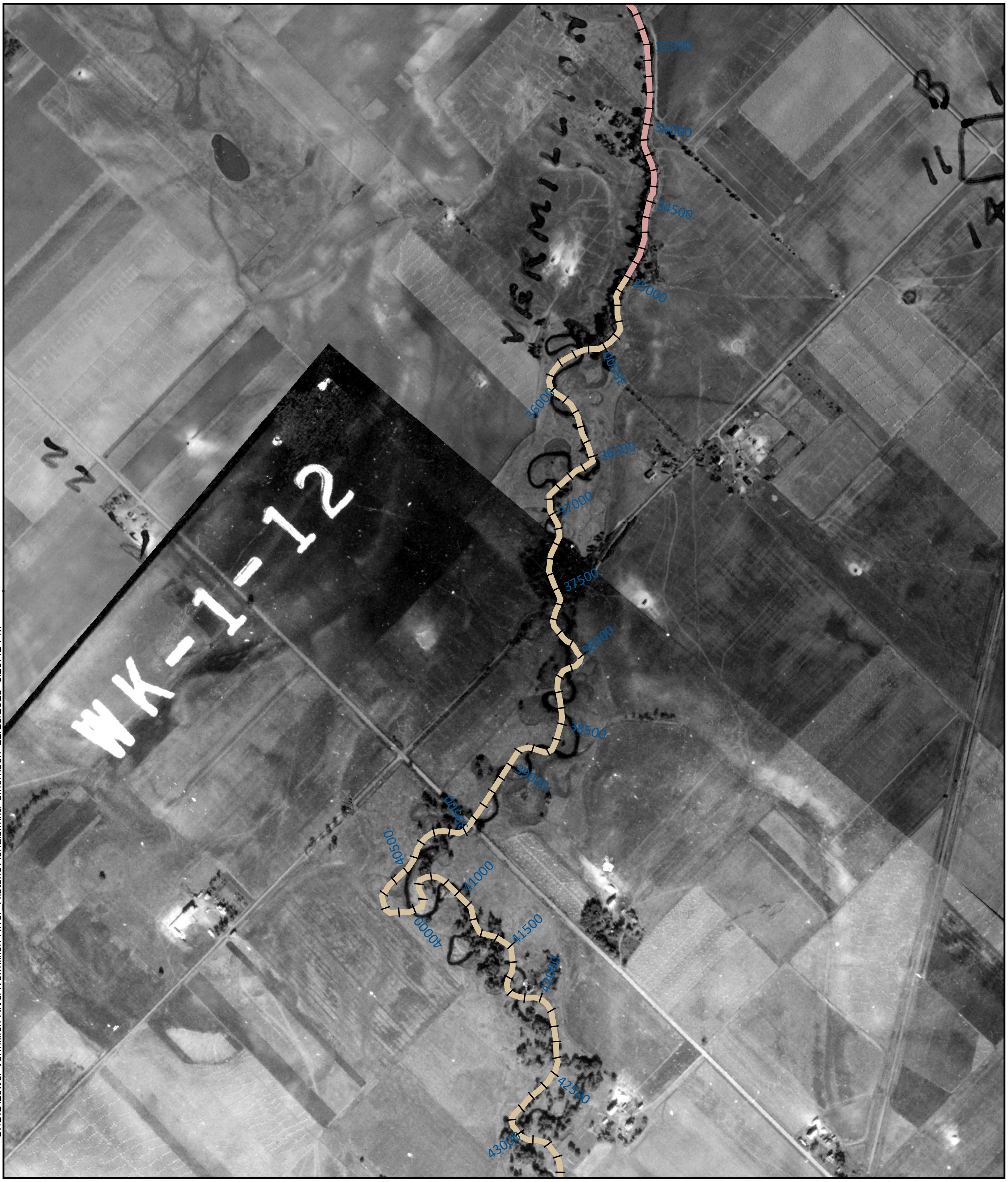
GLO Maps

0 1,000
Feet

N

Reaches
Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:29:42 PM

1937 Aerials

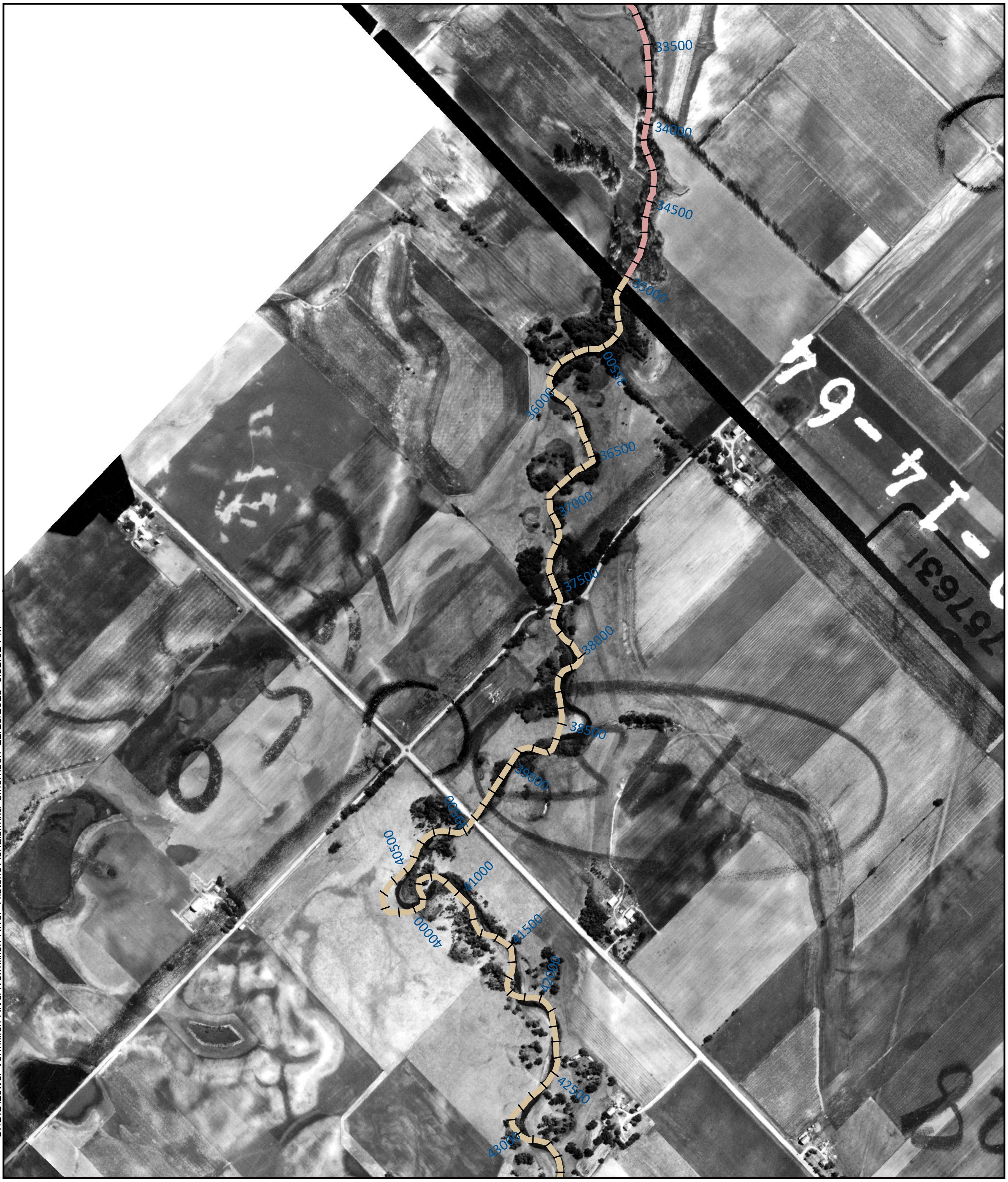
0 1,000 Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



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1964 Aerials

0 1,000 Feet

N

Reach Number

1
2
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6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:32:54 PM

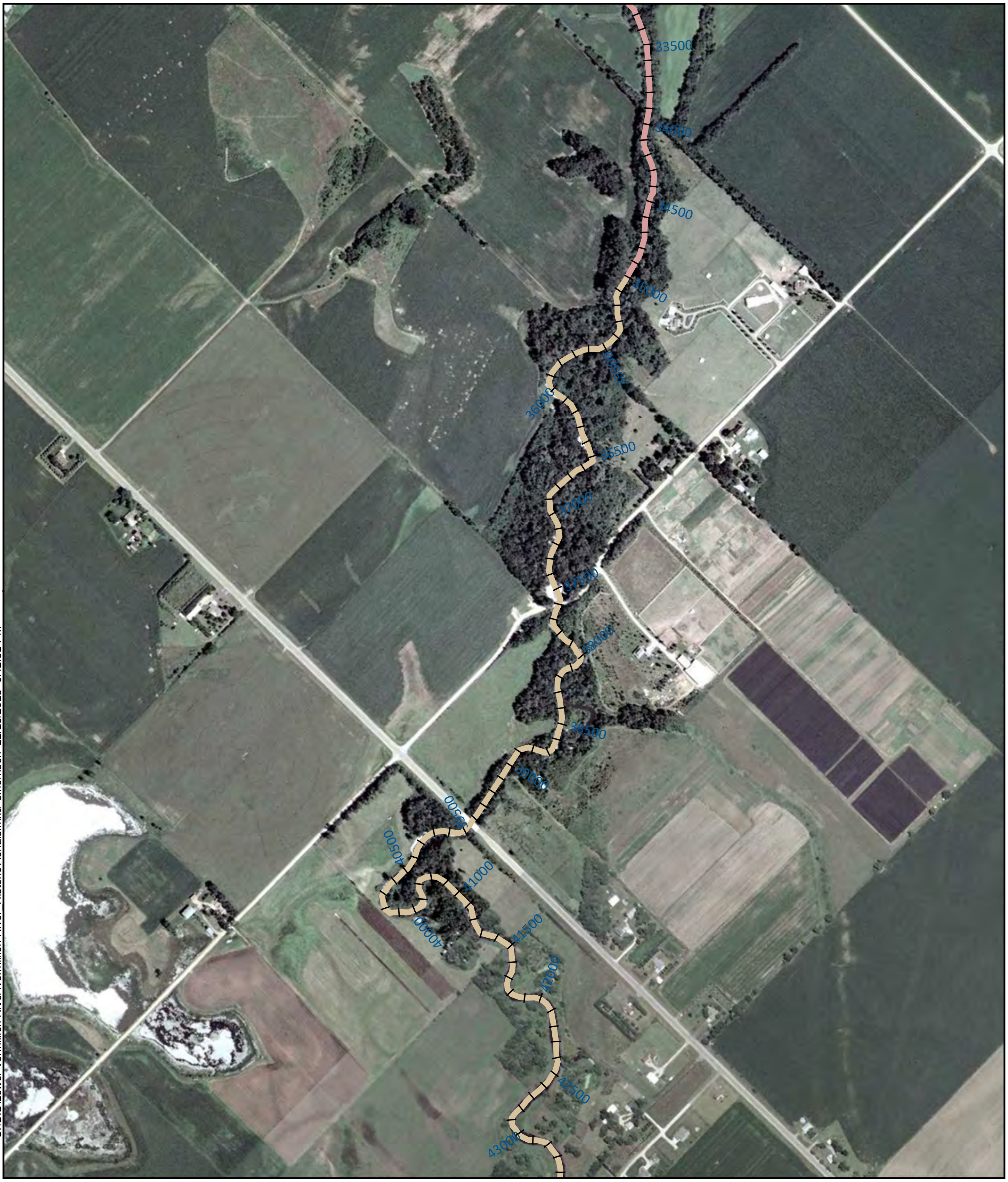
1991 Aerials

0 1,000
Feet

N

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



2003 Aerials

0 1,000
Feet

N

Reach Number
1
2
3
4
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:56:03 PM

2010 Aerials

0 1,000 Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

2016 Aerials

0 1,000 Feet

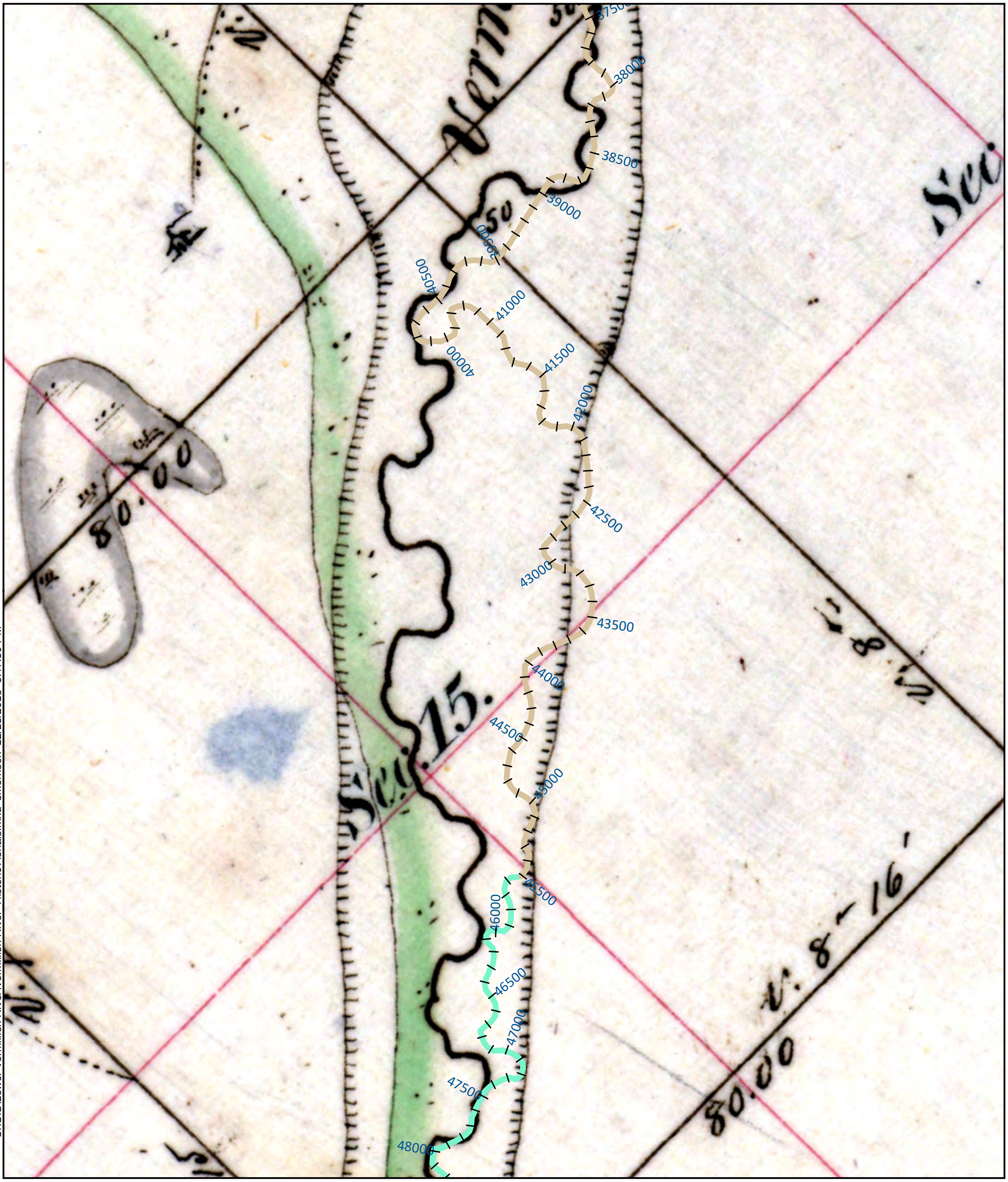
N

Reach Number

1
2
3
4
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:58:52 PM



GLO Maps

0 1,000 Feet

N

Reaches
Reach Number
1
2
3
4
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 5:47:59 PM

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:29:46 PM

1937 Aerials

inter·fluve

1964 Aerials

0 1,000 Feet

N

Reach Number
1
2
3
4
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:31:07 PM

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:33:00 PM

1991 Aerials

0 1,000 Feet

N

Reach Number
1
2
3
4
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:42:56 PM

2003 Aerials

0 1,000
Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:56:06 PM

2010 Aerials

0 1,000 Feet

N

Reach Number

1
2
3
4
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:58:56 PM

2016 Aerials

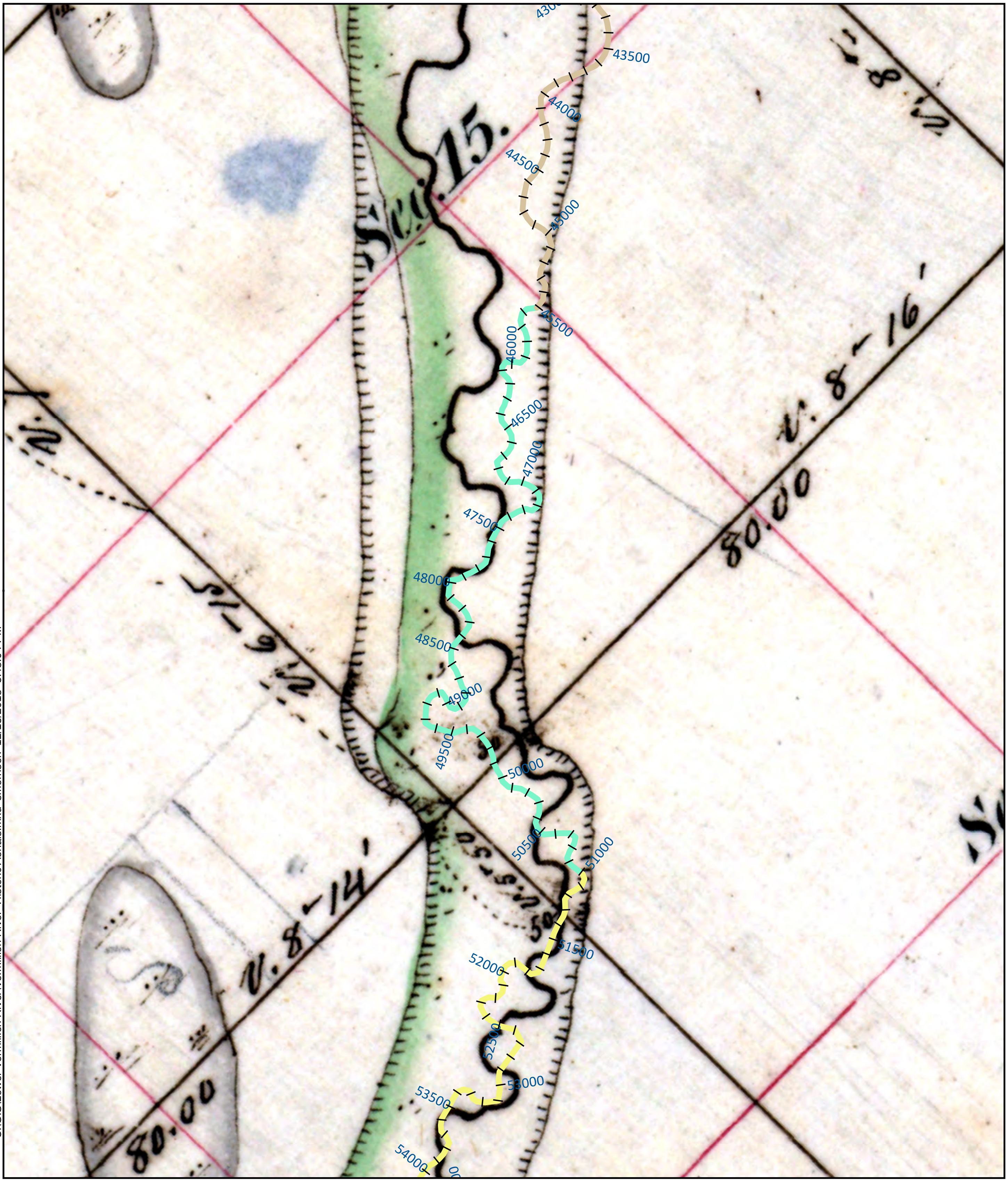
0 1,000 Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



