July 2013 version

ENVIRONMENTAL ASSESSMENT WORKSHEET

This Environmental Assessment Worksheet (EAW) form and EAW Guidelines are available at the Environmental Quality Board's website at: http://www.eqb.state.mn.us/EnvRevGuidanceDocuments.htm. The EAW form provides information about a project that may have the potential for significant environmental effects. The EAW Guidelines provide additional detail and resources for completing the EAW form.

Cumulative potential effects can either be addressed under each applicable EAW Item, or can be addresses collectively under EAW Item 19.

Note to reviewers: Comments must be submitted to the RGU during the 30-day comment period following notice of the EAW in the *EQB Monitor*. Comments should address the accuracy and completeness of information, potential impacts that warrant further investigation and the need for an EIS.

1. **Project title:** Central Draw Storage Facility (CDSF) Overflow Project: Phase II – Phase V

2. **Proposer:** South Washington Watershed District
   Contact person: Matt Moore
   Title: Administrator
   Address: 2302 Tower Drive
   City, State, ZIP: Woodbury, MN 55125
   Phone: (651) 714-3729
   Fax: (651) 714-3721
   Email: mmoore@ci.woodbury.mn.us

3. **RGU:** South Washington Watershed District
   Contact person: Matt Moore
   Title: Administrator
   Address: 2302 Tower Drive
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   Phone: (651) 714-3729
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4. **Reason for EAW Preparation:** (check one)

   Required:
   ☐ EIS Scoping
   ☐ Mandatory EAW

   Discretionary:
   ☐ Citizen petition
   ☐ RGU discretion
   ☒ Proposer initiated

   If EAW or EIS is mandatory give EQB rule category subpart number(s) and name(s):
   N/A

5. **Project Location:**
   County: Washington
   City/Township: Cottage Grove
   PLS Location (¼, ¼, Section, Township, Range): Traversing sections 11, 14, 22, 23, 26, 27, 34, 35 of Township 27 North, Range 21 West.
   Watershed (81 major watershed scale): #20 Mississippi River/ Twin Cities
   GPS Coordinates: N/A
   Tax Parcel Number: N/A

At a minimum attach each of the following to the EAW:

- **County map showing the general location of the project;**
- **U.S. Geological Survey 7.5 minute, 1:24,000 scale map indicating project boundaries (photocopy acceptable); and**
- **Site plans showing all significant project and natural features. Pre-construction site plan and post-construction site plan.**

The following are included within this EAW:

6. **Project Description:**

a. **Provide the brief project summary to be published in the *EQB Monitor*, (approximately 50 words).**

The Central Draw Storage Facility (CDSF) Overflow Project Phase II-V will provide a controlled emergency overflow outlet for runoff from 100-year flood precipitation events, from upstream developed lands in South Washington Watershed District's Northern Watershed to the Mississippi River, and stabilizes existing and anticipated erosion and flood damage in the East Ravine.

b. **Give a complete description of the proposed project and related new construction, including infrastructure needs. If the project is an expansion include a description of the existing facility. Emphasize: 1) construction, operation methods and features that will cause physical manipulation of the environment or will produce wastes, 2) modifications to existing equipment or industrial processes, 3) significant demolition, removal or remodeling of existing structures, and 4) timing and duration of construction activities.**

Explain the project purpose; if the project will be carried out by a governmental unit, explain the need for the project and identify its beneficiaries.

Are future stages of this development including development on any other property planned or likely to happen? ☐ Yes ☒ No
If yes, briefly describe future stages, relationship to present project, timeline and plans for environmental review.

Is this project a subsequent stage of an earlier project? ☒Yes ☐ No
If yes, briefly describe the past development, timeline and any past environmental review.

The South Washington Watershed District (SWWD) conducted a discretionary Environmental Assessment Worksheet (EAW) for the Central Draw Storage Facility Overflow (Phase 1). The EAW concluded on February 12, 2013 with the determination that an EIS was not required. However, the District committed to conducting environmental review on the remaining phases of the project as part of that decision and this EAW is fulfillment of that commitment by the proposer.

The Central Draw Storage Facility Phase II-V provides a controlled emergency overflow outlet for runoff to the Mississippi River, resulting from infrequent (1% chance or less frequent) yet reasonably foreseeable precipitation events. The need is to minimize and reduce the likelihood of flood damages and erosion risks for the infrequent precipitation event not only for the current condition (i.e., amount of development) but also the amount of future development as described by the Alternative Urban Area wide Review (AUAR) for the City of Cottage Grove and the City of Woodbury.

Hydrologic and hydraulic modeling completed by the SWWD has demonstrated that under current landscape conditions and infrequent precipitation events, particularly a series of low-probability precipitation events, several days of pumping from the Bailey Lake lift station to the Central Draw Storage Facility (CDSF) would result in water overflowing into the East and Central ravine areas within the City of Cottage Grove with the potential to cause flooding.

Further, the existing outlet facilities for Ravine Lake are inadequate to convey flood flows without overtopping at the park entrance facilities for even frequent flooding events under the current conditions without the project. The Project will redesign and construct a new outlet structure and park entrance road to match the approved park plan and the existing runout and bounce characteristics to preserve the functions and values of the lake and accommodate the infrequent increased flows.

Considerable technical analyses (**Appendix A** and **B**) have been completed to understand the erosion potential through the project area. The results from these analyses show that even without the CDSF Overflow Project, the erosion potential through the park is great with nearly 65% of the reach characterized as high or excessive risk for erosion. The Project will provide corrective actions within the East Ravine and appropriately site various erosion control practices that will protect the habitat, water quality and publicly owned recreation resources. These steps are needed to assure that the East Ravine is protected and preserved.

The project is needed in order for the SWWD to execute its approved Watershed Management Plan (WMP). The SWWD operates within an established watershed management plan (WMP) most recently amended in May 2011. The WMP identified the CDSF Overflow Project in the Implementation Work Plan.

Attachment 1 and **2** provide general location maps with **Attachment 1** including an identifier to the project phases. Phase II is ravine stabilization within a portion of the project area south of US Highway 61 to the confluence with the Mississippi River; this area is referred to within this EAW as the Lower East Ravine Creek. Phase III is a proposed reconstruction of the Ravine Lake Outlet structure. Phase IV is ravine stabilization for the project area north of US Highway 61 to the outlet of the overflow conveyance pipe; this area is referred to within this EAW as the Upper East Ravine. Phase V is the completion of the outlet conveyance from the Central Draw Storage Facility.

Ravine stabilization activities associated with Phase II and IV will be selected and applied in accordance with the analysis and minimum shear stress thresholds identified in the Cottage Grove Ravine Regional Park Erosion Analysis Engineers Report, Dated March, 2014 (**Appendix A**) and the Lower East Ravine Stabilization Memo, dated March, 2014 (**Appendix B**). In some cases the existing vegetation is adequate to withstand shear stress and the velocity. In these areas, no stabilization is necessary and no action would be proposed. These areas are typically where water is pooled behind a natural rise in the channel grade or in areas that have been previously cleared, particularly the powerline corridor. Based on the erosion potential rating of each section, stabilization measures will be selected, designed and implemented. Potential stabilization measures include vegetation management, constructed lined channel, lined existing channel, and check dams. In areas with the highest potential for erosion, potential stabilization techniques include stabilizing outside bends with rock vanes, woody debris, rootwads, and vegetated riprap. A riffle-pool design will be utilized; the riffles will be constructed from rock using multiple techniques.

Phase III is a reconfiguration of the outlet to Ravine Lake. The reconfiguration will include upgrading the structure to manage the existing high frequency of overtopping of the road, and assuring that the new outlet structure can pass design flows without exacerbating the existing flooding. The project does not propose to alter the existing runout elevation. The design will alleviate the existing flood prone nature of the outlet and provide improved access conditions for design flood events.

Phase V of the CDSF Overflow project consists of a 72" reinforced concrete pipe (RCP) running from an existing depression, called CP 4-3, to the north side of Cottage Grove Ravine Regional

Park. The pipe alignment follows the lowest profile in the landscape and will be approximately 5,690 feet in length. The pipe will have a slope of approximately 0.2%; starting at approximately elevation 882 and discharging into Cottage Grove Ravine Regional Park at approximately elevation 870. The depth of cover over the pipe ranges from a few feet to approximately 35 feet. A control structure with a gate will be constructed at the entrance to the pipe in CP 4-3. The gates are needed to prevent local flows from entering the pipe and increasing peak flow rates downstream. Manholes will be located generally every 200 feet along the overflow pipe alignment in order to accommodate access.

c. Project magnitude:

The following Project Magnitude Summary information uses the Project Extents as shown on **Attachment 1**. This area defines a boundary for assessing the environmental impacts of the proposed project. This boundary is greater than the proposed future condition area of inundation and the proposed construction (erosion control) features of the project. The Project area has been defined for purposes of this review as the East Ravine, Ravine Lake, and 400 foot buffer applied around those features to conservatively estimate any potential impact limits.

Table 1: Project Magnitude Summary

Total Project Acreage	267 ac.
Linear project length	5.5 miles
Number and type of residential units	n/a
Commercial building area (in square feet)	n/a
Industrial building area (in square feet)	n/a
Institutional building area (in square feet)	n/a
Other uses	n/a
Structure height(s)	n/a

7. Cover types: Estimate the acreage of the site with each of the following cover types before and after development:

This estimate used the Minnesota Land Cover Classification System Land Use data (**Attachment 3**).

Table 2: Cover Type Summary

Cover Type	Before	After	Cover Type	Before	After
Wetlands	13.09	13.09	Lawn/landscaping	0.00	0.00
Deep water/streams	25.43	25.43	Impervious surface	1.78	1.78
Wooded/forest	136.90	136.90	Stormwater Pond	0.00	0.00
Brush/Grassland	23.91	23.91	Other (Prairie)	4.88	4.88
Cropland	50.70	50.70	Other (Vegetation w/<50% impervious surface)	10.40	10.40
			TOTAL	**267.09**	**267.09**

8. **Permits and approvals required:** List all known local, state and federal permits, approvals, certifications and financial assistance for the project. Include modifications of any existing permits, governmental review of plans and all direct and indirect forms of public financial assistance including bond guarantees, Tax Increment Financing and infrastructure. *All of these final decisions are prohibited until all appropriate environmental review has been completed. See Minnesota Rules, Chapter 4410.3100.*

Table 3: Summary of Potential Permits and Approvals

Unit of Government	Type of Application	Status
MN Department of Natural Resources	General Permit No. 1997-0005 for Temporary Water Appropriations	To be applied for if necessary. Project does not anticipate need for dewatering.
MN Department of Natural Resources	Public Waters Work Permit	Components of the project may qualify for permit exemptions and general permits that have been issued for these activities. Public waters permitting will be complied with and appropriate approvals obtained.
MN Pollution Control Agency	National Pollution Discharge Elimination System (NPDES) permit	To be applied for if construction activity is projected to disturb one acre or more of soil; or if area is less than one acre as it is part of a larger common plan of development that is greater than one acre.
MN Pollution Control Agency	Stormwater Pollution Prevention Plan	To be developed as part of final project plans.
US Army Corps of Engineers	Section 404 Authorization.	To be applied for if necessary.
South Washington Watershed District	Wetland Conservation Act	To be applied for if necessary.

Cumulative potential effects may be considered and addressed in response to individual EAW Item Nos. 9-18, or the RGU can address all cumulative potential effects in response to EAW Item No. 19. If addressing cumulative effect under individual items, make sure to include information requested in EAW Item No. 19

9. **Land use:**
   a. **Describe:**
      i. **Existing land use of the site as well as areas adjacent to and near the site, including parks, trails, prime or unique farmlands.**

      Land use within the northern portion of the project, within Sections 11 and 14, is mainly agricultural farmland with an existing roadway (80th St. S.) between Sections 11 and 14. This area is characterized as upland soils and cropland with brush and grassland. Phase III and IV of the Project (within portions of Sections 14, 22, 23, and 26) are located within the ravine and at Ravine Lake, which reside in Cottage Grove Ravine Regional Park. The park offers ski trails, hiking trails, paved trails, play area, picnic shelter, and other amenities to the surrounding community. The park in dominated by wooded/forest and brush/grassland with wetlands, deep water/streams (Ravine Lake), and a small portion of prairie. Ravine Lake drains into the south reach of the ravine. Highway 61 is located directly south of Ravine Lake and crosses between the lake and the south reach of the ravine. The south reach of the ravine, traversing Sections 26, 27, 34, and 35, is dominantly wooded/forest and brush/grassland that is within an industrial land-use setting. The very southern portion of the project, nearest to the Mississippi River, lies adjacent to the 3M Cottage Grove Center.

ii. Plans. Describe planned land use as identified in comprehensive plan (if available) and any other applicable plan for land use, water, or resources management by a local, regional, state, or federal agency.

The *Washington County 2030 Comprehensive Plan* (September, 2010) is adopted by the County Board as a policy guide for decisions about the physical development of the county. The plan provides policies and strategies for future growth and development related to land use, transportation, parks, housing, natural resources, historic preservation, and public facilities. The County's land use plan aims to preserve the existing natural resources, retain the county's existing character, and provide high quality of life. The goals of this plan include utilizing land and related natural resources; support growth of attractive urban communities while preserving rural functions and appearances; and to support economic development by the design of the land use plan.

The *Cottage Grove 2030 Comprehensive Plan* (February 2011) recognizes Cottage Grove as a "Developing Community" and their city plan sets forth the course of future growth within the city in relation to land use, transportation, utilities, and parks. Goals and policies within the plan are identified to guide decisions on development and redevelopment in Cottage Grove. One quality of the city is its "small town character" in which is aimed to be retained. Land use goals and policies within this plan provide the blue print for future growth in the city. The defined land use goals are to maintain and revitalize existing residential, commercial, and industrial areas; environmental stability sought in land use decisions and investments in infrastructure; preserve and enhance unique character of Cottage Grove; and use the land use plan as a foundation for land use decisions.

The *SWWD Watershed Management Plan* (WMP) (May 2011) provides guidance for the SWWD to manage water and natural resources of the watershed through the year 2017. The plan is required to inventory resources, assess resource quality, and establish regulatory controls, programs or infrastructure improvements necessary to manage the resources within the watershed. The WMP must comply with MN R. 8410 and MN Statute 103B and 103D. Land use changes affect the rate, volume, and quality of surface water runoff, therefore land use planning and watershed management are interrelated. The SWWD intends to work closely with the cities within the watershed district as they hold the land use planning and zoning responsibilities. Water quantity, water quality, and natural resources within the watershed district are addressed by studies/evaluations/assessments; technical framework development; and on-the-ground watershed improvements. Projects and programs for implementation form a Long Range Work Plan for the SWWD.

The *Cottage Grove Ravine Regional Park Master Plan* (May 2007) is an update to the previous 1992 master plan. The updated plan is intended to guide park improvements into the future. The vision of the Park is the "create a regional park that focuses on preserving the ecological integrity of the land while providing appropriate recreational and educational opportunities." The Park offers a natural environment for walking/running/hiking, biking, non-pool swimming, fishing, picnicking, play area for children, and sightseeing. Park use is expected to increase as the population in the surrounding areas grows and as new recreational facilities and amenities within the park are developed, drawing new and more frequent visitors. The master plan identifies stewardship measures to support and maintain future park development into the future. Some of these stewardship priorities include water resources management upstream of the ravine; ravine stabilization; removing non-native invasive woody and herbaceous vegetation; and install native plant material.

The *Cottage Grove, Minnesota City Code* contains ordinances up to and including ordinance 919, passed October 2, 2013. The Cottage Grove Zoning Ordinance, Title 11 of the City Code, is adopted for the purpose of: A) Protecting public health, safety, morals, comfort, convenience and general welfare; B) Dividing the city into zones and districts and restricting and regulating therein the location, construction, reconstruction, alteration and use of structures and land; C) Promoting orderly development of the residential, business, industrial, recreational and public areas; D) Providing adequate light, air, and convenience of access to property; E) limiting congestion in the public right of way; F) Preventing overcrowding of land and undue concentrations of structures by regulating the use of land and buildings and the bulk of buildings in relation to the land and buildings surrounding them; G) Providing for the compatibility of different land uses and the most appropriate use of land throughout the City; H) Providing an orderly transition from a rural to an urban or suburban environment; and I) Establishing standards and procedures regulating land use (1971 Code § 28-2).

iii. Zoning, including special districts or overlays such as shoreland, floodplain, wild and scenic rivers, critical area, agricultural preserves, etc.

Zoning Districts

The Project is located within Agricultural Preservation (AG-1), Rural Residential (R-1), and Heavy Industry (I-3) zoning districts as provided on the *Cottage Grove Zoning Map* (**Attachment 4**) (dated 06/06/12). The northern portion of the Project, Phase V, the CDSF Overflow Conveyance, is within an Agriculture Preservation district. Phases III and IV, Ravine Lake Outlet Structure and Ravine Stabilization within Cottage Grove Ravine Regional Park are in an area zoned Rural Residential. Phase II, Ravine Stabilization, south of Highway 61 is in an area zoned Heavy Industry.

The Agricultural Preservation AG-1 district is established for areas with high quality soils, available water resources and/or highly productive agricultural capability to preserve, promote, maintain, and enhance the use of the land for long-term agricultural purposes, and to protect such land from encroachment by the premature conversion to nonagricultural uses. This district represents areas where services required for urban development will not be available within at least ten years (Ord, 617, 8-2-1995).

The Rural Residential R-1 district represents areas suitable for residential development that are well removed from utilities and other municipal facilities. These areas are designated as rural residential in the city's comprehensive plan. The intent is to maintain low densities in order to permit efficient re-subdivision of lots to urban densities at such time that public utilities become available (1971 Code § 28-53).

The Heavy Industrial I-3 district is to provide areas suitable for industrial uses which are more intense than General Industrial I-2 district and may have greater impact to noncommercial land uses. Property zoned I-3 are located outside the metropolitan urban service area.

Shoreland Overlay
The Project is not in a designated shoreland area.

Floodplain Overlay
The City of Cottage Grove and Washington County are both communities that participate in the National Flood Insurance Program (NFIP). Floodplain maps and designations are developed by the Federal Emergency Management Agency (FEMA). The current Digital Flood Insurance Rate Map identifies Special Flood Hazard Areas that are regulated through the participating community's floodplain ordinance. These areas subject to inundation by the 1% annual chance flood are designated by zones A, AE, AH, AO, AR, A99, V, AND VE. The 1% annual chance flood, also known as the base flood or 100-year flood, has a 1% chance of happening or being exceeded each year. Special Flood Hazard Areas are subject to flooding by 1% annual chance flood. The Base Flood Elevation is the water-surface elevation of the 1% chance flood.

There are two locations within the Project Area that have been identified within the Special Flood Hazard Zones; Ravine Lake and the very southern portion of the project nearest to the Mississippi (see **Attachment 5**).

Ravine Lake is an area designated as Zone A. No base (1% annual chance) flood elevations or depths are shown within this zone.

The very southern portion of the ravine channel, at the outlet of the channel to the Mississippi River, is designated as Zone AE. This designation represents an area where base flood elevations derived from hydraulic analysis for the 1% annual chance are shown within this zone. As shown in **Attachment 4**, there is a regulatory floodway along the Mississippi River that will not be impacted by the Project.

Wild and Scenic Rivers
The Project is not in one of the designated Minnesota Wild and Scenic Rivers segments.

Critical Area
The southern portion of Phase II of the Project, Ravine Stabilization south of Highway 61, is within the Critical Area Overlay Boundary (as shown on **Attachment 4**, the Cottage Grove Zoning Map). The Mississippi River Critical Area Program is a joint local and state program that provides coordinated planning and management for 72 miles of the Mississippi River, four miles of the Minnesota River, and 54,000 acres of adjacent corridor lands. The designated Mississippi River Critical Area Corridor stretches from Ramsey and Dayton, Minnesota, to the southern boundary of Dakota County on the west/south side of the river and the boundary with the Lower St. Croix National Scenic Riverway on the

east/north side of the river, and runs through the heart of Minneapolis-Saint Paul (Minnesota Department of Natural Resources, 2014).

Per the Cottage Grove, Minnesota City Code, the Mississippi River Corridor Critical Area Overlay District was established with the purpose and intent for the prevention and mitigation of irreversible damage to this resource and the preservation and enhancement of its natural, aesthetic, cultural and historic values is in furtherance of the health, safety and general welfare of the City (Sterling Codifiers, Inc., 2013).

b. Discuss the project's compatibility with nearby land uses, zoning, and plans listed in Item 9a above, concentrating on implications for environmental effects.

Washington County, and the Cities of Woodbury and Cottage Grove, have planned and collaborated in the development and implementation of the CDSF Overflow Project. This project conforms with the ongoing development of these communities.

<u>Land Use</u>
The Project is not significantly or permanently altering the land or its current uses, developing or building any new structures, nor shall its effects result in degrading below current environmental conditions in the area. The Project is compatible and compliant with current land uses within and surrounding the project area.

The Project (Phase II – Phase V) corresponds with the plans listed in 9.a.ii..

<u>Plans</u>

- <u>*Washington County 2030 Comprehensive Plan*</u> (September, 2010)
  The Project is incorporating stormwater management and erosion control techniques into the Project area to address current conditions and future concerns in regards to future growth and development in conjunction with preserving existing environmental conditions within the Project area. The Project contemplates and is compatible with the *Washington County 2030 Comprehensive Plan.*

- <u>*Cottage Grove 2030 Comprehensive Plan*</u> (February 2011)
  The Project is incorporating stormwater management and erosion control techniques into the Project area that will maintain existing environmental stability, specifically within the East Ravine channel, while also preserving existing environmental conditions of the area, which is known as a developing community expecting future growth. The Project contemplates and is compatible with the *Cottage Grove 2030 Comprehensive Plan.*

- <u>*SWWD Watershed Management Plan*</u> (WMP) (May 2011)
  The SWWD WMP identifies the CDSF Overflow Project within its Implementation Work Plan. The Project is needed to manage potential damaging environmental effects within the East Ravine and surrounding areas from infrequent yet reasonably foreseeable precipitation events. The Project directly facilitates the WMP and is, therefore, compatible with the *SWWD Watershed Management Plan.*

- *Cottage Grove Ravine Regional Park Master Plan* (May 2007)
  The Project directly facilitates the Park Master Plan's stewardship priorities of water resource management upstream of the ravine and with its planned ravine stabilization. The natural resources stewardship section of the plan identifies erosion stabilization and using a suite of measures from vegetation to hard armoring, upgrading the outlet, and realigning the park drive as part of the ongoing water resource management activities. The Project is addressing current and future environmental concerns within the Project area due to population growth within Washington County. The Project has considered the *Cottage Grove Ravine Regional Park Master Plan*. The project includes activities and features within the park that will be incorporated into the Master Plan, through a plan amendment. SWWD has identified the need to work with Washington County Parks and the Metropolitan Council on a plan amendment. All three parties have agreed to work together to assure that the plan amendment is completed. In addition, SWWD will work with Washington County Parks and Metropolitan Council when developing the final design for the specific practices and permanent features contemplated by the project.

- *Cottage Grove, Minnesota City Code*
  The CDSF Overflow Project has been in development for over 30 years for the purpose of providing regional flood protection primarily within the Cities of Woodbury and Cottage Grove. The concept of the Project is for a managed system utilizing floodwater storage, the infrequent use of a pipe connection to the Cottage Grove storm sewer system, and inter-basin pumping to reduce flood risks associated with 100 year and less frequent flood events. The Project and its role as part of the CDSF Overflow Project, is being implemented to protect public health, safety, and general welfare. The Project facilitates the promoting of orderly development within the area, therefore contemplating and complying with the *Cottage Grove, Minnesota City Code*.

Zoning

- Zoning Districts
  The Project is compatible with the zoning regulations including designated districts and overlays for Washington County and the City of Cottage Grove, in which the Project resides. The Project is not significantly or permanently altering the land or its current uses, nor developing or building any new structures. There are no significant implications of environmental effects of the project as the Project is addressing and enhancing the existing and foreseen future conditions of the Project area upon future development of the cities of Woodbury and Cottage Grove.

- Floodplain Overlay
  The project is compatible with floodplain regulations.

- Critical Area Overlay
  Per the Cottage Grove, Minnesota City Code, The Mississippi River Corridor shall be managed in a manner consistent with its natural characteristics and its existing development and in accordance with regional plans for the development of the Metropolitan Area (Sterling Codifiers, Inc., 2013, pp. 11-15-2, B.). The Project is incorporating stormwater management and erosion control techniques into the Project area and will maintain the area from further

erosional degradation. The Project is compatible and complies with the Mississippi River Corridor Critical Area Overlay District.

c. Identify measures incorporated into the proposed project to mitigate any potential incompatibility as discussed in Item 9b above.

No mitigation measures are proposed as the project is compatible as noted above.

10. Geology, soils and topography/land forms:

a. Geology - Describe the geology underlying the project area and identify and map any susceptible geologic features such as sinkholes, shallow limestone formations, unconfined/shallow aquifers, or karst conditions. Discuss any limitations of these features for the project and any effects the project could have on these features. Identify any project designs or mitigation measures to address effects to geologic features.

The geology characterized in the northern to southern extents of the Project is described as follows:

The northern portion of the Project, the area north of Highway 61 (location of Phase IV and V) is underlain by outwash deposits associated with the Superior Lobe. This outwash is composed of sand, gravelly sand, and gravel that is commonly overlain by two to five feet of loess.

Ravine Lake is underlain by organic deposits, also described as peat and muck.

The remainder of the Project area (location of Phase II, ravine stabilization) is characterized as upper River Warren terrace, middle River Warren terrace, Middle terraces, and bedrock near the surface, nearest to the ravine outlet and Mississippi River.

The Upper River Warren terrace is composed of sand, gravelly sand, and gravel with its surface 160 to 220 feet above floodplain level. Middle terrace deposits within this area are also comprised of sand, gravelly sand, and gravel. Surface of the terrace is about 115 to 140 feet above floodplain level. This terrace of the Mississippi River valley is commonly overlain by thick loamy sand and is stippled where bedrock valley commonly is within ten feet of the surface.

The bedrock, like that nearest to the outlet of the south reach of the ravine channel that flows into the Mississippi River, is typically seen as outcrops and near-surface Cambrian and Ordovician bedrock on steep slopes ranging from the Prairie du Chien Group to the Jordan Sandstone, St. Lawrence and Franconia Formations. The bedrock may be discontinuously exposed with a sandy to rocky mantle generally less than 5 feet thick.

No susceptible geologic features such as sinkholes, shallow limestone formations, unconfined/shallow aquifers, or karst conditions have been identified within or near the project area.

b. Soils and topography - Describe the soils on the site, giving NRCS (SCS) classifications and descriptions, including limitations of soils. Describe topography, any special site conditions relating to erosion potential, soil stability or other soils limitations, such as steep slopes, highly permeable soils. Provide estimated volume and acreage of soil excavation and/or

grading. Discuss impacts from project activities (distinguish between construction and operational activities) related to soils and topography. Identify measures during and after project construction to address soil limitations including stabilization, soil corrections or other measures. Erosion/sedimentation control related to stormwater runoff should be addressed in response to Item 11.b.ii.

The Washington County Soil Survey is presented in **Attachment 6**. Soils in the area are described as loamy sand, sandy loams, and silty loams. Mucks are also present within the low lying wet areas. Topography surrounding the Project area is depicted in **Attachment 7**. The land elevation decreases from 1,100 feet above sea-level at the most northern reaches of the project area, to 630 feet at the confluence with the Mississippi River. More locally, the ravine within the park is characterized as a one-half mile wide "tunnel valley" with frequent steep slopes approximately 80-100 feet deep from the ravine floor to the bluff tops. Vertical relief within the park nears 150 feet.

Attachment 7 illustrates the relief and the natural flow of water and runoff follow within and surrounding the Project area. The relief in the area gently slopes down from the north to south reaches of the Project Area, leading down to the Mississippi River.

The soils present on within the Project area are generally described as having high to moderate infiltration rates, which can have an increased erosion potential within the steeper slopes of the Project Area. Some rock outcropping is present at the outlet to the Mississippi River. **Table 4**, below, contains the Washington County Soil Survey details within the project extent.

Soils identified as Prime Farmland are present within the Project area. These soils are generally located within cultivated, northern portions of the Project area. One Soil of Statewide Importance is also identified within the cultivated areas on the north side of the Project area. No loss in farmland productivity is anticipated as part of the project, because the project features within these areas will be beneath the ground surface.

Table 4: Washington County Soil Survey Data within the Project Area

Map Unit Symbol	Map Unit Name	Acres in Project Area	Percent of Project Area
7B	Hubbard loamy sand, 1 to 6 percent slopes	1.9	0.7%
7C	Hubbard loamy sand, 6 to 12 percent slopes	1.3	0.5%
7D	Hubbard loamy sand, 12 to 18 percent slopes	42.5	15.9%
8	Sparta loamy sand, 0 to 2 percent slopes	3.0	1.1%
8B	Sparta loamy sand, 2 to 6 percent slopes	4.5	1.7%
8C	Sparta loamy sand, 6 to 15 percent slopes	19.5	7.3%
49	Antigo silt loam, 0 to 2 percent slopes	7.7	2.9%
49B	Antigo silt loam, 2 to 6 percent slopes	19.7	7.4%

Map Unit Symbol	Map Unit Name	Acres in Project Area	Percent of Project Area
49C	Antigo silt loam, 6 to 12 percent slopes	6.2	2.3%
49D	Antigo silt loam, 12 to 18 percent slopes	6.4	2.4%
155D	Chetek sandy loam, 12 to 25 percent slopes	3.8	1.4%
298	Richwood silt loam, 0 to 2 percent slopes	0.3	0.1%
301B	Lindstrom silt loam, 2 to 4 percent slopes	9.7	3.6%
329	Chaska silt loam	12.4	4.6%
411B	Waukegan silt loam, 2 to 6 percent slopes	2.8	1.1%
454B	Mahtomedi loamy sand, 0 to 6 percent slopes	0.4	0.1%
454C	Mahtomedi loamy sand, 6 to 12 percent slopes	5.9	2.2%
454D	Mahtomedi loamy sand, 12 to 25 percent slopes	0.9	0.4%
454F	Mahtomedi loamy sand, 25 to 40 percent slopes	38.0	14.2%
507	Poskin silt loam	0.1	0.0%
543	Markey much	14.0	5.3%
859B	Urban land-Zimmerman complex, 1 to 8 percent slopes	2.0	0.7%
1820F	Mahtomedi variant-Rock outcrop complex, 25 to 60 percent slopes	1.0	0.4%
1847	Barronett silt loam, sandy substratum	51.8	19.4%

Projected volumes and acreage of soil excavation and/or grading details will be determined as part of the development of the construction plans.

NOTE: For silica sand projects, the EAW must include a hydrogeologic investigation assessing the potential groundwater and surface water effects and geologic conditions that could create an increased risk of potentially significant effects on groundwater and surface water. Descriptions of water resources and potential effects from the project in EAW Item 11 must be consistent with the geology, soils and topography/land forms and potential effects described in EAW Item 10.

11. Water resources:

a. Describe surface water and groundwater features on or near the site in a.i. and a.ii. below.

i. Surface water - lakes, streams, wetlands, intermittent channels, and county/judicial ditches. Include any special designations such as public waters, trout stream/lake, wildlife lakes, migratory waterfowl feeding/resting lake, and outstanding resource value water. Include water quality impairments or special designations listed on the current MPCA 303d Impaired Waters List that are within 1 mile of the project. Include DNR Public Waters Inventory number(s), if any.

National Wetland Inventory (NWI): Three (3) NWI wetlands were identified within the Project Extents (**Attachment 8**). Wetland delineation has not been completed; other wetlands may be present. NWI wetlands within the project area include two Shallow Marsh Type 3 wetlands, and Ravine Lake is categorized as an Open Water Community (Type 5), with a forested and shrubby component on the basin fringes (Type 6, Shrub Carr & Type 7 Hardwood Swamp).

DNR Public Waters Inventory (PWI): One Public Waters Wetland, Unnamed #82-87W (Ravine Lake) exists within the Project Extents. Ravine Lake is identified by the MPCA as impaired for nutrients. The lake is 19 acres with a maximum depth of 16 feet. The entire shoreline is undeveloped and provides habitat for a variety of wildlife. The lake is habitat for egrets, herons, eagles, ospreys and other waterfowl. A shore fishing station and a fishing pier exist on the northeast shore. Ravine Lake is primarily managed for walleye and bluegill with secondary management emphasis on largemouth bass and black crappie.

According to the DNR, no calcareous fens, designated wildlife lakes, or trout streams are located within the project extents. The northwestern corner of Ravine Lake was identified as a rich fen wetland community as part of an environmental assessment conducted for the County Road 19 Corridor project in 2002.

The public waters inventory identifies the East Ravine channel as a natural watercourse, known as the Unnamed Tributary to the Mississippi River. The public water course is identified from Section 14, Township 27 North, Range 21 West to Section 35, Township 27 North, Range 21 West (**Attachment 8**). The proposed project also connects to the Mississippi River on the south side of the project extents. The majority of the ravine channel has been identified by the Minnesota Pollution Control Agency (MPCA) as an Impaired Stream (**Attachment 8**). The ravine itself is relatively flat when compared to its adjacent banks and bluffs. The ravine carries considerable flow following heavy rain events, eventually flowing into Ravine Lake. The majority of the ravine area is a wet-mesic hardwood forest system, with dry, open areas (man-made, cleared), and a cultivated pine area present to a much lesser extent.

ii. Groundwater – aquifers, springs, seeps. Include: 1) depth to groundwater; 2) if project is within a MDH wellhead protection area; 3) identification of any onsite and/or nearby wells, including unique numbers and well logs if available. If there are no wells known on site or nearby, explain the methodology used to determine this.

Depth to water table, as provided by the NRCS Web Soil Survey, is greater than 200 cm (6.56 feet) for the majority of the Project area. The exceptions are directly within the bottom of the north and south reach of the ravine and Ravine Lake. In these locations the water table is rated to be 15 to 0 cm, respectively, below the soil surface.

The NRCS data provided is not a definitive and adequate measure for depth to the water table because excavation depth for installing the overflow conveyance pipe is at maximum, approximately 45.5 feet. Soil borings advanced for Phase I overflow conveyance pipe installation did not show evidence that groundwater would be encountered during excavation. During construction and excavation for Phase I a small amount of groundwater is an isolated area was experienced, as was suspected from an isolated clay lens in the soil. The volume of water that was pumped was small, and was pumped onto a nearby agricultural field. There was no runoff associated with this process.

Previous discussion and documentation of the geotechnical exploration and analysis were developed prior to Phase I of the project and are available at the SWWD office.

Attachment 9 shows the nearest MDH wellhead protection area and locations of nearby wells. The Project is not within a MDH wellhead protection area. There is one well, nearest to the Project area, located south of Highway 61 on the east side of the Project boundary. Though it appears on the map as being within the Project buffer, its actual location is outside the buffer on the opposite side of Keats Ave. S. Its Unique Well Number is 233573 and **Appendix C** is a copy of the well's record retrieved through the MDH County Well Index online database.

b. Describe effects from project activities on water resources and measures to minimize or mitigate the effects in Item b.i. through Item b.iv. below.

i. Wastewater - For each of the following, describe the sources, quantities and composition of all sanitary, municipal/domestic and industrial wastewater produced or treated at the site.

There will be no wastewater generated by the Project.

1) If the wastewater discharge is to a publicly owned treatment facility, identify any pretreatment measures and the ability of the facility to handle the added water and waste loadings, including any effects on, or required expansion of, municipal wastewater infrastructure.

Not Applicable.

2) If the wastewater discharge is to a subsurface sewage treatment systems (SSTS), describe the system used, the design flow, and suitability of site conditions for such a system.