GLO Maps

0 1,000 Feet

N

Reaches

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 5:48:04 PM

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:29:51 PM

1937 Aerials

0 1,000
Feet

N

Reach Number
1
2
3
4
5
6

inter·fluve

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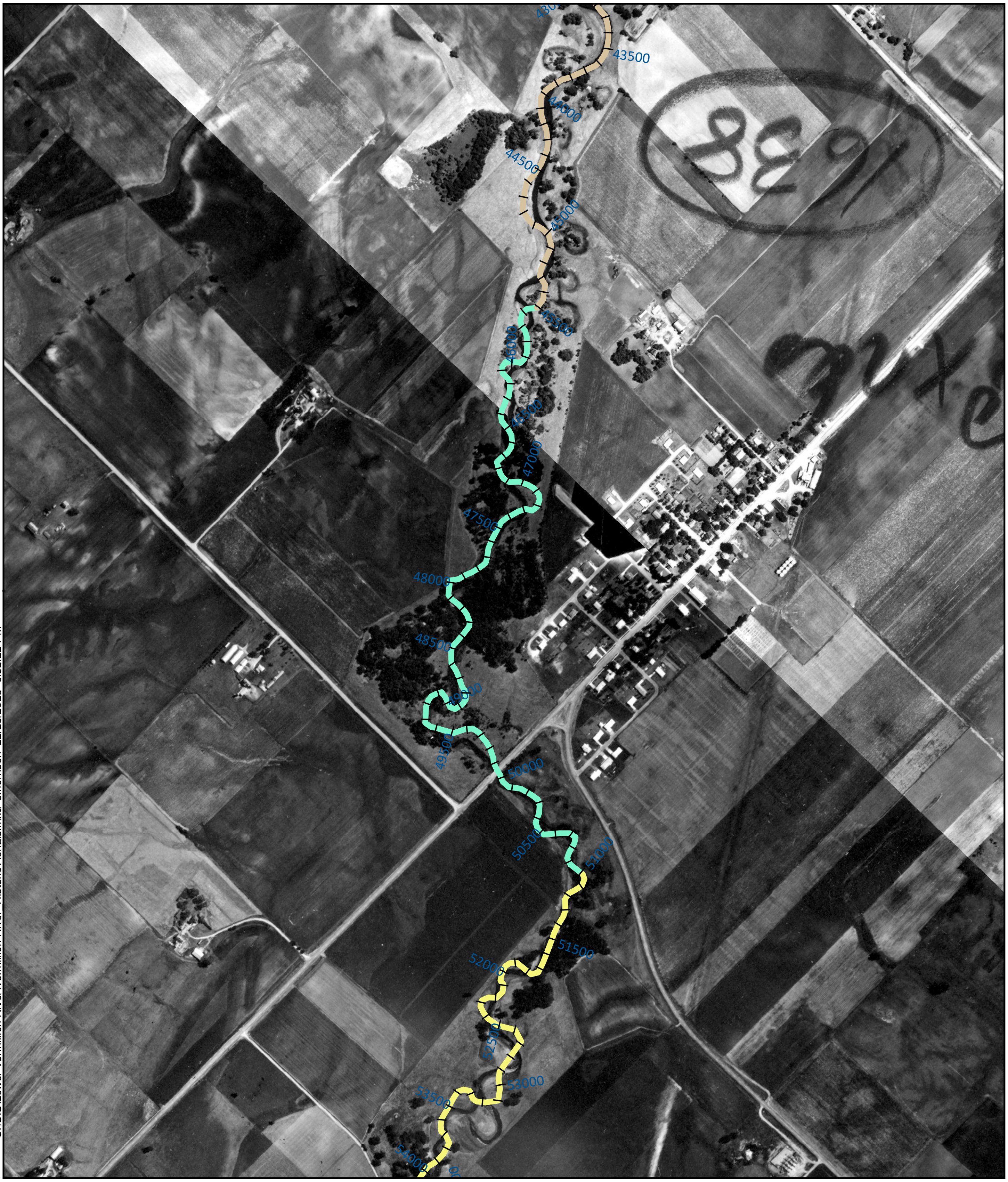

1964 Aerials

0 1,000
Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

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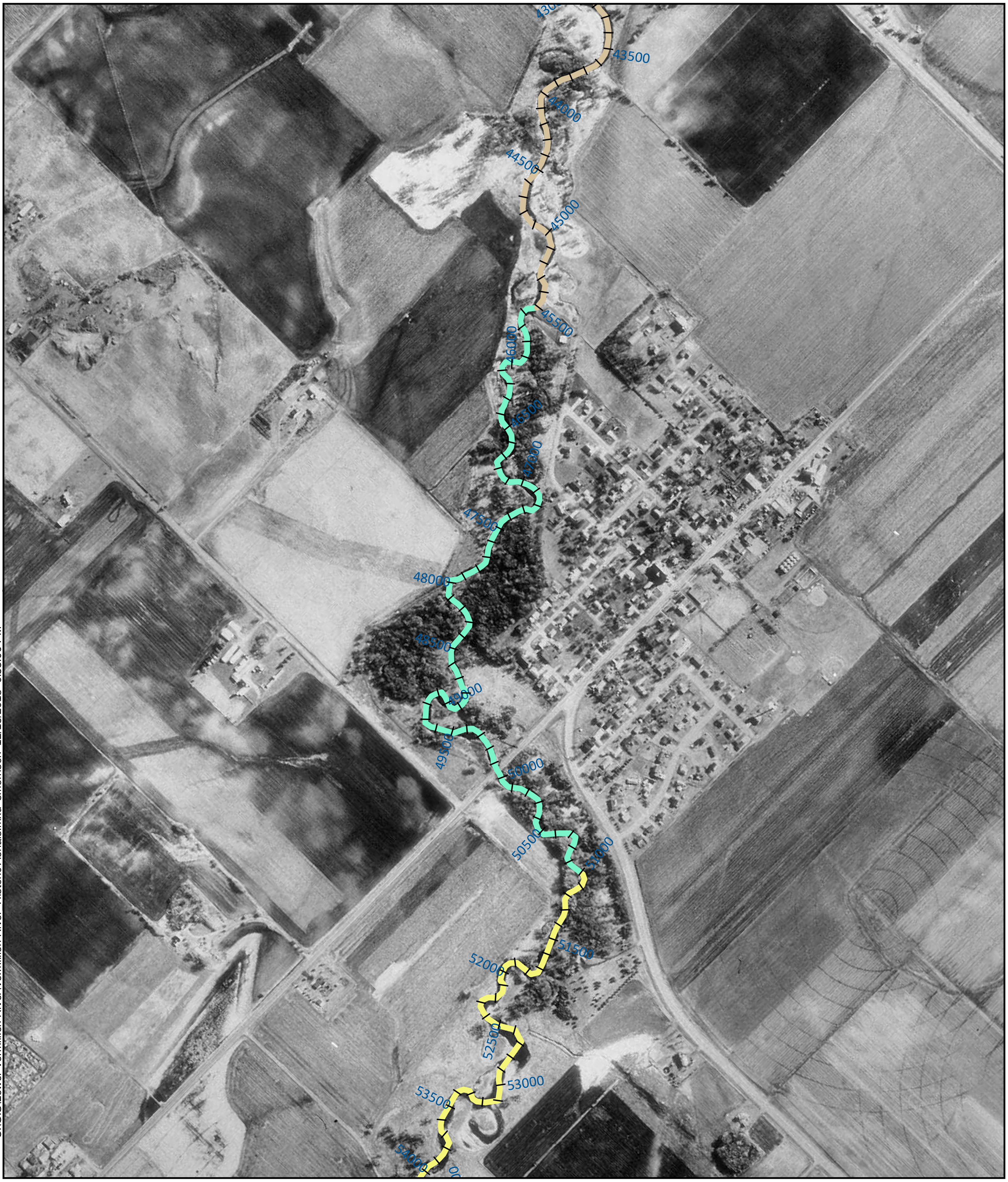


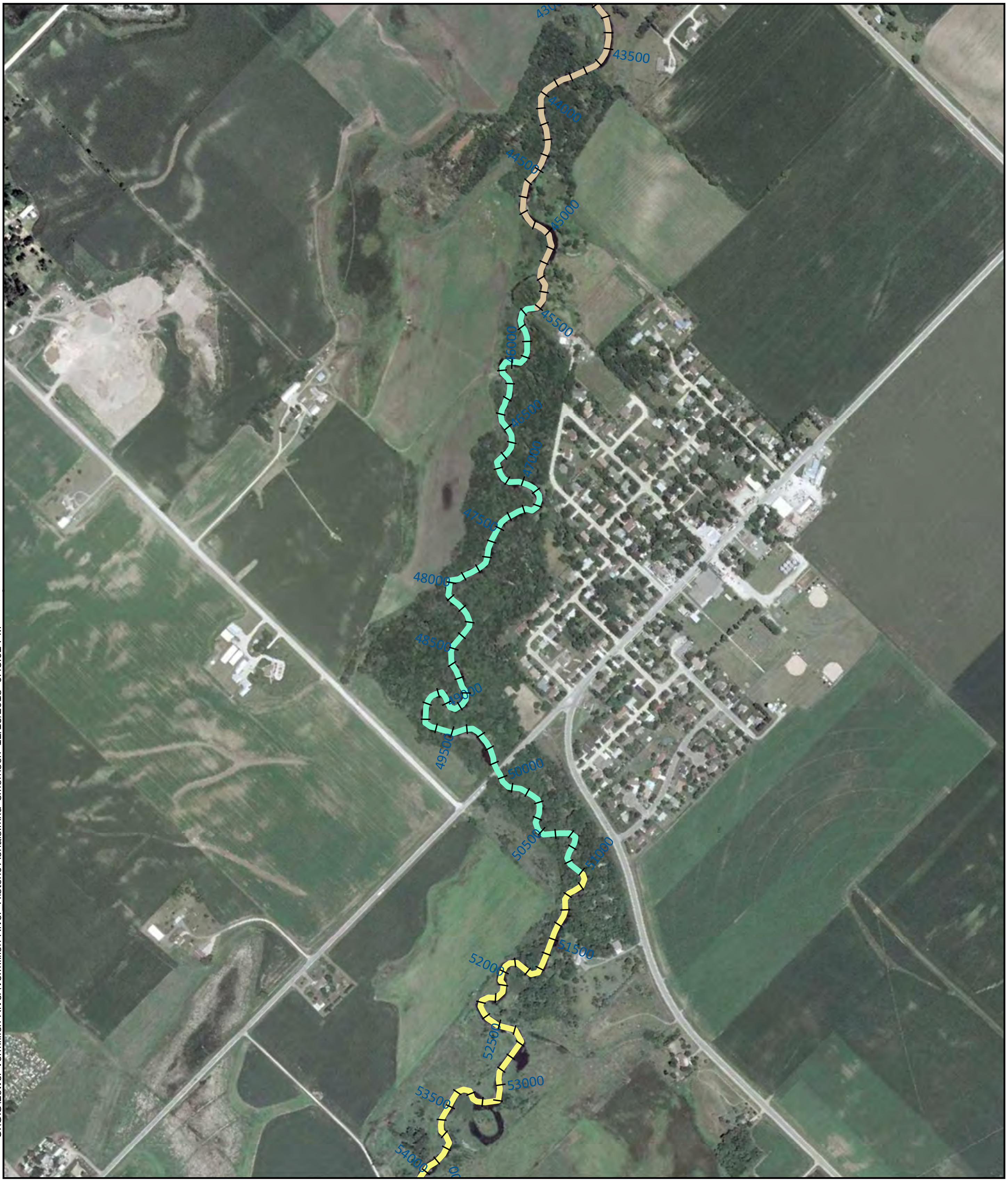
1991 Aerials

0 1,000
Feet

N

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



2003 Aerials

0 1,000 Feet

N

Reach Number
1
2
3
4
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:56:10 PM

2010 Aerials

0 1,000
Feet

N

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River Historic Aerials.mxd smorrison 12/13/2018 6:59:01 PM

2016 Aerials

0 1,000 Feet

N

Reach Number

1
2
3
4
5
6

inter·fluve

GLO Maps

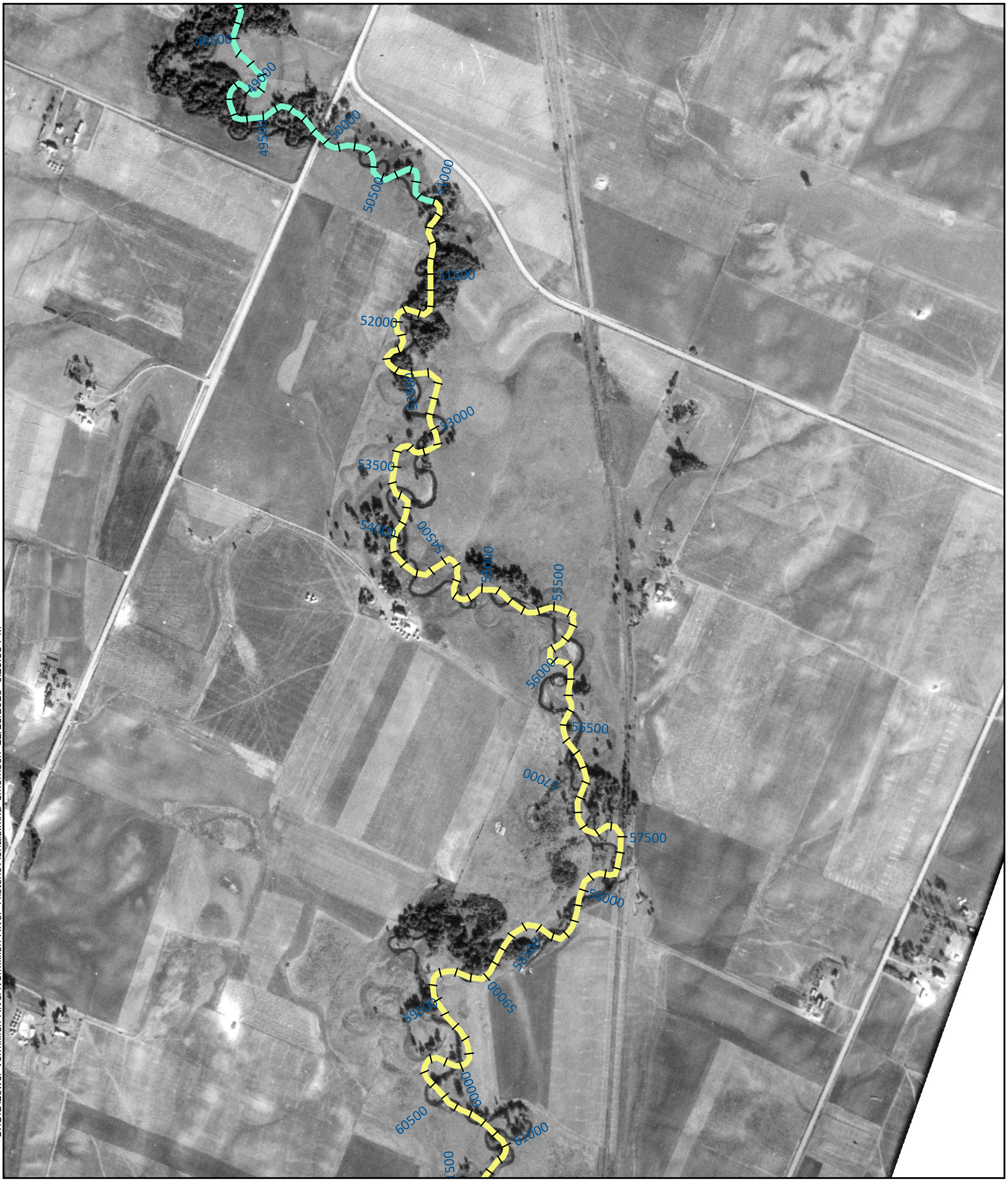
0 1,000
Feet

N

Reaches
Reach Number
1
2
3
4
5
6

inter·fluve

C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 5:48:09 PM



C:\GIS\Lower Vermillion River\Vermillion River_Historic Aerials.mxd smorrison 12/13/2018 6:29:55 PM