Not Applicable.

3) If the wastewater discharge is to surface water, identify the wastewater treatment methods and identify discharge points and proposed effluent

limitations to mitigate impacts. Discuss any effects to surface or groundwater from wastewater discharges.

Not Applicable.

ii. Stormwater - Describe the quantity and quality of stormwater runoff at the site prior to and post construction. Include the routes and receiving water bodies for runoff from the site (major downstream water bodies as well as the immediate receiving waters). Discuss any environmental effects from stormwater discharges. Describe stormwater pollution prevention plans including temporary and permanent runoff controls and potential BMP site locations to manage or treat stormwater runoff. Identify specific erosion control, sedimentation control or stabilization measures to address soil limitations during and after project construction.

The District has adopted water management standards to address the water quantity and water quality of stormwater discharges within the District. These are adopted within the Watershed Management Plan (WMP) and implemented by the city development codes. This assures that all new development will be managed for stormwater quality benefits. District standards and requirements for all land development or disturbance activity, including redevelopment, involve on-site as well as regional considerations. This approach ensures that activities in the watershed are managed not only at the scale of a specific development (i.e. on-site), but regionally as well. Standards set forth in the WMP are intended to provide a sufficient level of detail to establish clear expectations for the member cities. Design manuals and other Guidance Documents are utilized to add relevant detail and refine standards as appropriate. This approach provides flexibility for the WMP to incorporate and dovetail with state regulatory programs that address stormwater and water resources, such as TMDL studies and NPDES Phase II MS4 nondegradation loading assessments.

The effects of the CDSF on peak flows were reviewed (**Appendix A**) as part of the erosion analysis. When comparing the peak flow rates for the Build Out Condition to the With Project Condition, the peak flow rate for the With Project Condition is greater for only a very short distance. This area is from the location of the pipe outlet for the CDSF Overflow Project at station 8100 to the location where additional local drainage enters from the northeast at station 7648. Below this point, the existing peak flow rates far exceed the outlet flow rates from the CDSF Overflow Project. The maximum flow from the CDSF Overflow Project is approximately 140 cfs (see **Appendix A: Table 1**).

The water quality of the project was also considered (see **Appendix A: Section 7.2**). The CDSF Overflow Project is designed to be in use for the 100-year rainfall and larger events. Neither the State of Minnesota nor the SWWD manage water quality for this extreme of an event. The review projected that during operation of the CDSF Overflow Project, the concentration of total phosphorous (TP) within Ravine Lake will approach that of the incoming concentration of 70 ug/l. This TP concentration is within the current range of the existing water quality data from 1998-2012. Based on the review, water from the CDSF Overflow Project will not degrade the water quality beyond the existing condition of the lake.

Land-surface stormwater runoff within the Project area is naturally routed to the East Ravine, Ravine Lake, and is conveyed through the lake's outlet to the south reach of the ravine, inevitably reaching the Mississippi River. The only additional stormwater added by the project will be from the outlet of CP 4-3 under extreme storm events.
Specific erosion control and stabilization measures to be implemented within the north and south reaches of the ravine have not been identified at this time. Channel stability, flood extents, and erosion potential has been assessed in previous studies available at the SWWD office. Based on erosion potential identified within sections of the ravine, stabilization measures will be selected. A further discussion on erosion control measures is included in this EAW under the "Surface Waters" section (11.iv.b).

A Stormwater Pollution Prevention Plan (SWPPP) will be developed as part of the final project plans for the CDSF Overflow Conveyance (Project Phase V), which will describe temporary and permanent runoff controls and potential BMP site location to manage or treat stormwater runoff.

iii. Water appropriation - Describe if the project proposes to appropriate surface or groundwater (including dewatering). Describe the source, quantity, duration, use and purpose of the water use and if a DNR water appropriation permit is required. Describe any well abandonment. If connecting to an existing municipal water supply, identify the wells to be used as a water source and any effects on, or required expansion of, municipal water infrastructure. Discuss environmental effects from water appropriation, including an assessment of the water resources available for appropriation. Identify any measures to avoid, minimize, or mitigate environmental effects from the water appropriation.

The Project does not anticipate or propose to appropriate surface or groundwater. The Project does not anticipate a need for dewatering.

iv. Surface Waters

a) Wetlands - Describe any anticipated physical effects or alterations to wetland features such as draining, filling, permanent inundation, dredging and vegetative removal. Discuss direct and indirect environmental effects from physical modification of wetlands, including the anticipated effects that any proposed wetland alterations may have to the host watershed. Identify measures to avoid (e.g., available alternatives that were considered), minimize, or mitigate environmental effects to wetlands. Discuss whether any required compensatory wetland mitigation for unavoidable wetland impacts will occur in the same minor or major watershed, and identify those probable locations.

The project proposes channel stabilization measures within the ravine channel, which is not within the extent of the NWI identified wetlands or Ravine Lake. No wetland loss will occur from constructed project features or from stormwater flows after the project is complete.

No change in the hydrologic regime of wetlands or Ravine Lake will occur from the channel flows after project construction. There will be no draining, filling, permanent inundation, dredging or vegetative removal from any wetlands identified within the Project Extents. No compensatory mitigation will be necessary because no impacts are proposed. Constructed features within the East Ravine channel will reinforce and stabilize the current condition of the ravine channel, and will not result in a decrease in water quality of flows into Ravine Lake and ultimately the Mississippi River.

In the Build Out Condition with the Project, excess water will be removed from upstream and will be transported through the ravine during and after the 100-year rainfall events.

Peak Inundation Area:

The Existing Condition flood area and the proposed Build Out Condition with the Project flood areas result in a 1.24 acres of additional inundation area in the Build Out With Project Condition. **Table 5** provides the Peak Inundation Area for All Alternatives:

Table 5: Peak Inundation Area for All Scenarios

	Scenario 1: Existing Condition	Scenario 2: Build Out	Scenario 3: Build Out with Project
Peak Inundation Area (acres)	25.23	26.35	26.47

Inundation Duration:

The duration of inundation increases from approximately 3 days in the Existing Condition to 25 days in the Build Out Condition. **Table 6** provides a summary of the Average Daily Flows into Ravine Lake for the 100-year Rainfall event.

Because of the infrequency of water flow / inundation with the Build Out Condition, no wetland type change is expected to occur. NWI identified wetlands within the Project Extents are shown in **Attachment 8.**

Table 6: Average Daily Flows into Ravine Lake through Time for 100-year Rainfall Event

Station	Scenario 1 Existing Peak flow (cfs)	Scenario 2 Build Out Peak flow (cfs)	Scenario 3 With Project Peak flow (cfs)
Day 1	52.7	92.0	94.1
Day 2	2.4	36.3	52.8
Day 3	0.3	25.6	96.7
Day 4	-	22.6	108.5
…			
Day 8	-	20.7	140.5
…			

Station	Scenario 1 Existing Peak flow (cfs)	Scenario 2 Build Out Peak flow (cfs)	Scenario 3 With Project Peak flow (cfs)
Day 12	-	12.0	36.9
…			
Day 16	-	11.6	28.8
…			
Day 19	-	0.2	25.9
…			
Day 25	-	-	3.0
…			
Day 27	-	-	1.0

b) Other surface waters- Describe any anticipated physical effects or alterations to surface water features (lakes, streams, ponds, intermittent channels, county/judicial ditches) such as draining, filling, permanent inundation, dredging, diking, stream diversion, impoundment, aquatic plant removal and riparian alteration. Discuss direct and indirect environmental effects from physical modification of water features. Identify measures to avoid, minimize, or mitigate environmental effects to surface water features, including in-water Best Management Practices that are proposed to avoid or minimize turbidity/sedimentation while physically altering the water features. Discuss how the project will change the number or type of watercraft on any water body, including current and projected watercraft usage.

Phase III contemplates working with Washington County to reconfigure the outlet of Ravine Lake. Washington County currently has plans to modify the entrance to the park and upgrade the roadways within the park. The County is also proposing to possibly move the park access road to the South and remove the roadway from passing through Ravine Lake.

Providing an updated outlet and park access road is planned during Washington County's upgrades to the Park; these upgrades will accommodate both the flows from the local area under Build Out Condition and flows from the CDSF Overflow Project. The new outlet configuration would be designed to maintain current lake levels and minimize bounce during large rainfall events.

If the current park access road is not moved, the road would need to be raised 1 to 3 feet and a large culvert placed under the road with a control structure downstream. The control structure would likely be a two stage weir configuration; with a small weir length to maintain normal pool conditions and a large weir length at a higher elevation to accommodate larger flows. If the road is moved to the south a large culvert would be placed under the roadway, and a two stage weir control structure constructed on the upstream or downstream side of the road.

The hydraulic effects are discussed in Houston Engineering Draft Lower East Ravine Stabilization Memo, dated March, 2014. The hydraulic effects of the modified structure will not have a negative effect on the downstream flows. Ancillary effects of the outlet modification are the temporary construction disturbance, some fill either to raise the existing crossing or improve the existing southerly crossing. If the southerly route is ultimately selected the removal of the existing road from the lake bed and subsequent restoration of that portion of the lake would offset the fill associated with the improved southerly crossing. In either case the improved flow characteristics will improve the water level characteristics for the lake.

The outlet reconfiguration will be conducted in accordance with the park plan and in consultation with DNR fisheries managers to assure that the design conforms to the management goals for the fishery.

East Ravine Channel:
The Project will be imposing physical effects and alterations within and throughout the East Ravine channel, including stabilization techniques being implemented as erosion control methods.

Erosion potential (channel instability) studies were conducted in December 2013 and March of 2014 for the Upper East Ravine (**Appendix A**) and East Ravine (**Appendix B**), respectively. The studies included data regarding hydrology, hydraulics, and mapping for three different land use conditions – the Existing Condition (existing land use), the Built Out Condition (ultimate build out or "fully developed" land use and no CDSF Overflow Project), and the With Project Condition (ultimate build out land use, with CDSF Overflow Project operational) – associated with 100-year and less frequent flood events. Erosion potential classifications based on both shear stress and velocity were computed and tabulated for the three different land use conditions and shown spatially. **Attachments 10-12** are the erosion potential maps developed for the Upper East Ravine and **Attachments 13-15** are those developed for the Lower East Ravine.

These reports identify areas under the existing conditions that have high and excessive erosion potential due to predicted exceedance of shear stress and velocity thresholds within the ravine channel. Erosion within the ravine is an existing problem with specific reference to numerous instances of erosion within the park and erosion being identified as a significant issue within the park plan. Currently, for large precipitation events, the potential exists for the uncontrolled overflow of water from the northern watershed (Woodbury and Cottage Grove areas) into the East Ravine, and the potential to exacerbate natural resources damage within the ravine system.

Upper East Ravine:
Based on the evaluation completed for Existing Conditions within the Upper East Ravine, there is high and excessive risk along 5,150 feet of the 8,100 foot channel. Very little additional area shows high or excessive risk for the With Project Condition when compared to the Existing Conditions and none when compared to the Build Out Condition. For both Build Out and With Project Conditions, 5,200 feet of the ravine show high and excessive risk of bank erosion, an increase of 50 feet. This

length of the channel with high/excessive risk represents approximately 64% of the total length of the ravine, from the outlet of the CDSF Overflow Pipe to Ravine Lake. **Table 7**, below, summarizes this information.

Table 7: Upper East Ravine - Summary of Lengths for High and Excessive Erosion Potential

	Scenario 1: Existing Conditions	Scenario 2: Build Out	Scenario 3: With Project
Length with High and Excessive Erosion Potential (ft)	5,150	5,200	5,200
Total Length of Reach (ft)	8,100	8,100	8,100
Percent of Total Length	63.6%	64.2%	64.2%

Lower East Ravine:
Based on the evaluation completed for Existing Conditions within the Lower East Ravine, there is high and excessive risk along 6,440 feet of the 11,075 foot channel. Very little additional area shows high or excessive risk for the With Project Condition when compared to the Existing Conditions and none when compared to the Build Out Condition. For both Build Out and With Project Conditions, 6,500 feet of the ravine show high and excessive risk of bank erosion, an increase of 60 feet. This length of the channel with high/excessive risk represents approximately 59% of the total length of this portion of the ravine, from downstream of Ravine Lake from Highway 61 to the Mississippi River. **Table 8**, below, summarizes this information.

Table 8: Lower East Ravine - Summary of Reach Lengths with High and Excessive Erosion Potential

	Scenario 1: Existing Conditions	Scenario 2: Build Out	Scenario 3: With Project
Length with High and Excessive Erosion Potential (ft)	11,075	11,075	11,075
Total Length of Reach (ft)	6,440	6,500	6,500
Percent of Total Length	58.1%	58.7%	58.7%

Construction of the Project is mitigating erosion risks with the use of bank stabilization techniques throughout the ravine. Based on the erosion potential ratings for sections within the ravine channel (depicted in **Attachments 10-15**), stabilization measures will be selected. Potential stabilization techniques within the Upper East Ravine include vegetation management, constructed lined channel, lined existing channel, check dams. **Table 9** provides a summary of the stabilization measures with the maximum allowable shear stress associated with them. **Figures 1-5**, below, depict these stabilization techniques in a cross-sectional view.

Table 9: Stabilization Measure Shear Stress Threshold and Cost

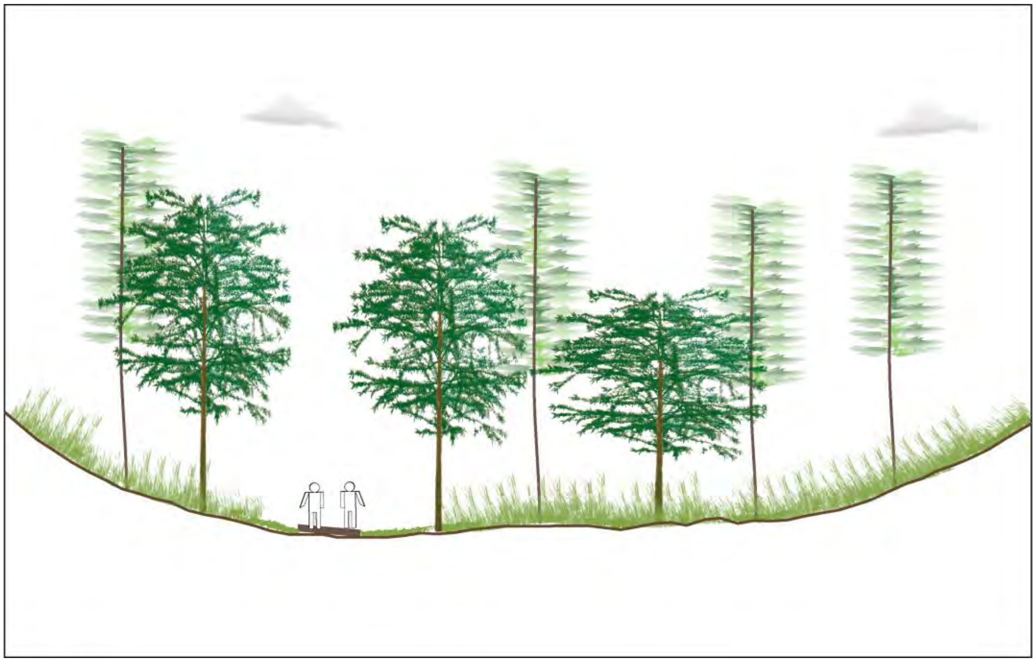
Stabilization Technique		Maximum Shear Stress (lb/sq. ft.)
None		0.4 - 2.5
Vegetation Management, Native Grasses		1.5
Constructed Channel Lining	Turf Reinforced Mat	3 - 8
	High Performance Turf Reinforced Mat	4 - 10
	9" D_{50} Riprap Lining	3.8
	12" D_{50} Riprap Lining	5.1
Line Existing Channel	9" D_{50} Riprap Lining	3.8
	12" D_{50} Riprap Lining	5.1
Check Dams		3-20

*Erosion potential due to velocity will be covered by all techniques.

The upper half of the Lower East Ravine is similar to the Upper East Ravine, within the Cottage Grove Ravine Regional Park, and the same stabilization measures shall apply throughout the area. However, the lower half of the Lower East Ravine, below the Railroad crossing (see **Attachment 1** for location of Railroad crossing), the channel becomes more incised and prevalent. Also, further south of the Railroad crossing, the 3M discharges water into the channel from their facility providing baseflow to the reach. Because of the more prevalent channel and the baseflow, stabilization work through this area will utilize additional stabilization techniques more consistent with a streambank stabilization and stream restoration project. Potential stabilization techniques include stabilizing outside bends with rock vanes, woody debris, rootwads, and vegetated riprap. A riffle-pool design will be utilized; the riffles will be constructed from rock using multiple techniques. These techniques are similar to one another with just slight variations of height, length, width, and density of rock placement. Figure 5 shows the variety of techniques that may be utilized in this most southern portion of the reach (McCullah, 2005). The stabilization measures for the lower portion of the Lower East Ravine will ultimately be selected to take into account effectiveness at stabilizing the reach, cost effectiveness, and the aesthetic needs of the 3M.

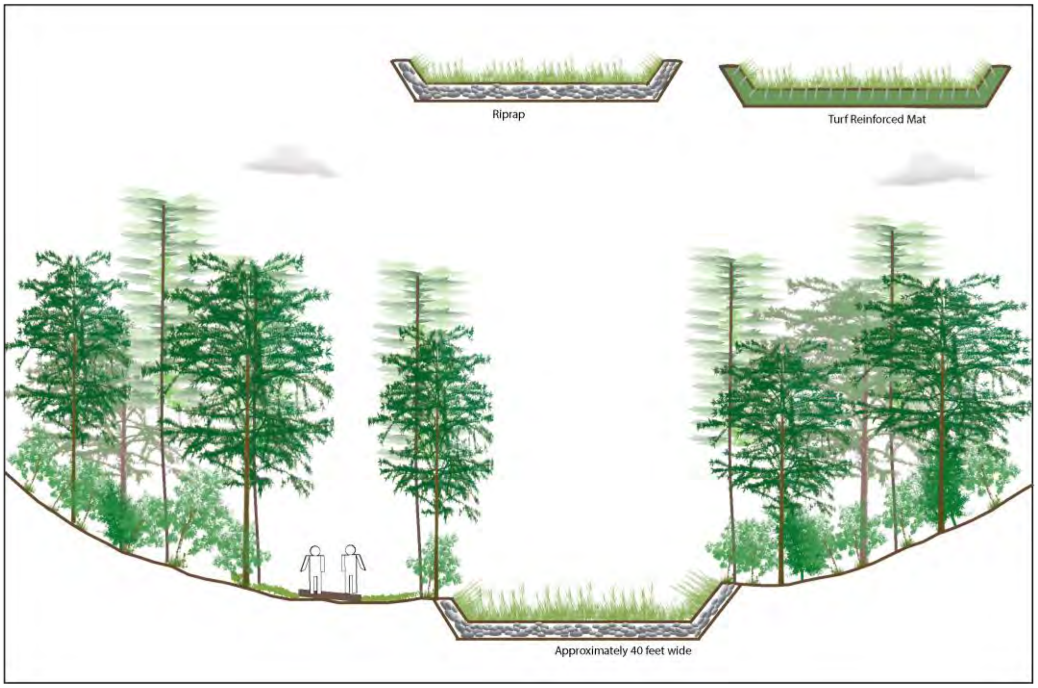
The Project's construction impacts and environmental effects are offset by the long term benefits of the project, which will be protecting the area from degradation.

Figure 1: Rendering Showing the Use of Vegetation Management



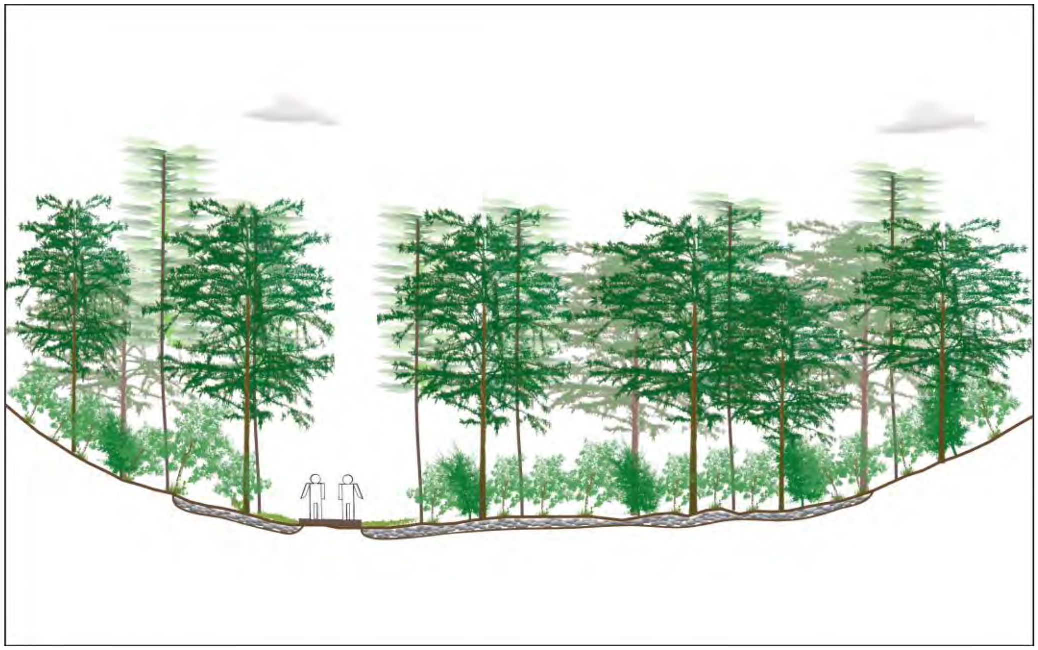
Managing the vegetation within the ravine is an option to provide stability to the channel in cases where more invasive techniques are not warranted. Restoring the ravine to native habitat would allow longer native grasses to grow and provide the necessary erosion protection. This stabilization alternative would require removal of the buckthorn, other thick underbrush, removal of deadfall, and removal of live trees to open the canopy. The area would then be seeded with native grasses.

Figure 2: Rendering Showing the Use of a Constructed Lined Channel



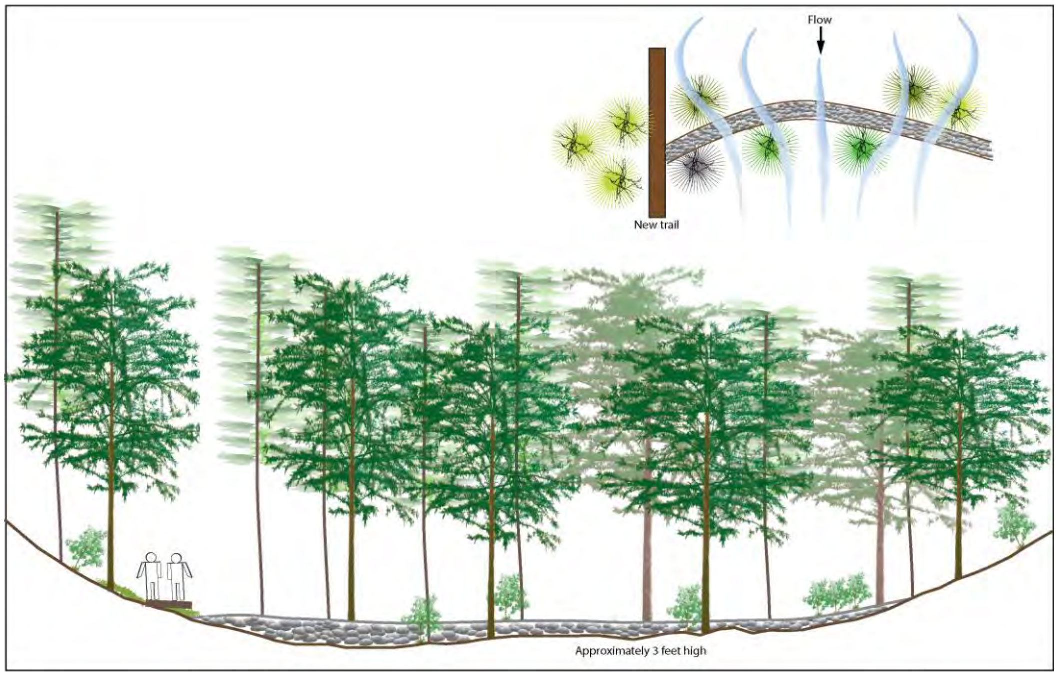
Constructing a channel to confine the flow and lining with a suitable material is another stabilization measure. The specific dimensions of the channel that would be constructed would depend on the location and the grade of the channel. The constructed channel could be lined with varying sizes of riprap or different grades of turf reinforced mat. The turf reinforced mat is a cheaper alternative than the riprap and may be more aesthetically appealing. The riprap is superior in its long term effectiveness, as it should remain effective longer. Because the turf reinforced mats are made of polypropylene or similar material, they will slowly degrade over time, with design life of 25 to 50 years. At that time they will not be totally ineffective, but the effectiveness will be reduced. In either case the area could be vegetated to increase the aesthetic appeal; this would require the addition of soil and seeding the area.

Figure 3: Rendering Showing a Lining of the Existing Channel



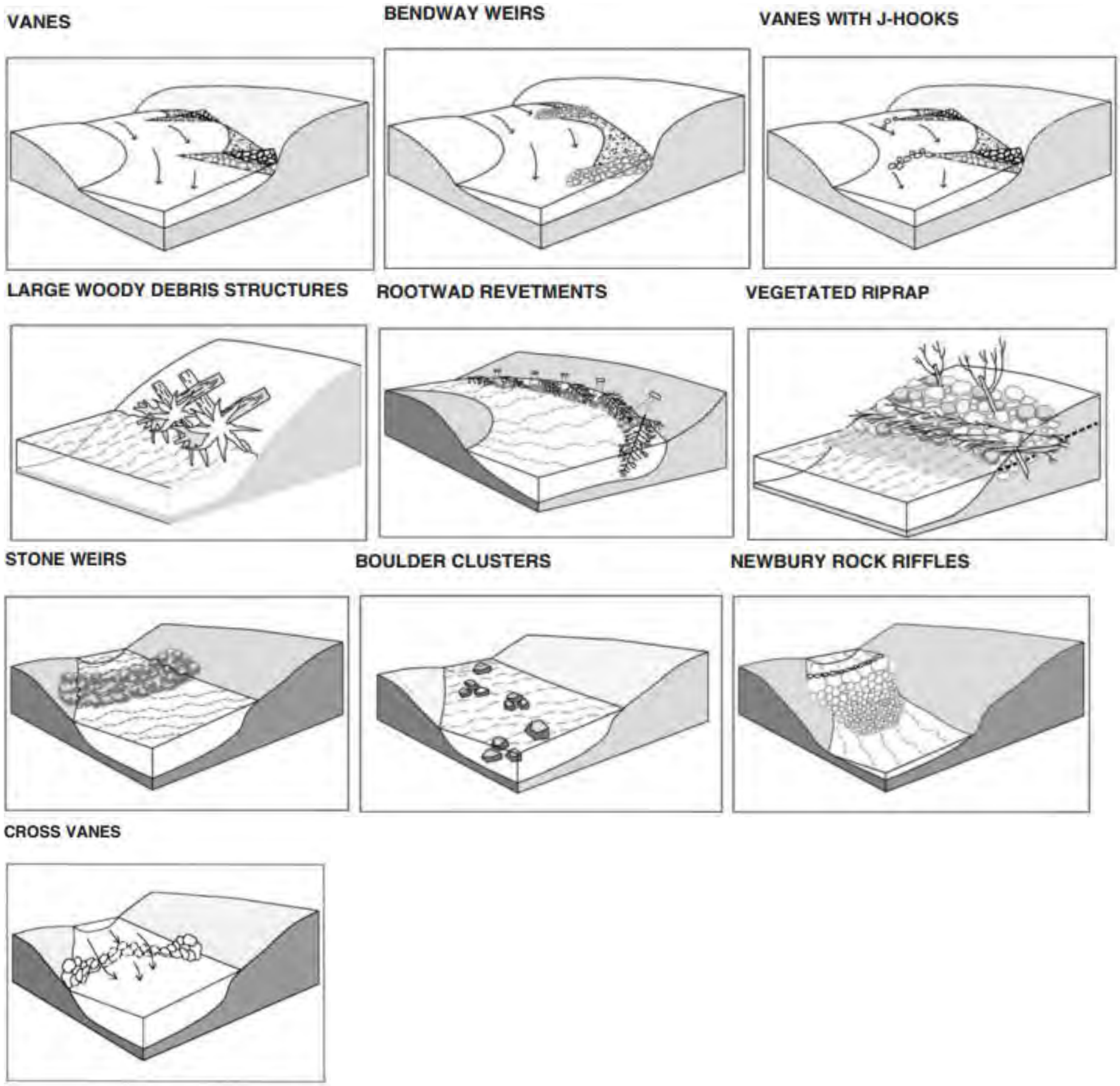
Lining the existing channel with riprap of appropriate size can also be done to stabilize the ravine. This measure can be utilized over a constructed channel when sparing specific large existing trees is warranted. Clearing of brush will need to take place to facilitate the placement of riprap. Areas needed for equipment access will also require clearing. This technique will be most cost effective where a defined channel already exists and the channel is narrowed. Due to the additional effort required to spare some trees, this measure is only as cost effective as a constructed channel for areas narrower than 50 feet.

Figure 4: Rendering Showing the Use of Check Dam



The check dam is a grade stabilization structure that reduces the effective grade upstream and dissipates the excessive energy over the structure. This stabilization measure can be the most cost effective technique, depending on the slope of the channel and how much length of the channel will be protected. While this technique will be one of the most visible and least natural appearances, it has the potential to be one of the least invasive in regards to the footprint of the work. This technique could provide stabilization to a reach and only disturb 15% or less of the reach. The riprap could also be covered with soil and seeded. There are also water quality benefits to these check dams. The temporary pools above the check dams allow a place for sediment to deposit.

Figure 5: Potential Stabilization - Lower portion of the Lower East Ravine



*This figure reproduced from McCullah and Gray, 2005.

12. **Contamination/Hazardous Materials/Wastes:**
   a. **Pre-project site conditions - Describe existing contamination or potential environmental hazards on or in close proximity to the project site such as soil or ground water contamination, abandoned dumps, closed landfills, existing or abandoned storage tanks, and hazardous liquid or gas pipelines. Discuss any potential environmental effects from pre-project site conditions that would be caused or exacerbated by project construction and operation. Identify measures to avoid, minimize or mitigate adverse effects from existing contamination or potential environmental hazards. Include development of a Contingency Plan or Response Action Plan.**

   The Project is not near any abandoned dumps, closed landfills, or existing or abandoned storage tanks. There is a natural gas pipeline owned by the Northern Natural Gas Company that bisects Ravine Lake Park, approximately mid-way through the north reach of the ravine, located just south of the Washington County South Service Center Site.

   There is one known existing perfluorochemical contamination site adjacent to the 3M facility within the most southerly extent the Project Area. The contamination was the result of historic 3M manufacturing and discharge activities. The perfluorochemicals accumulated as a result of permitted discharge of process water through a series of ponds and ditches, after passing through the wastewater treatment plant. 3M is currently implementing a clean-up plan to remove the perfluorochemical-impacted sediment from the ponds and ditches. Contaminated sediment has been removed from the site, and remediation activities, including a wetland restoration, are ongoing within the most southerly extent of the contaminated areas, just upstream of the outlet to the Mississippi River.

   The Project proposes channel stabilization measures upstream of the historically contaminated area. The channel stabilization features will be designed with consideration of the ongoing remediation efforts. Channel stabilization measures will be designed and constructed to support the integrity of the ongoing remediation and restoration project, and will not undermine 3M's efforts.

   b. **Project related generation/storage of solid wastes - Describe solid wastes generated/stored during construction and/or operation of the project. Indicate method of disposal. Discuss potential environmental effects from solid waste handling, storage and disposal. Identify measures to avoid, minimize or mitigate adverse effects from the generation/storage of solid waste including source reduction and recycling.**

   The Project does not involve generation or storage of solid wastes.

   c. **Project related use/storage of hazardous materials - Describe chemicals/hazardous materials used/stored during construction and/or operation of the project including method of storage. Indicate the number, location and size of any above or below ground tanks to store petroleum or other materials. Discuss potential environmental effects from accidental spill or release of hazardous materials. Identify measures to avoid, minimize or mitigate adverse effects from the use/storage of chemicals/hazardous materials including source reduction and recycling. Include development of a spill prevention plan.**

There will be no storage of hazardous materials within the Project area. Excavation, construction, and installation of the Project's Phases will require machinery and equipment that may be fueled by gasoline and diesel. There will be no storage of any chemicals/hazardous materials on-site. Any accidental releases of fuel from the machinery or equipment will follow Minnesota Pollution Control Agency guidelines; petroleum spills of more than five gallons must be reported to the Minnesota Duty Officer. Small spills, less than 50 gallons shall be stopped, if possible, and contained and recovered. A spill prevention plan is not planned to be developed for this Project.

d. Project related generation/storage of hazardous wastes - Describe hazardous wastes generated/stored during construction and/or operation of the project. Indicate method of disposal. Discuss potential environmental effects from hazardous waste handling, storage, and disposal. Identify measures to avoid, minimize or mitigate adverse effects from the generation/storage of hazardous waste including source reduction and recycling.

There will be no generation or storage of hazardous wastes with this Project.

13. Fish, wildlife, plant communities, and sensitive ecological resources (rare features):

a. Describe fish and wildlife resources as well as habitats and vegetation on or in near the site.

<u>Fish</u>
A fish survey of Ravine Lake was completed by the MN Department of Natural Resources in 2003. The survey identified an abundance Sunfish and Largemouth Bass population. Less abundant populations of Bluegill, Black Crappie, Largemouth Bass, and Walleye were also identified. No other fish resources are present within the Project Extent; however the Mississippi River, where the project connects, will maintain similar fish populations as those described for Ravine Lake. Additional fish species present in the Mississippi River at this location may include: Walleye, Sauger, Smallmouth, Largemouth and White Bass, Bluegill, Crappie, Northern Pike, and Catfish.

<u>Wildlife resources and habitats</u>
Wildlife and wildlife resources within the Project extents are typical of a suburban landscape. Common wildlife species include striped and spotted skunks, short and long-tailed weasel, coyotes, woodchucks, raccoons, ground squirrels, chipmunks, moles, gophers, bats, voles, rats, porcupines, mice and shrews. Common birds include American kestrel, killdeer, rock dove, mourning dove, common flicker, red-headed woodpecker, horned lark, tree swallow, barn swallow, blue jay, American robin, house wren, starling, house sparrow, red-wind blackbird, common grackle, brown headed cowbird, and American goldfinch. Herons, egrets, hawks and eagles can be frequently observed within the vicinity of Ravine Lake. No Wildlife Management Areas are found within the Project extents.

<u>Vegetation</u>
The northern first mile of the Project Extent is in agriculture production. The next 1.5 miles extend through Ravine Park, where the plant communities are generally described as Oak forest. Ravine Lake is an open water community, and the northern shoreline of Ravine Lake is a Shallow Marsh community. As the Project Extent continues across Highway 61, the ravine becomes a

steeper and more deeply cut, however the adjacent plant community remains forested as it connects to the Mississippi River.

Generally, the forested community within the Project area is a wet-mesic hardwood forest system. The area is represented by a dense canopy of deciduous trees over shade-adapted shrub and herbaceous layers. A dense layer of invasive shrub species, including buckthorn and honeysuckle is present. Much of the herbaceous layer is dominated by a state noxious weed garlic mustard.

Other area within the Project extents include dry, open areas that were cleared for utilities, including an underground pipeline and an aboveground transmission line. Additionally, a cultivated pine area is present within Ravine Lake Park.

b. Describe rare features such as state-listed (endangered, threatened or special concern) species, native plant communities, Minnesota County Biological Survey Sites of Biodiversity Significance, and other sensitive ecological resources on or within close proximity to the site. Provide the license agreement number (LA-677) and/or correspondence number (ERDB _____________) from which the data were obtained and attach the Natural Heritage letter from the DNR. Indicate if any additional habitat or species survey work has been conducted within the site and describe the results.

The MN DNR (Natural Heritage & Nongame Research Program) Rare Natural Features GIS data was researched to prepare a summary of features within and close to the proposed Project extents. The following discusses the species and communities that were identified, and a summary is provided in **Table 10**.

<u>Western Foxsnake</u>
The Western Foxsnake does not have a special status in Minnesota; however it was identified as being on the watchlist. The habitat is often along riparian habitats, upland hardwood forests, and other upland communities adjacent to a river or stream. See Appendix D for the MnDNR Fact Sheet.

<u>Blandings Turtle</u>
The Blandings Turtle is listed as Threatened in Minnesota. The habitat includes sandy uplands adjacent to wetlands and shallow aquatic habitats. Habitat fragmentation is the largest threat to their populations. High mortality exists in the population from turtles crossing roadways, to travel from their nesting sites to adjacent aquatic habitats. See Appendix D for the MnDNR Environmental Review Fact Sheet.

<u>Kitten Tails</u>
Kitten tails are a Threatened vascular plant species in Minnesota. Habitat includes dry prairies, woods and barrens.

<u>Long-Bearded Hawkweed</u>
Long-Bearded Hawkweed does not have any special status in Minnesota, however it is listed on the watchlist. Habitats include dry, sandy soil, prairies and open woods.

Paddlefish

The paddlefish is native to the Mississippi River Basin, and is listed as Threatened in Minnesota. Threats to the paddlefish population likely include habitat degradation and loss and dam construction that limits their navigation to complete their life cycle. See Appendix D for the MnDNR Fact Sheet.

Mississippi River Mussels

The following mussel species were identified within the database, as existing in the Mississippi River in the vicinity of the Project Extent: butterfly, spike, monkeyface, wartyback, rock pocketbook, Higgins eye, round Pigtoe, Black Sandshell, Ebonyshell, and Hickorynut. All of these species are threatened by a decline in habitat on the Mississippi River associated with its management as a navigational canal as well as increase sedimentation from runoff and channel dredging and channelization. See Appendix D for the MnDNR Fact Sheets.

Bald Eagle

While no longer listed, bald eagles may be present in the area during migrations. It is protected by the Eagle Protection Act and the Migratory Bird Treaty Act. No critical habitat for these species is present within or immediately adjacent to the Project Extents. See Appendix D for the MnDNR Fact Sheets.

Table 10: Rare Features Identified within and outside of the Project Extents (LA # 677)

Location	Common Name	Scientific Name	Category	MN Status
In Project Extents	Western Foxsnake	*Elaphe vulpina*	Vertebrate Animal	Watchlist
In Project Extents	Blandings Turtle	*Emydoidea blandingii*	Vertebrate Animal	Threatened
In Project Extents	Kitten Tails	*Besseya bulli*	Vascular Plant	Threatened
In Project Extents	Dry Sand – Gravel Prairie (Southern)	--	Ecological	--
In Project Extents	Northern Bulrush - Spikerush Marsh	--	Ecological	--
Outside Project Extents	Long Bearded Hawkweed	*Hieracium longipilum*	Vascular Plant	Watchlist
Mississippi River*	Paddlefish	*Polyodon spathula*	Vertebrate Animal	Threatened
Mississippi River*	Butterfly	*Ellipsaria lineolata*	Invertebrate Animal	Threatened
Mississippi River*	Spike	*Elliptio dilatata*	Invertebrate Animal	Threatened
Mississippi River*	Monkeyface	*Quadrula metanevra*	Invertebrate Animal	Threatened

Mississippi River*	Wartyback	*Quadrula nodulata*	Invertebrate Animal	Threatened
Mississippi River*	Rock Pocketbook	*Arcidens confragosus*	Invertebrate Animal	Endangered
Mississippi River*	Bald Eagle	*Haliaeetus leucocephalus*	Vertebrate Animal	Watchlist
Mississippi River*	Higgins Eye	*Lampsilis higginsii*	Invertebrate Animal	Endangered
Mississippi River*	Round Pigtoe	*Pleurobema sintoxia*	Invertebrate Animal	Special Concern
Mississippi River*	Black Sandshell	*Ligumia recta*	Invertebrate Animal	Special Concern
Mississippi River*	Ebonyshell	*Fusconaia ebena*	Invertebrate Animal	Endangered
Mississippi River*	Hickorynut	*Obovaria olivaria*	Invertebrate Animal	Watchlist
*within 1.5 miles of ravine channel outlet, and upstream of Lock and Dam No. 2.				

Native Plant Communities

Minnesota County Biological Survey (MCBS) identified several Native Plant Communities present within the Project extents (**Attachment 16**). These communities include Oak (Red Maple) Woodland which exists through Ravine Park, Northern Bulrush – Spikerush Marsh located within and around the fringes of Ravine Lake, and Dry Sand – Gravel Oak Savanna (Southern), which is present on the most southern end of the Project extents, adjacent to the ravine prior to its junction with the Mississippi River.

MCBS Sites of Biodiversity Significance

Two (2) Sites of Biodiversity Significance, as identified by the MBCS, exist partially within the Project extents (**Attachment 16**). In the Northern Reach, the Cottage Grove Ravine Lake Park has been identified as having moderate biodiversity significance. Moderate biodiversity significance is described as sites containing occurrences of rare species, moderately disturbed native plant communities, and landscapes that have a strong potential for recovery. In the Lower East Ravine, Cottage Grove 35 West is identified as a site with moderate biodiversity significance. An additional site is located just north of Cottage Grove 35, was included in the data, however it was not identified as being significant, as it was noted to be below minimum thresholds.

Regional Corridors and Environmentally Significant Areas (**Attachment 16**)

The Minnesota County Biological Survey, executed by the MnDNR, collected and interpreted ecological data throughout the state, and identifies quality habitat, native plant communities, and identifies corridors connecting these features to guide the decision making process.

Ravine Lake Park, and two other sites south of Highway 61 have been identified as Regionally Significant Ecological Areas (**Attachment 16**). These sites have been rated a “1”, defined as “sites that are smaller in size…may have less diversity of vegetation cover types, may have more adjacent cover types or land uses that could adversely affect the area, or may be an isolated plant community mapped and given a moderate score by the MCBS.”

As part of the initial phases of this proposed Project, several tree inventories have taken place within the wooded portions of the ravine, including within Ravine Lake Park (Ravine Lake Environmental Memo, 2013). The original tree inventory was conducted in 2002 and was updated in the summer of 2013.

c. Discuss how the identified fish, wildlife, plant communities, rare features and ecosystems may be affected by the project. Include a discussion on introduction and spread of invasive species from the project construction and operation. Separately discuss effects to known threatened and endangered species.

The project includes three separate unique phases, as described previously, for the purposes of providing a controlled conveyance to meet current and future stormwater needs from surrounding developed lands. These three phases (see **Attachment 1**) include:

1. Phase II & IV: the ravine stabilization / restoration activities throughout Ravine Lake Park and to the south to the Mississippi River.

2. Phase III: the replacement of the outlet structure at the south side of Ravine Lake;

3. Phase V: the CDSF Overflow Conveyance pipe construction that connects the previously constructed CDSF project from the north to the ravine channel,

<u>Phase II and IV: Ravine Stabilization:</u> The purpose of these phases is to construct ravine stabilization techniques to correct the current erosion and sedimentation risks that exist within the ravine. Phase II and IV will also provide stabilization for future stormwater overflows, as upstream development and build out continues into the future.

No negative impacts to fish are anticipated from the construction or function of Phase II and IV. The stabilization of the ravine will minimize sedimentation and nutrient delivery into Ravine Lake and the Mississippi River. Ravine stabilization measures may result in water quality improvements to Ravine Lake.

Wildlife may temporarily be impacted during construction. Heavy equipment and other machinery may be used to implement the ravine stabilization plan, which may temporarily draw wildlife species away from the area. Due to the quality habitat that is currently and will remain intact, wildlife species will return quickly after construction activities have ended.

Ravine stabilization methods range depending on the modeled shear stress and velocity erosion potential for each individual modeled segment. Methods for ravine stabilization will include a combination of vegetation management, construction of a lined channel, lining the existing channel, and the construction of check dams, so variability exists when defining potential plant community, rare features and ecosystem impacts. Tree clearing activities will likely be necessary in areas along the ravine, to allow for vegetation management and channel and check dam construction. The width of tree clearing will be limited to the estimated 150 foot construction right-of-way of the ravine channel bottom. No significant change in the overall ecosystem function of Ravine Lake Park or habitat loss within Ravine Lake Park, is anticipated by these activities. These stabilization activities do not interrupt the various ecological corridors, or lower biodiversity of the Ravine Lake site that was identified by the MCBS. Moreover, a portion of the ravine stabilization will include restoration via management of the invasive (buckthorn) shrub layer. No rare, threatened or endangered plant species were identified within the ravine construction footprint, or within those plant communities represented within the ravine stabilization area. Based on the surrounding landscape, it is not anticipated that these tree clearing activities will have an impact on the overall park ecosystem, habitat or plant community.

<u>Phase III: Ravine Lake Outlet Structure:</u>
Phase III of the Project entails the removal of the current control structure and the existing park access road, and the restoration within Ravine Lake where the current control structure / road exists. The new proposed control structure, along with the park access road, will be moved to the south around the most southerly shore of Ravine lake. Wildlife may be temporarily displaced during construction, but are expected to return quickly after construction ends. No permanent negative impacts are expected to wildlife, fish, rare features, ecosystems, or plant communities. The outlet structure will be placed at the same elevation, so lake water elevations will not change from the current condition.

A small amount of tree clearing will likely be necessary to provide an appropriate right of way for the park access road reroute and new outlet structure. Based on the surrounding landscape, it is not anticipated that these tree clearing activities will have an impact on the overall park ecosystem, habitat or plant community.

<u>Phase V: the CDSF Overflow Conveyance pipe construction</u>
No direct permanent impacts to fish, plant communities, rare species or ecosystems are anticipated from the construction of the CDSF Overflow Conveyance pipe. Wildlife may be displaced temporarily during construction activities, but are expected to return once construction is complete. The area where the pipe is to be constructed is currently in agricultural production, so no impacts to native plant communities or ecosystems are expected.

Indirectly, the pipe installation will connect the previously constructed upstream CD-P86 South Lobe to the entire ravine channel.

d. Identify measures that will be taken to avoid, minimize, or mitigate adverse effects to fish, wildlife, plant communities, and sensitive ecological resources.

No specific mitigation is identified with this project. The project is being designed to minimize and avoid the potential for significant effects from erosion and sedimentation that already exist and provides mitigation for current impacts to the natural resource communities by targeting the practices to the appropriate locations. The practices are also being designed to provide natural resource benefit, by utilizing practices that blend into the existing natural communities to the maximum degree possible.

SWWD has developed a Greenway Corridor Plan that includes the CDSF project area. The goal of the greenway is to create a multipurpose system of open space that provides a physical link to existing natural areas while also providing for the conveyance of stormwater runoff. Key functions of the SWWD Greenway Corridor include: connection of important natural areas, active and passive recreational opportunities, fish and wildlife habitat, rare species habitat, groundwater recharge, water quality protection, environmental education and erosion control. The CDSF project will provide the physical land connection necessary to continue the development of the restoration and connectivity elements of the greenway. This connection will provide a missing link between the Lake Elmo Park Reserve and Ravine Lake Regional Park.

14. Historic properties:
Describe any historic structures, archeological sites, and/or traditional cultural properties on or in close proximity to the site. Include: 1) historic designations, 2) known artifact areas, and 3) architectural features. Attach letter received from the State Historic Preservation Office (SHPO). Discuss any anticipated effects to historic properties during project construction and operation. Identify measures that will be taken to avoid, minimize, or mitigate adverse effects to historic properties.

Letter of request of a review of the archaeological and historic database for the Project area was sent by email to the State Historic Preservation Office, Monday, January 20, 2014. The results of the database search provided a listing of recorded archaeological sites and historic architectural properties that are included in the current SHPO databases (see **Appendix E** for correspondence). The Cottage Grove Ravine is listed within the inventory. The remainder of the identified items are nearby, but outside the Project boundary and will not be impacted by or during the construction phases of the Project.

In regards to the Cottage Grove Ravine, anticipated effects of the Project to this area will not be negative nor degrading the area below current environmental conditions.

15. Visual:
Describe any scenic views or vistas on or near the project site. Describe any project related visual effects such as vapor plumes or glare from intense lights. Discuss the potential visual effects from the project. Identify any measures to avoid, minimize, or mitigate visual effects.

The park master plan describes the area encompassed within the park as "a land area with impressive natural landscapes." The Park offers a natural area for the public with a trail systems and other facilities and amenities. Aside from the park, there are no other specifically designated scenic views or vistas. Potential project related visual effects would be limited to 1) construction and installation associated with the overflow conveyance pipe and the Ravine Lake outlet, and 2) erosion control measures and stabilization work within the ravine.

Construction of the Ravine Lake outlet and the CDSF Overflow Conveyance pipe will include heavy machinery, equipment and other construction vehicles. Emissions plumes from machinery and equipment should be expected, but neither excessive nor impacting visibility within the area. It is not expected that construction will be taking place during the night, so glare from intense lights will be minimal, if any. Visual impacts associated with the project phases are mainly temporary, as they relate to construction and will be during the planned construction periods/years as described in the Project Description.

Visual effects from ravine stabilization will vary based on the stabilization measure chosen. As there are a suite of possible techniques that may be implemented and visual impacts will be related to the degree of invasiveness of the stabilization feature to be installed. Visual effects from installation and final-implemented stabilization within the ravine are changes made within the ravine to enhance the area; therefore visual impacts will not be adverse.

16. Air:

a. Stationary source emissions - Describe the type, sources, quantities and compositions of any emissions from stationary sources such as boilers or exhaust stacks. Include any hazardous air pollutants, criteria pollutants, and any greenhouse gases. Discuss effects to air quality including any sensitive receptors, human health or applicable regulatory criteria. Include a discussion of any methods used assess the project's effect on air quality and the results of that assessment. Identify pollution control equipment and other measures that will be taken to avoid, minimize, or mitigate adverse effects from stationary source emissions.

There are no stationary sources resulting from this Project.

b. Vehicle emissions - Describe the effect of the project's traffic generation on air emissions. Discuss the project's vehicle-related emissions effect on air quality. Identify measures (e.g. traffic operational improvements, diesel idling minimization plan) that will be taken to minimize or mitigate vehicle-related emissions.

The effect of the project's traffic generation on air emissions will be minimal and temporary. Air emissions calculations are not estimated for the project since traffic generation is confined to the construction and installation periods of the Project's phases. No additional measures have been developed or are planned to minimize or mitigate vehicle-related emissions.

c. **Dust and odors - Describe sources, characteristics, duration, quantities, and intensity of dust and odors generated during project construction and operation. (Fugitive dust may be discussed under item 16a). Discuss the effect of dust and odors in the vicinity of the project including nearby sensitive receptors and quality of life. Identify measures that will be taken to minimize or mitigate the effects of dust and odors.**

Dust and odors will only be generated during the construction periods of the Project. Each phase of the Project is different and varies in amount of equipment and machinery necessary to complete project tasks. Sources of dust and odors are from the equipment and machinery, including vehicles that temporarily operate on-site. There are no immediate residential dwellings within the area, therefore citizen disturbances will be limited to those visiting the park area during construction. Dust control measures will be implemented during construction to minimize any disturbance. Odor disturbances will be limited to the construction equipment emissions, and will only occur within the immediate construction area.

17. Noise

Describe sources, characteristics, duration, quantities, and intensity of noise generated during project construction and operation. Discuss the effect of noise in the vicinity of the project including 1) existing noise levels/sources in the area, 2) nearby sensitive receptors, 3) conformance to state noise standards, and 4) quality of life. Identify measures that will be taken to minimize or mitigate the effects of noise.

Heavy machinery and other construction related vehicles will be a source of temporary, low to high intensity noise during the construction periods of each phase of the Project. Duration will be temporary and limited to the construction periods/years as outlined within the Project Description. The effect of the noise generated is not anticipated to be a conflict with current conditions within the area and there will be no long term noise effects. Noise levels will remain in conformance to state noise standards. It is not projected that the construction necessary to implement these stormwater management project phases will negatively impact the quality of life for those living around the Project area. Additional measures may be taken to limit and mitigate noise to the most practicable extent upon further defining phase plans for permitting.

18. Transportation

a. Describe traffic-related aspects of project construction and operation. Include: 1) existing and proposed additional parking spaces, 2) estimated total average daily traffic generated, 3) estimated maximum peak hour traffic generated and time of occurrence, 4) indicate source of trip generation rates used in the estimates, and 5) availability of transit and/or other alternative transportation modes.

No additional parking spaces are involved with the Project.

During construction of each Project phase, there may be an increase in traffic flux, which will disappear after each Phase has been implemented. It is projected that the total average daily traffic generated by the project will not affect current traffic flows. No estimates of total average traffic or maximum peak hour traffic have been generated at this time.

b. Discuss the effect on traffic congestion on affected roads and describe any traffic improvements necessary. The analysis must discuss the project's impact on the regional transportation system.
If the peak hour traffic generated exceeds 250 vehicles or the total daily trips exceeds 2,500, a traffic impact study must be prepared as part of the EAW. **Use the format and procedures described in the Minnesota Department of Transportation's Access Management Manual, Chapter 5** ***(available at: http://www.dot.state.mn.us/accessmanagement/resources.html)*** **or a similar local guidance,**

The project will have no effect on traffic congestion. The project will not exceed the daily peak hour vehicle or total daily trips.

c. Identify measures that will be taken to minimize or mitigate project related transportation effects.

No mitigation measures are proposed.

19. Cumulative potential effects: (Preparers can leave this item blank if cumulative potential effects are addressed under the applicable EAW Items).

a. Describe the geographic scales and timeframes of the project related environmental effects that could combine with other environmental effects resulting in cumulative potential effects.

The project contemplates the existing and future planned condition of the development in the watershed. The methods employed are designed to accommodate the future development and cumulative effects to the flow characteristics within the East Ravine. The result of the project will be a stable and healthy ravine ecosystem, in contrast to a degrading and unstable ravine if the project is not conducted.

b. Describe any reasonably foreseeable future projects (for which a basis of expectation has been laid) that may interact with environmental effects of the proposed project within the geographic scales and timeframes identified above.

The *Cottage Grove 2030 Comprehensive Plan* is anticipated to be executed as well as the *Cottage Grove Ravine Regional Park Mast Plan* (May 2007). The timing of the increased development and park improvements are dependent on an improved housing market and on the capital improvement approvals at the county.

c. Discuss the nature of the cumulative potential effects and summarize any other available information relevant to determining whether there is potential for significant environmental effects due to these cumulative effects.

The existing condition includes a riparian corridor within and adjacent to suburban areas experiencing growth. This riparian corridor carries considerable flow following heavy rain events. The lands that contribute runoff to the ravine include mostly rural cultivated lands from the north and east. This runoff is expected to increase over time, as the surrounding areas develop. The existing channel, with steep side slopes and sandy and silty loams and loamy sands, has a high potential for erosion. Considering the future planned expansion in development and the increase and the associated increase in stormwater flow, the long term cumulative effects are an increase in the future erosion potential throughout the Project Area. The proposed Project will allow for the stormwater flows to be removed from developed areas, and with the erosion stabilization practices described previously, the increase in the erosion potential will be minimized and mitigated.

20. Other potential environmental effects: If the project may cause any additional environmental effects not addressed by items 1 to 19, describe the effects here, discuss the how the environment will be affected, and identify measures that will be taken to minimize and mitigate these effects.

RGU CERTIFICATION. *(The Environmental Quality Board will only accept **SIGNED** Environmental Assessment Worksheets for public notice in the EQB Monitor.)*

I hereby certify that:

- The information contained in this document is accurate and complete to the best of my knowledge.
- The EAW describes the complete project; there are no other projects, stages or components other than those described in this document, which are related to the project as connected actions or phased actions, as defined at Minnesota Rules, parts 4410.0200, subparts 9c and 60, respectively.
- Copies of this EAW are being sent to the entire EQB distribution list.

Signature ______________________ Date 4-9-2014

Title SWWD ADMINISTRATOR

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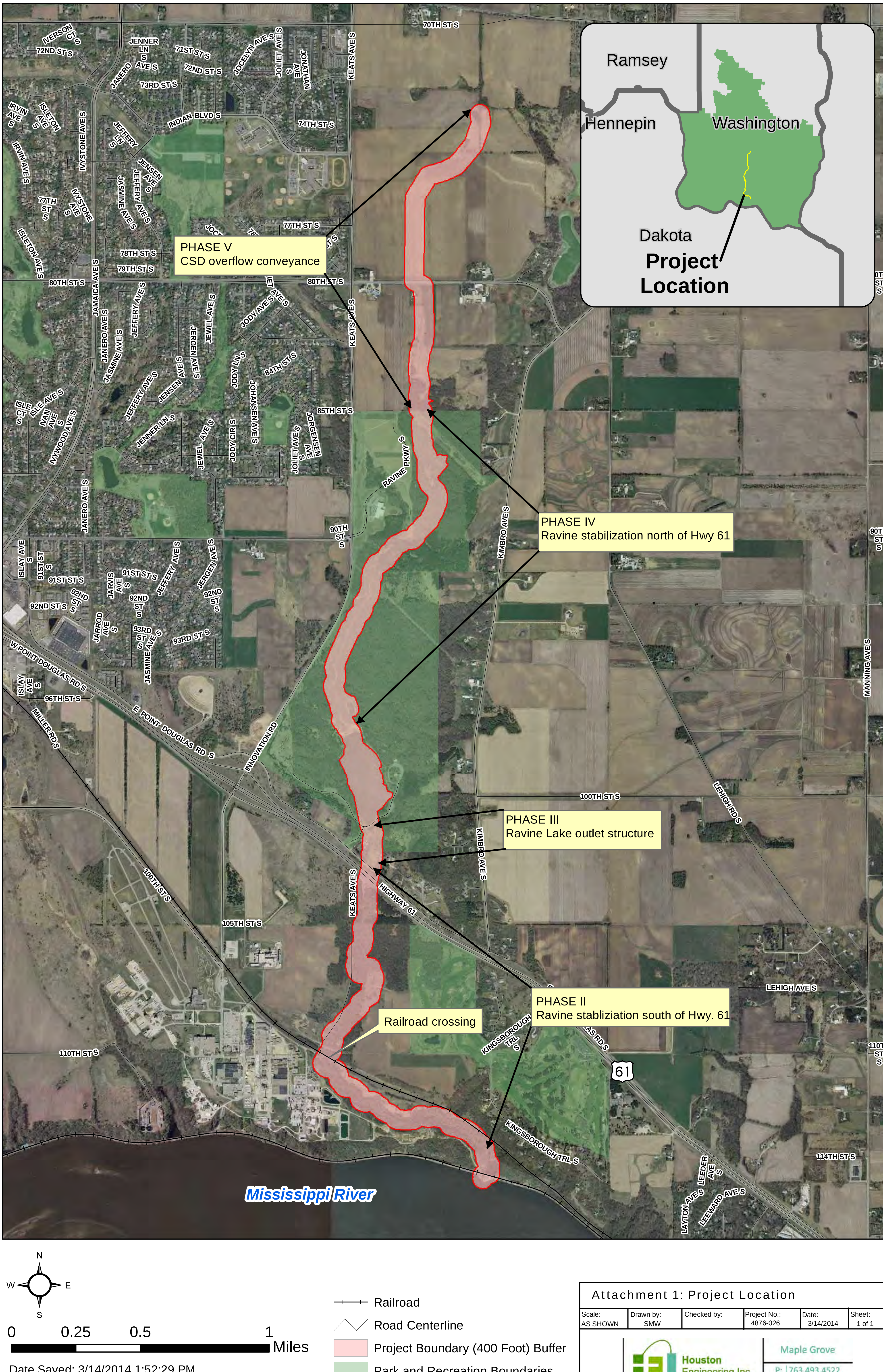

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- Railroad
- Road Centerline
- Project Boundary (400 Foot) Buffer
- Park and Recreation Boundaries

Attachment 1: Project Location

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	SMW		4876-026	3/14/2014	1 of 1

Houston Engineering Inc.
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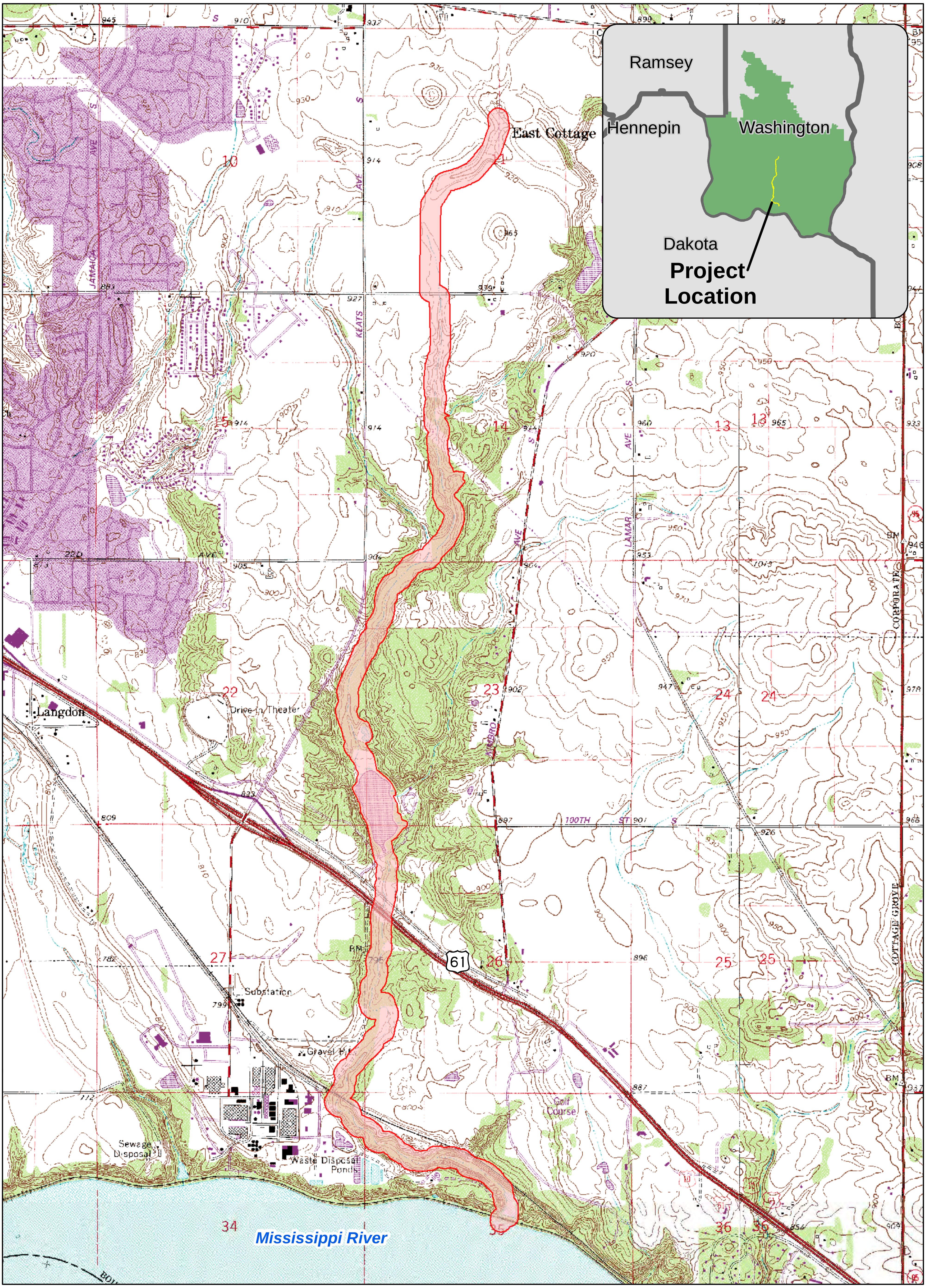
F: 763.493.5572



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Miles

Project Boundary (400 Foot) Buffer

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Attachment 2: USGS 7.5 Min. 1:24,000 Scale Project Extent Map

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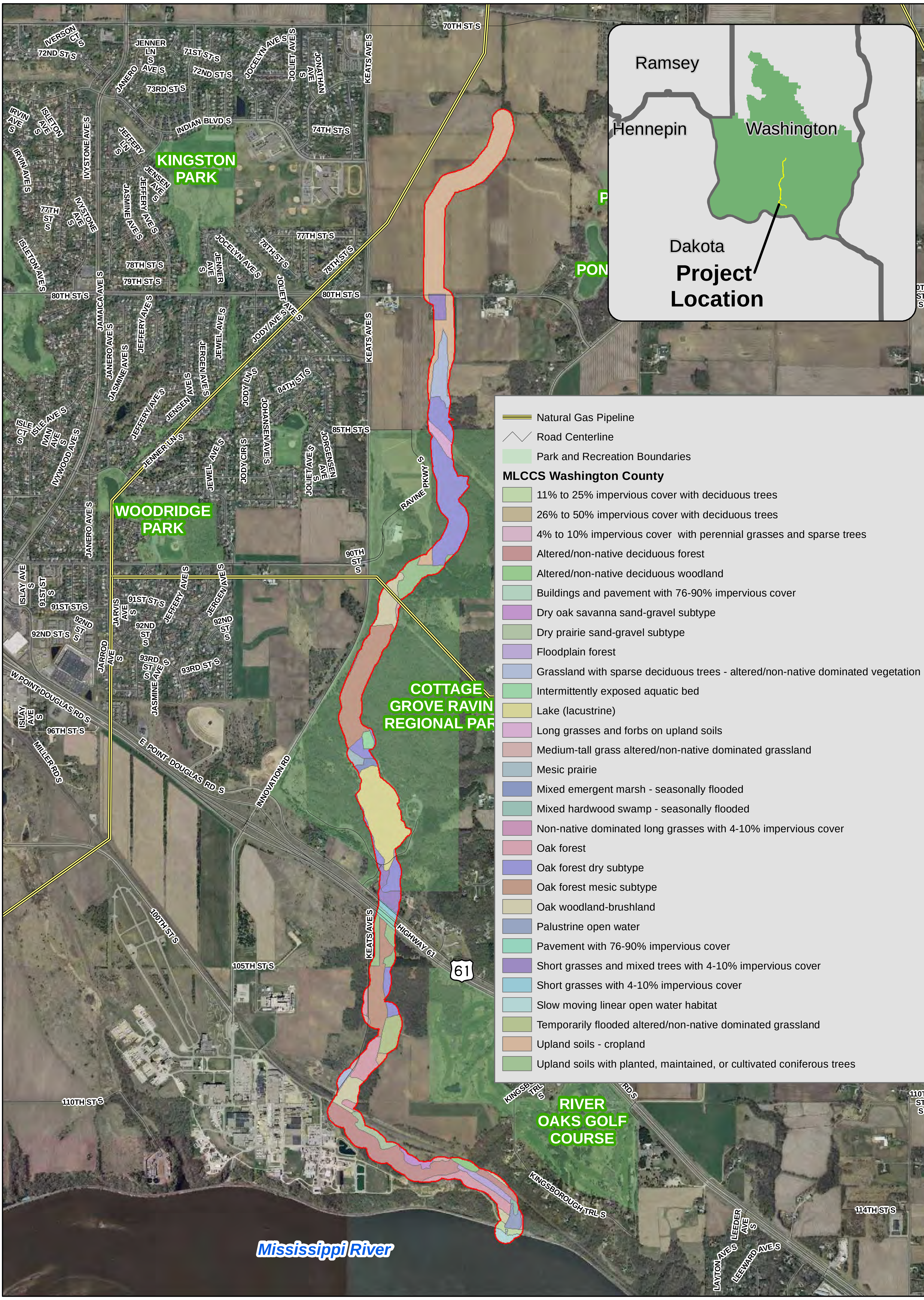

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Attachment 3: MN Land Cover Classification: Land Use

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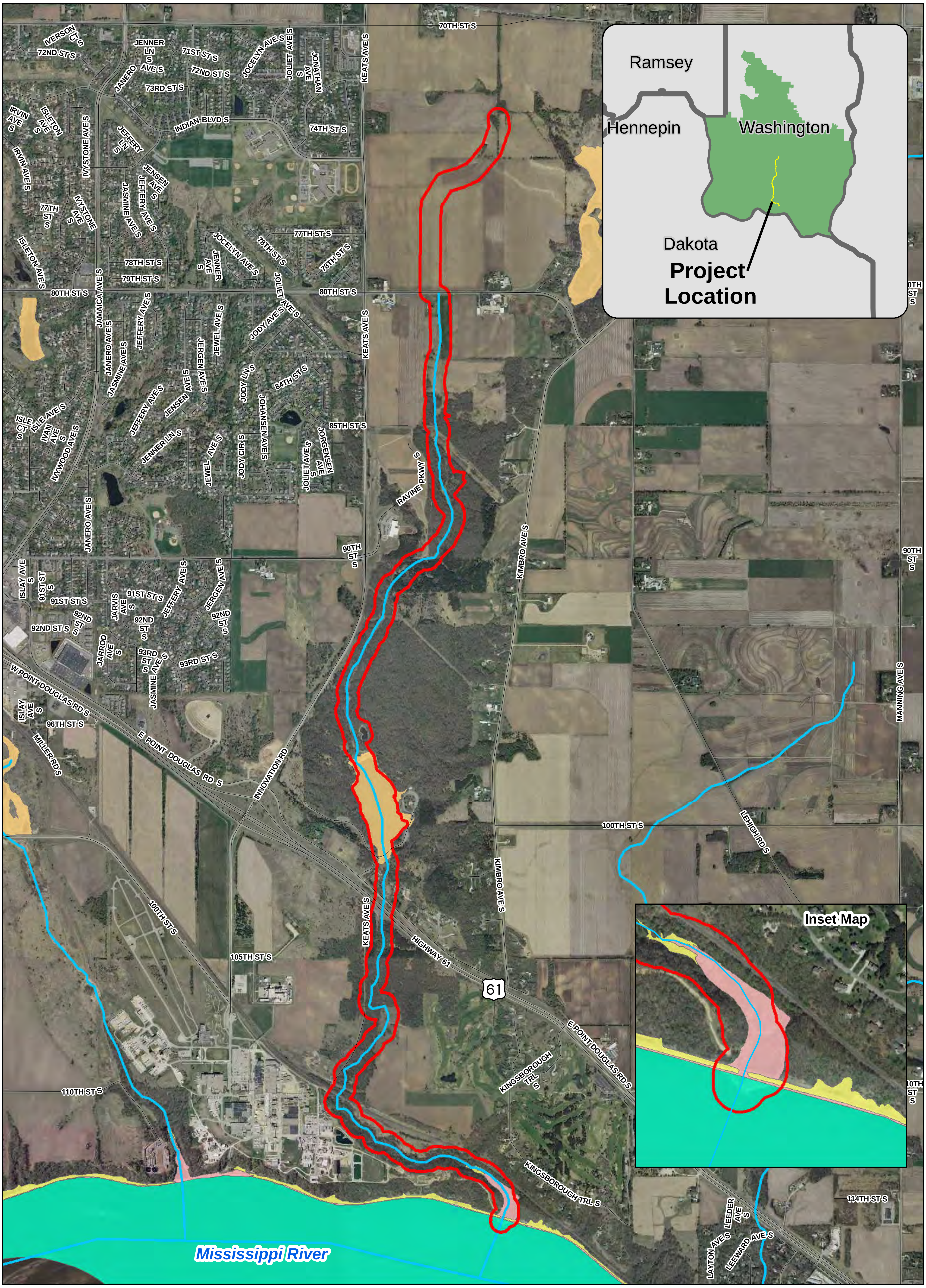
Attachment 4: City of Cottage Grove Zoning Map