1937 Aerials

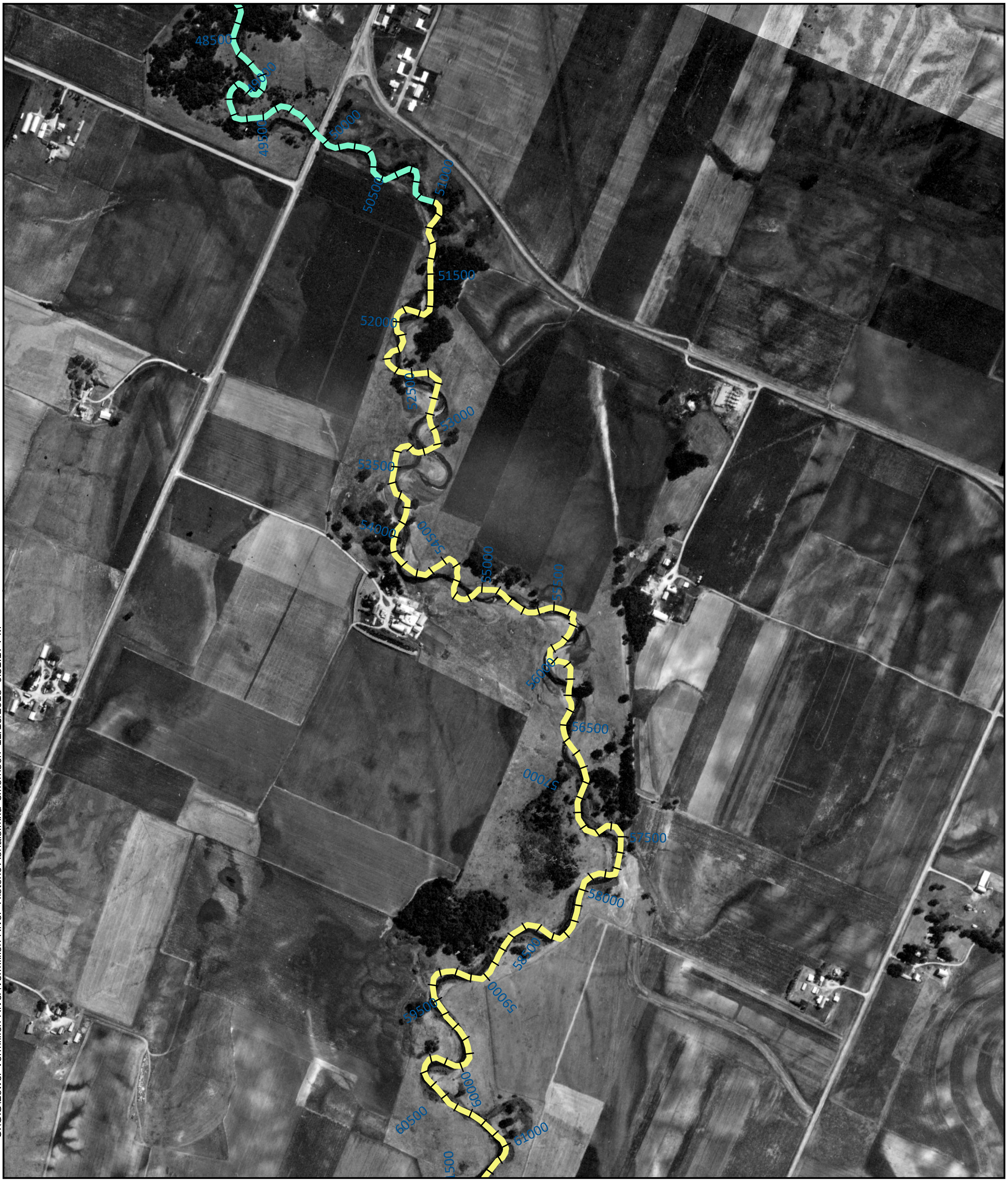
0 1,000 Feet

N

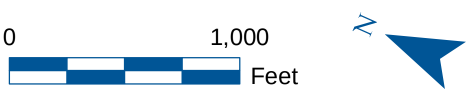
Reach Number

1
2
3
4
5
6

inter·fluve



1964 Aerials



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1991 Aerials

0 1,000 Feet

N

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

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2003 Aerials

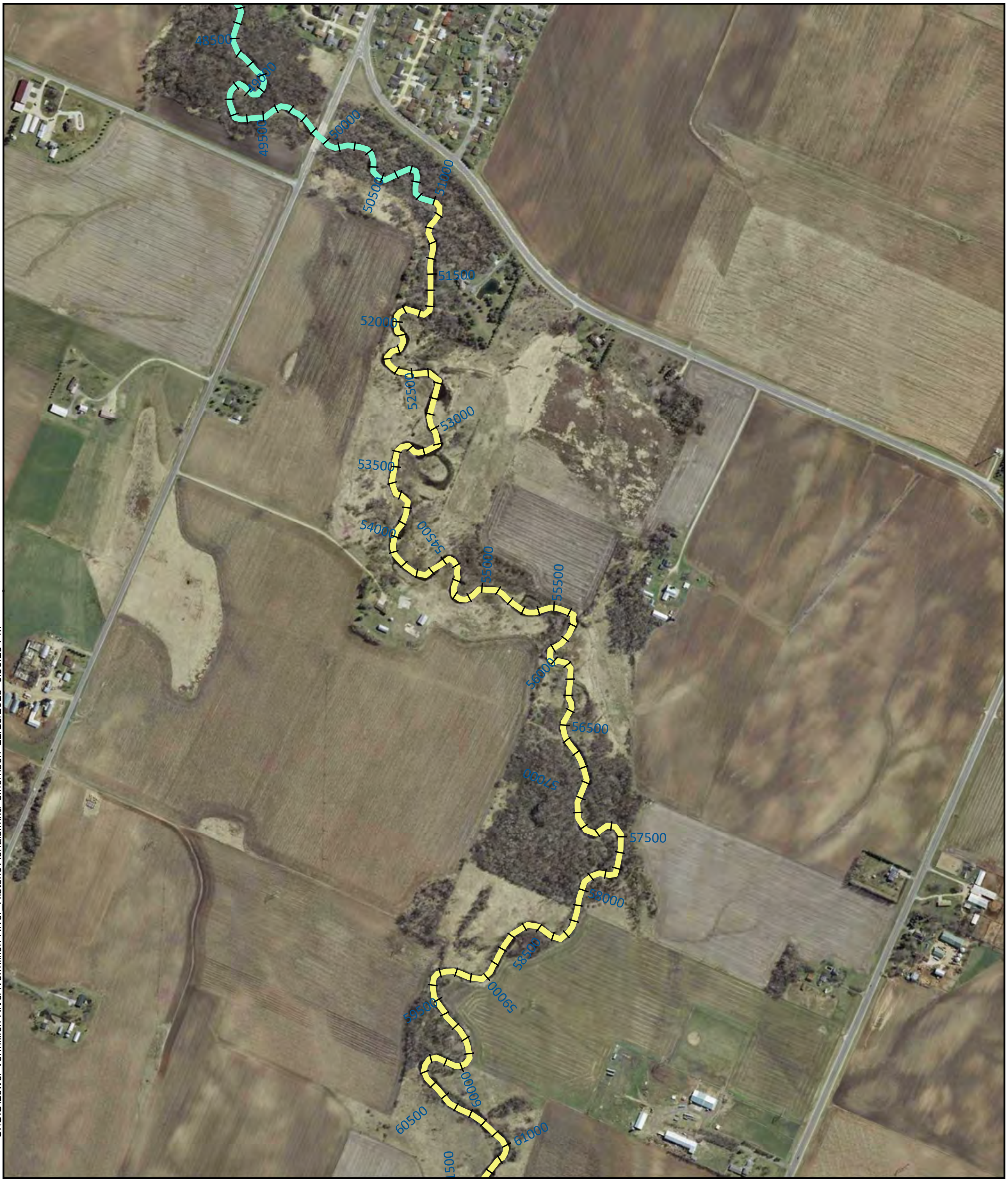
0 1,000 Feet

N

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



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2010 Aerials

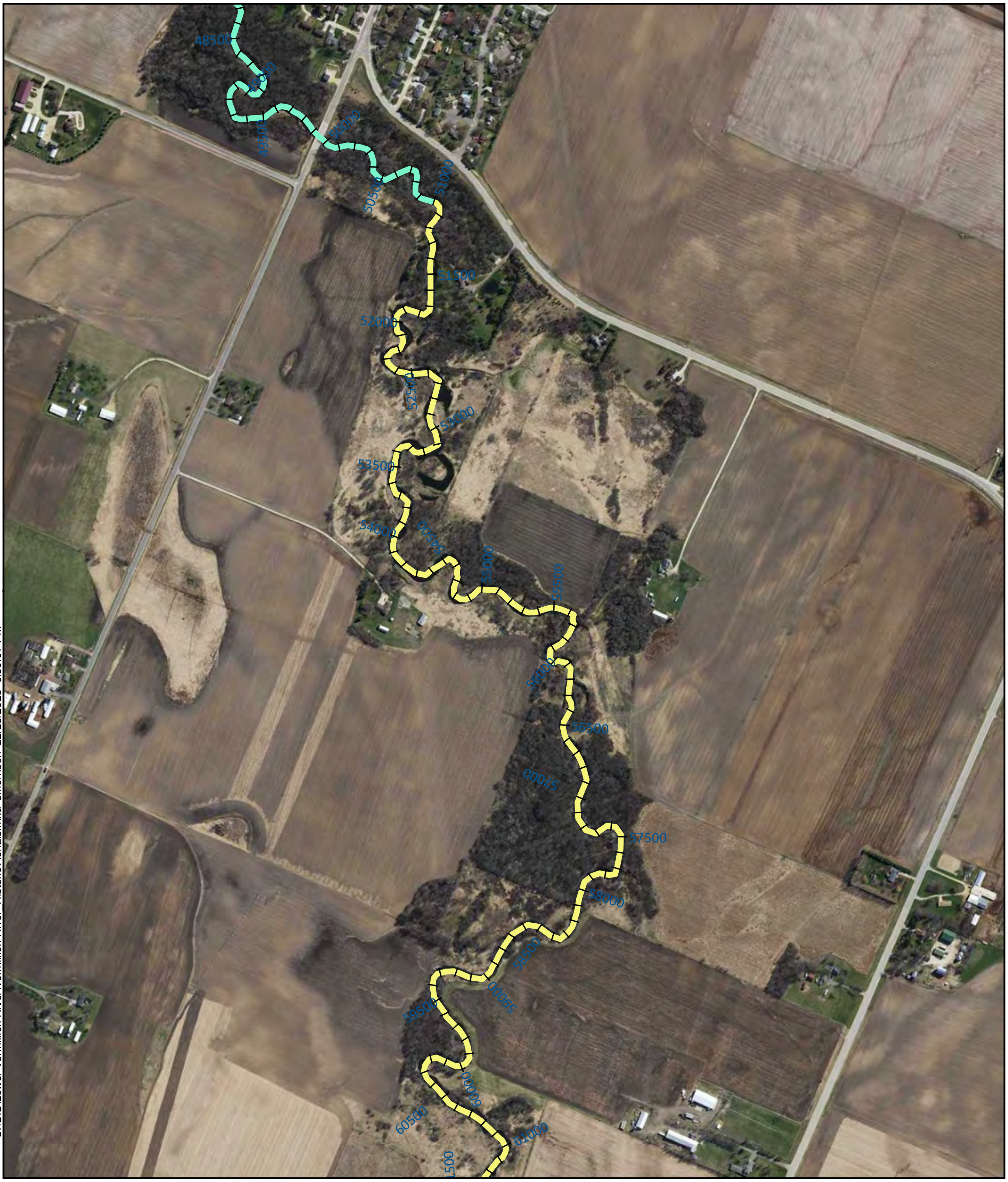
0 1,000 Feet

N

Reach Number

1
2
3
4
5
6

inter·fluve



2016 Aerials

0 1,000
Feet

N

Reach Number
1
2
3
4
5
6

inter·fluve

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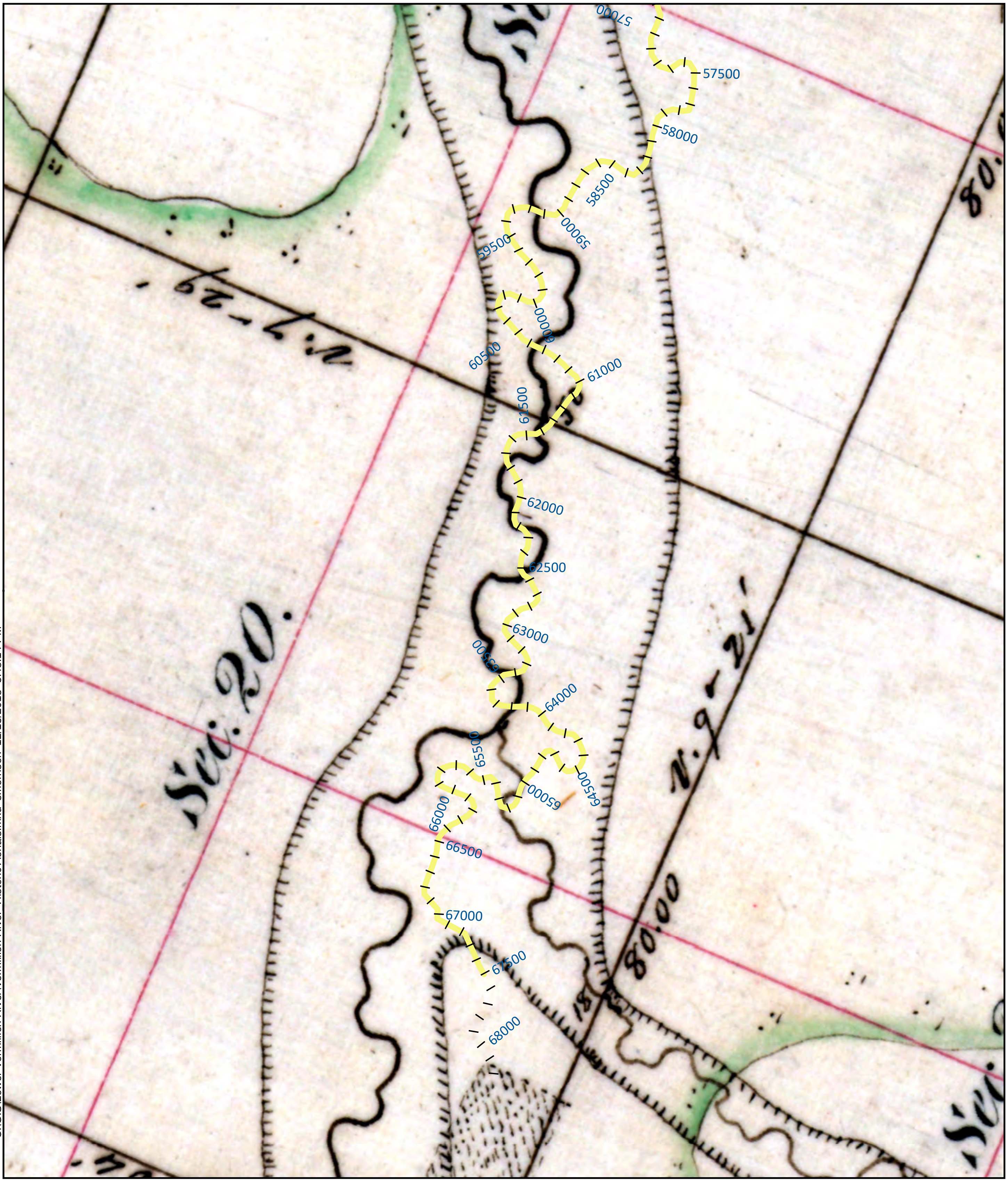

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GLO Maps

0 1,000 Feet

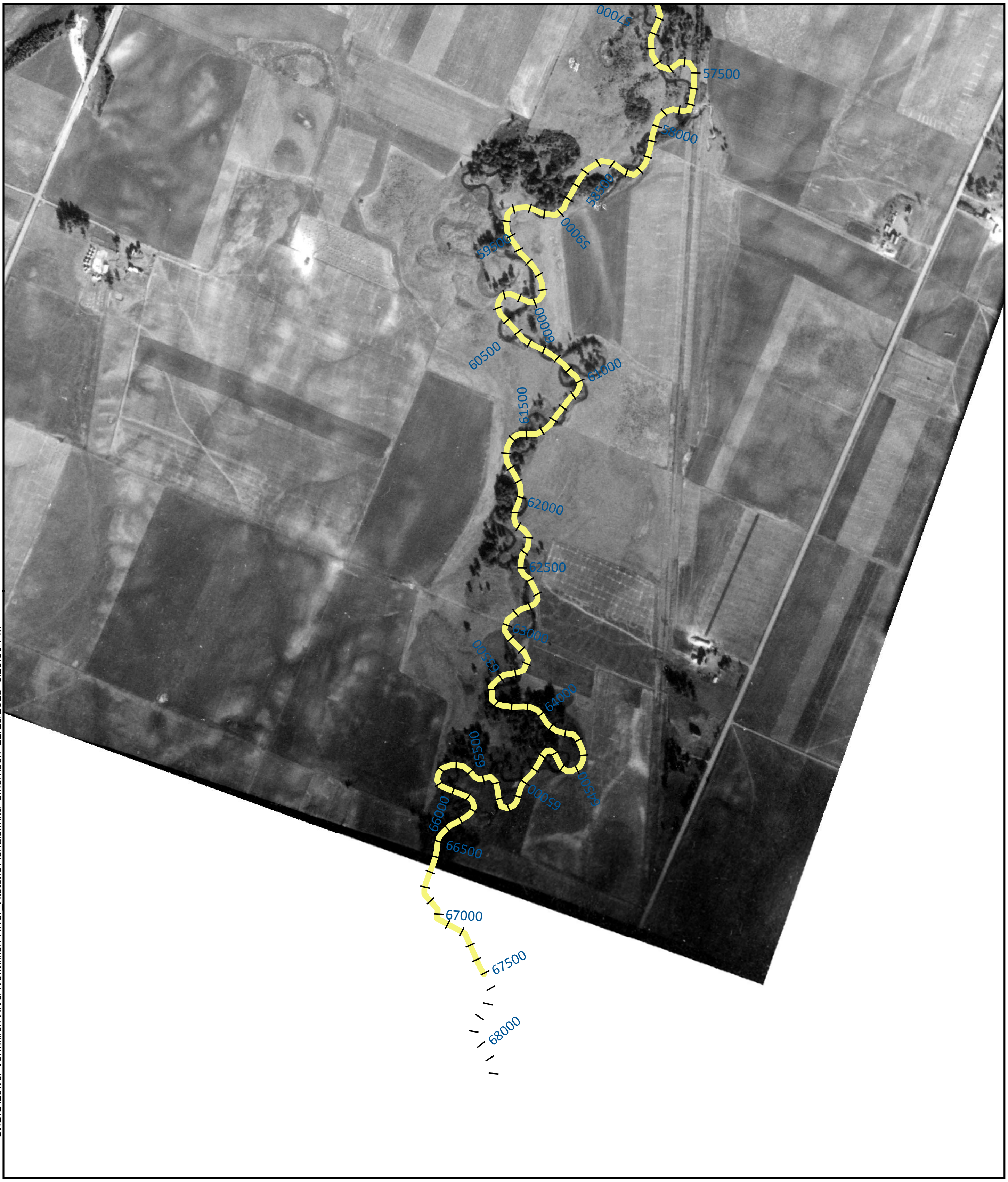
N

Reaches

Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



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1937 Aerials

0 1,000 Feet

N

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

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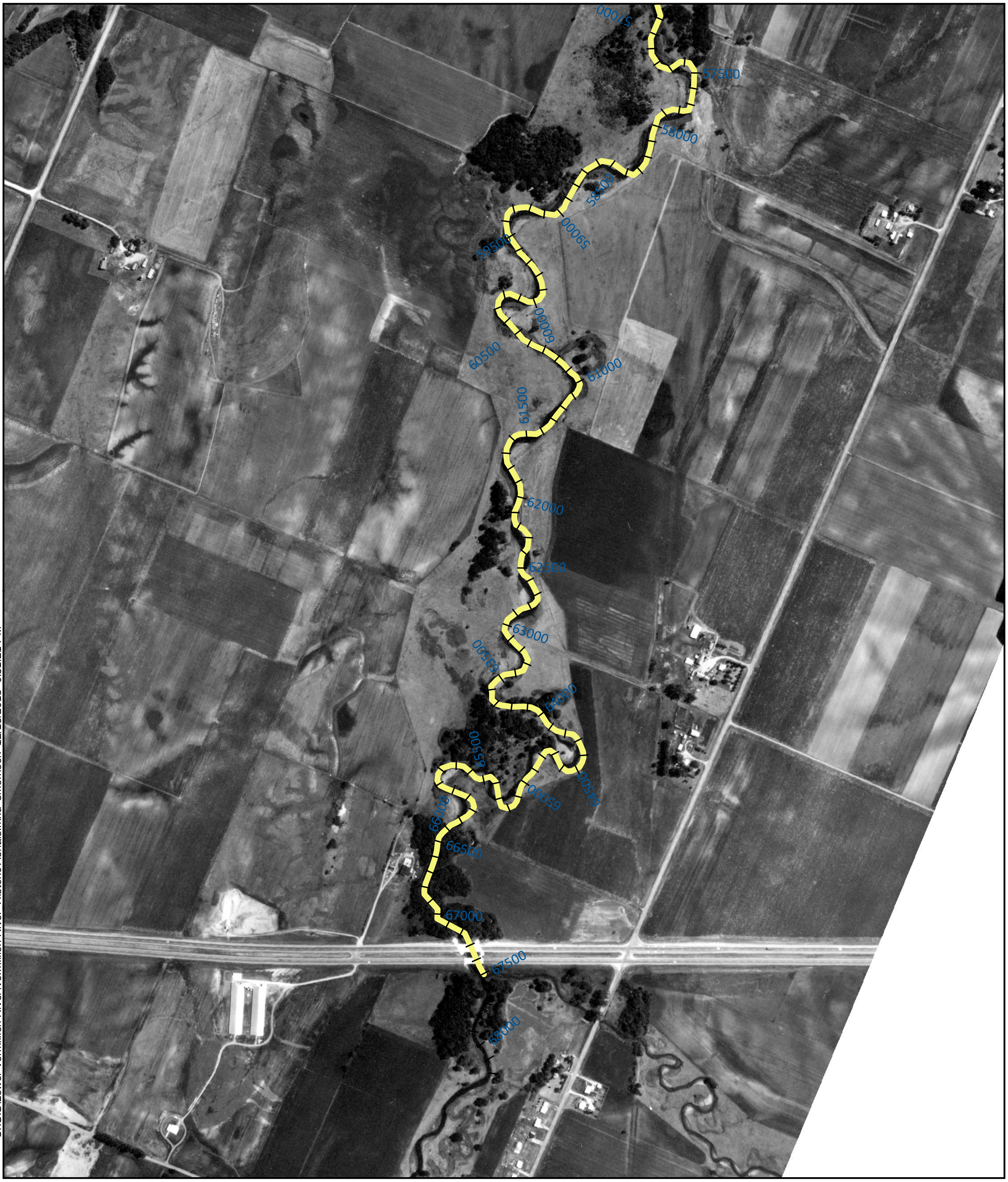


1964 Aerials

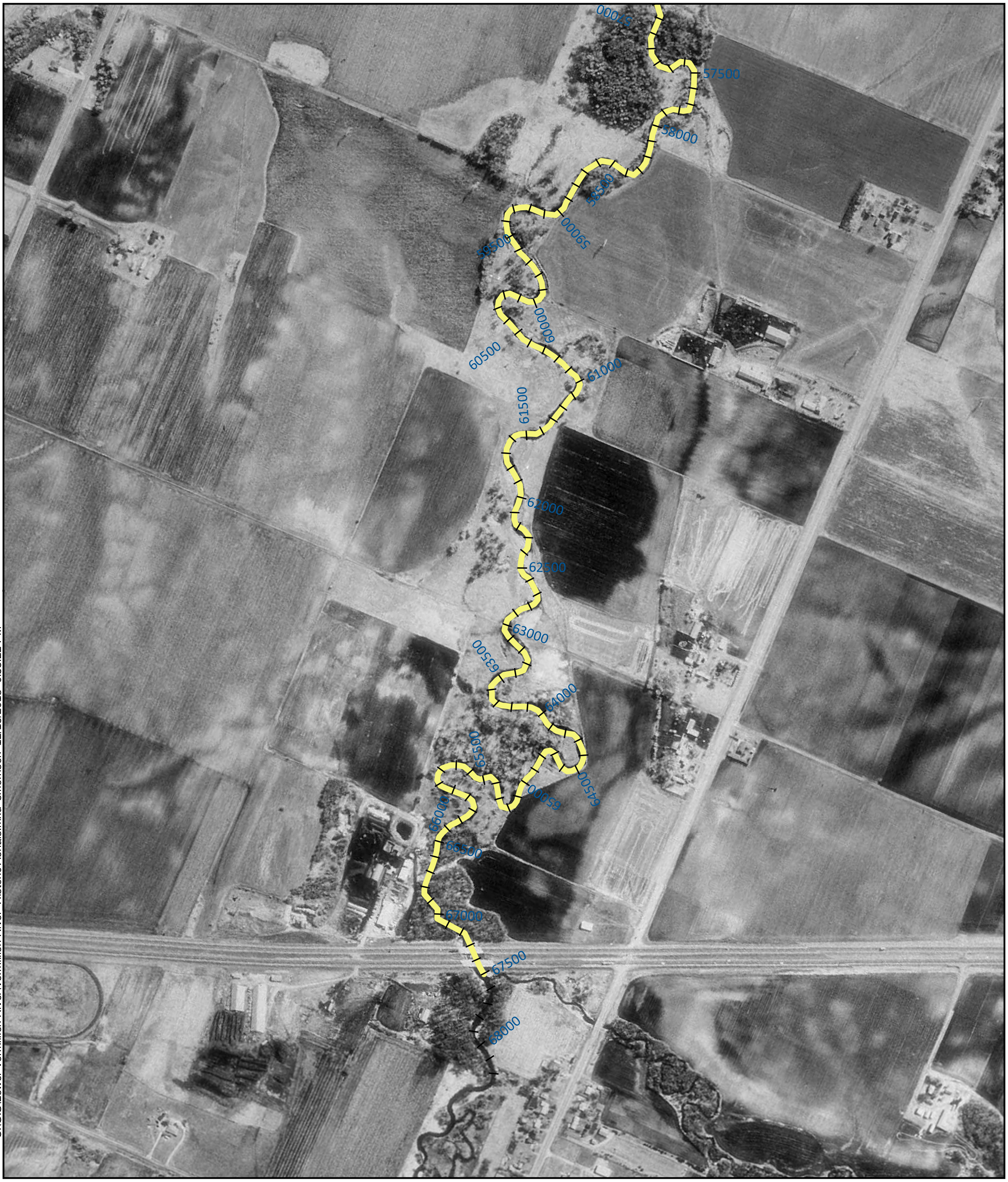
0 1,000 Feet

N

Reach Number

1
2
3
4
5
6

inter·fluve



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1991 Aerials

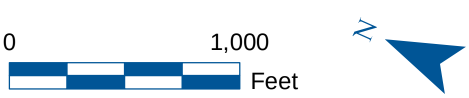
0 1,000
Feet

N

Reach Number
1
2
3
4
5
6

inter·fluve

2003 Aerials



Reach Number

- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

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2010 Aerials

0 1,000
Feet

N

Reach Number
1
2
3
4
5
6

inter·fluve

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2016 Aerials

0 1,000 Feet

N

Reach Number

1
2
3
4
5
6

inter·fluve

8. Appendix B

Channel Reconnaissance Forms

Channel Reconnaissance Form

Date	2018
Stream/Drainage	Lower Vermillion River
Stream Reach ID	Reach 1
Field Team	NN, SM

Station 16500 **To** 00000

General Channel Conditions

Sediment Particle Size Estimate	
Banks	sandy silt loam
Bars	sand silt
Bed	sand and gravel

Channel Shape (check)

Rectangular
Shallow Rectangular
Irregular
X Trapezoidal
Parabolic
Other _______________

Bar Types: Alternate lateral | Point / transverse | None
Mid-channel | Point / mid | X Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Vertically stable				
Lateral stability *deposition, erosion*	Appears laterally stable				
Erosion (excessive/site specific)	Localized erosion where mowing to edge				
Dominant bank erosion types (circle any that apply)	*Fluvial*	X Undercut / cantilever	Selective erosion of noncohesive laters	Dry flow	Seepage
	Gravitational	Rotational	Planar	Wedge	
Bank composition	*Notes (shape/character)*: Banks exposed				
Terrace/Valley	*Valley form* – Terraced Alluvial			*Land Use* – Narrow riparian corridor surrounded by farming	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Largely urban drainage with impervious surfaces, mowed areas and agriculture near river and riparian buffer.				
Bankfull/Channel forming flow indication	None				

Sediment Impacts

Riffle sediment type	Sand, gravel and cobble. Sparse boulders	Pool sediment type	Sand and silt
Sorting / Imbrication	NA		

Bars / depositional features

Sediment type/size	sand and silt
Mid, alternate, braided	Alternate
Bar Vegetation (type, age)	Grasses
Floodplain soils	Sandy silt loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	Varies
Width of veg. riparian corridor	Varies
Canopy coverage (%)	40%

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	Buckthorn, reed canary grass

Woody Species present	% of total tree community
Maple	10
Cottonwood	15

Tree Stand Age (if applicable)

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

Riparian Landuse

General Riparian Notes: Varying degree of use in riparian zone ranging from wide buffer, to agriculture, to mowed lawn, to naturalized prairie, to park space.

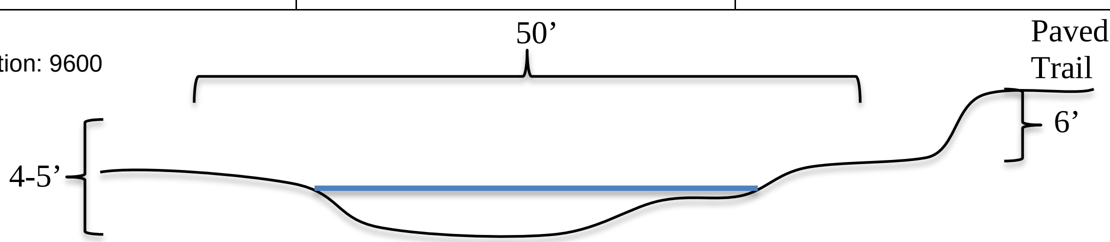
Channel Stability Form

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

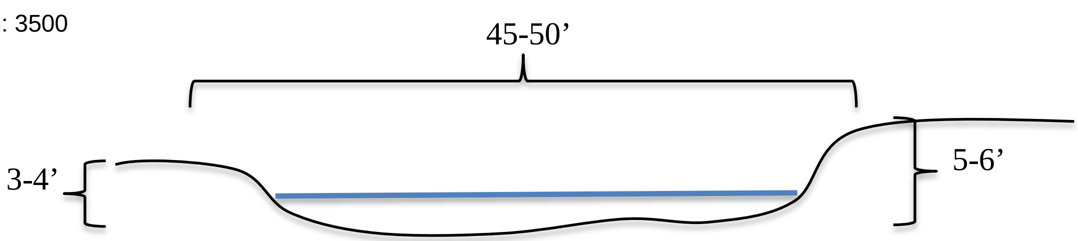
Representative cross-section sketch

Bankfull width = 50 ft Bankfull depth = 5 ft		

Station: 9600



Station: 3500



Channel Reconnaissance Form

Date	2018
Stream/Drainage	Lower Vermillion River
Stream Reach ID	Reach 2
Field Team	NN, SM

Station 21000 **To** 16500

General Channel Conditions

Sediment Particle Size Estimate	
Banks	sandy silt loam
Bars	sand silt
Bed	sand and sparse gravel

Channel Shape (check)

X Rectangular
Shallow Rectangular
Irregular
Trapezoidal
Parabolic
Other _______________

Bar Types: X Alternate lateral | Point / transverse | None | Mid-channel | Point / mid | Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Vertically stable				
Lateral stability *deposition, erosion*	Appears laterally stable				
Erosion (excessive/site specific)	None				
Dominant bank erosion types (circle any that apply)	*Fluvial*	X Undercut / cantilever	Selective erosion of noncohesive laters	Dry flow	Seepage
	Gravitational	Rotational	Planar	Wedge	
Bank composition	*Notes (shape/character)*: Banks exposed				
Terrace/Valley	*Valley form* – Terraced Alluvial			*Land Use* – Narrow riparian corridor surrounded by farming	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Farming near to riparian buffer				
Bankfull/Channel forming flow indication	None				

Sediment Impacts

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

Bars / depositional features

Sediment type/size	sand and silt
Mid, alternate, braided	Alternate
Bar Vegetation (type, age)	Grasses
Floodplain soils	Sandy silt loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	Varies
Width of veg. riparian corridor	Narrow
Canopy coverage (%)	5%

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	Buckthorn, reed canary grass

Woody Species present	% of total tree community
Silver Maple	20

Tree Stand Age (if applicable)

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

Riparian Landuse

General Riparian Notes: Narrow to nonexistent riparian corridor. Channel is rectangular and appears straight and incised.

Channel Stability Form

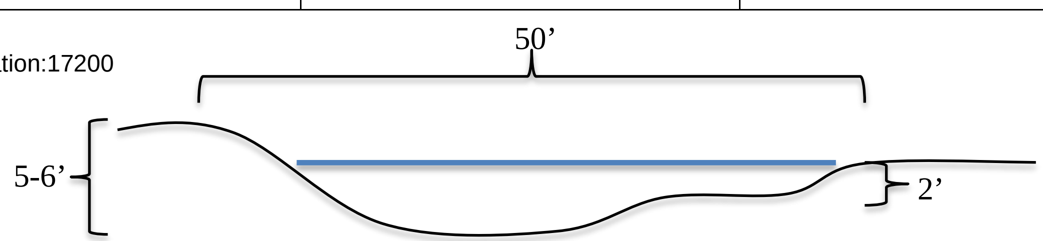
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr	X	>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	X
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	X	Low banks, overflows, surficial erosion	
Bar development	Poorly formed	X	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	X	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	X	High	
Channel pattern	Single thread	X	Single thread		Multiple thread/braided	
Average bank slope	<3:1		>3:1			
Vegetative bank protection	Poor		Extensive	X	Poor	
Field stability rating (add all cells)/9	**= 2.6**					

Representative cross-section sketch

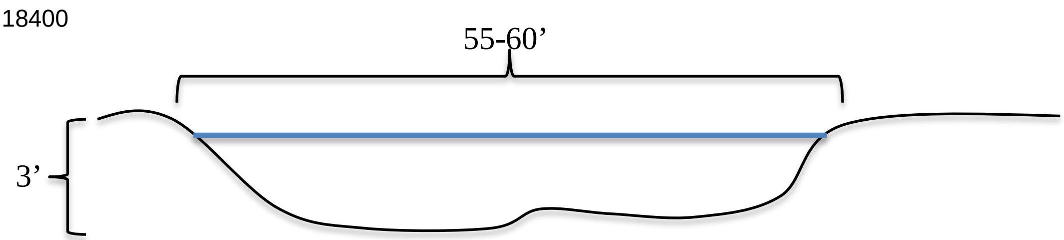
Bankfull width = 50 ft

Bankfull depth = 6 ft

Station:17200



Station: 18400



Channel Reconnaissance Form

Date	2018
Stream/Drainage	Lower Vermillion River
Stream Reach ID	Reach 3
Field Team	NN, SM

Station	35000	**To** 21000

General Channel Conditions

Sediment Particle Size Estimate	
Banks	sandy silt loam
Bars	sand silt
Bed	sand and gravel and cobbles

Channel Shape (check)

X Rectangular
Shallow Rectangular
Irregular
X Trapezoidal
Parabolic
Other ________________

Bar Types:	X Alternate lateral	Point / transverse	None
	X Mid-channel	Point / mid	X Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Vertically stable				
Lateral stability *deposition, erosion*	Appears laterally stable				
Erosion (excessive/site specific)	None				
Dominant bank erosion types (circle any that apply)	*Fluvial*	X Undercut / cantilever	Selective erosion of noncohesive laters	Dry flow	Seepage
	Gravitational	Rotational	Planar	Wedge	
Bank composition	*Notes (shape/character)*: Banks exposed, but held in place by roots				
Terrace/Valley	*Valley form* – Terraced Alluvial			*Land Use* – Narrow riparian corridor surrounded by farming	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Farming near to riparian buffer				
Bankfull/Channel forming flow indication	Debris in logjams, sand on floodplain				

Sediment Impacts

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

Bars / depositional features

Sediment type/size	sand and silt
Mid, alternate, braided	Alternate and mid-channel
Bar Vegetation (type, age)	Grasses
Floodplain soils	Sandy silt loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	Varies
Width of veg. riparian corridor	Varies
Canopy coverage (%)	50%

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	
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	Buckthorn, reed canary grass

Woody Species present	% of total tree community
silver maple	20%
Cottonwood	5%

Tree Stand Age (if applicable)

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

Riparian Landuse

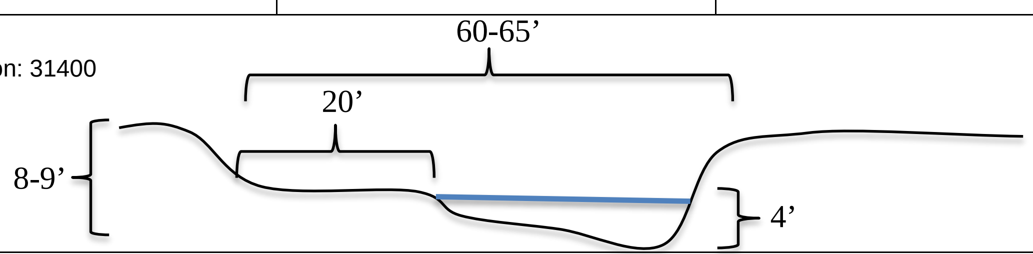
General Riparian Notes: Rural land use including restored prairie, floodplain forest, agricultural fields, and mowed lawns.