Attachment 5: FEMA Floodplain Map



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Road Centerline
Project Boundary (400 Foot) Buffer
MN DNR Public Waters (Watercourses)

DFIRM Flood Zone

- 0.2 % Annual Chance Flood Hazard
- ZONE A - 1% Annual Chance
- ZONE AE - 1% Annual Chance
- ZONE AE - Floodway

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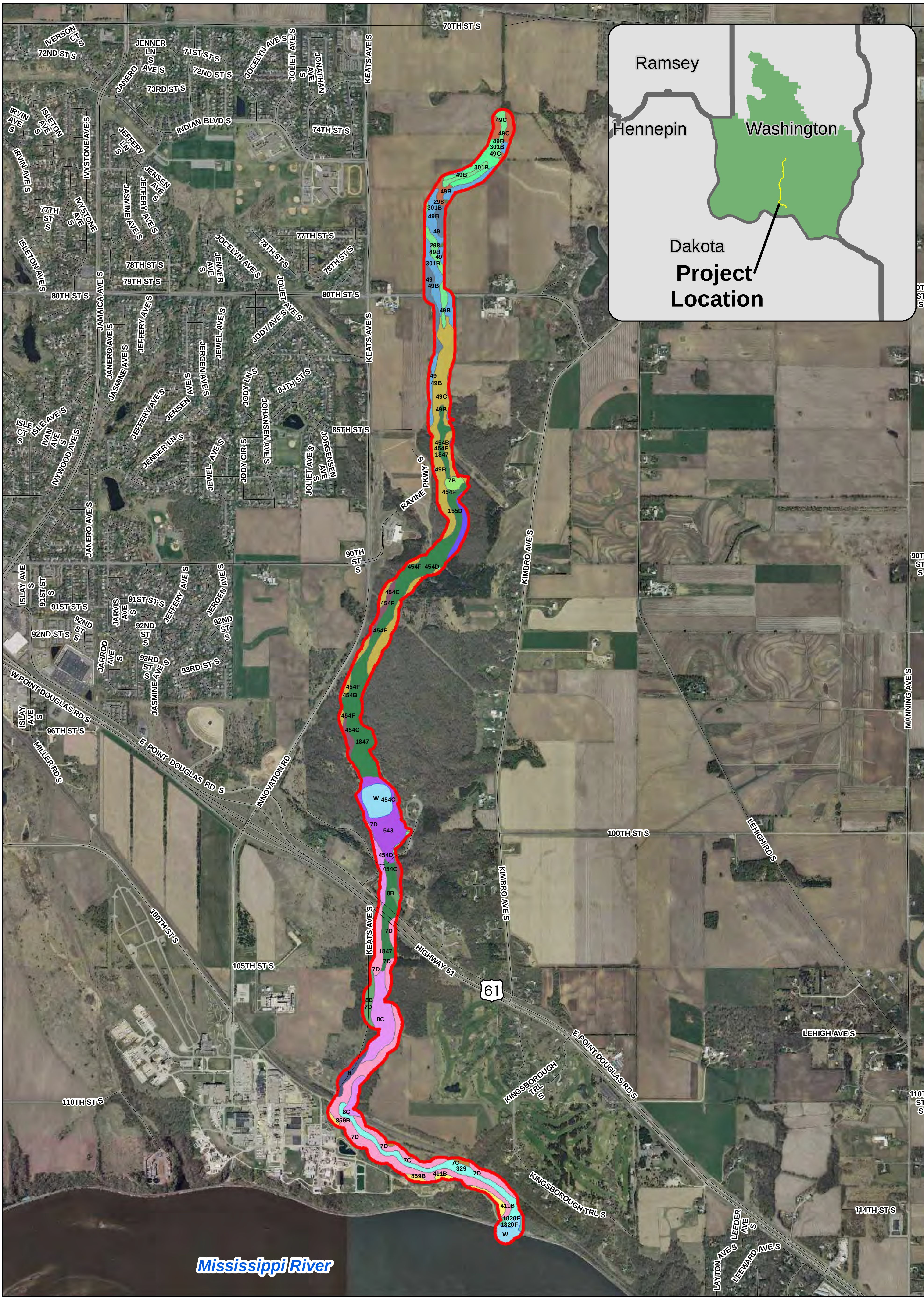

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Road Centerline

Project Boundary (400 Foot) Buffer

0 0.25 0.5 1 Miles

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Soil Symbol

155D	454B	49D	859B
1820F	454C	507	8B
1847	454D	543	8C
298	454F	7B	W
301B	49	7C	
329	49B	7D	
411B	49C	8	

Attachment 6: Washington County Soil Survey

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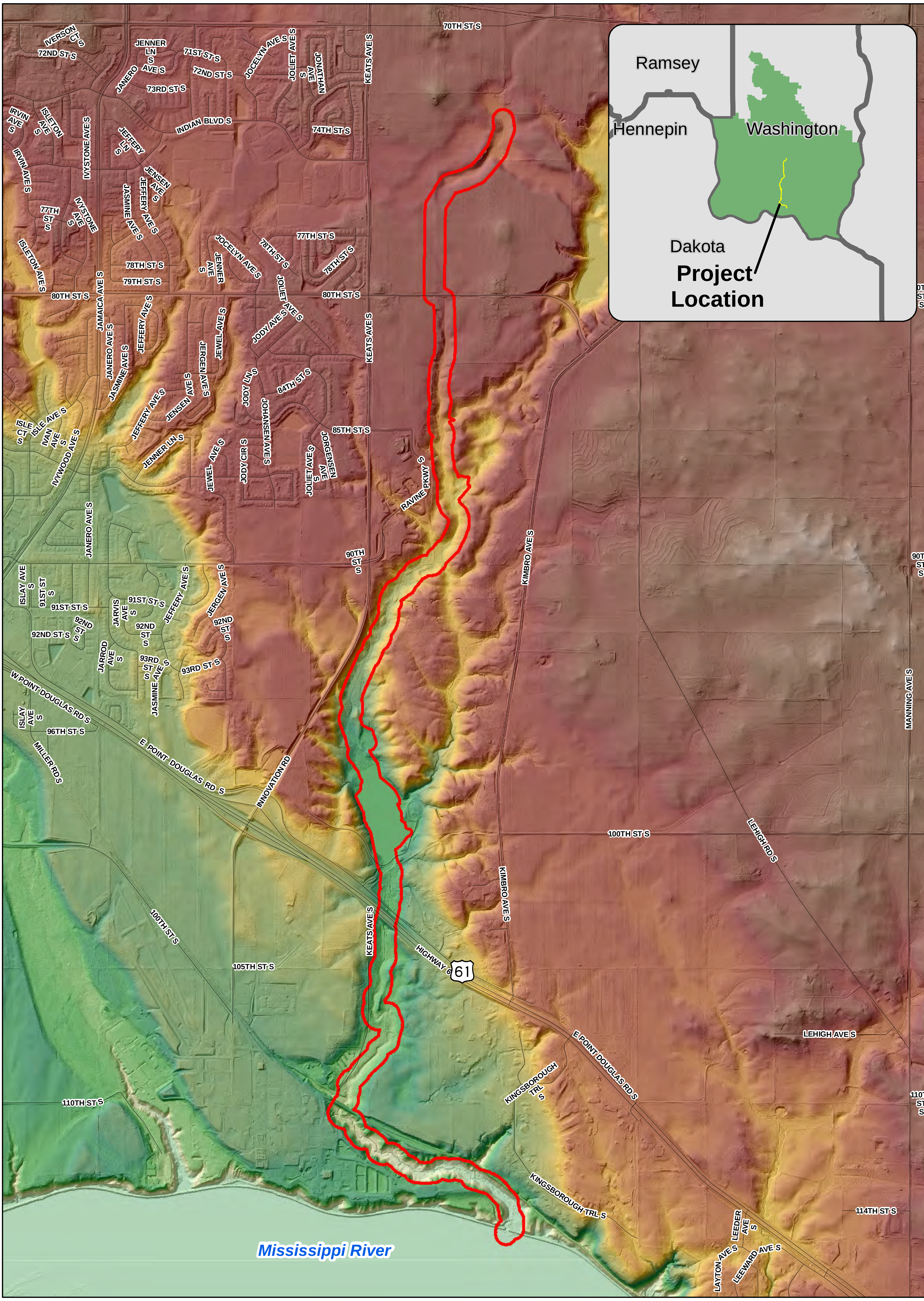

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Road Centerline

Project Boundary (400 Foot) Buffer

Digital Elevation Model (DEM) in Feet

High : 1102.18

Low : 633.079

Attachment 7: Topographic Map (LiDAR Hillshade Map)

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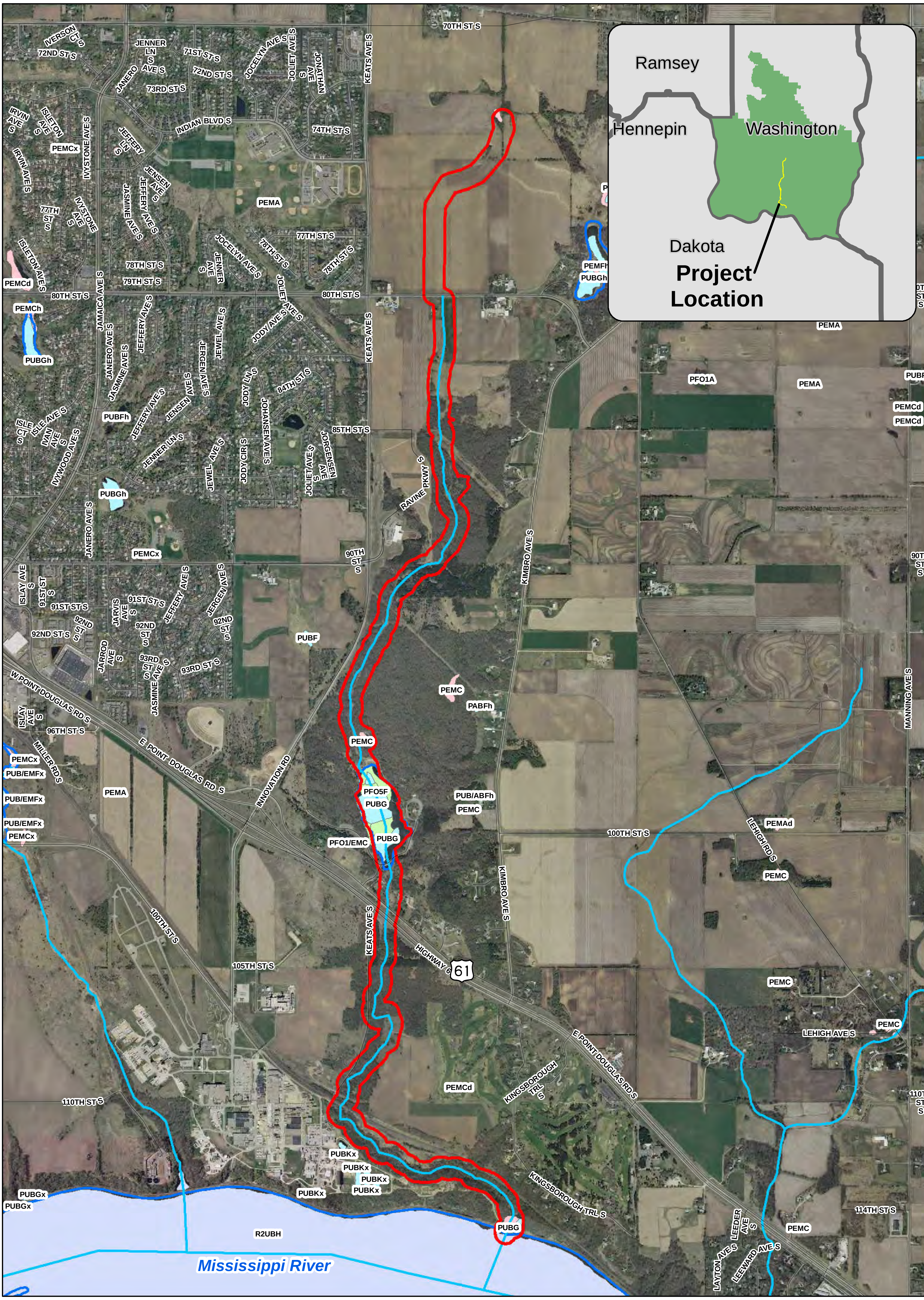

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Road Centerline
Project Boundary (400 Foot) Buffer
MN DNR Public Waters (Watercourses)
MN DNR Public Waters (Basins)

Wetland Type

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Palustrine Emergent Wetland
- Riverine

Attachment 8: NWI and PWI

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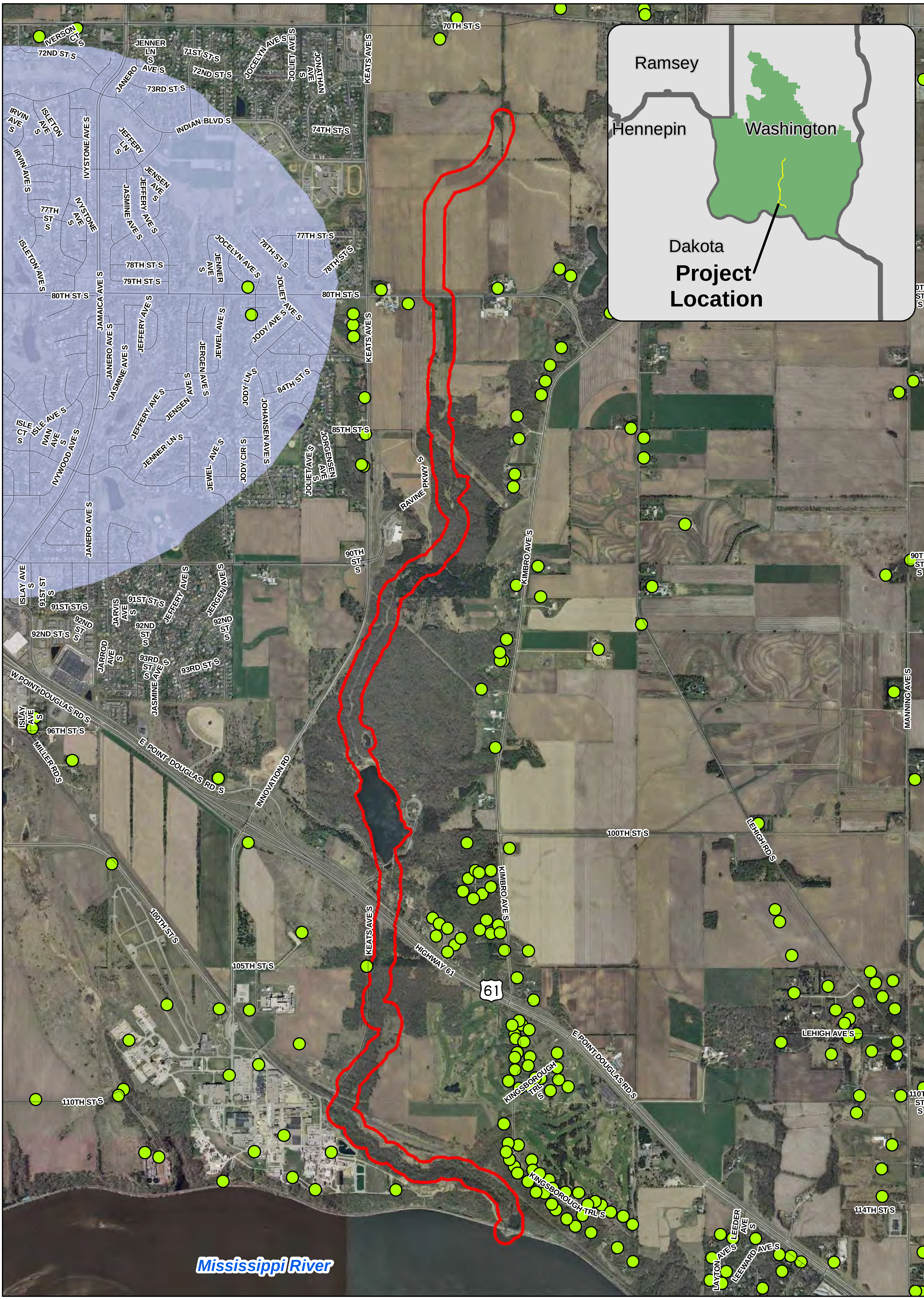

Road Centerline

County Well Index (Located and Digitized Wells)

Project Boundary (400 Foot) Buffer

Wellhead Protection Areas

N W E S

0 0.25 0.5 1 Miles

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Attachment 9: Existing Wells & Wellhead Protection Area

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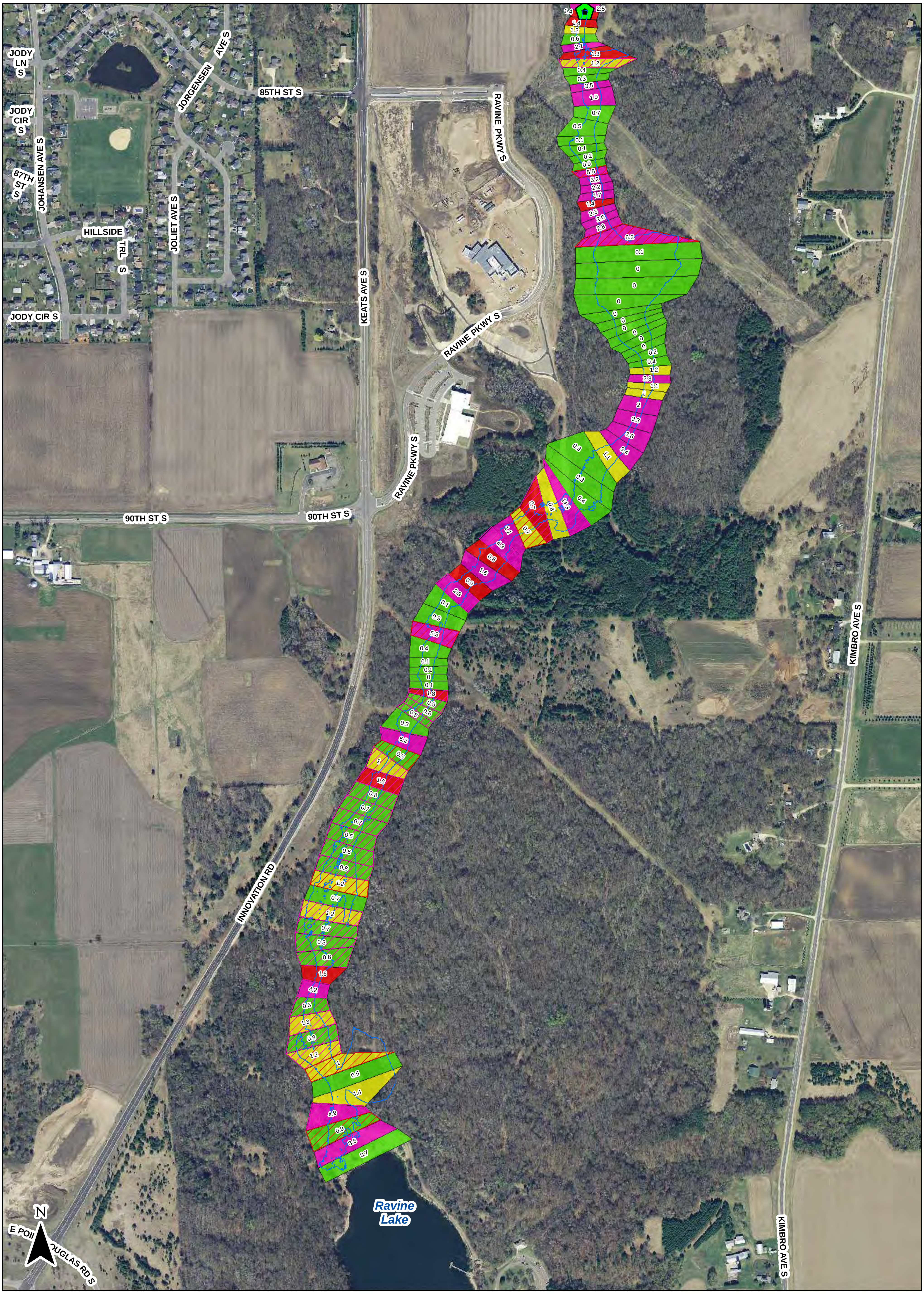

Proposed Outlet Location

Existing Conditions Flood Extent

Erosion Potential

Shear

- excesive
- high
- medium
- low

4.2 Shear Stress (lb/sq. ft.)

Erosion Potential

Velocity

- excesive
- high

0 300 600 1,200 Feet

Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

South Washington WATERSHED District

Attachment 10: Upper East Ravine-Erosion Potential for Existing Conditions					
Scale: AS SHOWN	Drawn By: SMW	Checked By:	Project No: 4876-024	Date: 11/25/2013	Sheet: 1 of 1

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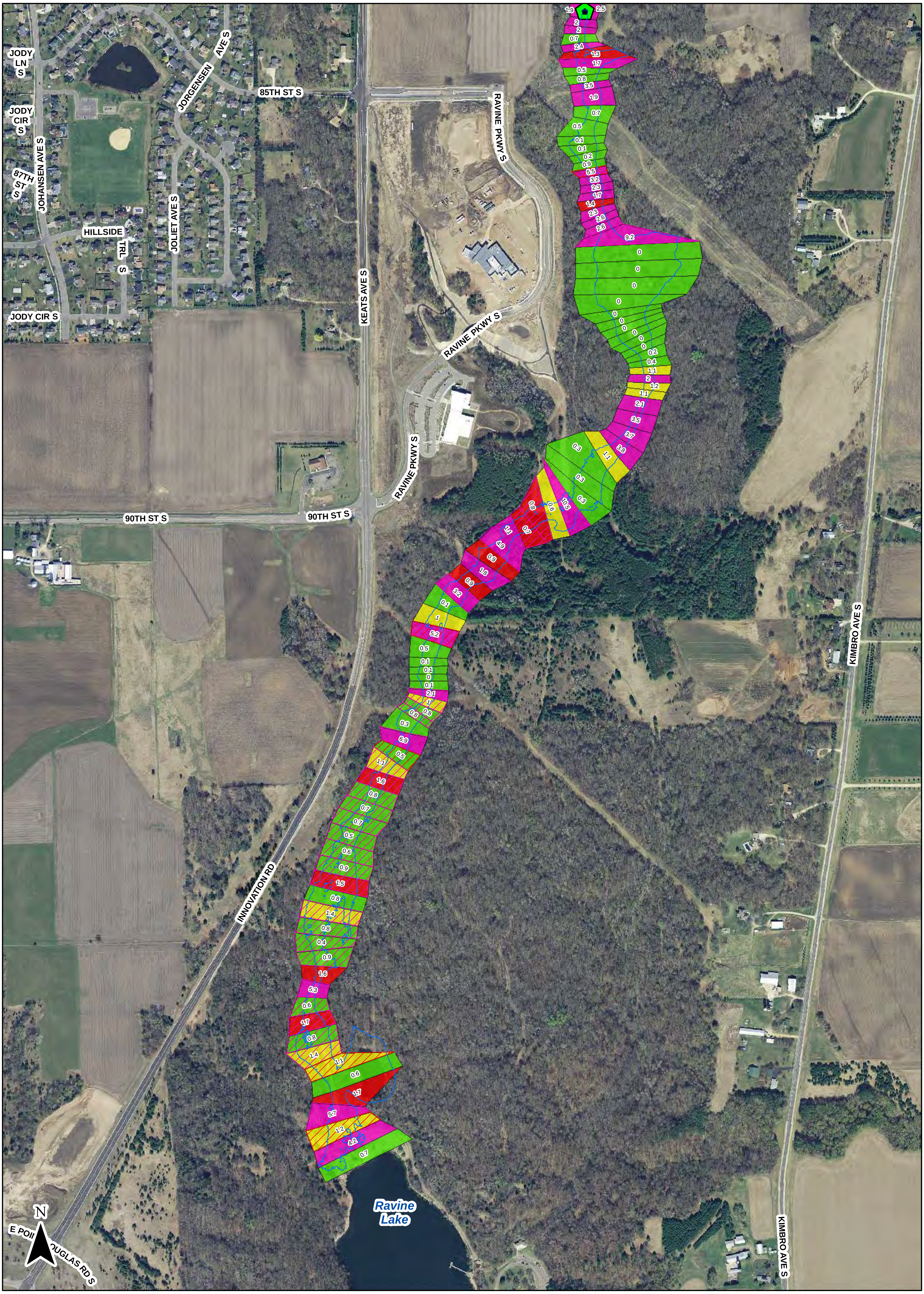

Proposed Outlet Location

Build Out Conditions Flood Extent

Erosion Potential

Shear

- excesive
- high
- medium
- low

4.2 Shear Stress (lb/sq. ft.)

Erosion Potential

Velocity

- excesive
- high

0 300 600 1,200 Feet

Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

Attachment 11: Upper East Ravine - Erosion Potential for Build Out Conditions					
Scale: AS SHOWN	Drawn By: SMW	Checked By:	Project No: 4876-024	Date: 11/25/2013	Sheet: 1 of 1

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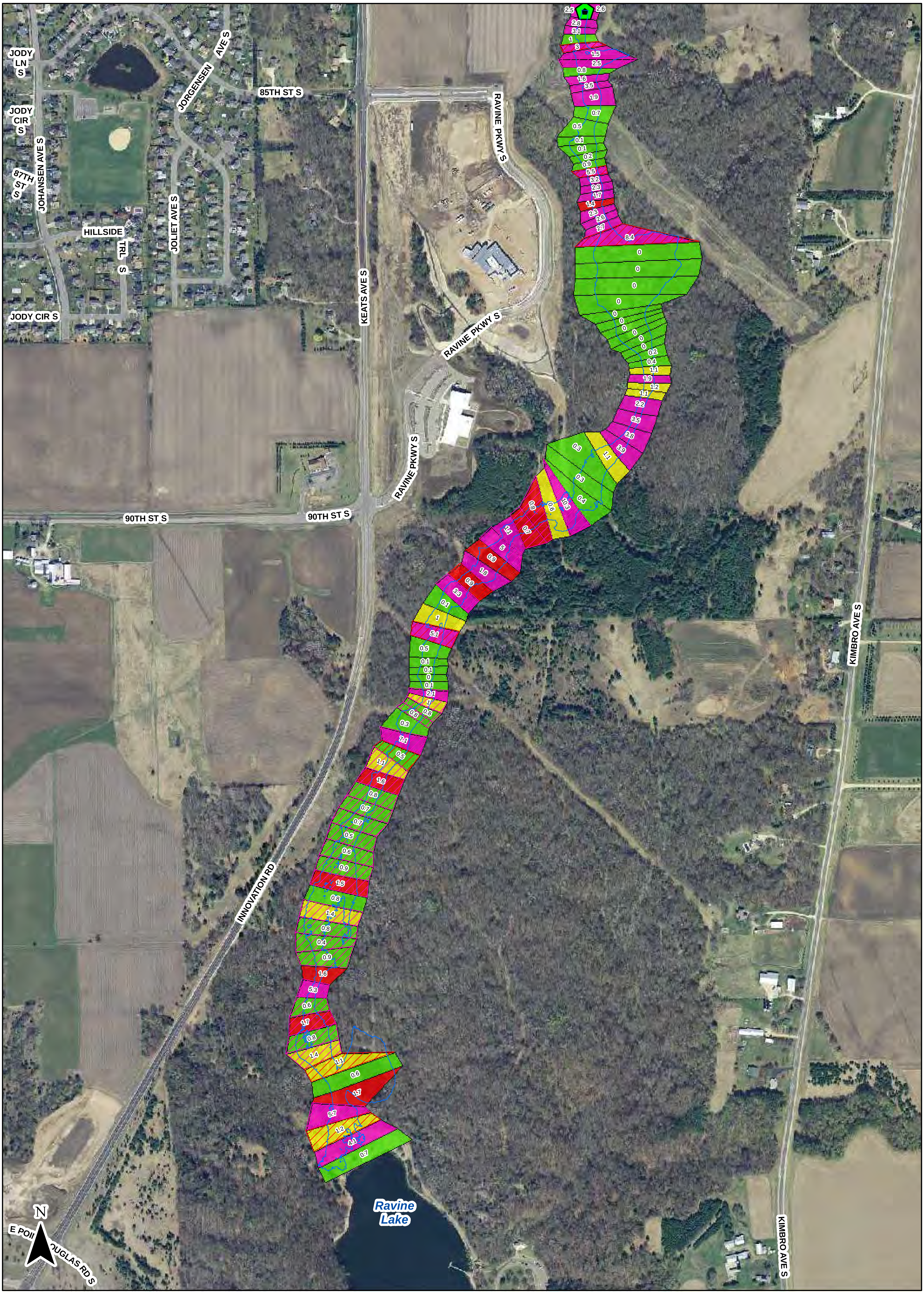

Proposed Outlet Location

With Project Conditions Flood Extent

Erosion Potential

Shear

- excesive
- high
- medium
- low
- 4.2 Shear Stress (lb/sq. ft.)

Erosion Potential

Velocity

- excesive
- high

0 300 600 1,200 Feet

Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

Attachment 12: Upper East Ravine - Erosion Potential for With Project Conditions					
Scale: AS SHOWN	Drawn By: SMW	Checked By:	Project No: 4876-024	Date: 11/25/2013	Sheet: 1 of 1

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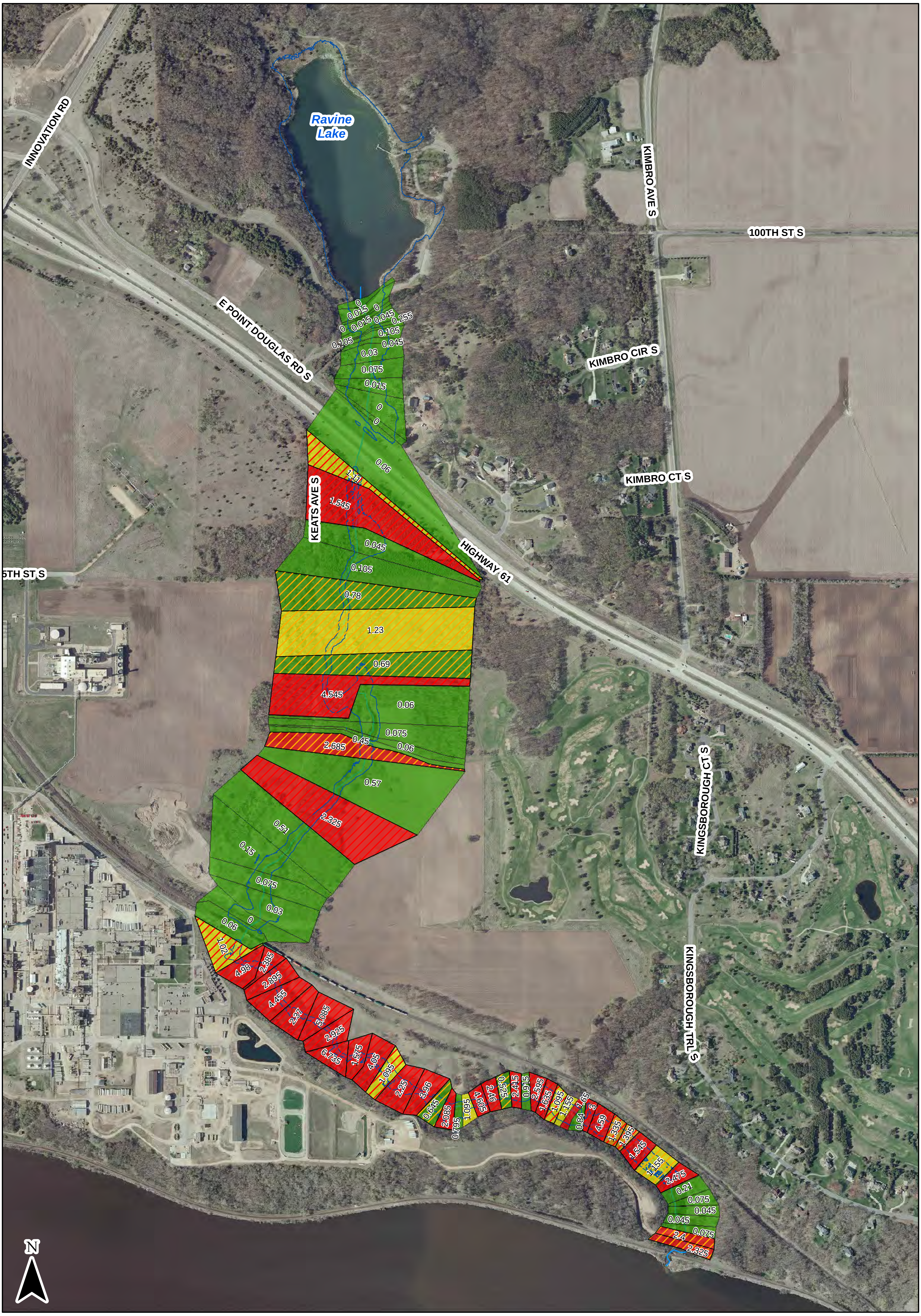

0 375 750 1,500 Feet

Erosion Potential

Shear
- Excessive
- High
- Medium
- Low

Velocity
- Excessive
- High
- Stream Centerline
- 100 year flood extent under existing conditions

Sources: SWWD, TLG, MN DOT
Aerial: 2013 Washington County, MN

South Washington WATERSHED District

Attachment 13: Lower East Ravine - Erosion Potential for Existing Conditions

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	ALD		4876-027	11/25/2013	1 of 1