Channel Stability Form

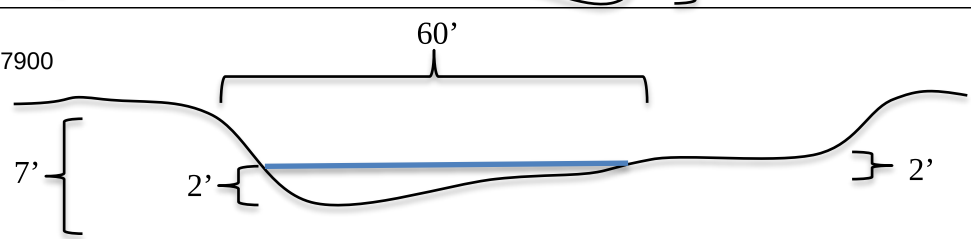
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	X	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	X
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial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

Representative cross-section sketch		
Bankfull width = 40 ft Bankfull depth = 6 ft		

Station: 31400



Station: 27900



Channel Reconnaissance Form

Date	2018
Stream/Drainage	Lower Vermillion River
Stream Reach ID	Reach 4
Field Team	NN, SM

Station 45500 **To** 35000

General Channel Conditions

Sediment Particle Size Estimate	
Banks	sandy silt loam
Bars	sand silt
Bed	sand and gravel

Channel Shape (check)

- Rectangular
- Shallow Rectangular
- Irregular
- X Trapezoidal
- Parabolic
- Other _______________

Bar Types:

Alternate lateral	Point / transverse	None
Mid-channel	Point / mid	X Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Vertically stable				
Lateral stability *deposition, erosion*	Laterally stable, evidence of avulsions				
Erosion (excessive/site specific)	localized near where farming to edge and scour pools near Logjams				
Dominant bank erosion types (circle any that apply)	*Fluvial*	X Undercut / cantilever	Selective erosion of noncohesive laters	Dry flow	Seepage
	Gravitational	Rotational	Planar	Wedge	
Bank composition	*Notes (shape/character)*: held in place by roots				
Terrace/Valley	*Valley form* – Terraced Alluvial			*Land Use* – Good Riparian vegetation	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Some development near to riparian buffer				
Bankfull/Channel forming flow indication	Debris in logjams				

Sediment Impacts

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

Bars / depositional features

Sediment type/size	sand and silt
Mid, alternate, braided	alternate
Bar Vegetation (type, age)	Grasses
Floodplain soils	Sandy silt loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	Varies
Width of veg. riparian corridor	Varies
Canopy coverage (%)	40%

Canopy structure : (check one)

none = anthro / maintained (lawn, field, pasture)	
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	

Woody Species present	% of total tree community
silver maple	20%
Shrub willow	40%

Exotic/invasive species: Buckthorn, reed canary grass

Tree Stand Age (if applicable)

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

Riparian Landuse

General Riparian Notes: Rural landuse including restored prairie, floodplain forest, agricultural fields, and mowed lawns.

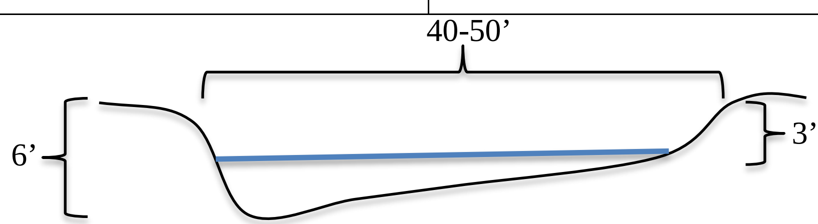
Channel Stability Form

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

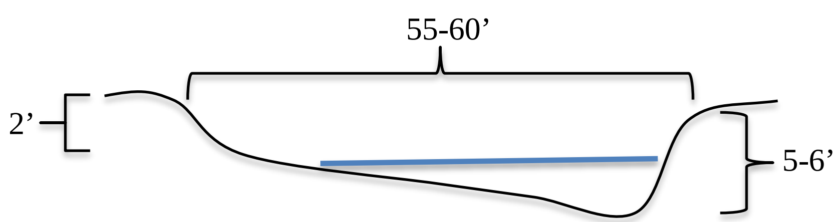
Representative cross-section sketch

Bankfull width = 46 ft Bankfull depth = 6 ft		

Station: 35500



Station: 40600



Channel Reconnaissance Form

Date	2018
Stream/Drainage	Lower Vermillion River
Stream Reach ID	Reach 5
Field Team	NN, SM

Station	51000	**To**	45500

General Channel Conditions

Sediment Particle Size Estimate	
Banks	sandy silt loam
Bars	sand silt
Bed	sand and gravel

Channel Shape (check)

Rectangular
Shallow Rectangular
Irregular
X Trapezoidal
Parabolic
Other ________________

Bar Types: Alternate lateral; Point / transverse; None; Mid-channel; Point / mid; X Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Vertically stable				
Lateral stability *deposition, erosion*	Laterally stable, evidence of avulsions				
Erosion (excessive/site specific)	localized near where farming to edge and scour pools near Logjams				
Dominant bank erosion types (circle any that apply)	*Fluvial*	X Undercut / cantilever	Selective erosion of noncohesive laters	Dry flow	Seepage
	Gravitational	Rotational	Planar	Wedge	
Bank composition	*Notes (shape/character)*: held in place by roots				
Terrace/Valley	*Valley form* – Terraced Alluvial			*Land Use* – Good Riparian vegetation	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Some development near to riparian buffer				
Bankfull/Channel forming flow indication	Debris in logjams				

Sediment Impacts

Riffle sediment type	Sand and gravel	Pool sediment type	Sand and silt
Sorting / Imbrication	NA		
Bars / depositional features			
Sediment type/size	sand and silt		
Mid, alternate, braided	alternate		
Bar Vegetation (type, age)	Grasses		
Floodplain soils	Sandy silt loam		
Overbank deposition	NA		

Riparian Vegetation and Floodplain

Root coverage of banks (%)	Varies
Width of veg. riparian corridor	Wide
Canopy coverage (%)	80%

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	
woody species	100%
bare/other	
Exotic/invasive species	buckthorn

Woody Species present	% of total tree community
silver maple	60%
Green ash	20%

Tree Stand Age (if applicable)

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

Riparian Landuse

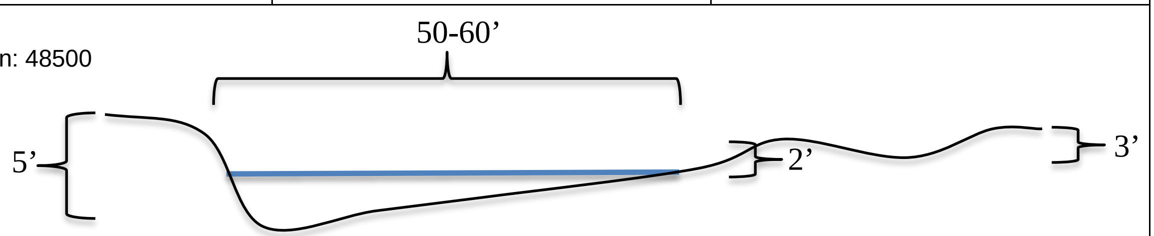
General Riparian Notes: Well developed riparian corridor with back channel and connected wetlands.

Channel Stability Form

Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	X	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	X
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	X	Low banks, overflows, surficial erosion	
Bar development	Poorly formed	X	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	X	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average	X	High	
Channel pattern	Single thread	X	Single thread		Multiple thread/braided	
Average bank slope	<3:1		>3:1	X		
Vegetative bank protection	Poor		Extensive	X	Poor	
Field stability rating (add all cells)/9		**= 2.44**				

Representative cross-section sketch		
Bankfull width = 51 ft Bankfull depth = 7 ft		

Station: 48500



Station:

Channel Reconnaissance Form

Date	2018
Stream/Drainage	Lower Vermillion River
Stream Reach ID	Reach 6
Field Team	NN, SM

Station	67500	**To**	51000

General Channel Conditions

Sediment Particle Size Estimate	
Banks	sandy silt loam
Bars	sand silt
Bed	sand and gravel

Channel Shape (check)

Rectangular
Shallow Rectangular
Irregular
X Trapezoidal
Parabolic
Other _______________

Bar Types:	Alternate lateral	Point / transverse	None
	Mid-channel	Point / mid	X Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Vertically stable				
Lateral stability *deposition, erosion*	Some minor erosion				
Erosion (excessive/site specific)	localized near where farming to edge and scour pools near Logjams				
Dominant bank erosion types (circle any that apply)	*Fluvial*	X Undercut / cantilever	Selective erosion of noncohesive laters	Dry flow	Seepage
	Gravitational	Rotational	Planar	Wedge	
Bank composition	*Notes (shape/character)*: Held in place by roots				
Terrace/Valley	*Valley form* – Terraced Alluvial			*Land Use* – generally shows good Riparian vegetation	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	old RR crossing, powerline crossing, tile drain directly to river				
Bankfull/Channel forming flow indication	Debris in logjams				

Sediment Impacts

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

Bars / depositional features

Sediment type/size	sand and silt
Mid, alternate, braided	alternate
Bar Vegetation (type, age)	Grasses
Floodplain soils	Sandy silt loam
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	Varies
Width of veg. riparian corridor	Varies
Canopy coverage (%)	50%

Canopy structure : (check one)

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

Primary veg forms present: (%)

grasses/forbs	40%
woody species	60%
bare/other	
Exotic/invasive species	buckthorn

Woody Species present	% of total tree community
silver maple	70%
black willow	5%

Tree Stand Age (if applicable)

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

Riparian Landuse

General Riparian Notes: Generally shows well developed riparian community except where farmed to edge

Channel Stability Form

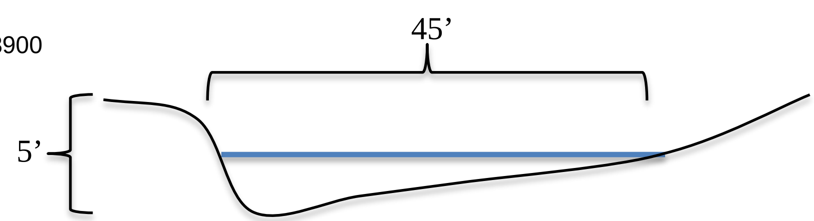
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	X	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	X
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial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

Representative cross-section sketch

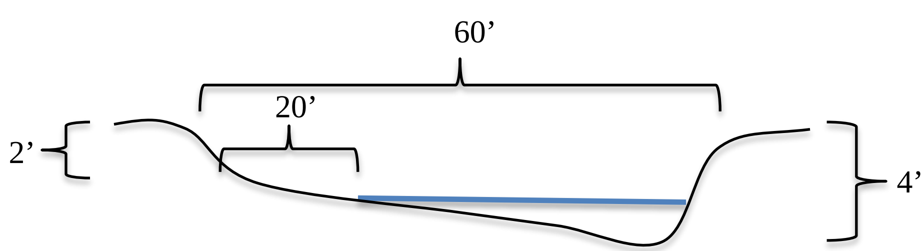
Bankfull width = 45 ft

Bankfull depth = 6 ft

Station: 53900

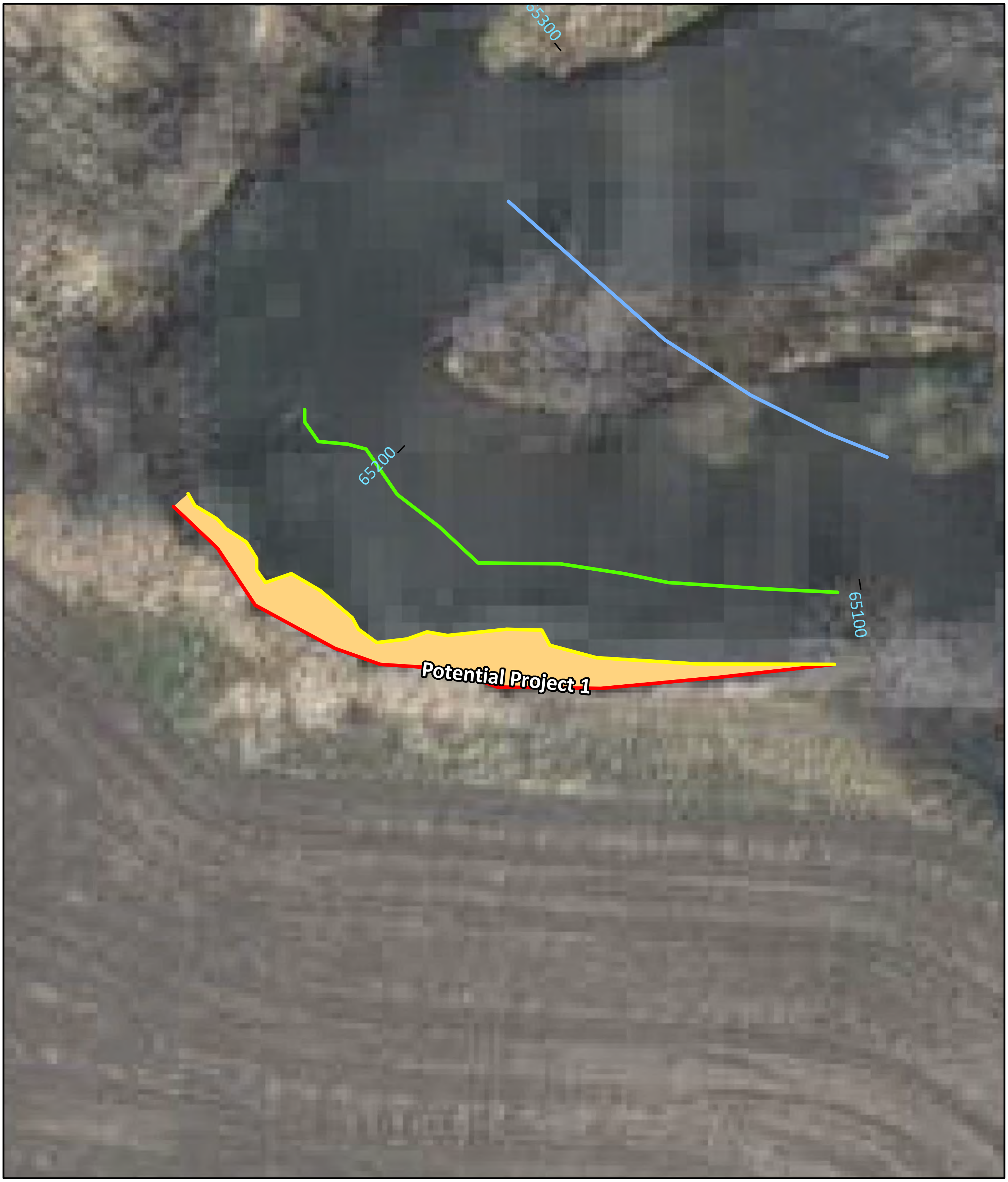


Station: 66000



9. Appendix C

Bank Erosion Analysis



Potential Project 1

Bank location

1937
1964
1991
2010
2016

2010-2016 Area

River Station (ft)