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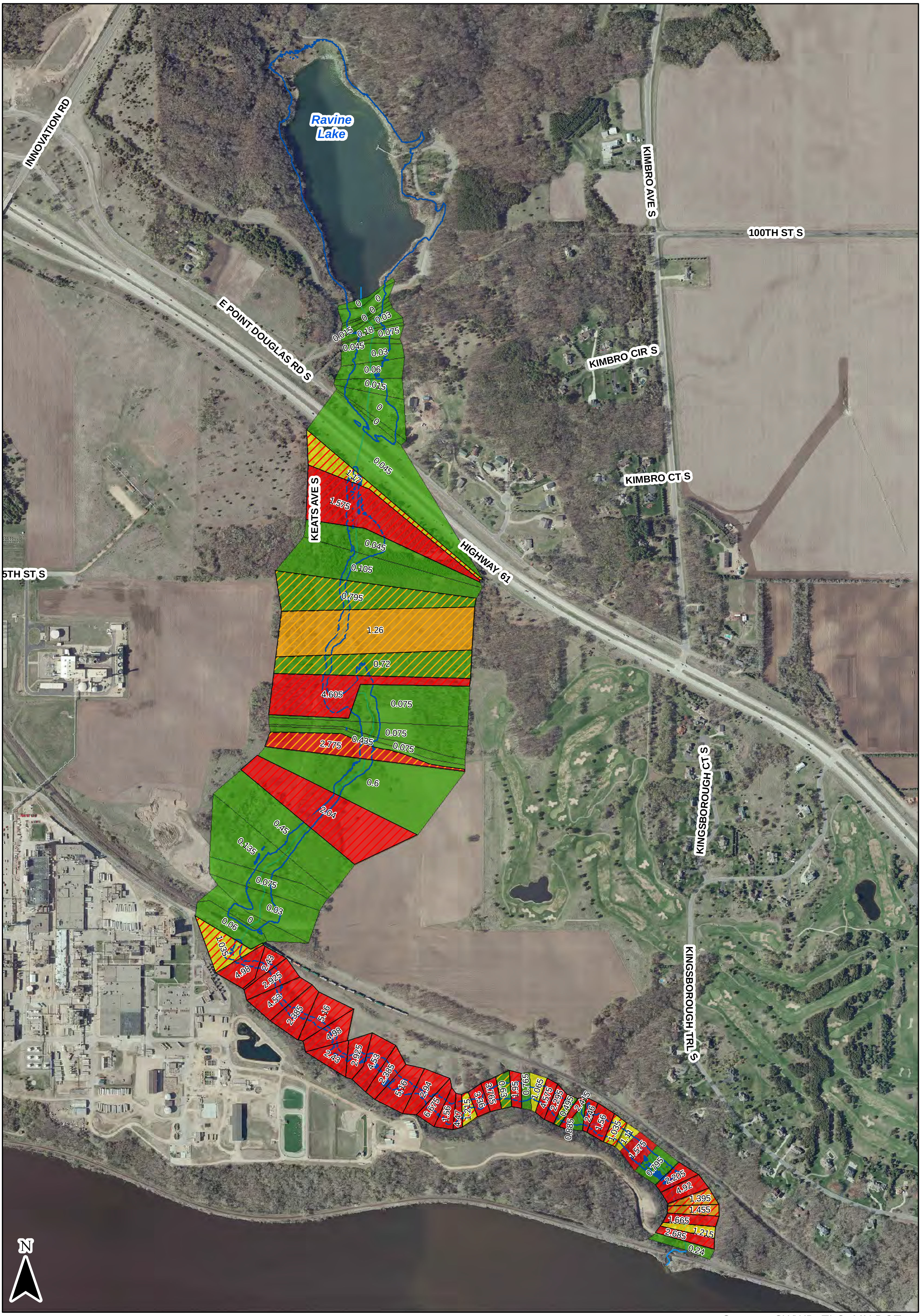

0 375 750 1,500 Feet

Sources: SWWD, TLG, MN DOT
Aerial: 2013 Washington County, MN

Erosion Potential

Shear

- Excessive
- High
- Medium
- Low

Velocity

- Excessive
- High
- 100 year flood extent under build out conditions
- Stream Centerline

South Washington WATERSHED District

Attachment 14: Lower East Ravine - Erosion Potential for Build Out Conditions

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	ALD		4876-027	11/25/2013	1 of 1

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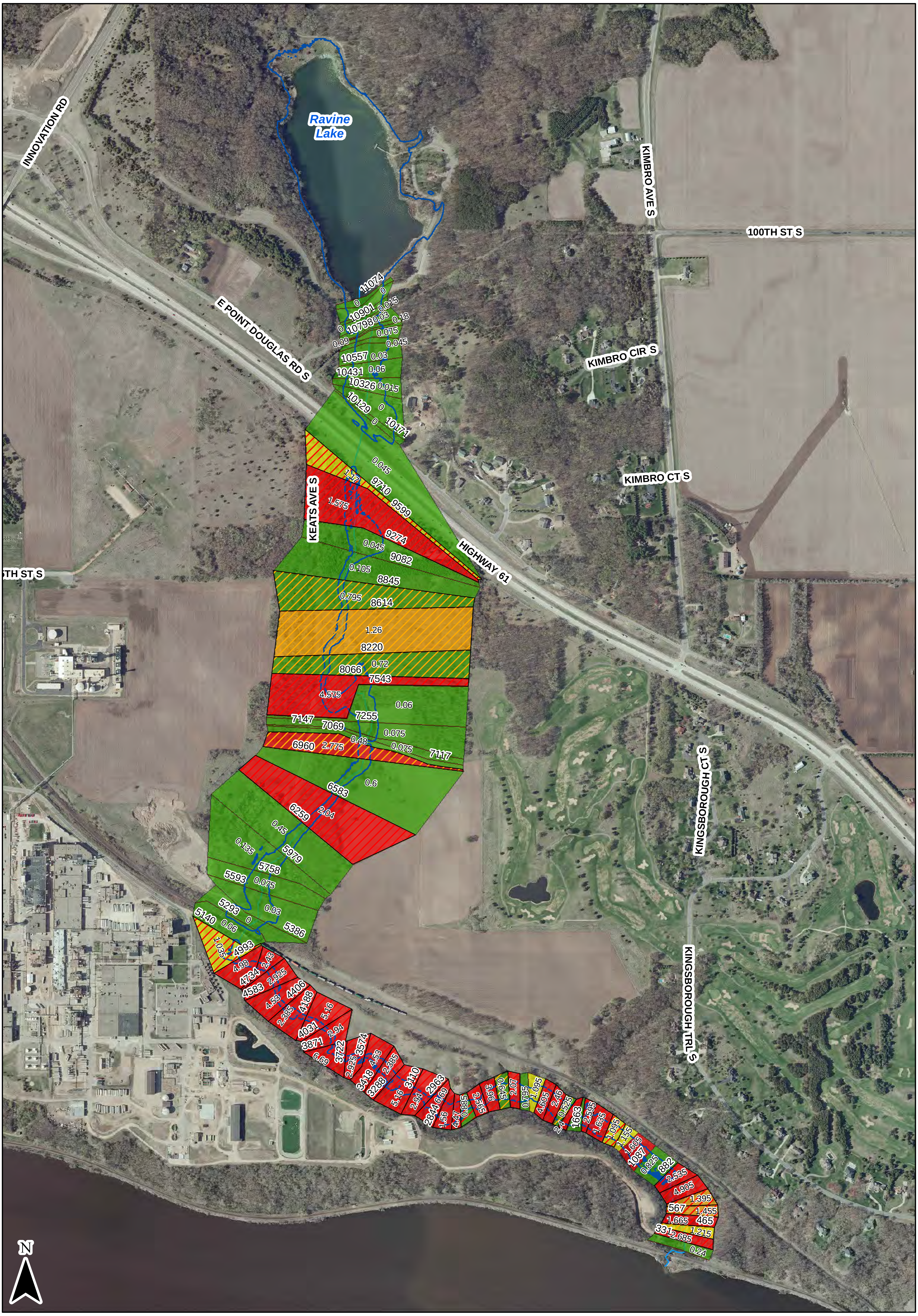

0 375 750 1,500 Feet

Erosion Potential

Shear
- Excessive
- High
- Medium
- Low

Velocity
- Excessive
- High
- 100 year flood extent under project conditions
- Stream Centerline

Sources: SWWD, TLG, MN DOT
Aerial: 2013 Washington County, MN

South Washington WATERSHED District

Attachment 15: Lower East Ravine - Erosion Potential for With Project Conditions					
Scale: AS SHOWN	Drawn by: ALD	Checked by:	Project No.: 4876-027	Date: 11/25/2013	Sheet: 1 of 1

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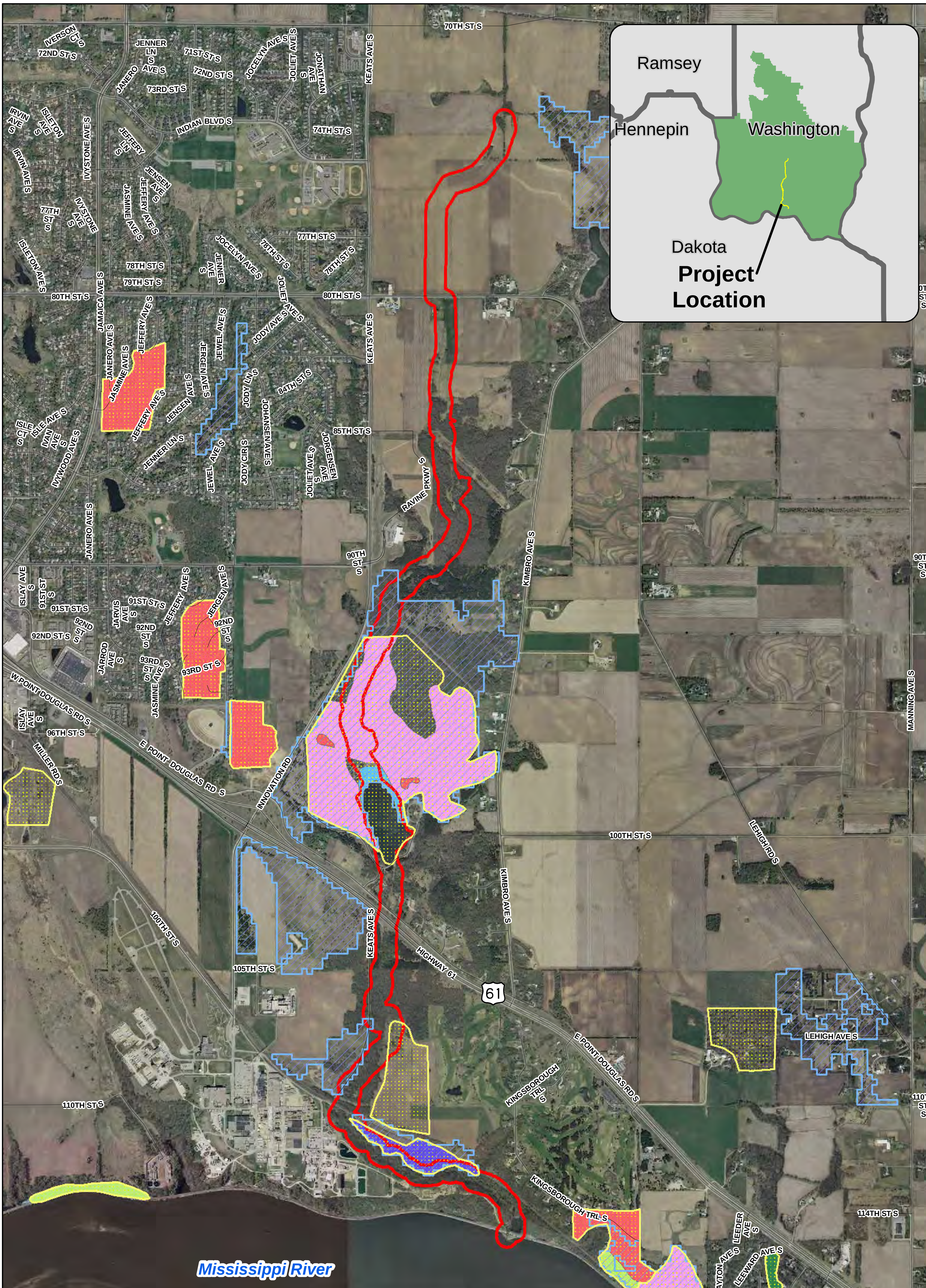

N / W / E / S

Legend	
Road Centerline	
MCBS Sites of Biodiversity Significance	
Regionally Significant Ecological Corridors	
Project Boundary (400 Foot) Buffer	

MCBS Native Plant Communities

- Dry Bedrock Bluff Prairie (Southern)
- Dry Sand - Gravel Oak Savanna (Southern)
- Dry Sand - Gravel Prairie (Southern)
- Northern Bulrush-Spikerush Marsh
- Oak - (Red Maple) Woodland
- White Pine - Oak - Sugar Maple Forest

0 0.25 0.5 1 Miles

Date Saved: 3/14/2014 11:20:09 AM

Attachment 16: Plant Community & Ecological Resources

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	SMW		4876-026	3/14/2014	1 of 1

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Cottage Grove Ravine Regional Park Erosion Analysis

Final Report **March 31, 2014**

Houston Engineering Inc.

South Washington Watershed District

DRAFT ENGINEER'S REPORT

Cottage Grove Ravine Regional Park Erosion Analysis

12/11/13

South Washington Watershed District

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of Minnesota.

Michael Lawrence, P.E.
License No. 49191

Date: March 31, 2014

Houston Engineering Inc.
6901 East Fish Lake Road, Suite 140
Maple Grove, MN 55369
Ph. (763) 493-4522
HE Project No. 4876-024

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EXECUTIVE SUMMARY

BACKGROUND

The potential for erosion (i.e., channel instability) within the ravine through the Cottage Grove Ravine Regional Park has been identified as a potential impact of the Central Draw Storage Facility (CDSF) Overflow Project, which provides flood protection to the Cities of Woodbury and Cottage Grove. The South Washington Watershed District (SWWD) retained Houston Engineering to update previous outdated studies that evaluated the potential for channel instability as a result of the CDSF Overflow Project. Provide recommended measures to improve stability and develop an Preliminary Opinion of Probable Construction Cost (POPCC). The analyses presented within this report evaluate channel stability issues for three land use conditions: i.e., the Existing Condition (existing land use), the Build Out Condition (ultimate build out or "fully developed" land use and no CDSF Overflow Project), and the With Project Condition (ultimate build out land use, with CDSF Overflow Project operational). Analyses were also completed relative to the potential mortality to mature trees within the ravine and the water quality within Ravine Lake.

RESULTS AND SUMMARY OF CONCLUSIONS

Flood Extents Resulting from the CDSF Overflow Project - The extents or amount of area inundated during the peak discharge to the east ravine is nearly the same for all three scenarios. The results reflect the fact that the peak flow rates to the ravine are similar for three scenarios. The ravine currently receives considerable runoff from directly adjacent land. When comparing the With Project Condition to Existing Conditions an additional 1.24 acres is inundated by the discharge for the 100-year flood along the 8100 foot reach and an additional 0.12 acres is inundated when comparing the With Project Condition and the Build Out. The area inundated is located almost completely within the Park and no homes or buildings are impacted.

Erosion Potential – The potential for the ravine to erode (laterally and downward) can be characterized by its shear stress. The potential can also be evaluated using the maximum water velocity within the ravine. Both the shear stresses and maximum velocities were computed at an interval of ~ 100 feet for the entire channel length for the three modeling scenarios. The estimated shear stresses and maximum velocities were then compared to commonly accepted thresholds considering the soil type and vegetative cover present. By dividing the 8100 foot channel into sections, locations needing stabilization (i.e., where the maximum shear stress or velocity exceeded the threshold) were identified. Erosion within the ravine is an existing problem. Based on the analyses completed the Existing Conditions scenario shows high and excessive risk along of 5,150 feet of the ravine. Very little additional area show high or excessive risk for the With Project Condition when compared to the Existing Conditions and none when compared to the Build Out Condition. For both Build Out and With Project Conditions, 5,200 feet of the ravine show high and excessive risk, an increase of 50 feet. This length represents approximately 64% of the total length of the ravine, from Ravine Lake to the outlet of the CDSF Overflow pipe.

The analysis shows that the erosion potential under existing conditions is high, and would require nearly the same amount of stabilization with or without the CDSF Overflow Project. Shear stress values have been identified for sections throughout the park with different stabilization measures identified based on various shear stress values. The stabilization measures ultimately selected will take into account effectiveness at stabilizing the reach, cost effectiveness, and the aesthetic needs for the Cottage Grove Ravine Regional Park.

Potential Impacts to Mature Trees – A previously expressed concern is the mortality of mature trees (primarily oaks and ash) located adjacent to the ravine, because they become inundated. Tree mortality occurs when the depth of water is sufficient to submerge the tree crown for sufficient duration to result in oxygen loss within the soil. An additional 50 trees will experience some additional water (less than 0.35 feet) at the base of the tree for the With Project Condition compared to the Existing Condition. An additional 5 mature trees will experience some additional inundation for the With Project Condition compared to the Build Out Condition. An estimated 1229 trees are flooded under Existing Conditions compared to 1279 under With Project Conditions. An estimated 297 and 339 trees are inundated to depths above 2 feet, respectively. No trees become fully submerged. A study completed on tree mortality related to long term increased flooding in reservoirs appears to be most consistent with the conditions the mature trees in the ravine will experience during infrequent flooding events. The study determined that flooding of trees for less than 30 days during the growing season of one year was insufficient to kill any established tree. Based on the maturity of trees in the assessment area and the shallow flood depths associated with the flow in the ravine, the long term viability of the trees located within the ravine will not be impacted by flows and no long term impacts from inundation would be anticipated.

Water Quality Impacts to Ravine Lake – Although the CDSF Overflow Project will discharge infrequently to the ravine and add water to Ravine Lake, concern about water quality has been expressed by the review agencies and is of importance to SWWD, which has a management and restoration plan for the lake (Houston Engineering, Inc. 2013). Various methods were used to assess the potential adverse or beneficial impacts to water quality within Ravine Lake. Operation of the CDSF Overflow Project is expected to add an additional 2257 ac-ft of water to the total volume of water into Ravine Lake for a 27 day period on average once every 100 years. The hydraulic residence time, a measure of how often the volume of water is replaced within the lake, will temporarily decrease from 3.88 days to 1.58 days when comparing the Build Out to the With Project Condition for the 100 year flood event. Because of the short residence time, algae within the lake will have little time to utilize any additional phosphorus and a bloom is not expected. In fact, the water quality of Ravine Lake should approach the quality of the water discharged to the ravine, by the CDSF Overflow Project. This water comes from an area upstream of considerable storage, which should improve water quality. The amount of water quality data representing the quality of water discharged by the CDSF project is limited. The assumed incoming concentration of 70 ug/L is based upon a single sample from above the Bailey Lake Lift Station that was operating during a series of rainfall events. This TP concentration is within the current range of the existing water quality data within Ravine Lake. The yearly mean Total Phosphorous concentrations for the summer season range from 50.9 to 174.4 ug/L for the time period 1998 to 2012. Based on these data, water from the CDSF Overflow Project is not expected to degrade the water quality of Ravine Lake.

1 INTRODUCTION

Central Draw Storage Facility Overflow Project

The Central Draw Storage Facility Overflow Project (referred to hereafter as the CDSF Overflow Project) has been in development for over 30 years for the purpose of providing regional flood protection primarily within the Cities of Woodbury and Cottage Grove. The project concept is for a managed system utilizing floodwater storage, the infrequent use of a pipe connection to the Cottage Grove storm sewer system, and inter-basin pumping to reduce flood risks associated with 100 year and less frequent flood events. The northern portion of the watershed, generally the area north of Bailey Lake within the South Washington Watershed District (SWWD), is essentially landlocked and for certain precipitation events needs a controlled outlet. Currently for large precipitation events, the potential exists for the uncontrolled overflow of water from the northern watershed into the east ravine, and the potential for natural resources damage. The CDSF Overflow Project contemplates the installation of a surface connection from the existing storage facilities to the East Ravine.

For storm events more frequent than the 100 year event, the storm water rate and volume can be accommodated with the existing infrastructure. However, during infrequent larger events the lack of a surface water outlet will cause large-scale flooding. The CDSF Overflow Project is designed to only release water downstream to Ravine Lake during a 100-year rainfall event or larger. The 100-year rainfall event has a 1% probability of occurring in any given year on average.

The SWWD has been evaluating and planning for the CDSF Overflow Project since the District was formed in 1993. Working with numerous partners, many alternatives have been reviewed and analyzed. The District selected the CDSF overflow route through East Ravine as the preferred alternative after careful consideration of the environmental benefits and consequences, technical feasibility, and cost. Construction began on Phase 1 of the CDSF Overflow project in the spring of 2013. Phase I consisted of connecting the CDSF to the Cottage Grove stormwater network and constructing a 72" pipe from the CDSF to another storage area, called CP4-3. Four additional phases of the project are planned to be constructed over approximately the next five years, as shown in **Figure 1**. These Phases consist of providing stabilization to existing channels, updating the lake outlet structure, and constructing a pipe segment. This report examines issues associated with Phase IV. The analyses presented within the report anticipate the full build out (i.e., complete development) of the watershed and the construction and operation of the CDSF Overflow project. This report identifies the features necessary to correct for existing as well as anticipated future erosion within the East Ravine.

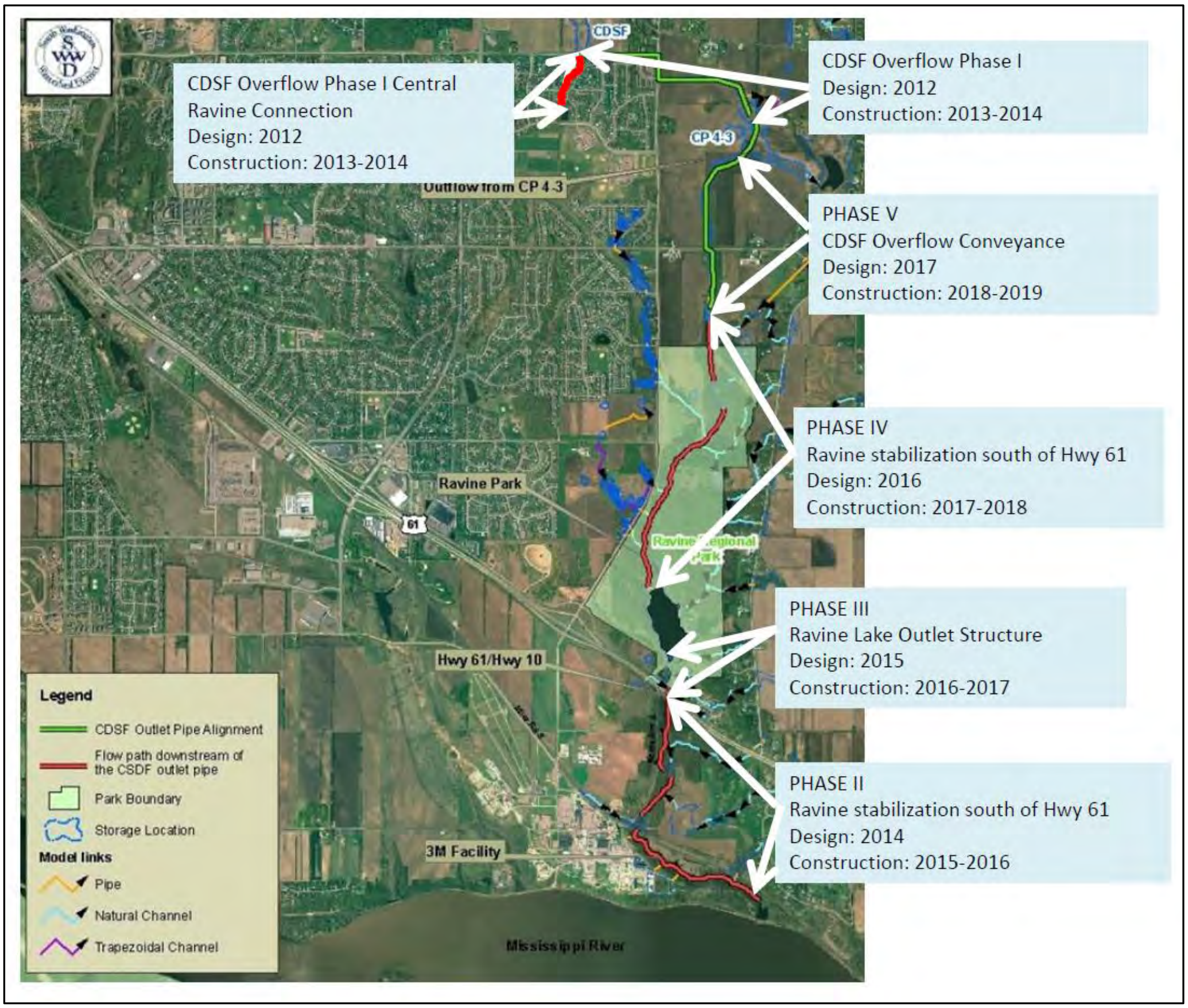
Erosion Analysis and Impacts to Cottage Grove Ravine Regional Park

The channel stability within the ravine through the Cottage Grove Ravine Regional Park was identified as a potential impact of the CDSF Overflow Project within the report titled *Environmental Assessment for County Road 19 Corridor* and dated January 18, 2002 (EOR 2002a). The analyses within this report include the evaluation of erosion through Cottage Grove Ravine Regional Park, in addition other impacts to the Park. The limits of the analyses are shown in **Figure 2**, and are referred to hereafter as the assessment area. The upstream limit is the proposed outfall of the CDSF Overflow Project and the downstream limit is Ravine Lake.

Erosion analyses regarding the stability of the ravine were previously completed by the SWWD; these studies are discussed in **Section 2**. These previous analyses need to be updated for a variety of reasons. First, the flow rates and durations as a result of the Overflow Project need to be explicitly defined in order to complete the assessment of potential impacts. Second, the original report did not consider erosion risk posed by existing local flows or form increased flow resulting from planned development in the watershed. Finally, the report needed to be updated to reflect projects (i.e. pipeline and trail construction), which altered the landscape in the ravine area. The pipeline project altered the land cover in portions of the ravine and needs to be explicitly accounted for in the analysis.

Other potential impacts to the Cottage Grove Ravine Regional Park are also analyzed. The two areas analyzed in detail in this report are the potential impacts to trees throughout the ravine corridor from the increased inundation and the impacts to Ravine Lake.

Figure 1: CDSF Overflow Project Phases.



Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

0 300 600 1,200 Feet

Proposed Outlet Location

Assessment Area

Washington County Service Center

Park Boundaries

South Washington WATERSHED District

Figure 2: Assessment Area Location					
Scale: AS SHOWN	Drawn by: SMW	Checked by:	Project No.: 4876-024	Date: 11/25/2013	Sheet: 1 of 1

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2 RELEVANT PREVIOUS STUDIES

A number of studies evaluating the Overflow Project have been completed. The erosion potential through the Park was initially assessed using a velocity analysis in a report titled *Environmental Assessment for County Road 19 Corridor* and dated January 18, 2002 (EOR 2002a). That analysis was subsequently updated with a shear stress analysis in a report *titled Erosion Potential by Shear Stress Analysis of Cottage Grove Ravine Regional Park* and dated January 28, 2002 (EOR 2002b). That report was a preliminary erosion analysis of the Cottage Grove Ravine as part of an Environmental Assessment of the County Road 19 Corridor, motivated by the proposed routing of the CDSF Overflow project through the county park ravine in Cottage Grove. The erosion potential through the ravine was determined using a shear stress analysis at assumed flows of 90, 120, 150, and 180 cfs. These were assumed flow rates from the CDSF, but an explicit flow from the CDSF Overflow Project was not defined at that time, nor were existing conditions flows.

The potential for erosion analysis completed by EOR used a shear stress approach; i.e., the force required to move the ground surface. Shear stress was calculated using the hydraulic radius and slope of the energy grade line obtained at each cross section from an XP-SWMM model developed for the velocity analysis of the main channel of the ravine. Maximum shear stress was determined by multiplying the calculated shear by a factor of 1.5 to account for local variations in velocity. Erosion potential was then determined in each section of the ravine by comparing the calculated maximum shear stress to threshold values that were assigned based on vegetation and soil descriptions of the ground surface. The resulting erosion potential was classified as being low, medium, high, or excessive. Areas having low erosion potential had maximum shear stress values below the lower limit of the shear stress threshold range. Medium erosion potential had values between the lower limit and the midpoint of the shear stress threshold range. High erosion potential areas were identified as those values between the midpoint and the upper limit of the shear stress threshold range. Excessive erosion potential values are those areas above the upper limit of the shear stress threshold range.

In the main ravine where both velocity and shear stress analyses were conducted, EOR recommended vegetation management in areas of medium erosion potential and grade control structures (primarily “check” dams) or new lined channels in areas of high or excessive erosion potential. Based on their analysis 59% of the channel would require stabilization at a flow rate of 90 cfs, and 60% of the channel at a flow rate of 180 cfs.

Houston Engineering, Inc. (HEI) is following a very similar methodology for the shear stress analysis as EOR, which is discussed in detail in **Section 4.3** of this report. The primary difference is the use of improved estimates of the planned flows following completion of the CDSF Overflow Project. The current erosion potential is also evaluated within this report.

3 HYDROLOGY

Hydrology is the rate that water leaves the landscape and enters the ravine. Extensive hydrologic and hydraulic modeling has been completed to analyze the flow through the watershed to Ravine Lake in addition to the area that contributes runoff to the CDSF Overflow Project. The hydrology used for the Project comes from modeling completed by HDR Engineering, Inc. using the XP-SWMM model for three scenarios, listed in **Section 3.3**. The modeling conditions, assumptions, and results are outlined in a memorandum dated October 3, 2013 (HDR Engineering, Inc. 2013). The following section summarizes this memorandum and presents results from the models. A summary of the results is necessary because these flows were used in the analyses presented within this report. The watershed for the assessment area under existing conditions is shown in **Figure 3**, with the modeled sub-watersheds displayed.

3.1 PRECIPITATION

The design precipitation event was used for all modeling is a 6.3 inch rainfall event with a 24-hour SCS Type II Distribution. All flows listed in this report are for the 100-year rainfall event. Although the CDSF Overflow Project was designed for the 6.3 inch event, additional modeling has shown that the CDSF Overflow Project can accommodate increase runoff resulting from greater precipitation events (e.g. the new Atlas 14 design event, 7.8" 95% Confidence Interval storm, and back to back design events). Under all of these extreme conditions, outflow from the CDSF Overflow Project is limited by the permitted operation plan for the City of Woodbury's Bailey Lake Lift Station. Therefore the peak runoff rates from the CDSF Overflow Project will not increase even for greater rainfall events.

3.2 LAND USE

Two land use conditions were used in the hydrologic modeling. The existing land use condition is based on 2009 aerial photography and site development plans for government facilities adjacent to the park provided by SWWD. The future land use conditions representing ultimate build out are based on the 2006 Cottage Grove Alternative Urban Area-wide Review (AUAR). This AUAR condition is the planned land use and is considered the ultimate build out condition; no specific timeline is associated with this condition.

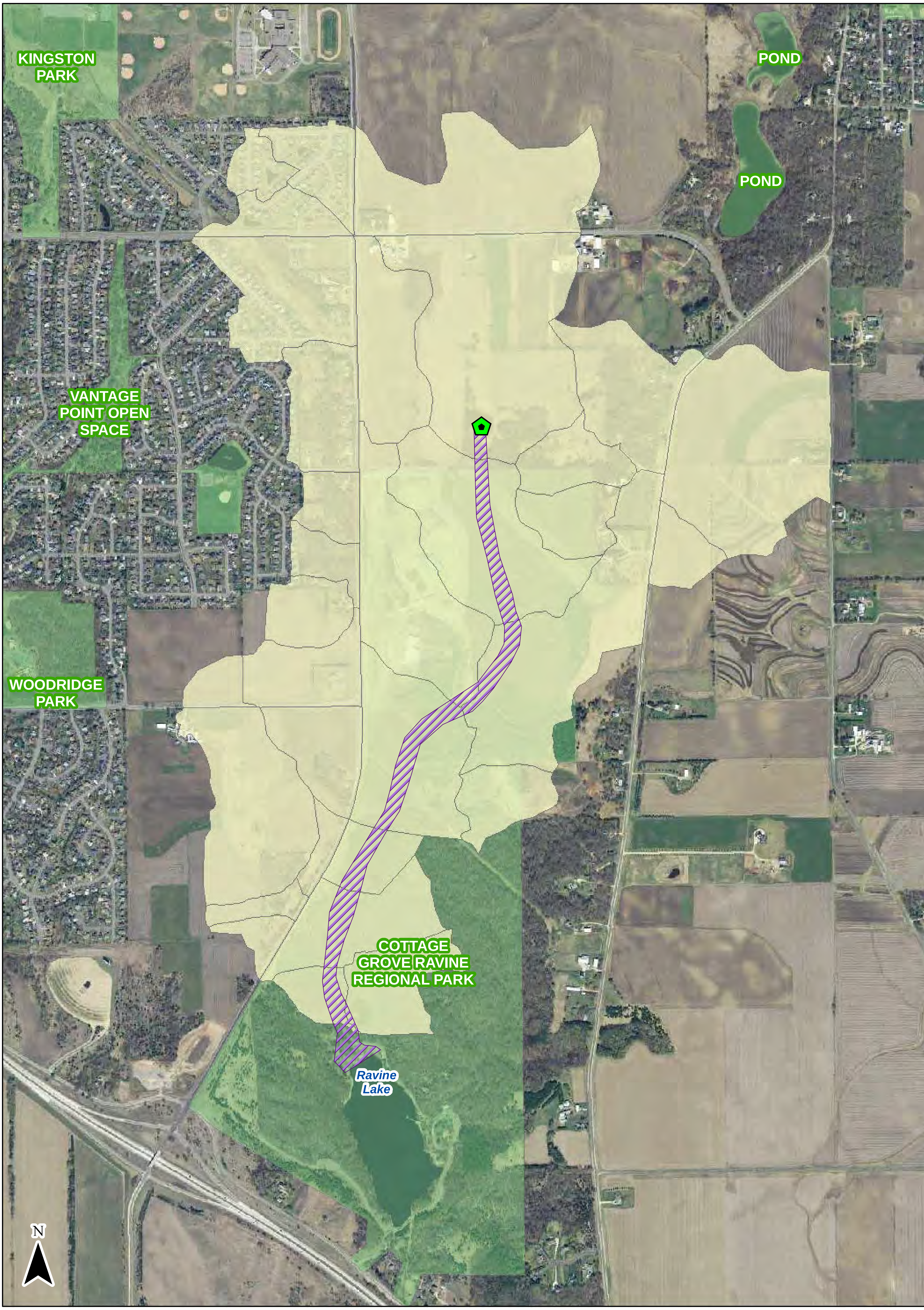
3.3 MODELED SCENARIOS

The hydrology for three scenarios was evaluated as follows:

Scenario 1. Existing Conditions - This represents the current land use within the contributing drainage area and no stormsewer connection from the CDSF Overflow Project to the East Ravine.

Scenario 2. Build Out Conditions (CDSF not constructed) - This scenario consists of the future (ultimate build out) land use and no stormsewer connection from the CDSF Overflow Project to East Ravine. This scenario provides a sense of the future erosion within the East Ravine, in the absence of the CDSF Overflow Project. This change in the erosion potential as a result of the CDSF Overflow Project is compared to this condition.

Scenario 3. With Project Conditions (Build-out Conditions with CDSF constructed and gates open) – This represents the future (ultimate build out) land use and an operational CDSF Overflow Project.



Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

0 550 1,100 2,200 Feet

Outlet Location
Assessment Area
Asssesment Area Sub-Watersheds
Park Boundaries

South Washington WATERSHED District

Figure 3: Assessment Area Watershed

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3.4 PEAK FLOW RATES

The peak flow rates for the three scenarios are summarized in **Table 1.** The location along the ravine is described by stationing in feet moving upstream from Ravine Lake; the stationing is shown in **Figure 6**, **Section 4** of this report**.** Station 7600 is the northern boundary of Cottage Grove Ravine Regional Park. The relationships between discharge and time (i.e., hydrographs) for the 100-year rainfall event at two locations are shown in **Figure 4** and **Figure 5,** the northern boundary of Cottage Grove Ravine Regional Park and Ravine Lake, respectively. In both figures, the initial peak flows at approximately hour 12 are shown, and the CDSF Overflow Project flow is shown extending through time.

When comparing the peak flow rates for the Build Out Condition (Scenario 2) to the With Project Condition (Scenario 3), the peak flow rate for the With Project Condition is greater for only a very short distance. This area is from the location of the pipe outlet for the CDSF Overflow Project at station 8100 to the location where additional local drainage enters from the northeast at station 7648. Below this point, the existing peak flow rates far exceed the outlet flow rates from the CDSF Overflow Project. The maximum flow from the CDSF Overflow Project is approximately 140 cfs.

For the purposes of reviewing the tree impacts to the park, daily average flows were used. The flows used for that analysis are shown in **Table 1**.

.

Table 1: 100-year Peak Flows used for Hydraulic Modeling.