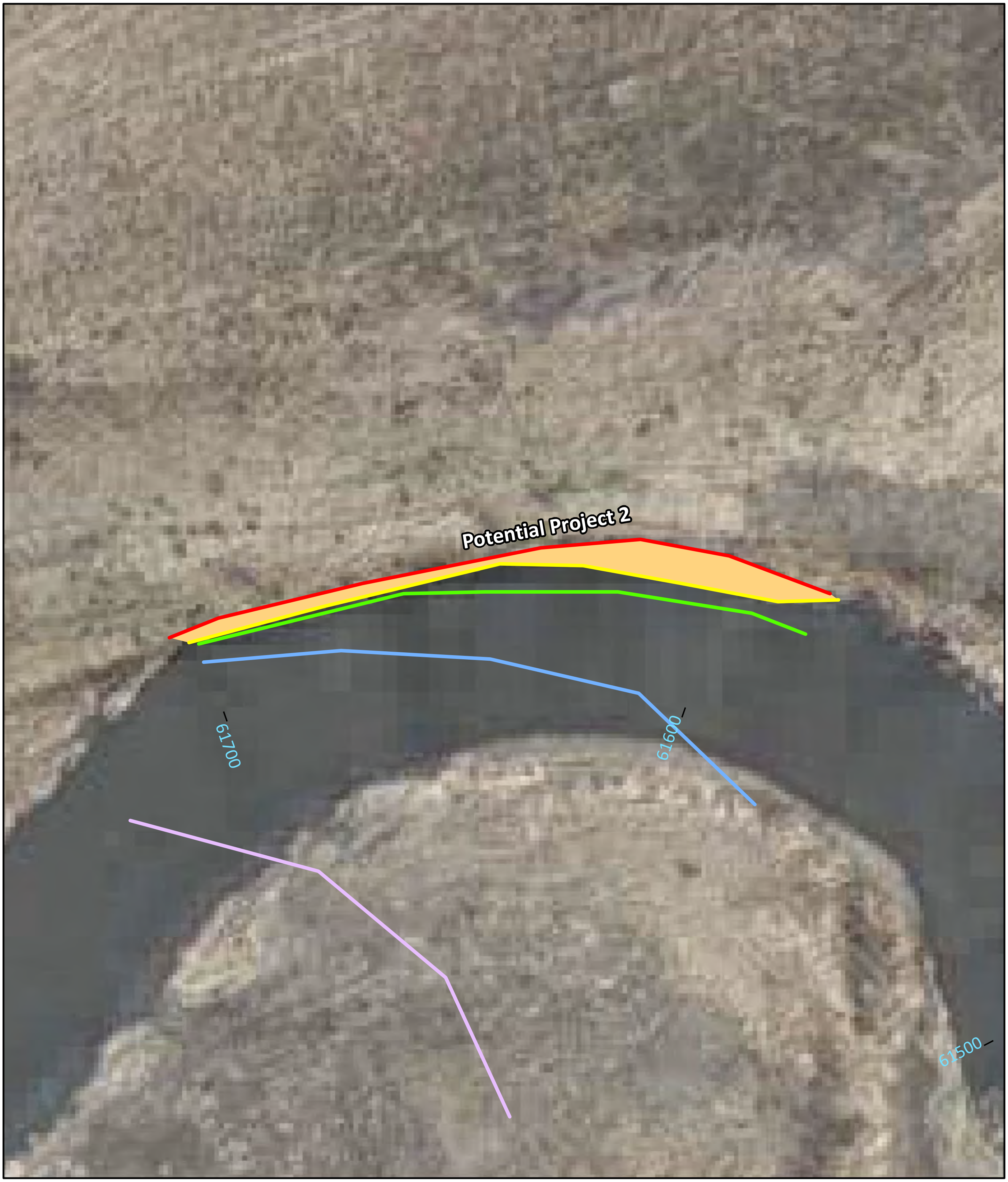
Notes:
1. Aerial Image from MnGeo WMS servic 2016 color 7-county
2. River Stationing based on National Hydrography Dataset 2017

N

Feet

0 100

inter·fluve



Potential Project 2

Bank location
1937
1991
1964
2010
2016

2010-2016 Area

River Station (ft)

Notes:
1. Aerial Image from MnGeo WMS servic 2016 color 7-county
2. River Stationing based on National Hydrography Dataset 2017

N

Feet
0
100

Potential Project 4

Notes:
1. Aerial Image from MnGeo WMS servic 2016 color 7-county
2. River Stationing based on National Hydrography Dataset 2017

Bank location: 1937, 1964, 1991, 2010, 2016

2010-2016 Area

River Station (ft)

inter·fluve

N

Feet

0 100

Potential Project 9

Bank location
1937 1991
1964 2010
2016

2010-2016 Area

River Station (ft)

inter·fluve

Notes:
1. Aerial Image from MnGeo WMS servic 2016 color 7-county
2. River Stationing based on National Hydrography Dataset 2017

N

Feet

0 100

Potential Project 14

Bank location
- 1937
- 1964
- 1991
- 2010
- 2016

2010-2016 Area

River Station (ft)

inter·fluve

Notes:
1. Aerial Image from MnGeo WMS servic 2016 color 7-county
2. River Stationing based on National Hydrography Dataset 2017

N

Feet
0 100

Potential Project 17

Bank location
1937
1964
1991
2010
2016

2010-2016 Area

River Station (ft)

inter·fluve

Notes:
1. Aerial Image from MnGeo WMS servic 2016 color 7-county
2. River Stationing based on National Hydrography Dataset 2017

N

Feet
0 100

Potential Project 29

Bank location
- 1937
- 1964
- 1991
- 2010
- 2016

2010-2016 Area

River Station (ft)

inter·fluve

Notes:
1. Aerial Image from MnGeo WMS servic 2016 color 7-county
2. River Stationing based on National Hydrography Dataset 2017

N

Feet
0 100

10. Appendix D

Potential Project Forms

Potential Project PP01

Stream: Lower Vermillion River	Problem description: 6 ft tall, 100 ft long eroding bank. ~30 ft between bank top and farm field
Station: 65100-65200, right bank Reach: 6	
Solution: expand and plant riparian buffer with native trees and shrubs. Use large wood to stabilize bank and provide aquatic habitat.	

	Score	***Notes***
Pollutant loading	5	Bank erosion and proximity to agriculture
In-stream ecological benefit	3	Small site
Project cost	3	Requires engineering design for large wood
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	3	Requires engineering design for large wood
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project PP02

Stream: Lower Vermillion River	Problem description: Bank erosion upstream of rootwad restoration
Station: 61500-61700, left bank Reach: 6	
Solution: extend large wood stabilization upstream. Plant native trees and shrubs along bank for added bank stabilization.	

	Score	***Notes***
Pollutant loading	5	Bank erosion and proximity to agriculture
In-stream ecological benefit	3	Small site
Project cost	3	Requires engineering design for large wood
Fish passage	1	NA
Riparian ecological benefit	1	Small site
Infrastructure risk	1	NA
Project complexity	3	Requires engineering design for large wood
Aesthetic impact	1	No impact
Property ownership	5	Past project suggests public ownership
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP03**

Stream: Lower Vermillion River	Problem description: Narrow riparian corridor between farm and channel. Past bank work used angular boulders that may not be serving the original intended purpose as well as plastic fabric that is still exposed. In addition, minor bank erosion was observed along 120 ft of bank with 4 ft bank heights.
Station: 59500-60000, right bank Reach: 6	

Solution: Widen riparian corridor. Remove plastic where exposed. Large wood could be used to stabilize the bank and replace the angular boulders, but the erosion is not extensive.

	Score	***Notes***
Pollutant loading	3	Reduce bank erosion
In-stream ecological benefit	3	Small site
Project cost	7	No bank work, just plantings
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	7	No bank work, just plantings
Aesthetic impact	3	Remove past project materials from river
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP04**

Stream: Lower Vermillion River	Problem description: 10in plastic drain pipe emptying into river at top of bank causing localized erosion. This may also be contributing to the eroding bank downstream that extends for about 200ft long with 6 ft high banks.
Station: 59100-59300, left bank Reach: 6	
Solution: Expand riparian zone. Create floodplain wetland which drain can empty into to limit sediment and nutrient loads to the river. If this is not possible, consider lowering the pipe outlet to be below the elevation of the low flow water surface to reduce the localized erosion. Stabilize the downstream bank with large wood. This is under utility lines, so vegetation planting would likely need to be limited to shrubs and smaller trees.	

	Score	***Notes***
Pollutant loading	7	Pipe drains agricultural field and bank erosion
In-stream ecological benefit	5	Increase canopy cover
Project cost	3	Requires engineering design
Fish passage	1	NA
Riparian ecological benefit	5	Widen riparian zone
Infrastructure risk	1	NA; power poles are not at edge of the river
Project complexity	3	Requires engineering design
Aesthetic impact	3	Improved aesthetic for paddlers
Property ownership	1	Private, though maybe an easement for the utility
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP05**

Stream: Lower Vermillion River	Problem description: Angular riprap and plastic fabric in bank, narrow riparian corridor
Station: 58100-58400, right bank Reach: 6	
Solution: Expand riparian corridor, remove plastic where exposed	

	Score	***Notes***
Pollutant loading	3	Small site; minimal existing loading
In-stream ecological benefit	3	Small site
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	3	Remove past project materials from river
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project PP06

Stream: Lower Vermillion River	Problem description: Narrow riparian zone and minor erosion on bank
Station: 56700-56800, right bank Reach: 6	
Solution: Expand and plant riparian corridor	

	Score	***Notes***
Pollutant loading	3	Small site
In-stream ecological benefit	3	Small site
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP07**

Stream: Lower Vermillion River	Problem description: Stream crossing made from railroad flat bed. Bottom of bridge is close to the water surface at low flow, so this likely restricts higher flows. Utilities run along the bridge.
Station: 56600, channel spanning Reach: 6	
Solution: Remove bridge if not needed and replace utilities.	

	Score	*Notes*
Pollutant loading	1	NA
In-stream ecological benefit	3	Small site
Project cost	3	Assumes utility relocate
Fish passage	1	NA
Riparian ecological benefit	1	NA
Infrastructure risk	5	Existing infrastructure need to be removed/replaced
Project complexity	5	Assumes utility relocate
Aesthetic impact	3	Improved aesthetic for paddlers
Property ownership	1	Private; though easement for utilities unknown
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP08**

Stream: Lower Vermillion River	Problem description: Concrete slabs along eroding bank
Station: 55500-55700, right bank Reach: 6	
Solution: Remove concrete slabs, stabilize with large wood	

	Score	***Notes***
Pollutant loading	3	Small site and minimal erosion
In-stream ecological benefit	3	Small site
Project cost	3	Assumes engineering design for large wood stabilization
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	3	Assumes engineering design for large wood stabilization
Aesthetic impact	3	Remove past project materials from river
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project PP9

Stream: Lower Vermillion River	Problem description: Minor eroding 6-ft bank along 200 ft of channel. No trees and shrubs to provide root stabilization, but far from active agriculture.
Station: 54700-54900, left bank Reach: 6	
Solution: Plant native trees and shrubs	

	Score	*Notes*
Pollutant loading	3	Minimal existing loading; far from agriculture fields
In-stream ecological benefit	1	Small site
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project PP10

Stream: Lower Vermillion River	Problem description: Minor bank erosion along 4-ft bank. Few trees in riparian corridor.
Station: 55200-55400, left bank Reach: 6	
Solution: Plant with native riparian trees and shrubs.	

	Score	***Notes***
Pollutant loading	3	Small site; minor current erosion
In-stream ecological benefit	1	Small site
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP11**

Stream: Lower Vermillion River	Problem description: Concrete slab riprap along 300 ft long, 2 ft high bank. Mowed to edge of bank. No riparian buffer
Station: 51400-51700, right bank Reach: 6	
Solution: Remove concrete slabs. Limit active mowing within about 30 feet of the channel. Plant native trees and shrubs and seed. If needed, stabilize the bank, but this does not appear necessary geomorphically.	

	Score	***Notes***
Pollutant loading	3	Runoff with no buffer; fertilizer or herbicide application unknown; little erosion
In-stream ecological benefit	1	Small site
Project cost	7	Planting
Fish passage	1	NA
Riparian ecological benefit	5	Build riparian habitat along currently mowed edge
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	3	Remove past project materials from river
Property ownership	1	Private
Public education	1	NA

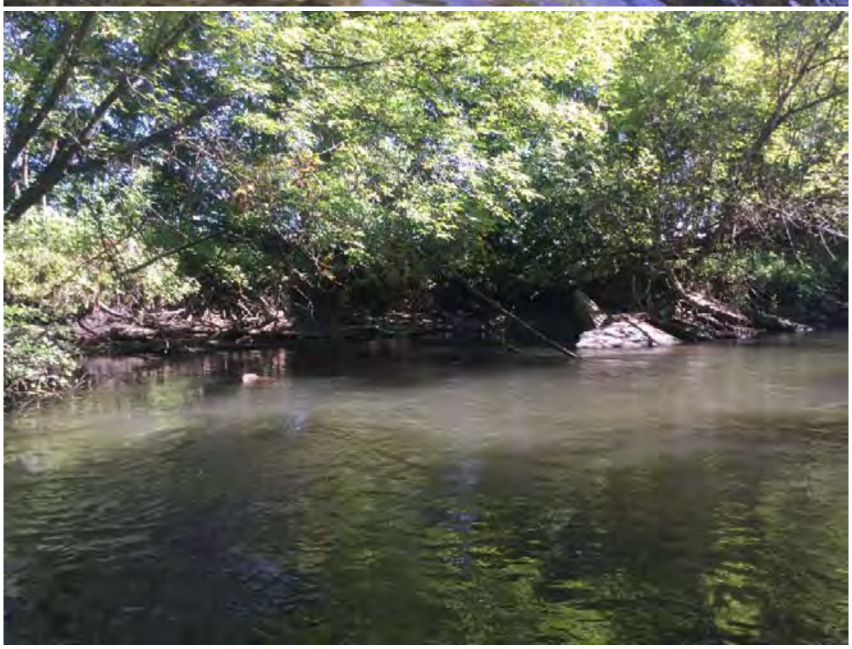
Project Area Photo/Map Location

Potential Project **PP12**

Stream: Lower Vermillion River	Problem description: 5 ft high 100 ft long bank with sporadically placed concrete riprap. Eroding between riprap. Narrow riparian zone at Station 48000
Station: 47900-48100, left bank Reach: 5	
Solution: Remove concrete. Expand riparian buffer zone at Station 48000. Only stabilize banks if landowner is concerned.	

	Score	***Notes***
Pollutant loading	3	Minor erosion
In-stream ecological benefit	3	Small site
Project cost	7	Plantings only, assumes no engineering design required
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	7	Plantings only, assumes no engineering design required
Aesthetic impact	3	Remove past project materials from river
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location



Potential Project PP13

Stream: Lower Vermillion River	Problem description: Mowed close to edge with little riparian buffer.
Station: 47100-47250, right bank Reach: 5	
Solution: Expand and plant riparian zone with native trees and shrubs.	

	Score	***Notes***
Pollutant loading	3	Assumes use of fertilizers on lawn
In-stream ecological benefit	1	Small site
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP14**

Stream: Lower Vermillion River	Problem description: 150' of eroding bank 7-8' tall Few trees and shrubs; agriculture is not close.
Station: 46300-46500, left bank Reach: 5	
Solution: Expand and plant riparian zone. Use Large wood to stabilize bank.	

	Score	*Notes*
Pollutant loading	5	Eroding bank and narrow riparian buffer
In-stream ecological benefit	3	Increase canopy cover
Project cost	3	Assumes large wood stabilization
Fish passage	1	NA
Riparian ecological benefit	5	Improve riparian buffer
Infrastructure risk	1	NA
Project complexity	3	Engineering design require for large wood stabilization
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	3	Close to neighborhoods

Project Area Photo/Map Location

Potential Project **PP15**

Stream: Lower Vermillion River	Problem description: Few trees on bank; little riparian habitat and cover; <10% canopy cover over the channel
Station: 44900-45100, right bank 44700-44900, left bank Reach: 5	
Solution: Plant riparian zone with native trees and shrubs. This is primarily needed on the right bank, but also select areas on the left bank.	

	Score	***Notes***
Pollutant loading	3	Minor erosion
In-stream ecological benefit	3	Increase canopy cover
Project cost	7	Planting
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	7	Planting
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	5	Close to neighborhoods and an easy project for public participation

Project Area Photo/Map Location

Potential Project **PP16**

Stream: Lower Vermillion River	Problem description: Little riparian tree cover; minor bank erosion; little in stream habitat
Station: 42700-43100, left bank 43200-43600, right bank Reach: 4	
Solution: Plant expanded riparian zone with native trees and shrubs. Could actively stabilize banks, but we recommend expanded the riparian zone with plantings first and monitoring.	

	Score	***Notes***
Pollutant loading	3	Minor erosion
In-stream ecological benefit	3	Bank work, but longer project area
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	3	Bank work, but longer project area
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project PP17

Stream: Lower Vermillion River	Problem description: Little riparian tree cover; little in stream habitat; concrete slabs in channel, minor erosion
Station: 39800-40400, left bank Reach: 4	
Solution: Remove concrete from channel. Expand and plant riparian zone with native trees and shrubs. Use large wood to increase habitat	

	Score	***Notes***
Pollutant loading	3	Minor erosion
In-stream ecological benefit	3	Increase canopy cover
Project cost	3	Assumes use of large wood
Fish passage	1	NA
Riparian ecological benefit	3	Slightly longer reach
Infrastructure risk	1	NA
Project complexity	3	Assumes use of large wood
Aesthetic impact	3	Remove past project materials
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP18**

Stream: Lower Vermillion River	Problem description: Narrow riparian buffer; minor erosion
Station: 38600-38700, right bank 38800-38900, left bank Reach: 4	
Solution: Plant trees along top of bank and along a wider riparian buffer. If desired, the bank could be stabilized with wood.	

	Score	***Notes***
Pollutant loading	5	Eroding bank and narrow buffer
In-stream ecological benefit	3	Both banks
Project cost	5	Plantings
Fish passage	1	NA
Riparian ecological benefit	3	Both banks
Infrastructure risk	1	NA
Project complexity	5	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP19**

Stream: Lower Vermillion River	Problem description: Riprap from historic bridge constricts river causing erosion or river right and deposition on river left. This may exacerbate flooding and unstable conditions near the downstream bridge.
Station: 37500, channel spanning Reach: 4	
Solution: Model flood flows to determine if removal of remnant bridge pieces will reduce flooding potential or instability around the downstream bridge.	