Station	Scenario 1 Existing Peak flow (cfs)	Scenario 2 Build Out Peak flow (cfs)	Scenario 3 With Project Peak flow (cfs)
8100	45.3	80.9	142.2
7648	195.2	196.2	198.1
5700	126.2	143.6	149.3
4800	184.1	222.3	229.2
4600	211.1	251.9	259.3
2800	267.3	287.8	287.6
2000	285.5	383.0	382.8
1100	326.9	463.1	462.7
200	304.3	395.0	394.6

The values in the table reflect the flow in the hydraulic model by station.

Figure 4: Hydrographs near northern boundary Cottage Grove Ravine Regional Park (Station 7700).

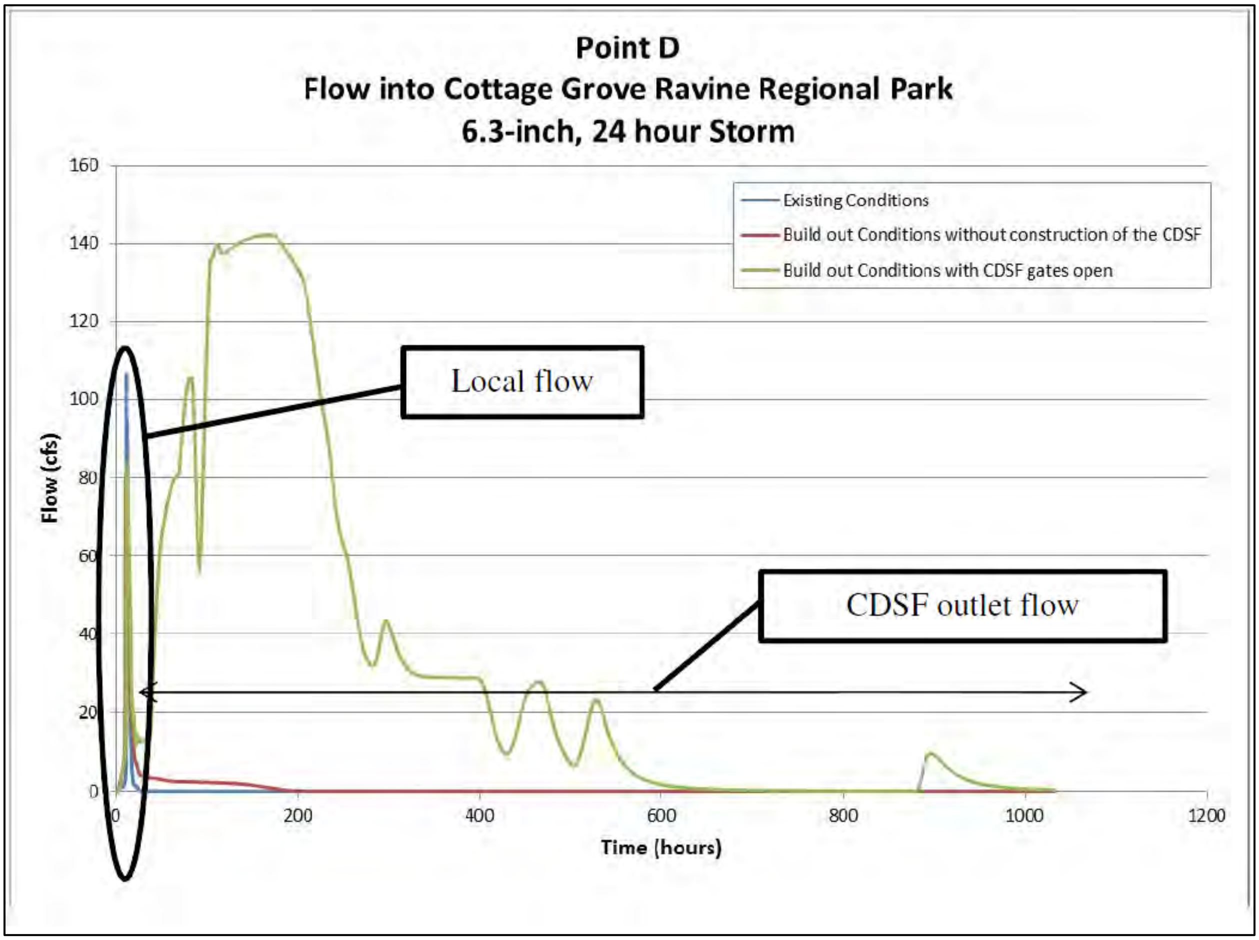


*Figure reproduced from HDR Memorandum (HDR Engineering, Inc. 2013).

Figure 5: Hydrograph at Outlet into Ravine Lake (Station 0).

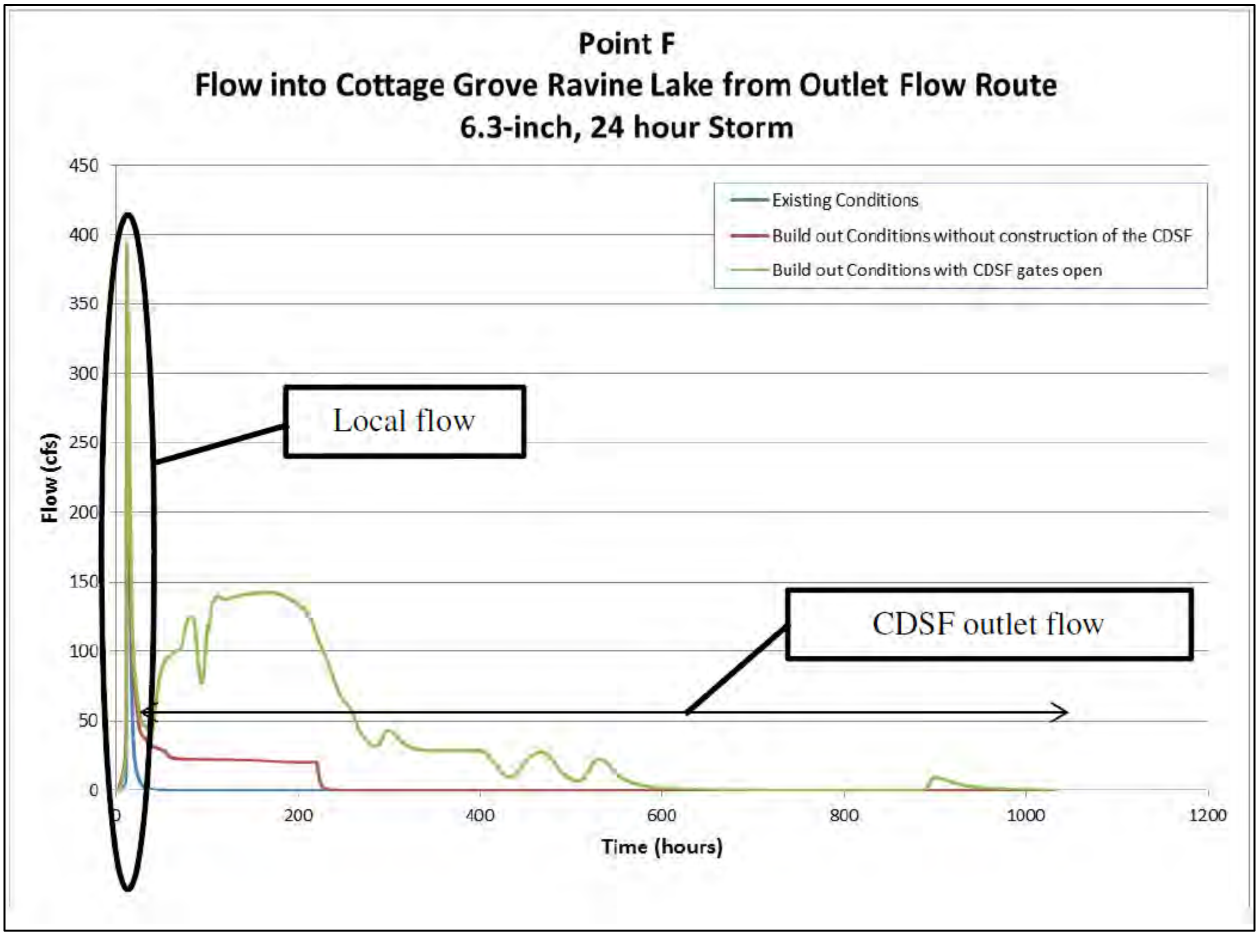


*Figure reproduced from HDR Memorandum (HDR Engineering, Inc. 2013).

Table 2: Average Daily Flows into Ravine Lake through Time for 100-year Rainfall Event.

Station	Scenario 1 Existing Peak flow (cfs)	Scenario 2 Build Out Peak flow (cfs)	Scenario 3 With Project Peak flow (cfs)
Day 1	52.7	92.0	94.1
Day 2	2.4	36.3	52.8
Day 3	0.3	25.6	96.7
Day 4	-	22.6	108.5
…			
Day 8	-	20.7	140.5
…			
Day 12	-	12.0	36.9
…			
Day 16	-	11.6	28.8
…			
Day 19	-	0.2	25.9
…			
Day 25	-	-	3.0
…			
Day 27	-	-	1.0

4 HYDRAULICS

Hydraulics is the elevation and velocity of water within the ravine. This section describes the methods used to complete the hydraulic analyses including a description of model development and use for analyzing the range of conditions.

4.1 MODEL DEVELOPMENT

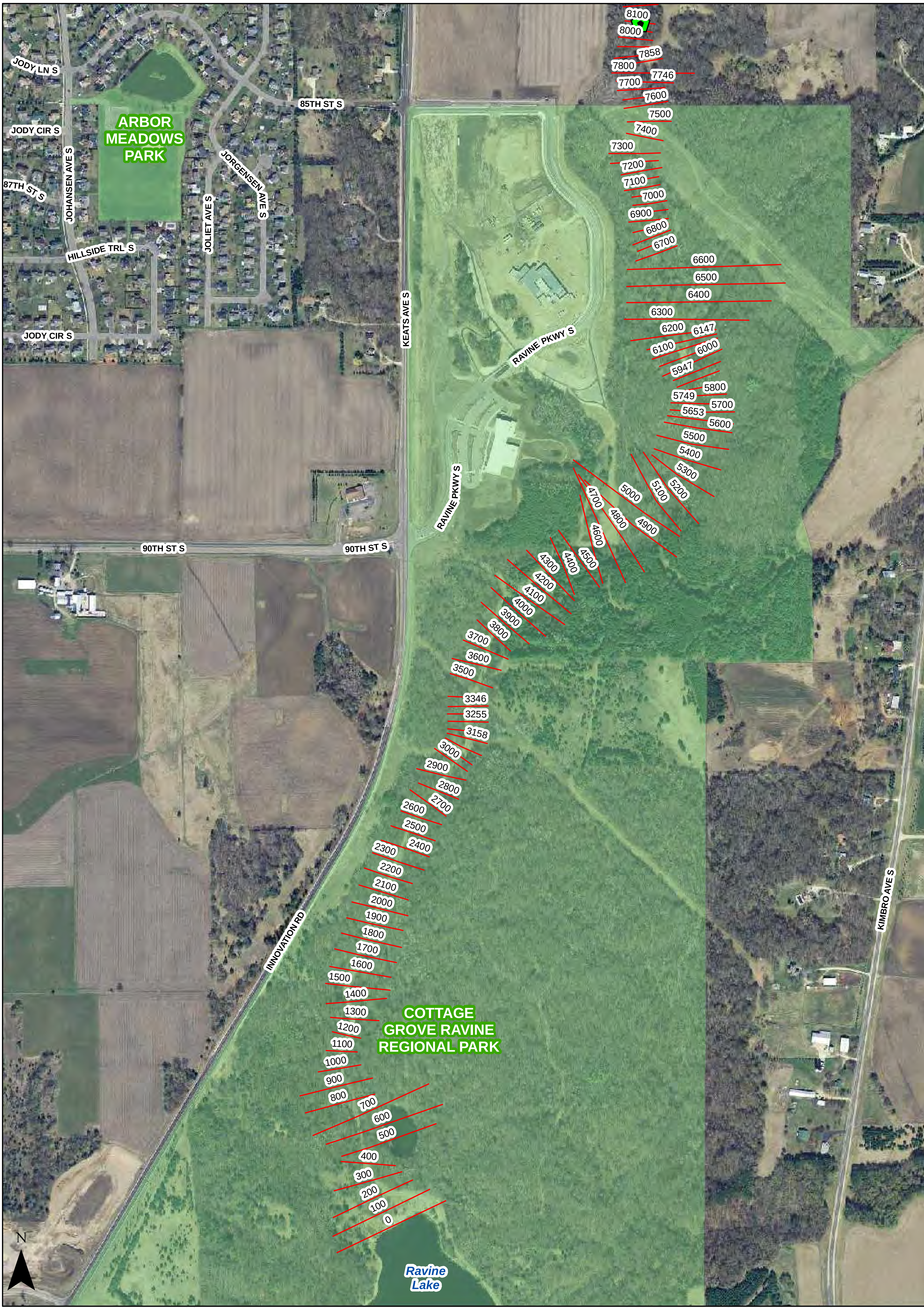
The U.S. Army Corps of Engineer's Hydraulic Engineering Center's River Analysis System (HEC-RAS) model, version 4.1.0, was selected for use in this analysis. HEC-geoRAS, a GIS software tool, was used to help develop the geometry data used to describe the alignment and cross-sectional area of the ravine in the hydraulic model for the reach. The overall model extents and cross section layout are shown in **Figure 6**. These cross section stations are referenced in **Section 4.3** for the various analyses.

Houston Engineering, Inc. surveyed the assessment area in the spring of 2013. Elevation data for the cross sections were collected along the ravine, in addition to the cleared area along the trail and the asphalt trail as a result of the 3M pipeline work.

The surveyed cross section data were compared to the 1-meter Digital Elevation Model (DEM) of the State of Minnesota Light Detection and Ranging (LiDAR) elevation data. The LiDAR data for the Twin Cities metropolitan region was collected in the Spring and Fall of 2011, with some reflights in the Spring of 2012. The Root Mean Square Error (RMSE) for the LiDAR data, which is a measure of vertical accuracy, is 11.4 cm for Washington County. The HEI survey compared very well to the LiDAR data, with most of the survey points agreeing within 0.1 feet of the LiDAR. For this reason, the cross section geometry in the HEC-RAS model is created entirely from the State of Minnesota LiDAR elevation data. By using only one source for the cross section elevation data, a consistent source of all elevation data is used in the model and provides greater flexibility in determining cross section location and spacing during the modeling analysis.

Figure 6 shows the location of the cross sections along with the cross section station number. Station numbering along the ravine is in feet beginning at 0 at Ravine Lake. The modeling was carried to station 9300; the proposed outlet from the CDSF Overflow Project is located at approximately station 8100. Because the exact location and final design has not been completed on the outlet, modeling results will be available for this upstream area if needed.

The modeling completed as a part of this analysis was as a steady state condition, meaning that the discharge is constant through time. The peak discharge rates in Table 1 are the flow condition simulated. The flow can change from one cross section to the next, which it does as more local inflow is added, but remains constant through time. This can be seen in the previous table of flows, **Table 1.**



Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

0 300 600 1,200 Feet

Proposed Outlet Location
Cross Sections
Park Boundaries
6400 Cross Section Station Number

South Washington WATERSHED District

Figure 6: HEC-RAS Model Cross Sections

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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4.1.1 MANNING'S N-VALUES

Manning's n-values are used in the HEC-RAS model to perform calculations for each cross section. The n-value characterizes the channel roughness or resistance to flow. Three n-values were assigned based on a simplified land cover type using typical values from literature; the values are detailed in **Table 3**. The survey data of the clearing and the asphalt trail were used to define the limits of the n-values within the cross section.

Table 3: Manning's n-value.

Land Cover	Manning's n-value
Trees	0.15
Grass	0.03
Paved Trail	0.015

4.1.2 INEFFECTIVE FLOW AREAS

The HEC-RAS model allows the user to set ineffective flow areas to account for obstructions or areas that do not convey water in the channel. Ineffective flow areas were assigned to adjust for ponds attached to the main channel, confluences of other ravines, and unconnected flow paths.

4.1.3 BOUNDARY CONDITIONS

In a steady state model, the downstream boundary condition for the model must be defined. The downstream end of the model is Ravine Lake. The boundary condition was defined as normal flow using a channel slope of 0.03 ft/ft, a representative slope of the upstream channel. This is a more conservative approach when doing the shear stress or velocity analysis, as it will result in higher velocities. Using a specific water surface elevation for Ravine Lake corresponding to higher flows would result in a higher elevation at those downstream cross sections and show a reduced erosion potential.

4.1.4 SHEAR STRESS

Shear stress is calculated in the HEC-RAS model using the following equation:

$$\tau = \gamma R S_f$$

Where: $\tau =$ calculated shear stress (lb/ft^2)

$\gamma =$ specific weight of water (lb/ft^3)

$R =$ hydraulic radius $= \frac{Area}{Wetted\ Perimeter}$ (ft^2/ft)

$S_f =$ friction slope (ft/ft)

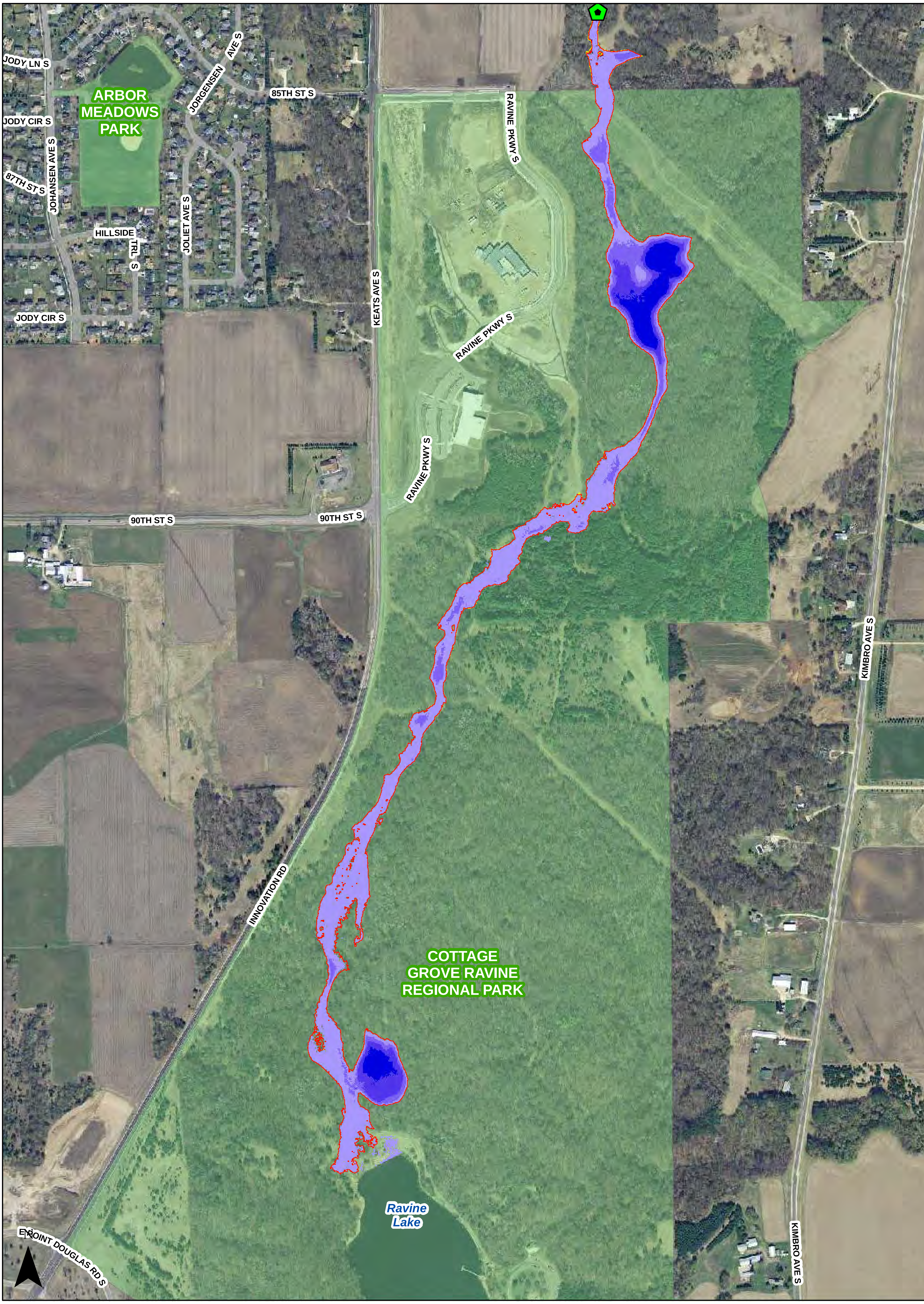
Shear stress is calculated in the channel, left and right overbank areas, and a total cross section. For the purpose of this project, the total cross section shear stress is used with a maximum shear factor. A maximum shear factor of 1.5 was multiplied to the total cross section shear to account for local variations within the cross section (Chang 1988). This maximum shear factor was also used in the previous erosion analysis. This factor was also tested within HEC-RAS by calculating the shear stress for just the critical areas of the channel; this value was typically found to be 1.3 to 1.5 times the total cross section shear and supports the use of the 1.5 maximum shear factor.

4.2 INUNDATED AREA

The HEC-RAS model computes a water surface elevation at each cross section. These water surface elevations can be mapped onto the digital elevation model (DEM) derived from the LiDAR collected topographic data to produce a flooding extent. This was done for the peak flows for all three scenarios. The resulting inundated areas for the peak discharges are shown in **Figure 7**. These maximum inundated areas are shown in two manners. For the Existing Conditions a depth grid is presented, which shows the depth of flooding over the ground surface. For the Build Out and With Project Conditions, a simple flood extent is shown. The extent of the peak flooding for all three scenarios is nearly the same, as would be expected since the peak flow rates are nearly the same for all three scenarios. The inundated areas under peak flows are presented in **Table 4**. When comparing the With Project Condition to Existing Conditions only an additional 1.24 acres is inundated, and when comparing the With Project Condition to Build Out Conditions only an additional 0.12 acres is inundated.

Table 4: Peak Inundated Areas for All Scenarios.

	Scenario 1: Existing Conditions	Scenario 2: Build Out	Scenario 3: With Project
Peak Inundated Area (acres)	25.23	26.35	26.47



0 305 610 1,220 Feet

Outlet Location

Park Boundaries

Build Out Conditions

With Project Conditions

Existing Condtions

Flooded Depth (ft)

0

0-2

2-4.5

4.5-7.5

7.5-11.6

Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

Figure 7: Maximum Inundation Area for all Three Scenarios					
Scale: AS SHOWN	Drawn by: SMW	Checked by:	Project No.: 4876-024	Date: 11/25/2013	Sheet: 1 of 1

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4.3 EROSION ANALYSIS

This section describes the process used to determine the erosion potential in each section of the assessment area.

4.3.1 SHEAR STRESS AND VELOCITY THRESHOLDS

Shear stress and velocity thresholds indicative of the potential to erode the ground surface were set based on plant cover and soil descriptions. These thresholds were assigned over areas of similar composition longitudinally along the east ravine. All soils were sandy loam, causing plant cover to be the differentiating factor. The table of permissible shear values from Fisch Engineering, shown in **Table 5**, used in the original shear stress analysis (EOR 2002b) was used as a basis for determining the allowable shear stresses in this analysis. A description of the cross sections and the assigned thresholds are in **Table 6**. Photographs of representative cross sections can be found in **Appendix A**.

4.3.2 EROSION POTENTIAL DETERMINATION

The following process was used to determine the erosion potential for each portion of the ravine including the portion through the Cottage Grove Ravine Regional Park.

1. Scenario maximum shear stress occurring in the channel was determined by multiplying the shear stress calculated in the HEC-RAS model by 1.5 to account for local variations in velocity and accelerations (see **Section 4.1.4**).
2. Erosion potential was determined by comparing the maximum shear stress occurring in each cross section to the corresponding shear stress threshold and the modeled velocity to the velocity threshold listed in **Table 6**. The erosion potential at each cross section was classified by maximum shear stress or velocity within the following ranges for each classification. The sections are defined as the downstream area below each cross section.

    a. Low Below the lower limit of the threshold range
    b. Medium Between the lower limit and midpoint of the threshold range
    c. High Between the midpoint and upper limit of the threshold range
    d. Excessive Above the upper limit of the shear stress threshold range

Table 5: Permissible Shear Stress from Fisch Engineering.

Boundary Category	Boundary Type	Permissible Shear Stress (lbs/sq ft)	Permissible Velocity (ft/s)
Soils	Fine colloidal sand	.02 - .03	1.5
	Sandy loam (noncolloidal)	.03 - .04	1.75
	Alluvial silt (noncolloidal)	.045 - .05	2
	Silt loam (noncolloidal)	.045 - .05	1.75 – 2.25
	Firm loam	.075	2.5
	Fine gravels	.075	2.5
	Stiff clay	.26	3 – 4.5
	Alluvial silt (colloidal)	.26	3.75
	Graded loam to cobbles	.38	3.75
	Graded silts to cobbles	.43	4
	Shales and hardpan	.67	6
Gravel/Cobble	1-inch	0.33	2.5 – 5
	2-inch	0.67	3 – 6
	6-inch	2.0	4 – 7.5
	12-inch	4.0	5.5 – 12
Vegetation	Class A Turf	3.7	6 – 8
	Class B Turf	2.1	4 - 7
	Class C Turf	1.0	3.5
	Long Native Grasses	1.2 – 1.7	4 – 6
	Short Natives & Bunch Grass	0.7 - .95	3 – 4
	Reed Plantings	0.1-0.6	N/A
	Hardwood Tree Plantings	0.41-2.5	N/A
Temporary Degradable RECP's	Jute Net	0.45	1 – 2.5
	Straw with Net	1.5 – 1.65	1 – 3
	Coconut Fiber with Net	2.25	3 – 4
	Fiber Glass Roving	2.00	2.5 – 7
Non-Degradable RECP's	Unvegetated	3.00	5 – 7
	Partial Establish	4.0-6.0	7.5 – 15
	Fully Vegetated	8.00	8 – 21
Riprap	6 – inch d_{50}	2.5	5 – 10
	9 – inch d_{50}	3.8	7 – 11
	12 – inch d_{50}	5.1	10 – 13
	18 – inch d_{50}	7.6	12 – 16
	24 – inch d_{50}	10.1	14 – 18
Soil Bioengineering	Reed fascine	0.6-1.25	5
	Coir Roll	3 - 5	8
	Vegetated Coir Mat	4 - 7	9.5
	Live Brush Mattress (initial)	0.4	4
	Live Brush Mattress (grown)	3.90-4.60	12
	Brush Layering (initial/grown)	1.1-6.25	12
	Live Fascine	1.25-3.10	6 – 8
	Live Willow Stakes	2.10-3.10	3 – 6
Hard Surfacing	Gabions	10	14 – 19
	Concrete	12.5	>18

[1] Ranges of values generally reflect multiple sources of data or different testing conditions.

*Table reproduced from Erosion Potential by Shear Stress Analysis (EOR 2002b).
**RECP: rolled erosion controlled product.

Table 6: Shear and Velocity Thresholds for Existing Vegetation.

Cross Section Station Range	Existing Vegetative Cover	Estimated Shear Threshold (lb/sf)	Estimated Velocity Threshold (fps)
0+00 - 2+00	Wetland. High grass.	1.5 - 2.5	4.0 - 6.0
3+00 - 10+00	Wooded Forest. 10' Paved Trai, 30-35' Mowed Grass corridor. Trail on channel's left bank.	1.0 - 2.0	1.75 - 3.0
11+00 - 23+00	Wooded Forest. 10' Paved Trai, 30-35' Mowed Grass corridor. Trail in middle of channel.	1.0 - 2.0	1.75 - 3.0
24+00 - 28+00	Wooded Forest. 10' Paved Trai, 30-35' Mowed Grass corridor. Trail on channel's left bank.	1.0 - 2.0	1.75 - 3.0
29+00 - 34+00	Wooded Forest. 20-25' Mowed Grass corridor.	1.0 - 2.0	1.75 - 3.0
35+00 - 38+00	Wooded Forest. 10' Paved Trai, 30-35' Mowed Grass corridor. Trail in middle of channel.	1.0 - 2.0	1.75 - 3.0
39+00 - 47+00	Pine plantation. Light ground cover.	0.4 - 1.0	1.75 - 2.0
48+00 - 59+00	Wooded forest. Medium density underbrush. Medium tree density.	1.0 - 1.5	1.75 - 3.0
60+00 - 65+00 (Pond)	Weedy area. Reed canary grass and nettles and forbs.	1.5 - 2.5	4.0 - 6.0
66+00 - 72+00	Wooded (medium density) with heavy deadfall. Low to medium density under-brush.	1.0 - 1.5	1.75 - 3.0
73+00 - 76+00	Power line corridor. Grass cover. Maintained.	1.5 - 2.5	6.0 - 8.0
76+00 - 82+00	Wooded (medium density) with heavy deadfall. Low to medium density under-brush.	1.0 - 1.5	1.75 - 3.0
83+00 - 93+00	Pasture. Good Grass cover.	1.5 - 2.5	6.0 - 8.0

A computed value greater than the table value indicates the potential for erosoin.

4.3.3 RESULTS

The erosion potential classification for each cross section was calculated for all three scenarios based on the peak flow rates. The erosion potential classifications based on both shear stress and velocity were computed and tabulated. The results are presented in tabular format in **Appendix B.** These results are shown spatially in **Figure 8**, **Figure 9**, and **Figure 10**; the shear stress value is shown for each section in all of the figures.

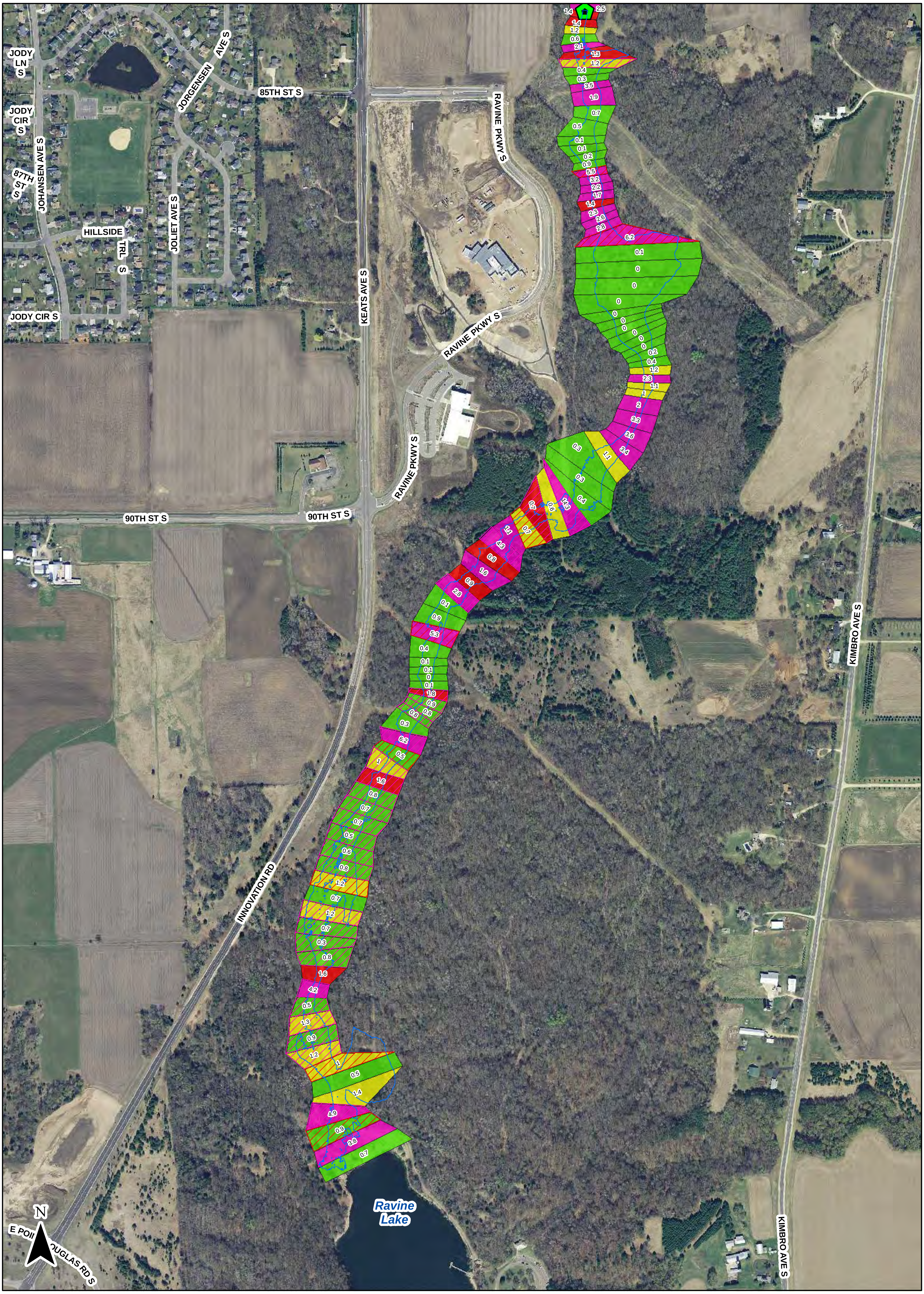
Table 7 provides a summary of the lengths of the ravine that are classified as high or excessive. Sections classified as high or excessive in either the shear or velocity, are areas that will most likely see erosion and may require stabilization. The table shows that very little additional area is classified as high or excessive for the With Project Condition when compared to the Existing Conditions. When comparing the With Project Condition to the Build Out condition there is no additional area. There are increases in shear values in the most upstream cross sections, but the classification category or the potential stabilization measures do not change.

Table 7: Summary of Lengths for High and Excessive Erosion Potential.

	Scenario 1: Existing Conditions	Scenario 2: Build Out	Scenario 3: With Project
Length with High and Excessive Erosion Potential (ft)	5150	5200	5200
Total Length of Reach (ft)	8100	8100	8100
Percent of Total Length	63.6%	64.2%	64.2%

Some sections show low potential for erosion based on the shear analysis, but have very high velocities. This typically happens when flow is wide and shallow throughout the cross section with high velocities. An example of this are sections 2000 to 2500. These sections have high erosion potential even though the shear stress analysis does not indicate potential erosion.

The type of stabilization measures that may be required for each section will be discussed in **Section 5**. The shear stress values shown in the figures will be used to select the stabilization measure that will be adequate for each section.



Proposed Outlet Location

Existing Conditions Flood Extent

Erosion Potential

Shear

- excessive
- high
- medium
- low

4.2 Shear Stress (lb/sq. ft.)

Erosion Potential

Velocity

- excessive
- high

0 300 600 1,200 Feet

South Washington WATERSHED District

Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

Figure 8: Erosion Potential for Existing Conditions

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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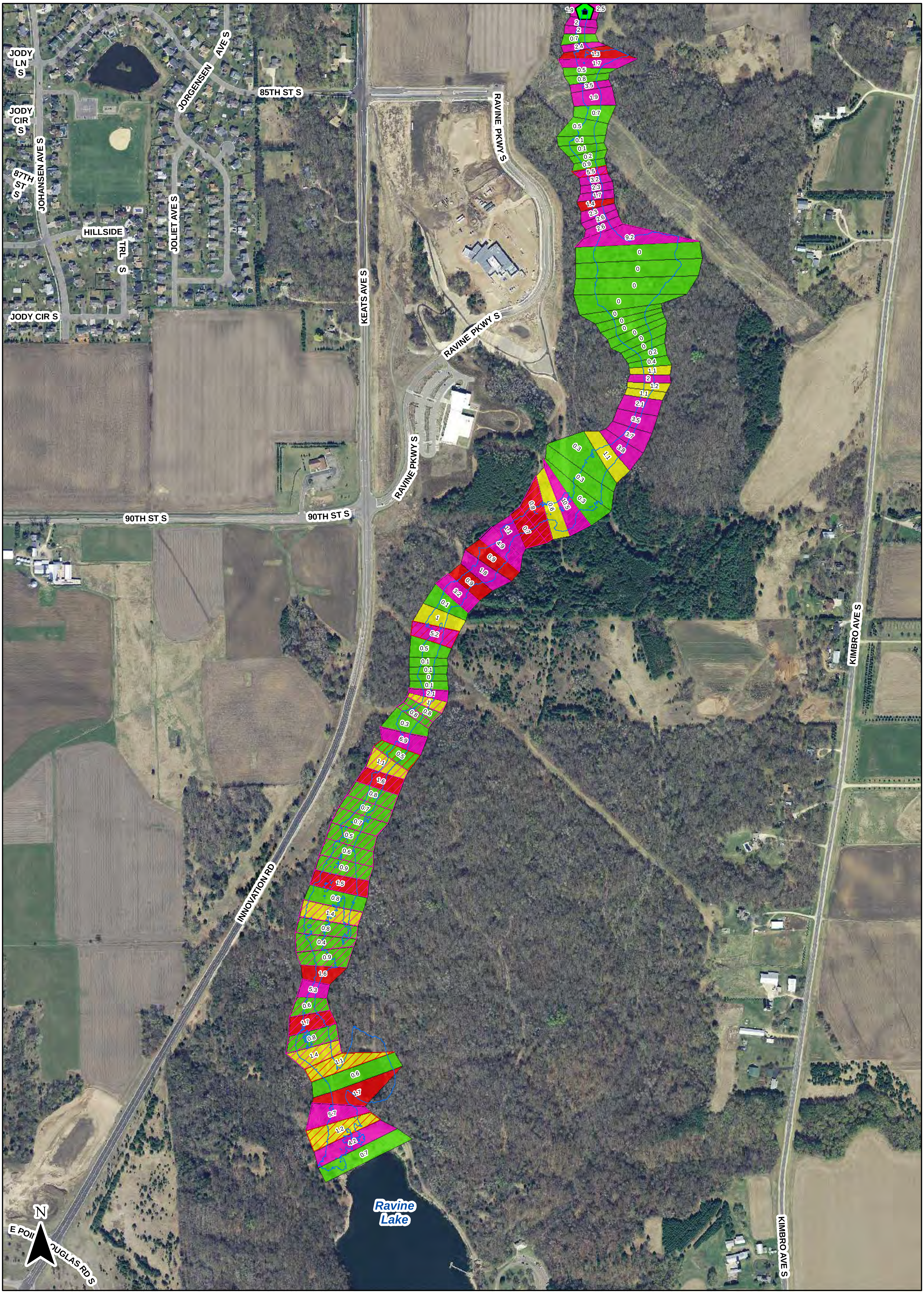

0 300 600 1,200 Feet

Proposed Outlet Location

Build Out Conditions Flood Extent

Erosion Potential

Shear

- excessive
- high
- medium
- low
- 4.2 Shear Stress (lb/sq. ft.)

Erosion Potential

Velocity

- excessive
- high

Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

South Washington WATERSHED District

Figure 9: Erosion Potential for Build Out Conditions					
Scale: AS SHOWN	Drawn by: SMW	Checked by:	Project No.: 4876-024	Date: 11/25/2013	Sheet: 1 of 1

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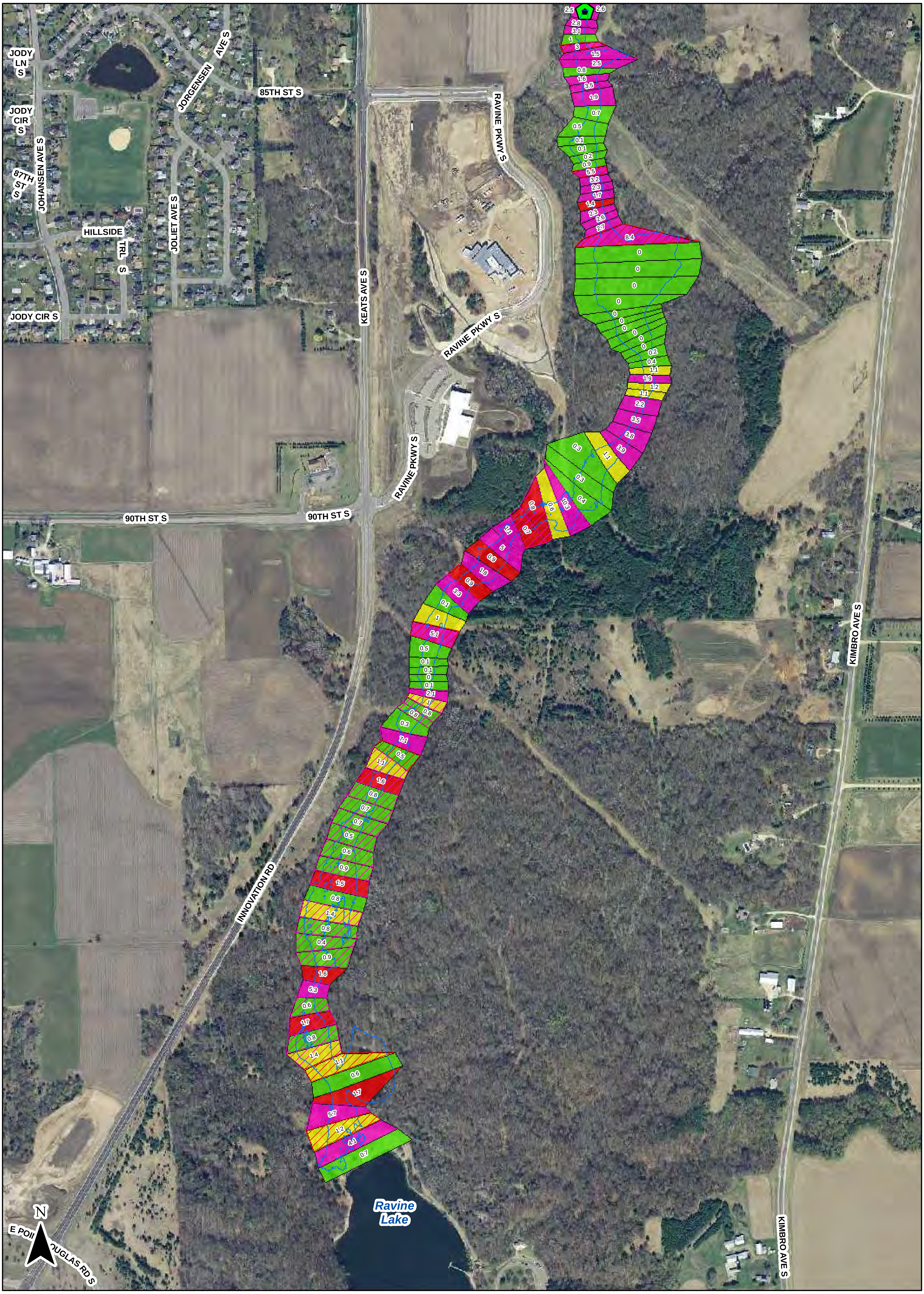

0 300 600 1,200 Feet

Proposed Outlet Location

With Project Conditions Flood Extent

Erosion Potential

Shear

- excesive
- high
- medium
- low
- 4.2 Shear Stress (lb/sq. ft.)

Erosion Potential

Velocity

- excesive
- high

Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

South Washington WATERSHED District

Figure 10: Erosion Potential for With Project Conditions

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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4.4 SEDIMENT TRANSPORT ANALYSIS

A sediment transport analysis was conducted using the sediment transport routine within HEC-RAS. The HEC-RAS model is able to perform mobile bed sediment transport analysis (US Army Corps of Engineers 2010). For this analysis to be fully applied there must be a defined channel bed that is relatively free of vegetation due to being regularly submerged by normal stream flow (i.e., a perennial stream). Based on the nature of the main channel in Cottage Grove Ravine Regional Park, a mobile bed model would not be an accurate depiction of the erosion phenomena taking place as the effect of the vegetation will not be taken into account.

While the explicit results of the sediment transport analysis shouldn't be used, the sediment transport modeling did provide a general understanding of what areas will see erosion and which will see deposition. The results of the sediment transport align with that of the shear stress and velocity analysis; areas with high velocities and shear stresses are areas of erosion, while low velocity areas show deposition. The results for this analysis are presented in **Appendix C**.

5 STABILIZATION TECHNIQUE ALTERNATIVES

Based on the erosion potential rating of each section, stabilization measures will be selected. Potential stabilization measures include vegetation management, constructed lined channel, lined existing channel, and check dams. Each of these stabilization measures are described in the following sections. **Table 8** provides a summary of the stabilization measures with the maximum allowable shear stress and an approximate cost per 100 feet of stabilizations. Where a cost range is given, the cost for that technique is heavily dependent on the specific conditions where it is utilized.

The shear stress and velocity erosion potential are based on average for the cross section, rather than a specific location along the cross section. The edge of the paved trail may also be an area where isolated erosion may take place, particularly if the trail crosses the channel. The trail can be protected by moving the trail or by tying in riprap to the edges of the trail. These isolated areas of potential erosion will be addressed in the final design. The stabilization measures ultimately selected will take into account effectiveness at stabilizing the reach, cost effectiveness, and the aesthetic needs of the County.

Table 8: Stabilization Measure Shear Stress Threshold and Cost.

Stabilization Technique		Maximum Shear Stress (lb/sq. ft.)
None		0.4 - 2.5
Vegetation Management, Native Grasses		1.5
Constructed Channel Lining	Turf Reinforced Mat	3 - 8
	High Performance Turf Reinforced Mat	4 - 10
	9" D_{50} Riprap Lining	3.8
	12" D_{50} Riprap Lining	5.1
Line Existing Channel	9" D_{50} Riprap Lining	3.8
	12" D_{50} Riprap Lining	5.1
Check Dams		3-20

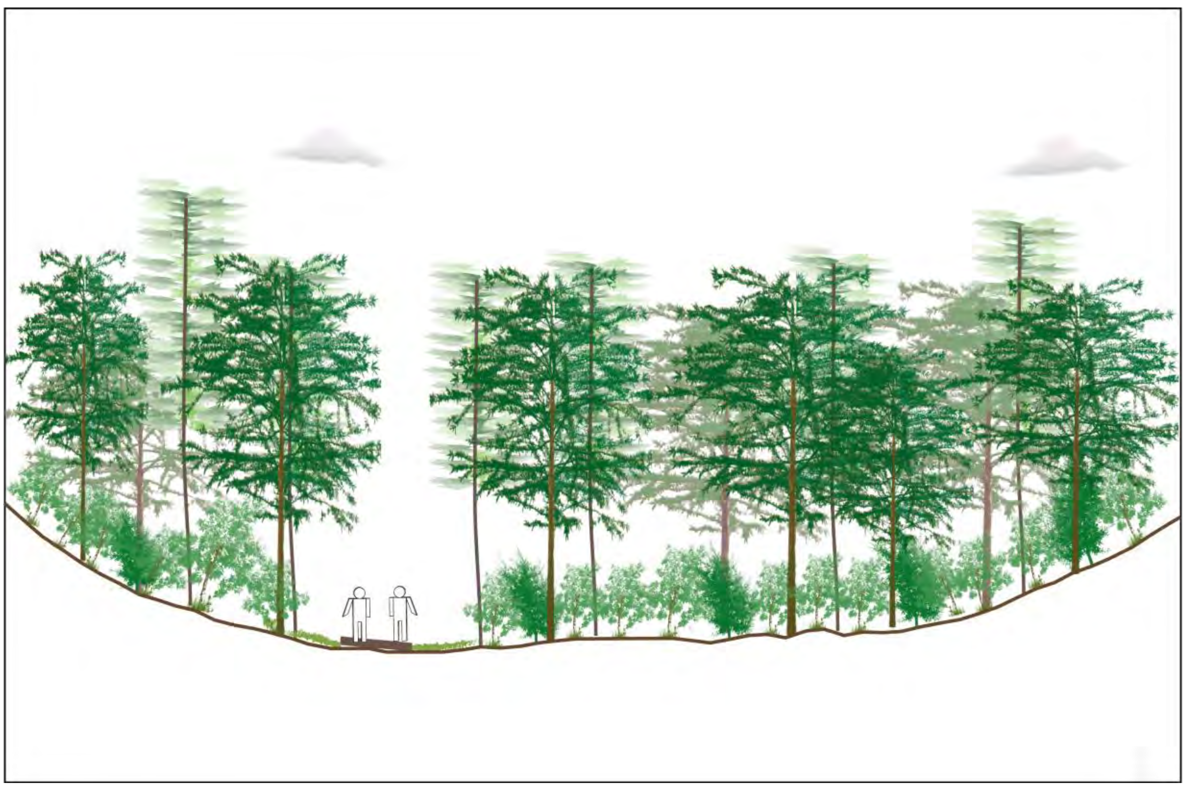
*Erosion potential due to velocity will be covered by all techniques.

5.1 EXISTING VEGETATION

The existing vegetation consists of a forest with a thick canopy of large oak species, and an understory dominated by species of green ash, American elm, and hackberry. The shrub layer is dominated by dense stands of buckthorn and to a lesser extent, honeysuckle. Prickly ash and Russian olive (invasive), were also observed and add to the density of the shrub layer. Clearings are present throughout the project area, because of the presence of utilities. There is a large powerline corridor on the north side of the park, an underground natural gas pipeline that crosses the ravine, and the 3M pipeline work that was completed along the majority of the ravine. **Figure 11** is a rendering of the existing conditions vegetation in a portion of the ravine that contains the asphalt trail and clearing associated with the 3M pipeline work. This rendering is applicable from approximately station 200 to 4000.

In some cases the existing vegetation is adequate to withstand shear stress and the velocity and no stabilization is required. These areas are typically where water is pooled behind a natural rise in the channel grade or in areas that have been cleared, particularly the powerline corridor.

Figure 11: Rendering Showing the use of Existing Conditions Vegetation to Stabilize the Ravine.



5.2 VEGETATION MANAGEMENT

Managing the vegetation within the ravine is an option to provide stability to the channel in cases where more invasive techniques are not warranted. Restoring the ravine to native habitat would allow longer native grasses to grow and provide the necessary erosion protection. This stabilization alternative would require removal of the buckthorn, other thick underbrush, removal of deadfall, and removal of live trees to open the canopy. The area would then be seeded with native grasses. **Figure 12** shows what this may look like along the trail corridor.

A shear threshold of 1.5 lb/sq.ft. was assigned to this stabilization technique, based on long native grasses. This technique will provide velocity protection up to 6 feet per second. Velocities throughout the modeled reach are 6 feet per second and below, so any area that has erosion potential due to velocity can use this technique to stabilize the channel. This technique would be most useful where shear stresses are low, but velocities are high. Many of these areas are along the trail corridor where flow is widespread and shallow, which results in low shear and high velocities.

Figure 12: Rendering Showing the Use of Vegetation Management.

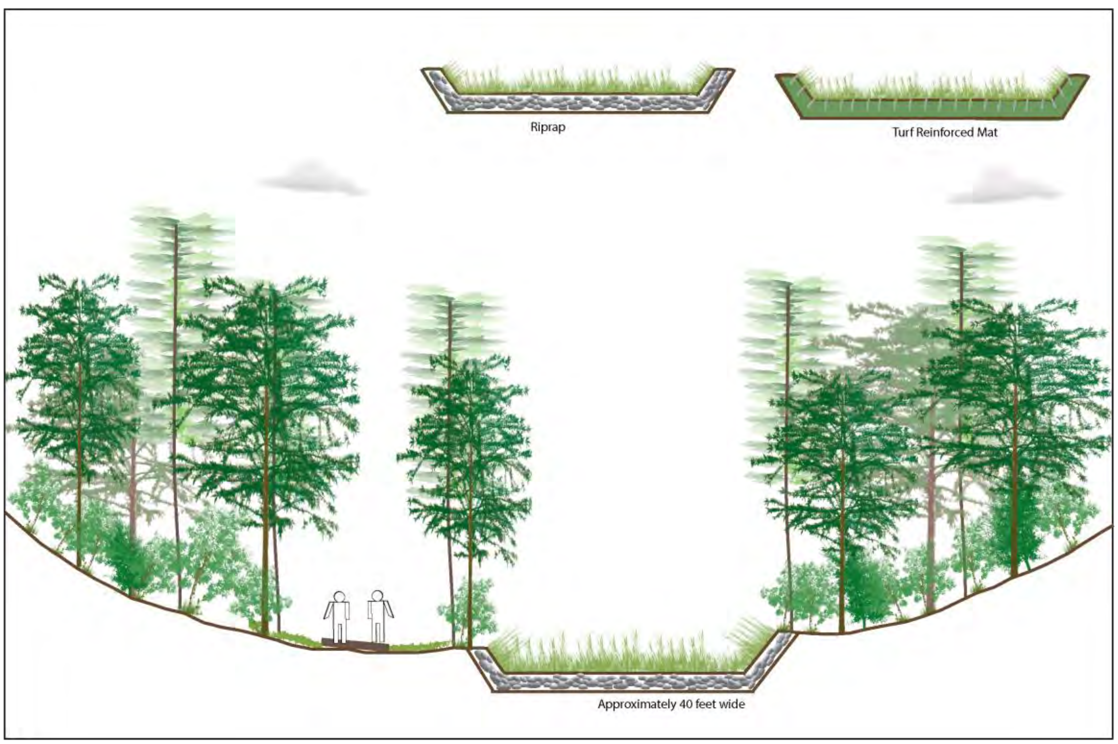
5.3 CONSTRUCTED LINED CHANNEL

Constructing a channel to confine the flow and lining with a suitable material is another stabilization measure as shown in **Figure 13**. A channel would be constructed that is approximately 40 feet wide and 2 feet deep. The specific dimensions depend on the location and the grade of the channel. The constructed channel could be lined with varying sizes of riprap or different grades of a turf reinforced mat (referred to as a non-degradable RECP in the Fisch Engineering table). In either case the area could be vegetated to increase the aesthetic appeal; this would require the addition of soil and seeding the area.

The maximum shear stress threshold for the turf reinforced mat range from 3 lb/sq. ft. to 10 lb/sq. ft. This broad range of values reflects the range in different types of mats available and the specific site conditions the mat is placed. Factors such as the grade, side slopes, and amount of vegetation established all affect the allowable shear stress on the turf reinforced mat. The maximum shear threshold for 9" D_{50} riprap and 12" D_{50} riprap is 3.8 lb/sq. ft. and 5.1 lb/sq. ft., respectively. Larger riprap could also be utilized, which would correspond to a higher maximum shear threshold. In the case of this project, 12" riprap should be adequate in nearly all cases.

The turf reinforced mat is a cheaper alternative than the riprap and may be more aesthetically appealing. The riprap is superior in its long term effectiveness, as it should remain effective longer. Because the turf reinforced mats are made from polypropylene or similar material, they will slowly degrade over time, with design life of 25 to 50 years. At that time they will not be totally ineffective, but the effectiveness will be reduced.

Figure 13: Rendering Showing the Use of a Constructed Lined Channel.

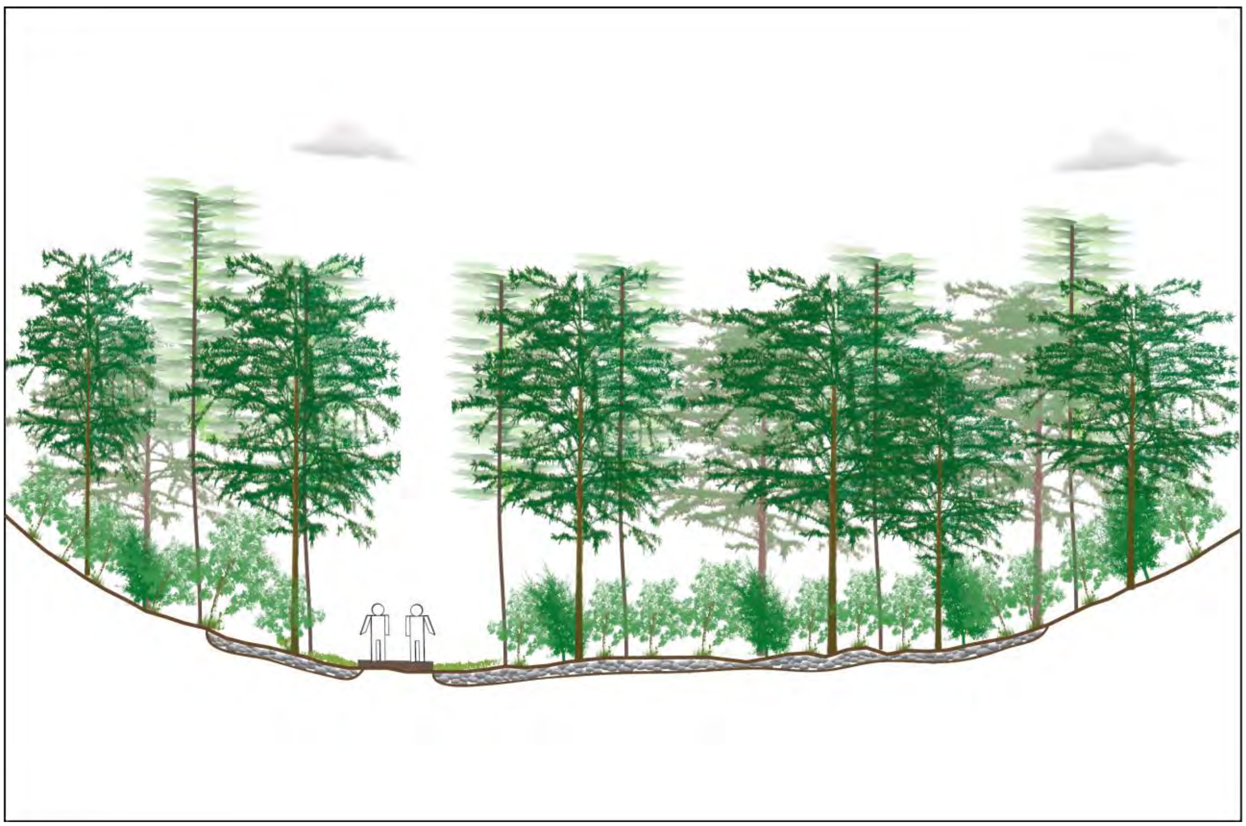


5.4 LINED EXISTING CHANNEL

Lining the existing channel with riprap of appropriate size can also be done to stabilize the ravine. This measure can be utilized over a constructed channel when sparing specific large existing trees is warranted. Clearing of brush will need to take place to facilitate the placement of riprap. Areas needed for equipment access will also require clearing. This technique will be most cost effective where a define channel already exists and the channel is narrowed. The cost will be dependent on the width of the channel. Due to the additional effort required to spare some trees, this measure is only as cost effective as a constructed channel for areas narrower than 50 feet. Lining the existing channel will be substantially more costly in areas that are wider than 50 feet. The riprap could be covered with soil and vegetated, as shown in **Figure 14**, or left alone depending on the aesthetic needs.

The maximum shear threshold for 9" D_{50} riprap and 12" D_{50} riprap is 3.8 lb/sq. ft. and 5.1 lb/sq. ft., respectively. Larger riprap could also be utilized, which would correspond to a higher maximum shear threshold. In the case of this project, 12" riprap should be adequate in nearly all cases.

Figure 14: Rendering Showing a Lining of the Existing Channel.



5.5 CHECK DAMS

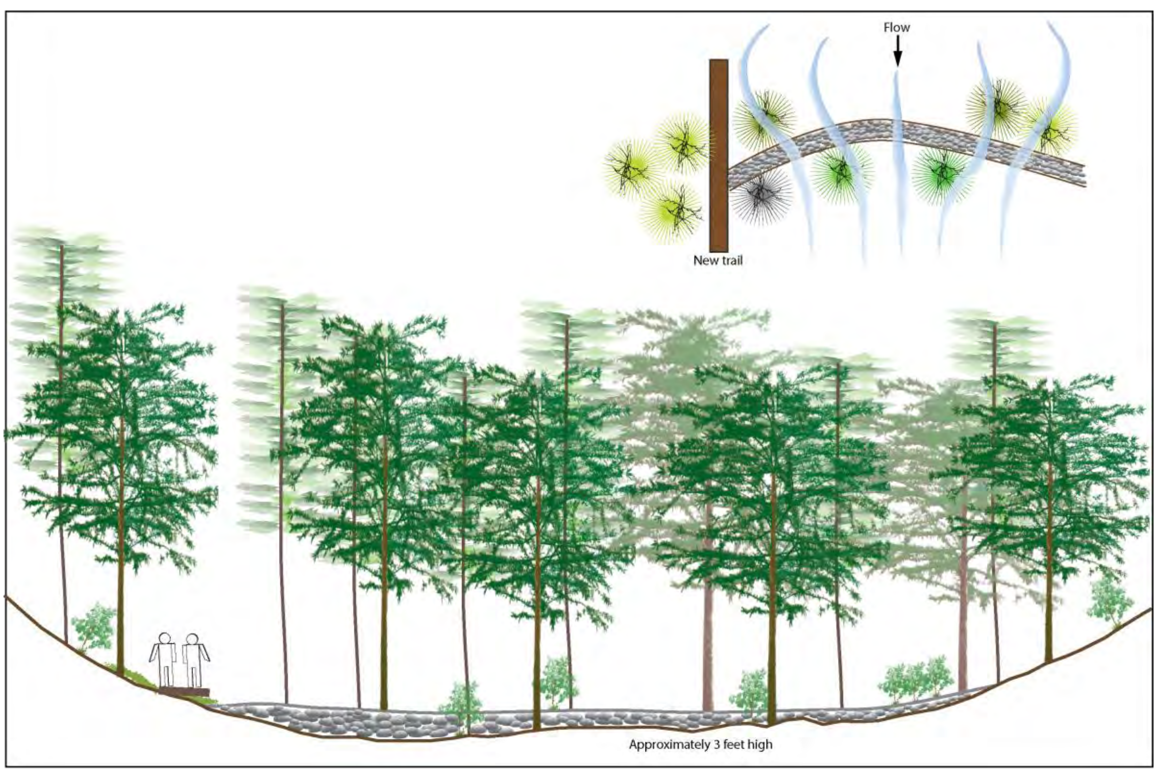
The final potential stabilization measure planned for use is check dams across the channel. The check dam is a grade stabilization structure that reduces the effective grade upstream and dissipates the excess energy over the structure. The check dams will be approximately 3 feet high and consist of appropriately sized riprap at approximately a 3:1 slope on the upstream and downstream faces spanning the channel. The final selected height will depend on the specific location. If this technique is used next to the trail, the trail will need to be located to the side of the ravine.

This stabilization measure can be the most cost effective technique, depending on the slope of the channel and how much length of the channel will be protected. The check dams are most applicable where grades are moderate as they will provide the greatest cost benefit. The cost variation in **Table 8** for the check dams, comes from the varying length of protection that will be provided and whether a trail needs to be relocated.

While this technique will be one of the most visible and least natural appearances, it has the potential to be one of the least invasive in regards to the footprint of the work. The footprint of the check dam will be approximately 30 feet long in the direction of the flow, and could provide protection for up to 200 feet or more of channel. This technique could provide stabilization to a reach and only disturb 15% or less of the reach. The riprap could also be covered with soil and seeded.

There are also water quality benefit to these check dams. The temporary pools above the check dams allow a place for sediment to deposit.

Figure 15: Rendering Showing the Use of Check Dam and Trail Relocation.



6 TREE IMPACTS

Impacts to trees from the CDSF Overflow Project were identified as a potential problem in the report titled *Environmental Assessment County Road 19 Corridor* (EOR 2002a). There were concerns that existing Oak, Cherry, and Aspen trees would be subject to mortality due to flooding if the project was in place. The following section provides the updated methodology that was used to determine flood depths and durations, along with the flood tolerance of the existing trees.

6.1 TREE INVENTORY

A tree inventory of the ravine was conducted in 2002 (EOR 2002a) . Data about the tree species present and their size (diameter at breast height, dbh) for an estimated 2,000 trees were gathered. An updated inventory was conducted during 2013 on approximately 10% of the previously inventoried trees to obtain an understanding whether the vegetation composition has change. Tree species were found to be the same with only small increase in diameter. It is also important to note that the forest condition in the inventory reach is identified as a highly disturbed system and influenced by a dominance of invasive terrestrial species. Details of this 2013 inventory can be found in **Appendix A**.

Since the 2002 inventory, a new open corridor has been created. The updated inventory focused on trees along the new corridor, including the oak species that were spared from clearing activities along the new trail construction and on species adjacent to the ravine channel. Based on the 2013 inventory of the cleared area, approximately 200 trees were removed that were inventoried in 2002. As part of the update, an additional more detailed tree inventory was completed around the wetland area just north of Ravine Lake, which had not previously been completed.

The final tree inventory used in this analysis has 1758 trees. **Figure 16** shows the location of the trees inventoried along the Project area. The tree inventory is extensive and provides an excellent representation of the tree community along the ravine, but due to the large scale of the inventory, every single tree may not be accounted for along the reach.

6.2 TREE FLOODING

Using GIS, a ground elevation was assigned to each tree point using the LiDAR DEM. The HEC-RAS model was run for each of the three condition's peak flow rate and all average daily flows following the peak until average daily flows were less than 1 cfs. The flows used are discussed in **Section 3**.Using the model results of water surface elevation at each cross section, a water surface elevation was assigned to each tree. By subtracting the ground surface elevation from the water surface elevations, the daily flooded depth of each tree was calculated. The number of surveyed trees flooded at each of the depths during each modeled day is listed in **Table 9** through **Table 11**. The trees that are either flooded or dry during the With Project condition are displayed in **Figure 16**.

Table 12 provides a summary comparing each scenario. Using the peak flows, the With Project condition will only flood an additional 50 trees when compared to the Existing condition. When compared to the Build Out condition, only 5 additional trees are flooded. Of those trees only 297 and 339 trees are inundated to depths above 2 feet for the Existing condition and the With Project Condition, respectively.

There are 266 trees that are located in low lying areas that see water even after flow has diminished to less than 1 cfs. This can be seen in the last column of the summary of each condition. These trees are likely inundated frequently in much smaller local runoff events.

Table 9: Tree Flooding Summary Existing Conditions.

Flooded Depth	Existing Conditions Number of Trees			
(feet)	Peak Flow	Day 1	Day 2	Day 3
<0 (Dry)	529	952	1405	1492
0-1	505	556	232	151
1-2	427	123	30	29
2-3	137	34	24	27
3-4	50	27	32	30
4-5	37	30	25	24
>5	73	36	10	5
Total Flooded	1229	806	353	266

Table 10: Tree Flooding Summary Build Out Conditions.

Flooded Depth (feet)	Build Out Conditions																			
	Number of Trees																			
	Peak Flow	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18	Day 19
<0 (Dry)	484	841	996	1030	1020	1025	1029	1025	1035	1042	1060	1151	1151	1154	1161	1162	1162	1169	1395	1488
0-1	474	574	525	506	516	513	510	519	514	511	503	436	436	434	427	427	427	424	239	156
1-2	466	199	114	105	105	103	102	97	93	89	82	62	62	61	61	60	60	56	32	28
2-3	165	38	32	27	27	27	27	29	28	28	29	30	30	30	30	30	30	31	24	28
3-4	48	32	29	32	33	33	34	33	33	33	31	28	28	28	28	28	28	29	34	28
4-5	41	33	28	26	24	24	23	23	23	23	22	22	22	23	23	23	23	22	23	23
>5	80	41	34	32	33	33	33	32	32	32	31	29	29	28	28	28	28	27	11	7
Total Flooded	1274	917	762	728	738	733	729	733	723	716	698	607	607	604	597	596	596	589	363	270

Table 11: Tree Flooding Summary With Project Conditions.

Flooded Depth (feet)	Project Complete Conditions																											
	Number of Trees																											
	Peak Flow	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20	Day 21	Day 22	Day 23	Day 24	Day 25	Day 26	Day 27
<0 (Dry)	479	833	911	762	738	685	670	666	667	687	758	869	973	958	999	1008	1009	1012	1091	1065	1022	1158	1128	1061	1251	1335	1391	1425
0-1	475	573	527	521	511	509	505	504	505	510	520	515	516	513	504	504	503	505	480	497	508	432	453	504	360	292	242	210
1-2	465	207	176	280	298	330	337	338	340	328	284	216	136	152	130	123	123	119	76	81	109	59	67	80	42	33	32	34
2-3	170	37	46	69	79	96	105	109	105	96	69	54	40	40	35	33	33	32	30	30	29	30	30	29	29	27	26	25
3-4	47	34	30	43	48	46	48	47	48	45	44	29	31	31	29	30	30	30	29	31	30	28	28	31	33	32	32	30
4-5	42	33	31	38	35	39	39	40	39	39	38	36	28	28	28	27	27	27	22	23	28	23	22	22	21	26	24	23
>5	80	41	37	45	49	53	54	54	54	53	45	39	34	36	33	33	33	33	30	31	32	28	30	31	22	13	11	11
Total Flooded	1279	925	847	996	1020	1073	1088	1092	1091	1071	1000	889	785	800	759	750	749	746	667	693	736	600	630	697	507	423	367	333

Table 12: Summary of Trees Flooded by Scenario.

	Comparison of Scenarios																											
	Number of Trees Flooded																											
	Peak Flow	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20	Day 21	Day 22	Day 23	Day 24	Day 25	Day 26	Day 27
Existing	**1229**	806	353	266	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*	266*
Build Out	**1274**	917	762	728	738	733	729	733	723	716	698	607	607	604	597	596	596	589	363	270	266*	266*	266*	266*	266*	266*	266*	266*
With Project	**1279**	925	847	996	1020	1073	1088	1092	1091	1071	1000	889	785	800	759	750	749	746	667	693	736	600	630	697	507	423	367	333
Additional Trees Flooded With Project compared to Existing	**50**	119	494	730	754	807	822	826	825	805	734	623	519	534	493	484	483	480	401	427	470	334	364	431	241	157	101	67
Additional Trees Flooded With Project compared to Build Out	**5**	8	85	268	282	340	359	359	368	355	302	282	178	196	162	154	153	157	304	423	470	334	364	431	241	157	101	67

*266 trees are flooded under a zero flow condition (i.e. these trees are located where higher ground downstream will flood these trees

Sources: SWWD, TLG, MN DOT
Aerial: 2012 Twin Cities

0 300 600 1,200 Feet

Outlet Location

Trees Flooded at Peak for With Project

- Dry
- Flooded
- Park Boundaries

South Washington WATERSHED District

Figure 16: Tree Inventory and Flooding

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	SMW		4876-024	11/25/2013	1 of 1

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6.3 FLOOD TOLERANCE

One of the original purposes of the tree inventory was to identify which trees may be at risk to exposure of long duration flows in the ravine. Flood tolerance was discussed in a memorandum on the 2013 tree inventory, which can be found in **Appendix A**. Based on the review of additional data sources the flood tolerance for mature trees from infrequent flood events differs from the criteria used in the 2002 analysis. No sources were cited for the flood tolerance levels in that analysis.

The Bell and Johnson (Bell 1974) study appears to be most consistent with the conditions the mature trees in the ravine will experience during infrequent flooding events. The study measured tolerances to growing season flooding in several reservoirs throughout Illinois during abnormally high water conditions. The study identified flood tolerance ranges for 24 tree species, 10 of which were identified within the assessment area. The study determined that flooding of trees for less than 30 days during the growing season of one year was insufficient to kill any established tree.