	Score	***Notes***
Pollutant loading	1	Minimal pollutants under existing conditions
In-stream ecological benefit	1	Small site; no habitat work
Project cost	5	Could vary widely depending on model results and solution.
Fish passage	1	NA
Riparian ecological benefit	1	NA
Infrastructure risk	3	Minor – bridge is downstream
Project complexity	3	Could vary widely depending on model results and solution.
Aesthetic impact	1	No impact
Property ownership	1	Private, though not sure the exact boundary location between here and the bridge
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP20**

Stream: Lower Vermillion River	Problem description: Mowed to edge
Station: 36400-36600, left bank Reach: 4	
Solution: Expand and plant riparian buffer	

	Score	***Notes***
Pollutant loading	3	Assumes use of fertilizer on lawn
In-stream ecological benefit	3	Small site but plantings will provide some cover
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	3	Small site but plantings will improve adjacent ecology
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP21**

Stream: Lower Vermillion River	Problem description: No trees along riparian vegetation; minor erosion
Station: 32800-33000, left bank Reach: 3	
Solution: Expand and plant riparian buffer	

	Score	***Notes***
Pollutant loading	3	Minor erosion
In-stream ecological benefit	3	Small site; vegetations will provide cover
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	3	Small site, but plantings
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP22**

Stream: Lower Vermillion River	Problem description: Narrow riparian buffer to agricultural field
Station: 31200-31300, left bank 30200-30600, left bank 29300-29500, left bank 28400-28600, left bank Reach: 3	
Solution: Expand and plant riparian zone and plant trees along bank	

	Score	***Notes***
Pollutant loading	5	Narrow riparian buffer near agricultural field, minor erosion
In-stream ecological benefit	3	Primarily floodplain project
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	5	Could potentially cover large area
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location.

Potential Project PP23

Stream: Lower Vermillion River	Problem description: Few riparian trees No large wood/habitat in channel Narrow riparian corridor 25100-26600
Station: 25100-27700, both banks Reach: 3	
Solution: Plant trees and shrubs in an expanded riparian corridor. Install large wood in channel and banks to increase aquatic habitat.	

	Score	***Notes***
Pollutant loading	7	Narrow riparian buffer near agricultural field
In-stream ecological benefit	5	Increase canopy cover over large area
Project cost	5	Assumes plantings only
Fish passage	1	NA
Riparian ecological benefit	5	Improve riparian are over large area
Infrastructure risk	1	NA
Project complexity	7	Assumes plantings only
Aesthetic impact	3	Improved aesthetic for paddlers
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP24**

Stream: Lower Vermillion River	Problem description: Few riparian trees No large wood habitat in channel Bridge is undersized bottomless arch with no riparian passage Plastic and concrete in channel from historic bank stabilization project
Station: 23000-24400, both banks 22600-22700, right bank Reach: 3	
Solution: Plant riparian zone with trees. Install large wood to provide in-stream habitat. Replace bridge with one that can pass revised flood flows and provide terrestrial passage.	

	Score	***Notes***
Pollutant loading	3	Minor erosion
In-stream ecological benefit	3	
Project cost	1	Without the bridge work, this would receive a score of 5.
Fish passage	3	NA
Riparian ecological benefit	3	
Infrastructure risk	3	Undersized crossing – it is not in imminent danger, but it appears to be undersized so that large floods put added pressure on the bridge infrastructure.
Project complexity	3	Bridge designs and large wood designs needed
Aesthetic impact	3	Remove past project materials
Property ownership	1	Private
Public education	5	Easily accessible

Project Area Photo/Map Location

Potential Project **PP25**

Stream: Lower Vermillion River	Problem description: Narrow riparian corridor to agriculture and grazing Little riparian tree cover and in-stream habitat Grazed meander scars Mowed to edge
Station: 16800-20900 both banks 22000-2400, left bank Reach: 2	
Solution: Expand and plant riparian buffer with native trees and shrubs. Eliminate grazing in meander scars and restore these as wetlands, some of which may be stream-connected wetlands.	

	Score	***Notes***
Pollutant loading	5	Little erosion, but a long reach with narrow riparian buffer
In-stream ecological benefit	7	Increased canopy cover over large area
Project cost	3	Large area = large costs
Fish passage	1	NA
Riparian ecological benefit	7	Plantings
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	5	Improved aesthetic for paddlers
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project **PP26**

Stream: Lower Vermillion River	Problem description: Mowed to edge on river right from 12900-13500; river left from 12200-13100. No riparian buffer between lawn and river
Station: 12200-13500, both banks Reach: 1	
Solution: Expand and plant riparian zone with native trees and shrubs and seed. Fertilizer and herbicide application to lawns unknown. Little bank erosion, so it is mostly in need of riparian vegetation.	

	Score	***Notes***
Pollutant loading	5	Assumes fertilizer use on lawns
In-stream ecological benefit	3	Lengthy area for overhanging veg to provide some benefit
Project cost	7	Mostly planting
Fish passage	1	NA
Riparian ecological benefit	7	Plantings
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	5	Great opportunity to educate residents and have contributions during planting.

Project Area Photo/Map Location

Potential Project PP27

Stream: Lower Vermillion River	Problem description: Narrow riparian buffer between river and farm fields
Station: 11200-11650, right bank Reach : 1	
Solution: Expand and plant riparian zone	

	Score	***Notes***
Pollutant loading	3	Minor
In-stream ecological benefit	3	Small site
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	3	Easy access

Project Area Photo/Map Location

Potential Project **PP28**

Stream: Lower Vermillion River	Problem description: Mowed to edge
Station: 10600-11200, river left Reach: 1	
Solution: Expand and plant riparian buffer	

	Score	***Notes***
Pollutant loading	3	Assumes fertilizer use on lawns
In-stream ecological benefit	3	Increase canopy cover
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	5	Increase riparian area
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	5	Can educate multiple abutters, who can also be involved in planting

Project Area Photo/Map Location

Potential Project PP29

Stream: Lower Vermillion River	Problem description: Mowed to edge
Station: 8200-9100, left bank 9600-9700, left bank Reach: 1	
Solution: Expand and plant riparian zone	

	Score	***Notes***
Pollutant loading	5	Little erosion, but a long reach of runoff; use of fertilizers and herbicides is unknown
In-stream ecological benefit	3	Increase canopy cover
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	5	Increase riparian area
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	5	Can educate multiple landowners and have them involved in planting

Project Area Photo/Map Location

Potential Project **PP30**

Stream: Lower Vermillion River	Problem description: Slightly eroding bank leading into the stabilized levee on river left.
Station: 7100-7400, left bank Reach: 1	
Solution: Stabilize with large wood	

	Score	***Notes***
Pollutant loading	3	Minor erosion
In-stream ecological benefit	3	Increase large wood habitat
Project cost	5	For large wood stabilization
Fish passage	1	NA
Riparian ecological benefit	1	Bank erosion
Infrastructure risk	1	NA
Project complexity	5	For large wood stabilization
Aesthetic impact	1	Little impact
Property ownership	1	Private
Public education	1	NA

Project Area Photo/Map Location

Potential Project PP31

Stream: Lower Vermillion River	Problem description: Mowed to edge between the flood control levees on the right side and the channel.
Station: 5700-6300 Reach: 1	
Solution: Expand and plant riparian buffer while still allowing for flood control.	

	Score	***Notes***
Pollutant loading	1	No existing load
In-stream ecological benefit	3	Increase canopy cover
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	5	Improve riparian zone
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	3	Minor improvements for owner
Property ownership	1	Private
Public education	5	Close to densely populated neighborhoods; could engage residents to help plant

Project Area Photo/Map Location

Potential Project **PP32**

Stream: Lower Vermillion River	Problem description: Minor bank erosion and few riparian trees.
Station: 5000-5300, right bank Reach: 1	
Solution: Stabilize with large wood and plant native trees and shrubs	

	Score	***Notes***
Pollutant loading	3	Minor erosion
In-stream ecological benefit	3	Small site
Project cost	5	Large wood stabilization
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	1	NA
Project complexity	5	Large wood stabilization
Aesthetic impact	1	No impact
Property ownership	1	Private
Public education	5	Near large residential population; easy access

Project Area Photo/Map Location

Potential Project **PP33**

Stream: Lower Vermillion River	Problem description: 8' tall Eroding bank near road
Station: 4400-4500, left bank Reach: 1	
Solution: Model and analyze the hydraulics at this location for proper design. As the channel is migrating towards the road, this is a critical bank stabilization project. The designs could include large wood for bank stabilization, but there may not be sufficient room for this method, so rock may need to be used instead.	

	Score	***Notes***
Pollutant loading	3	Eroding bank
In-stream ecological benefit	3	Small site
Project cost	5	Small site but critical spot with the road nearby
Fish passage	1	NA
Riparian ecological benefit	3	Small site
Infrastructure risk	5	Road at the outside of the meander bend
Project complexity	3	Road nearby – tight construction
Aesthetic impact	3	Minor improvements
Property ownership	1	Town owned?
Public education	3	Easy access

Project Area Photo/Map Location

Potential Project PP34

Stream: Lower Vermillion River	Problem description: Mowed to edge
Station: 3500-3800, right bank Reach: 1	
Solution: Expand and plant riparian buffer	

	Score	*Notes*
Pollutant loading	3	No buffer to prevent runoff
In-stream ecological benefit	1	Small site
Project cost	7	Plantings
Fish passage	1	NA
Riparian ecological benefit	1	Small site
Infrastructure risk	1	NA
Project complexity	7	Plantings
Aesthetic impact	1	No impact
Property ownership	1	Unsure of ownership
Public education	1	Assumes private property

Project Area Photo/Map Location

11. Appendix E

Potential Project Summary

Reach Number	6											5			4						3				2	1								
Potential Project Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Pollutant loading	5	5	3	7	3	3	1	3	3	3	3	3	3	5	3	3	3	5	1	3	3	5	7	3	5	5	3	3	5	3	1	3	3	3
In-stream Ecological Benefit	3	3	3	5	3	3	3	3	1	1	1	3	1	3	3	3	3	3	1	3	3	3	5	3	7	3	3	3	3	3	3	3	3	1
Project Cost	3	3	7	3	7	7	3	3	7	7	7	7	7	3	7	7	3	5	5	7	7	7	5	1	3	7	7	7	7	5	7	5	5	7
Fish Passage	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	1	1
Riparian Ecological Benefit	3	1	3	5	3	3	1	3	3	3	5	3	3	5	3	3	3	3	1	3	3	5	5	3	7	7	3	5	5	1	5	3	3	1
Infrastructure Risk	1	1	1	1	1	1	5	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1	1	3	1	1	1	1	1	1	1	1	5	1
Project Complexity	3	3	7	3	7	7	5	3	7	7	7	7	7	3	7	7	3	5	3	7	7	7	7	3	7	7	7	7	7	5	7	5	3	7
Aesthetic Impact	1	1	3	3	3	1	3	3	1	1	3	3	1	1	1	1	3	1	1	1	1	1	3	3	5	1	1	1	1	1	3	1	3	1
Property Ownership	1	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Public Education	1	1	1	1	1	1	1	1	1	1	1	1	1	3	5	1	1	1	1	1	1	1	1	5	1	5	3	5	5	1	5	5	3	1
Total Potential Project Metric Score	22	24	30	30	30	28	24	22	26	26	30	30	26	26	32	28	22	26	18	28	28	32	36	28	38	38	30	34	36	22	34	28	30	24

Primary Project Type
Bank Stabilization
Infrastructure Improvement
Riparian Management

inter·fluve

Metrics for scoring potential projects

Metric Score:	*1*	*3*	*5*	*7*
Pollutant loading	No reduction in sediment/nutrient loading	Reduction in rate of bank erosion	Reduction in rate of bank erosion, establish buffer to reduce runoff	Reduction in bank erosion, establish buffer to reduce runoff, bank erosion poses infrastructure risk
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
Project cost	> $300K	$201 - $300K	$51 - 200K	$0 - $50K
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)
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
Infrastructure risk	No risk to infrastructure with no action, no infrastructure present, or no risk to public safety	Low to moderate infrastructure risk and minimal risk to public safety with no action, or inf. value <$50,000	Infrastructure at moderate but not immediate risk, moderate public safety risk, no potential injury, or infrastructure value <$500,000	Infrastructure at high, immanent risk of failure with no action, or potential loss of life. Public safety at risk or infrastructure value >$500,000
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
Aesthetic impact	No impact	Low impact	Moderate positive impact	High positive impact
Property Ownership	1: private property	3: NA	5: public property	7: NA
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

12. Appendix F

Reach and Potential Project Location Maps

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Reach 1

0 1,000 Feet

N

Restoration Type
- Bank Stabilization
- Infrastructure Improvement
- Riparian Management

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve

Reach 1

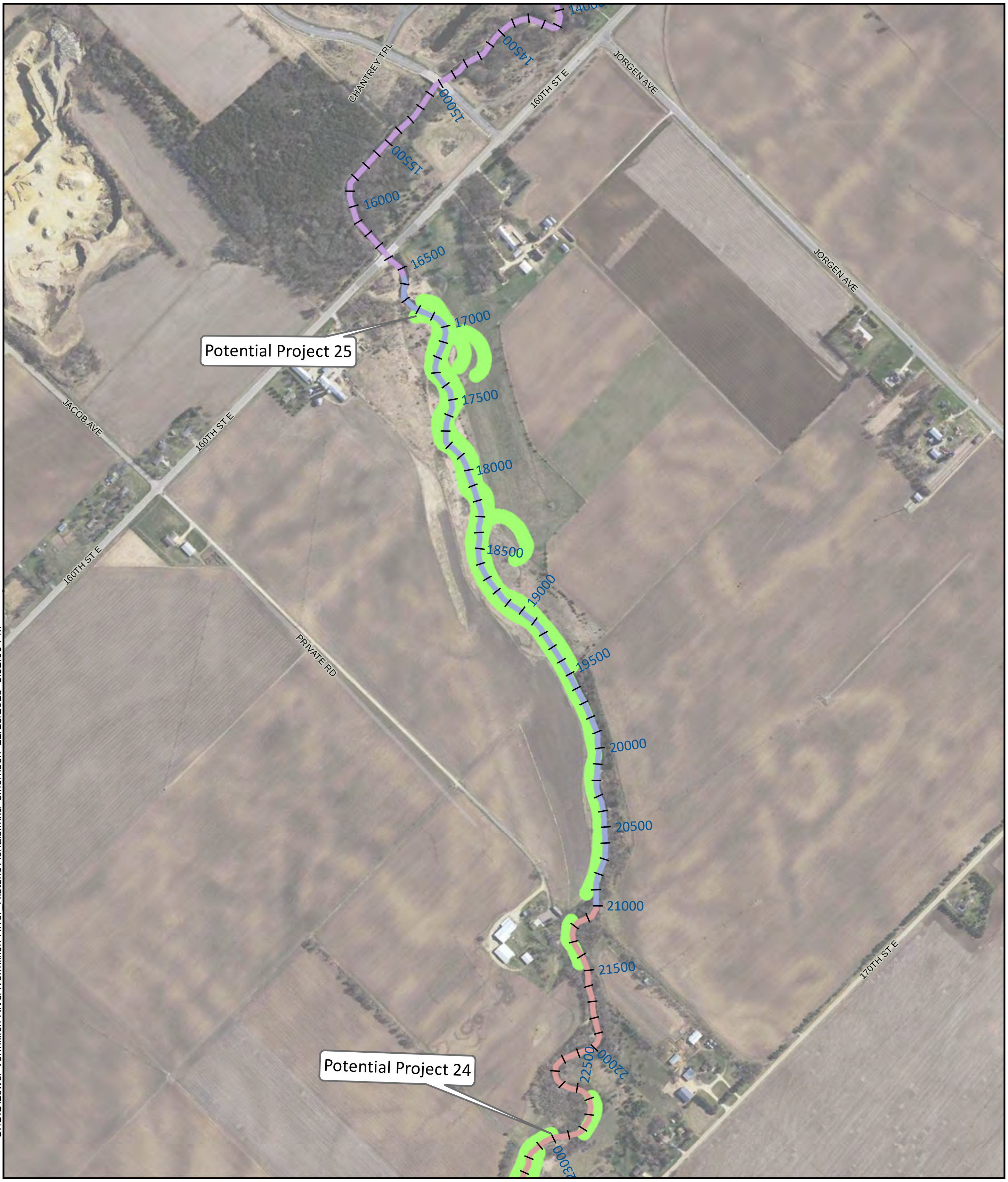
0 1,000
Feet

N

Restoration Type
Bank Stabilization
Infrastructure Improvement
Riparian Management

Reach Number
1
2
3
4
5
6

inter·fluve



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Reach 2

0 1,000 Feet

N

Restoration Type
Bank Stabilization
Infrastructure Improvement
Riparian Management

Reach Number
1
2
3
4
5
6

inter·fluve

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Reach 3

0 1,000 Feet

N

Restoration Type
Bank Stabilization
Infrastructure Improvement
Riparian Management

Reach Number
1
2
3
4
5
6

inter·fluve

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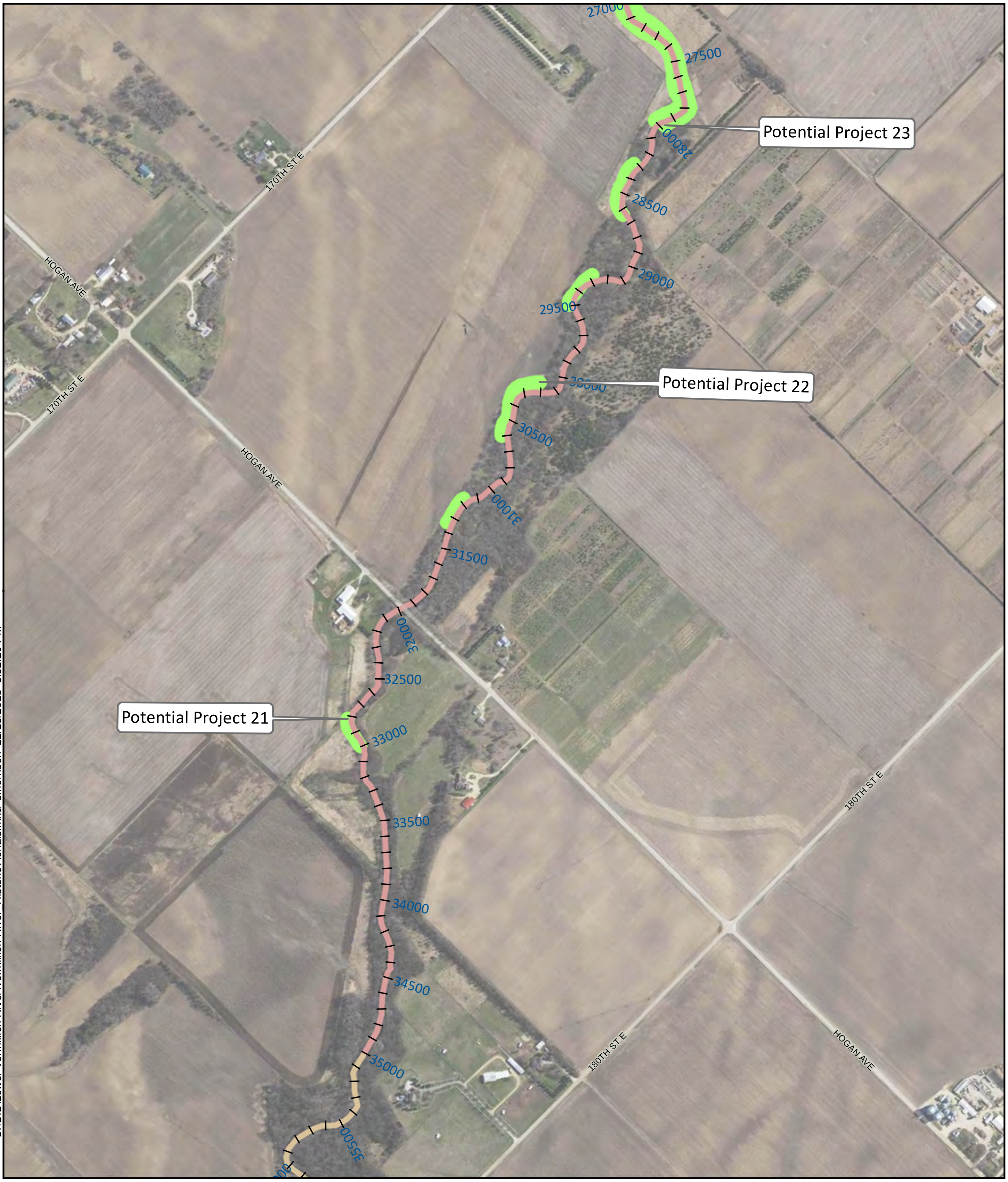


Reach 3

0 1,000 Feet

N

Restoration Type
Bank Stabilization
Infrastructure Improvement
Riparian Management

Reach Number
1
2
3
4
5
6

inter·fluve

Reach 4

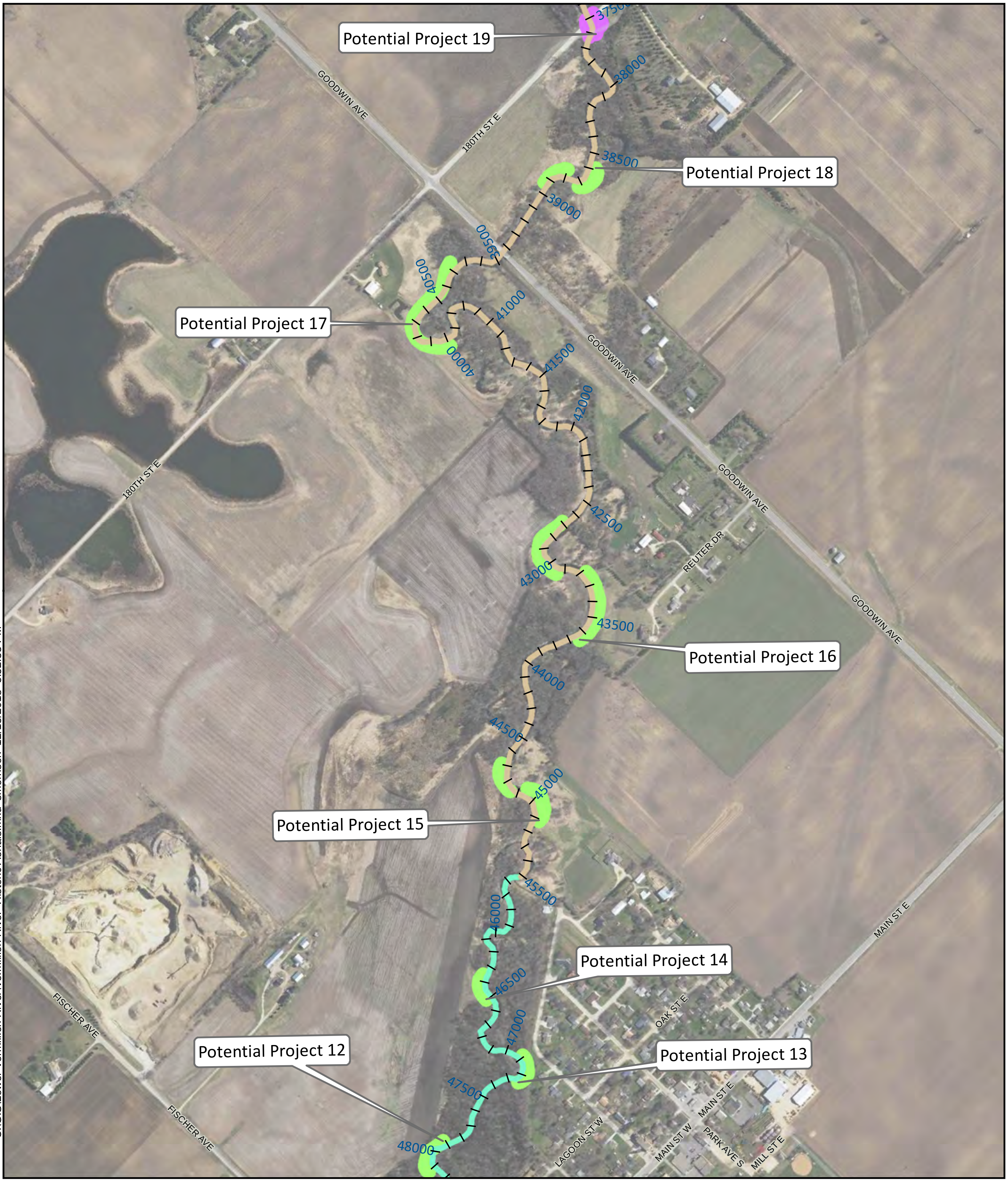
0 1,000 Feet

N

Restoration Type
Bank Stabilization
Infrastructure Improvement
Riparian Management

Reach Number
1
2
3
4
5
6

inter·fluve



Reach 4

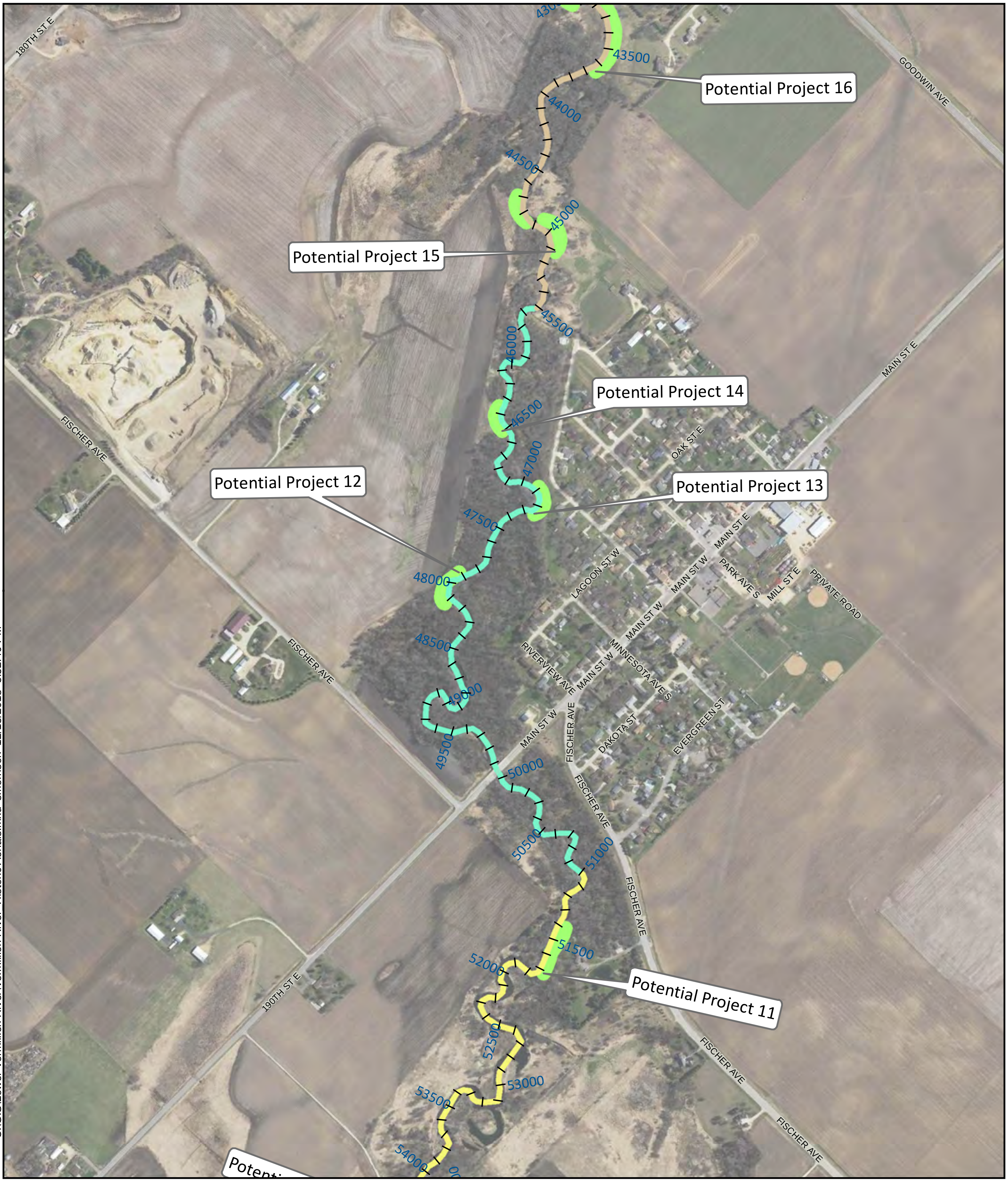
0 1,000 Feet

N

Restoration Type
- Bank Stabilization
- Infrastructure Improvement
- Riparian Management

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



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Reach 5

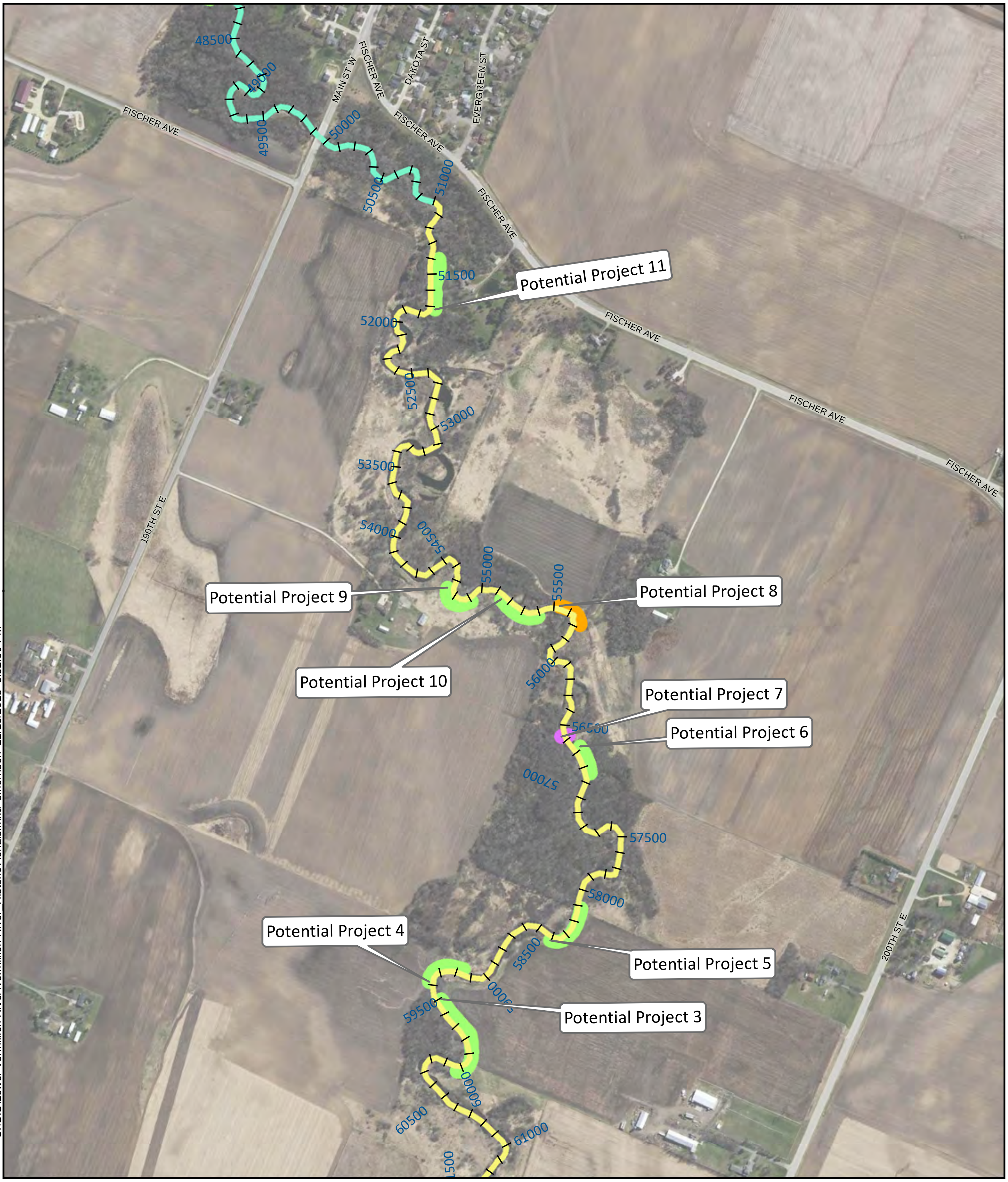
0 1,000 Feet

N

Restoration Type
Bank Stabilization
Infrastructure Improvement
Riparian Management

Reach Number
1
2
3
4
5
6

inter·fluve



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Reach 6

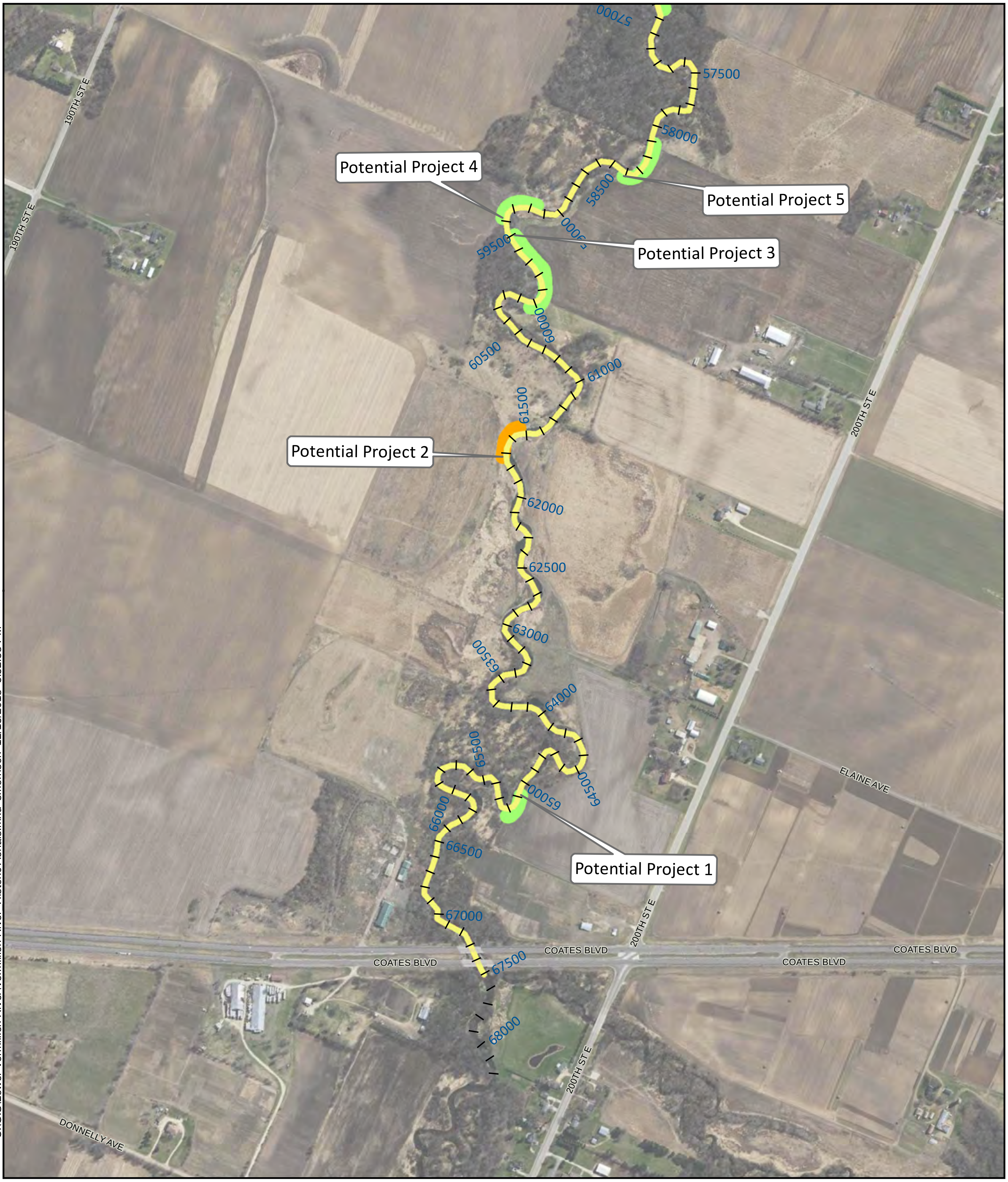
0 1,000 Feet

N

Restoration Type
- Bank Stabilization
- Infrastructure Improvement
- Riparian Management

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve



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Reach 6

0 1,000 Feet

N

Restoration Type
- Bank Stabilization
- Infrastructure Improvement
- Riparian Management

Reach Number
- 1
- 2
- 3
- 4
- 5
- 6

inter·fluve