The response of any given tree to inundation will vary as it interacts with a wide range of environmental conditions, including soil chemistry and composition, flood sizes and durations and climate conditions and also the individual tree size and health. The investigation shows that there will be a very small change in the total number of trees affected by 100 year flood flows under any scenario. The predicted change in duration of flooding is below the 30 day threshold (maximum inundation period of 27 days). The trees that are subject to the longest durations of flooding are in the lower portions of the channel or low adjacent areas that are currently subject to more frequent inundation and adapted to the current floodplain conditions. The CDSF Overflow Project will not be operated except for more rare and infrequent precipitation events, which will only affect a very infrequent hydrologic condition for the forest ecosystem. Based on the maturity of trees in the assessment area and the shallow flood depths associated with the flow in the ravine, the long term viability of the trees located within the ravine will not be impacted by flows and no long term impacts from inundation are anticipated to the forest composition from the CDSF Overflow Project.

7 RAVINE LAKE IMPACTS

7.1 LAKE DESCRIPTION

Ravine Lake is located within the Cottage Grove Ravine Regional Park. The lake is currently listed as impaired for excess nutrients by the State of Minnesota and significant development is planned for its watershed in the coming years. The lake will receive water from the CDSF Overflow Project. To help understand the existing and future issues facing the lake and upstream ravine, a management plan for Ravine Lake was developed by Houston Engineering, Inc. (Houston Engineering, Inc. 2013).

Ravine Lake is a 26.4-acre lake with a maximum depth of 16 feet. Ravine Lake's watershed includes upland and ravine areas and ultimately drains (through Ravine Lake) to the Mississippi River. The watershed is approximately 4,336 acres; however, the Existing Conditions Model (SWMM) of the watershed indicates that only about 1,704 acres of the watershed currently contributes surface water flow and pollutant loading to Ravine Lake (**Figure 17**) under a 100-year event. The contributing subwatersheds consist primarily of developed urban area to the west, wooded ravine in the central portion, and farmland to the east.

Figure 17: Contributing Watershed Area for Existing Conditions.

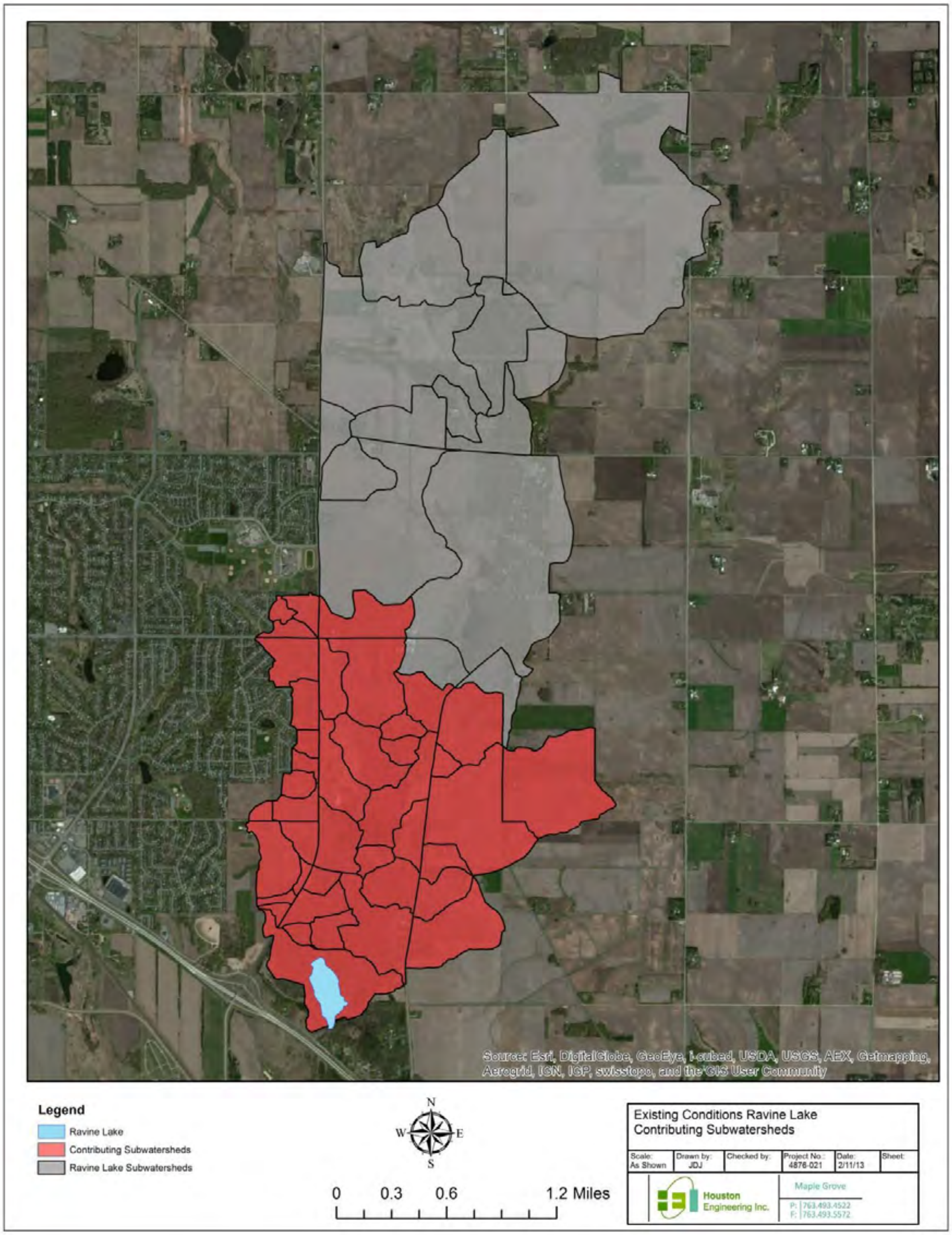

*Figure reproduced from Ravine Lake Management Report (Houston Engineering, Inc. 2013).

7.2 RAVINE LAKE WATER QUALITY

7.2.1 WATER QUALITY SAMPLING

The water quality of Ravine Lake has been assessed through monitoring since 1998. All samples were collected in the upper three feet of the lake. Monitoring of Ravine Lake continues through support from the SWWD and Metropolitan Council and is performed by the Washington Conservation District. A summary of the water quality data by year for the summer season (June 1 through September 30) is shown in **Table 13**. The summer season is used to be consistent with the averaging period for the state's numeric water quality standards. The yearly mean Total Phosphorous concentrations for the summer season range from 50.9 to 174.4 ug/L for the time period 1998 to 2012. The average yearly Total Phosphorous concentration for the summer season is 87.5 ug/L.

Table 13: Ravine Lake Water Quality Data Yearly Summary for Summer Season.

Year	Total Phosphorus			Chlorophyll-*a*			Secchi Disk Transparency		
	n, Sample Size	(ug/L)		n	(ug/L)		n	(meters)	
		Mean	Median		Mean	Median		Mean	Median
Concentrations									
1998	9	174.4	170.0	---	---	---	9	0.54	0.50
1999	10	75.0	75.0	---	---	---	10	1.04	0.85
2000	8	98.8	95.0	---	---	---	8	0.54	0.45
2001	8	121.3	120.0	8	33.81	38.00	8	0.28	0.30
2002	9	108.3	107.0	9	71.00	69.00	9	0.33	0.30
2003	6	64.5	58.0	7	31.93	30.00	8	0.69	0.55
2004	9	62.7	53.0	9	30.89	25.00	9	0.67	0.60
2005	9	50.9	46.0	9	26.17	24.00	9	1.81	1.68
2006	4	118.0	124.0	4	29.50	29.50	4	1.56	1.68
2007	4	59.0	57.5	4	15.78	16.00	4	1.79	1.83
2008	5	80.8	74.0	5	23.00	19.00	5	2.29	2.29
2009	4	52.5	51.5	4	12.50	10.10	4	2.59	2.59
2010	4	72.3	68.5	4	28.35	19.50	4	1.46	1.25
2011	4	68.0	72.0	4	45.98	37.00	4	2.17	1.83
2012	5	106.0	85.0	5	105.40	66.00	5	1.10	1.07

7.2.2 WATERSHED MODELING

The movement of water and Total Phosphorus (TP) from the watershed into Ravine Lake was determined using two P8 models. The Existing Conditions and Build Out Conditions models incorporated a number of factors that encompass inflow, outflow, and the movement of sediment-related particles (including TP) through a watershed. The P8 models were used to estimate the seasonal total runoff volume and TP loading to Ravine Lake over a 50-year continuous period from 1962-2011.

7.2.3 MODEL RESULTS COMPARING EXISTING AND BUILD OUT CONDITIONS LOADING

The P8 models were ran for a 50-year simulation using data from 1962-2011, and the results are summarized in **Table 14**. The results of the Build Out Conditions model show significant changes in the Ravine Lake watershed under the future conditions scenario in both the contributing area and the percent developed. **Table 14** summarizes some of these differences, showing the increased volume of surface water that is forecasted to reach Ravine Lake, as well as the increased surface water TP loads. The TP loads shown in the table for the Build Out Conditions assume that SWWD rules are not applied to the future development.

Table 14. Ravine Lake Average Volumes and Loads, 50 year Averages.

	Scenario 1: Existing Conditions	Scenario 2: Build Out Conditions
% Developed*	8.7%	38.4%
Contributing Area (acres)	1,704	2,944
1962-2011		
Average Summer Seasonal Volume (acre-feet)	103	429
Average Summer Seasonal TP Load (lbs)	186	416
Average Annual Volume (acre-feet)	262	982
Average Annual TP Load (lbs)	281	696

* Developed includes only land classified as "urban", based on entire Ravine Lake watershed

7.3 CDSF OVERFLOW IMPACTS ON RAVINE LAKE

The CDSF Overflow Project is designed to be in use for the 100-year rainfall and larger events. Neither the State of Minnesota nor the SWWD manage water quality for this extreme of an event. Therefore, to assess the water quality impacts of this event for the three conditions, total cumulative flow from the event and resulting hydraulic residence time are being assessed. **Section 7.2** provided volumes and loads to Ravine Lake on average annual basis, while this section address flows and volumes related to a large single rainfall event (100-year). While direct comparisons cannot be made, they do help provide an understanding of the magnitude of the volumes and loads.

The total volume of water flowing into Ravine Lake for the three conditions is listed in **Table 15**. The number of lake volumes was calculated using a volume of 184 ac-ft for Ravine Lake. This is the number of times that the lake volume will be replaced. The average hydraulic residence time was calculated by dividing the number of days of runoff by the number of lake volumes replaced. These volumes

Table 15: Ravine Lake Inflow Volume and Hydraulic Residence Time for 100-year Rainfall.

Condition	Total Lake Inflow Volume (ac-ft)	Number of Lake Volumes	Length of runoff (days)	Average Hydraulic Residence Time (days)
Existing	245	1.33	3	2.26
Build Out	905	4.90	19	3.88
With Project	3162	17.11	27	1.58

Based on the total lake inflow volumes, operation of the Overflow Project will add an additional 2257 ac-ft of water to the total volume into Ravine Lake for a 27 day period on average once every 100 years. The hydraulic residence time of the lake will temporarily decrease from 3.88 days to 1.58 days when comparing the Build Out to the With Project Condition. The volumes listed in **Table 14** help provide some context to the volumes shown in **Table 15.**

Because the CDSF Overflow Project will only operate during events above the 100-year rainfall, the exact water chemistry of the water flowing through the project is not known. The best reference available is a single water quality grab sample that was taken after several large rainfall events when the Bailey Lift Station was in operation in 2011. The Bailey Lift Station will provide the main source of water which will flow through the Overflow pipe when the CDSF Overflow Project is operational. The sample was taken from CD-P85. The sample had a Total Phosphorous (TP) concentration of 70 ug/L. When this concentration is applied to the CDSF Overflow Project water volume, the resulting load is 429 pounds of TP, as shown in **Table 16**.

Table 16: Total Phosphorous Load Calculation for CDSF Overflow Project Volume.

Volume	2257.1	Ac-ft
Assumed Concentration	70	ug/L of P
Load	429	lb of TP

To provide some context, this 429 lb TP load from the CDSF Overflow Project can be compared to the summer season annual load for Existing and Build Out conditions, which are 186 lbs and 416 lbs, respectively. While this summer season load represents approximately the average load for the lake, because this is from a large storm event and the hydraulic residence time is only a few days, this load will have little time to react in the lake. It is anticipated during operation of the CDSF Overflow Project, that the concentration of TP within Ravine Lake will approach that of the incoming concentration of 70 ug/l. This TP concentration is within the current range of the existing water quality data from 1998-2012, shown in **Table 14**.

Based on this data, water from the CDSF Overflow Project will not degrade the water quality beyond the existing condition of the lake.

8 PERMITTING

Projects that affect water resources are often regulated by a variety of local, state, and federal agencies. Regulated activities may be authorized with or without a permit and with or without conditions. The following identifies the probable regulatory approvals that may be necessary for this erosion stabilization project. Detailed design features have not been developed as part of this feasibility report. A detailed regulatory review to identify the specific regulated water bodies, activities and appropriate districts will be conducted to assure that the final project receives all necessary approvals prior to implementation of the project.

8.1 LOCAL AUTHORITIES

Local governments that may have regulatory oversight of the project include the City of Cottage Grove, Washington County and SWWD.

SWWD implements it's standards through the municipalities within the district. The project has been reviewed and consistent with the watershed management plan and Municipal Local Surface Water Management Plans. The wetland conservation act is implemented by local units of government. The Wetland Conservation Act (WCA) requires projects that would drain, fill, or excavate a wetland be subject to sequencing. Sequencing is a process that requires proponents to first try to avoid disturbing the wetland; second, to minimize impact to wetlands; and, finally, to replace any lost wetland acres, functions, and values through on-site or off-site mitigation. The act provides exempt activities that can proceed without further regulation. The SWWD is the WCA authority for the project.

The City and/or County may regulate activities within floodplain or shoreland districts by ordinance. Activities that would involve vegetation removal, grading, or filling within a shoreland district above the ordinary high water mark (OHWM), may require approval by the zoning authority. Activities within designated regulatory floodplains that would impact flood elevations are managed through a local floodplain ordinance. The activities associated with this project that may require floodplain approvals include grading, filling, and temporary storage of materials.

8.2 STATE AGENCIES

The project is proposed within a designated public watercourse that is tributary to Ravine Lake and the Mississippi River. Public waters are regulated by the Department of Natural Resources in accordance with M.S. 103G and MN Rules Chapter 6115. Activities below the OHWM that would change the course, current, or cross section of public waters are subject to public waters permit authority. As with WCA, there are specific exemptions from permitting requirements that may apply. In addition a general permit has been issued for erosion control activities that utilize bioengineering or riprap. The project may have components that are exempt, allowed under general permit, or may need an individual permit depending on the specific features chosen.

Stormwater discharges are regulated under the National Pollution Discharge Elimination System (NPDES) permit program of the Pollution Control Agency. NPDES permits are generally required for any construction activity disturbing one acre or more of soil; or if an area is less than one acre, if it is part of a larger common plan of development that is greater than one acre. Most construction activities are covered by a general NPDES stormwater permit for construction activity, but some construction sites need individual permit coverage. It is anticipated that the project activities would not require an individual permit and that a Stormwater Pollution Prevention Plan (SWPPP) will be developed as part of the final project plans.

8.3 FEDERAL AGENCIES

The Section 404 of the Clean Water Act requires a permit from the US Army Corps of Engineers (USACE) for the discharge of dredged or fill material into waters of the U.S. Many waterbodies and wetlands in the nation are waters of the U.S. and are subject to the Corps' Section 404 regulatory authority. The USACE utilizes general permits to authorize some minor activities or activities that may require a public waters permit or authorization by WCA. The USACE also has implemented abbreviated letter-of-permission authorization procedures for many projects that are not eligible for general permits.

9 ENGINEER'S RECOMENDATION

Considerable technical analyses have been completed to understand the erosion potential through Cottage Grove Ravine Regional Park for three scenarios. The results from these analyses show that even without the CDSF Overflow Project, the erosion potential through the park is great with nearly 65% of the reach characterized as high or excessive risk for erosion.

A suite of stabilization techniques are available, the decision on the specific techniques utilized comes down to a risk management decision. The more invasive techniques typically provide less risk of erosion. Stabilization techniques such as vegetation management do present a greater risk to erosion over time as they are not a completely designed solution, but are one of the least invasive techniques. The construction of check dams may provide a sort of compromise. While the check dams are more visible, the footprint of the structure can be less invasive and the technique is highly effective at preventing erosion.

The specific measures that are selected in the project will be decided on in partnership with Washington County and the Metropolitan Council and will be incorporated in the Cottage Grove Ravine Regional Park Master Plan.

10 REFERENCES

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11 LIST OF APPENDICES

APPENDIX A: RAVINE LAKE ENVIRONMENTAL REPORT 2013.

APPENDIX B: EROSION POTENTIAL RESULTS TABLE.

APPENDIX C: SEDIMENT TRANSPORT RESULTS TABLE.

APPENDIX A

MEMO

(External Correspondence)

To:	John Loomis Matt Moore	**From:**	Emmy Baskerville
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Date:	August 1, 2013		
Cc:	File 4876-024	**Subject:**	Ravine Lake Environmental Report 2013

I. INTRODUCTON

On behalf of the South Washington Watershed District, Houston Engineering completed a field investigation to assess and document the environmental conditions and characterize the composition of the existing plant community of the ravine within the Cottage Grove Ravine Regional Park. An in-depth analysis of this area was previously completed in 2002[1]. The SWWD retained HEI to update and supplement this previously completed analysis because of the lapse in time and potential change in conditions since completion. The results of this assessment are one component needed to assess potential impacts and complete an erosion analysis for high infrequent flooding events through Cottage Grove Ravine Regional Park. The stability of the ravine through the park was identified as a potential impact of the Central Draw Storage Facility and Overflow Project (referred to hereafter as Overflow Project). A number of studies evaluating the Overflow Project have been completed. The erosion potential through the Park was assessed using a velocity analysis in the 2002 report, which included the tree inventory. The Area of Investigation for this assessment is the ravine and areas adjacent to the ravine north of Ravine Lake (**Figure 1, Project Location Map**). The landscape consists almost entirely of a heavily wooded ravine with considerable topographic relief. Portions of the Area of Investigation have been disturbed by both tree-clearing and historic tree-planting activities. Additionally, several linear utilities lines bisect the area.

The ravine itself is relatively flat when compared to its adjacent banks and bluffs. The ravine carries considerable flow following heavy rain events eventually flowing into Ravine Lake. The lands that contribute runoff to the ravine include mostly rural cultivated lands from the north and east.

II. NATURAL COMMUNITIES

A. Historical

The Area of Investigation is within the eastern temperate deciduous forest biome, and the Oak Savanna ecological subsection of Minnesota. According to the Marschner Presettlement Vegetation Map (**Marschner's Map of the Original Vegetation of Minnesota, Figure 2**) the area is identified as Oak Openings and Barrens. Oak barrens are fire-dependent, savanna type communities on dry sites. These areas typically do not have a full forest canopy (like what is present today), and will have oak species interspersed with dry prairie openings. It is clear that human settlement and the absence of fire have allowed the tree canopy to develop into the thick, forested community that is present today, no longer reflecting the pre-settlement condition.

[1] South Washington Watershed District / EOR. 2002. Environmental Assessment, County Road 19 Corridor. Phase I and II Report.

B. Current Condition

1. Wetlands

Two wetland areas were identified and assessed within the Area of Investigation. Wetland Area 1 (see **Photolog**) (as identified in **Figure 3, Natural Communities**) is a PUBG (palustrine, unconsolidated bottom, intermittently exposed), Type 5 Open Water wetland, which is surrounded by a heavily forested community. Dominant tree species observed adjacent to the wetland included bur oak (*Quercus macrocarpa*), pin oak (*Quercus ellipsoidalis*), American elm (*Ulmus americana*), and to a lesser extent, boxelder (Acer negundo), hackberry (Celtis occidentalis), green ash (*Fraxinus pennsylvanica*), locust (*Gelditsia spp*.), quaking aspen (*Populus tremuloides*), and maple (*Acer spp.).* The understory consists of a dense population of invasive common buckthorn (*Rhamnus cathartica*), which was heavily dominant throughout the site most notably on the eastern side. The maximum water depth within the wetland at the time of our investigation was approximately 3 feet, and vegetation was sparse. A small alluvial fan (of sediment) is present on the western side, which may indicate that high water from the adjacent ravine periodically flows into the isolated basin.

The previously completed report (SWWD, 2002) described the area surrounding this wetland as an old field perimeter, and the 2002 and 2003 aerial photography indicates such. At the time of the field visit and based on recent aerial photography, it appears that the water levels have increased moderately and the field perimeter has filled in with tree cover.

Wetland Area 2 (as identified in **Figure 3**) is a Rich Fen habitat on the north side of Ravine Lake. Vegetation observed at the time of our field visit included several species of *Carex*, and *Eleocharis (*See **photolog**) which was abundant throughout the fen area. The invasive species reed canarygrass (*Phalaris arundinacea*) was also observed to be dominant within the southwestern side of the fen area.

2. Ravine Lake

Ravine Lake (**Figure 3, Photolog**) is located on the most southern portion of our Area of Investigation. According to the Minnesota Department of Natural Resources, the maximum depth is approximately 15 feet. Based on the location of the Rich Fen, there appears to be an area of groundwater inflow on the north side of the lake. The shoreline surrounding the lake appeared to be well vegetated at the time of our site visit. Previous studies[2] have indicated that its current state is eutrophic, but improving.

3. Forested Communities

The majority of the Area of Investigation is forested (**Figure 3, Photolog**). A detailed tree inventory was completed as part of the 2002 report and an update was completed as part of this field investigation. The tree inventory information can be found in **Section III**.

Generally, the forested community within the Area of Investigation is a wet-mesic hardwood forest system. This area is represented by a dense canopy of deciduous

[2] South Washington Watershed District. 2003. Comprehensive Lake Management Plan for Ravine Lake, Washington County, Minnesota, 2003.

trees over shade-adapted shrub and herbaceous layers. **Table 1** presents a partial list of the herbaceous, shrub and tree species that were observed throughout the Area of Investigation. This lists what was observed at the time of our investigation (early through mid-June, 2013) and does not represent a complete list of plant species.

Especially present within the Area of Investigation s a dense layer of invasive shrub species, including buckthorn (*Rhamnus spp.*) and honeysuckle (*Lonicera spp.*), and to a much lesser extent, Russian olive (*Elaeagnus angustifolia*). The herbaceous noxious weed (MN) garlic mustard (*Alliaria petiolata*) was also present throughout the Area of Investigation at large densities; however it was not observed to be as widely distributed as the shrubby invasives.

Table 1: Plant species observed within the forested portions of the Area of Investigation during early-mid June, 2013.

Tree		Shrub	
Acer negundo	boxelder	*Rubus idaeus*	American red raspberry
Populus tremuloides	quaking aspen	*Rhamnus spp., Frangula spp.*	buckthorn
Quercus rubra	northern red oak	*Lonicera spp.*	honeysuckle
Quercus macrocarpa	bur oak	*Zanthozylum americanum*	prickly ash
Celtis occidentalis	hackberry	*Salix spp.*	willow species
Ulmus americana	American elm	*Elaeagnus angustifolia*	Russian olive
Fraxinus pennsylvanica	green ash	*Rhus glabra*	smooth sumac
Robinia spp.	locust		
Herb		**Vine**	
Typha x glauca	hybrid cattail	*Vitis riparia*	river bank grape
Taraxacum officionale	dandelion	*Parthenocissus quinquifolia*	Virginia creeper
Bromus inermis	smooth brome		
Quercus spp.	oak (sapling)		
Alliaria petiolata	garlic mustard		
Impatiens capensis	jewelweed		
Onoclea sensibilis	sensitive fern		
Maianthemum racemosum	false Solomon's seal		
Galium aparine	cleavers		
Urtica dioica	stinging nettle		
Poa pratensis	kentucky bluegrass		
Arctium minus	lesser burdock		
Arisaema triphyllum	jack in the pulpit		

4. Dry Open Areas

Several man-made open areas were identified and characterized during our field investigation. The corridors, including an underground pipeline and an aboveground transmission line, and the trail clearings are shown within **Figure 3**. Vegetation observed within these clearings included garlic mustard, dandelion, Kentucky blue grass, wild violet (*Viola spp.*), Canada thistle (*Cirsium arvense*), yellow sweet clover (*Melilotus officinalis*), and lesser burdock. An additional open area was also observed in and adjacent to the ravine on the north side of the Area of Investigation (**Figure 3**).

This area is highly disturbed. Dominant vegetation includes thick stands of burdock and stinging nettle, which are both heavily present in the area and indicate more recent disturbances, as these species tend to be pioneer species at the density levels that were observed at the time of our site visit.

5. Pine Cultivation Area

A historic non-native tree plantation area exists within the northern portion of the Area of Investigation (**Figure 3**). The ravine channel cuts through the plantation. The area is a thick stand of red pine, white pine, jack pine (*Pinus spp*.) and spruce species (*Picea spp.)*. Relatively no understory was observed. Prior to the plantation, this area was likely oak woodland similar to the adjacent forested areas.

III. TREE INVENTORY UPDATE

A. Methods

A complete tree inventory was completed in 2002. The purpose for this 2013 update was to collect data on approximately 10% of the previously inventoried trees to gather an understanding on if/how the site has changed since the initial inventory was completed. The original inventory collected data including species and DBH (diameter at breast height) on approximately 2,000 trees; the 2013 collection data included species and DBH on 225 trees (**Figure 4, Tree Inventory)**. For the purposes of this update inventory, the definition of a tree was a woody plant greater than 3 inches DBH. **Figure 4** shows the trees that were inventoried in 2002 and in 2013. A portion of these data included new inventory information that was collected around Wetland Area 1.

Two areas were the focus of the update inventory. Since the 2002 inventory, the trail through the park has been expanded and paved, and some tree clearing activities have taken place, and a pipeline has been constructed along and adjacent to the new paved trail. A new open corridor has been created, and therefore the updated inventory partially focused on trees along this new corridor, including the oak species that were spared from clearing activities along the new trail construction. In addition, the updated inventory focused on species adjacent to the ravine channel. Tree species were sampled along the ravine channel and compared to previously collected species. In these two areas, trees were randomly sampled and inventoried, DBH measured and the species verified and marked with Trimble GEO-XT, sub-meter accurate handheld GPS device. These inventory data was then utilized to compare to the 2002 data.

In addition to the inventory update, a more detailed tree inventory was completed around Wetland Area 1, which had not previously been completed. In this area, each tree was inventoried to a width of approximately 50 feet from the wetland boundary. Each tree species was identified and the DBH measured, and each tree location determined using a handheld GPS device.

B. Results

Table 2 presents a general summary of the 2002 tree inventory dominant species, counts and DBH ranges. This table presents the dominant tree species inventoried over the entire Area of Investigation. Non-dominant tree species are excluded. For this comparison, oak species have been grouped together into one category.

Based on these data and the data collected from 2013, it appears that the forest community remains of similar species composition as the 2002 inventory data. Specifically, the oak species are the dominant group within the Area of Investigation. A shift has been observed in the sizes as a result of growth, which is to be expected. For example, the 2013 inventory saw a larger percentage of 11-20 inch and 21-30 inch oak species. This mimics what was also observed in boxelder, poplar species, and to a lesser extent, in elms. A greater percentage of new (5-10 inch category) ash and hackberry were seen in the 2013 inventory, indicating an expansion of these two species. As was noted in the 2002 report, invasive species persist throughout the forest shrub layer.

The 2002 inventory appears to be spatially accurate. Most of the individual 2013 tree points were within 12 feet of the 2002 tree points. These small differences can be attributed to the thick tree canopy and steep site topography, which proved to be obstacles to obtaining the wide range of satellite signals necessary to record spatial point data. Additionally, technological updates in GPS technology between 2002 and 2013 may have added to the spatial differences between the two inventories.

Since the time of the 2002 report, the trail area has been cleared of trees (widened) and an underground pipeline installed. HEI surveyed the area where the tree clearing took place (**Figure 3**) and has identified that approximately 200 trees had been removed by the pipeline installation/trail construction activities. It should be noted that at the time of our field visits, it was clear that some oak species remained within this corridor, and they had purposefully been left.

Table 2: Dominant tree species and percentage of total species inventoried in the 2002 Ravine Lake Tree Inventory.

Species and DBH (in.)	Count	Percentage of total 2002 Inventory (dominant species only)
Oak		
5-10	320	17.10%
11-20	208	11.12%
21-30	93	4.97%
>30	4	0.21%
Green Ash		
5-10	19	1.02%
11-20		
21-30	1	0.05%
>30		
Boxelder		
5-10	91	4.86%
11-20	20	1.07%
21-30	1	0.05%
> 30		
Cedar		
5-10	26	1.39%
11-20	19	1.02%
21-30	2	0.11%
>30		
Elm		
5-10	524	28.01%
11-20	74	3.96%
21-30	7	0.37%
>30		
Hackberry		
5-10	33	1.76%
11-20	6	0.32%

Species and DBH (in.)	Count	Percentage of total 2002 Inventory (dominant species only)
21-30		
>30		
Maple		
5-10	20	1.07%
11-20	3	0.16%
21-30	3	0.16%
>30		
Poplar		
5-10	164	8.77%
11-20	38	2.03%
21-30		
>30		

IV. FLOOD TOLERANCE

One of the original purposes of the tree inventory was to identify which trees may be at risk to exposure of long duration flows in the ravine. **Table 3** presents the original criteria identified in the 2002 Environmental Assessment. Flood tolerance levels of the tree species that have been inventoried on the site will vary. There appears to be a variability in the flood tolerance estimates for any given tree species, depending on the publication and the landscape setting. This is due in part to the responses of any given tree as it interacts with a wide range of environmental conditions, including soil chemistry and composition, flood sizes and durations and climate conditions and also the individual tree size and health. Generally speaking, it appears to be a mix of flood tolerance levels within the tree species found within the ravine. In all species, crown inundation will result to in death in less than one month[3] regardless of the level of tolerance to saturation and trunk inundation; however, that depth of inundation is not a concern for this project. **Table 3** also presents the Flooding Tolerance of tree species found in the Ravine from several different sources. Based on the review of other sources it appears that the flood tolerance for mature trees and infrequent flood events are greater than the original criteria.

The Bell and Johnson[4] study appears to be most consistent with the conditions the mature trees in the ravine will experience during large infrequent flooding events. The study measured tolerances to growing season inundation in several reservoirs throughout Illinois during abnormally high water conditions. The study identified flood tolerance ranges for 24 tree species, 10 of which were identified within the Ravine Lake Area of Investigation. In addition to the flood tolerance values presented in **Table 3**, the study determined that inundation of trees for less than 30 days during the growing season of one year was insufficient to kill any established tree.

[3] US Fish and Wildlife Service. Flood Tolerance of Trees. http://www.na.fs.fed.us/spfo/pubs/n_resource/flood/toler.htm
[4] Bell, D.T., and F.L. Johnson. 1974. Flood-Caused Tree Mortality Around Illinois Reservoirs. Trans. Ill. State Acad. Sci. Vol 67 (1): 28-37. Accessed on 8/2/2013 from http://www.il-acad-sci.org/transactions_pdf_files/6706.pdf

V. CONCLUSIONS

The Cottage Grove Ravine Lake Park encompasses a range of various natural and non-native communities including a mesic hardwood oak forest, open uplands, wetland communities, tree plantation areas, and cleared utility corridors and paved trails. The mesic hardwood oak forest is of relatively good quality, but has extensive invasive species dominance in the shrub layer that will continue to degrade the forest community. The forest has a thick canopy of large oak species, and a rich understory dominated by species of green ash, American elm, and hackberry. The shrub layer is dominated by dense stands of buckthorn and to a lesser extent, honeysuckle. Prickly ash and Russian olive (invasive), were also observed, and add to the density of the shrub layer. Large expanses of the invasive garlic mustard were also present on the forest floor; however these stands are not widespread throughout the forest.

Two wetland areas were identified, and the 2002 descriptions match what was observed during our field visits, with one exception: Wetland Area 1 was described as having an old field perimeter. This is not what was observed at the time of our field visits. The basin appeared to have standing surface water up to a wooded buffer consisting of American elm, quaking aspen, locust and boxelder on the east side, and predominantly oak species on the western side, with a thick buckthorn shrub later throughout.

A comparison of the 2002 and 2013 tree inventory indicated that the species composition has remained the same. The tree sizes and locations match well between the two inventories. The 2002 tree inventory is still accurate and can be utilized to assess impacts of the proposed Overflow Project with a few minor changes. These changes include removing trees from the inventory that were cleared along the trail corridor and adding to the inventory trees around the wetland area.

An updated erosion analysis for the ravine has yet to be completed. When the analysis is completed, impacts to trees for three scenarios will be developed; existing conditions, future conditions, and future conditions with the Overflow Project in place.

Table 3: Flood Tolerance of Tree Species Found in the Ravine.

Species	Common Name	Wetland Indicator (Midwest)	Tolerance to Flooding (Original 2002 SWWD/EOR CR 19 Corridor Environmental Assessment)	Tolerance to Flooding (Bell and Johnson 1974)[5]	Relative tolerance of trees to flooded or waterlogged soil. Iowa State Extension Service (Sinclair, Lyon, and Johnson, 1987)[6]
Acer negundo	boxelder	FAC	<30 days/growing season	tolerant[7] (survival at >150 days of inundation)	Intermediate*
Acer rubrum	red maple	FAC	one growing season		tolerant*
Acer saccarinum	Silver maple	FACU	<30 days/growing season	tolerant (survival at >150 days of inundation)	intermediate
Betula alleghaniensis	yellow birch	FAC	<5 days/growing season		
Betula papyifera	paper birch	FACU	<5 days/growing season		
Celtis occidentalis	Hackberry	FAC	One growing season	somewhat tolerant (some individuals killed by < 90 days of flooding and some individuals survived > 150 days flooding)	intermediate
Fraxinus pennsylvanica	green ash	FACW	More than 1 year	somewhat tolerant (some individuals killed by < 90 days of flooding and some individuals survived > 150 days flooding)	tolerant
Juniperus virginiana	red cedar	FACU	<5 days/growing season		Intolerant*
Picea glauca	white spruce	FACU	<5 days/growing season		intolerant
Pinus banksiana	jack pine	FACU	<5 days/growing season		intolerant
Pinus resinosa	red pine	FACU	<5 days/growing season		intolerant
Pinus strobus	white pine	FACU	<5 days/growing season		intolerant
Populus deltoides	cottonwood	FAC	one growing season	tolerant (survival at >150 days of inundation)	intermediate
Populus tremula	quaking aspen	FAC	<5 days/growing season		intermediate
Prunus serotina	black cherry	FACU	<5 days/growing season	intolerant (severe mortality with <50 days inundation)	intolerant
Pyrus malus	apple	n/a	<5 days/growing season		
Quercus alba	white oak	FACU	<5 days/growing season	slightly tolerant (most individuals survive >50 days but <100 days of flooding)	intolerant
Quercus ellipsoidalis	northern pin oak	n/a	<5 days/growing season		
Quercus macrocarpa	bur oak	FAC	<30 days/growing season	tolerant (survival at >150 days of inundation)	intermediate
Quercus rubra	red oak	FACU	<5 days/growing season	slightly tolerant (most individuals survive >50 days but <100 days of flooding)	intolerant
Tilia americana	American basswood	FACU	<30 days/growing season		intolerant
Ulmus americana	American elm	FACW	<30 days/growing season	somewhat tolerant (some individuals killed by < 90 days of flooding and some individuals survived > 150 days flooding)	intermediate

*No definition provided in the referenced document. Definitions of tolerant and intolerant do not coincide with definitions given in the Bell and Johnson 1974 study.

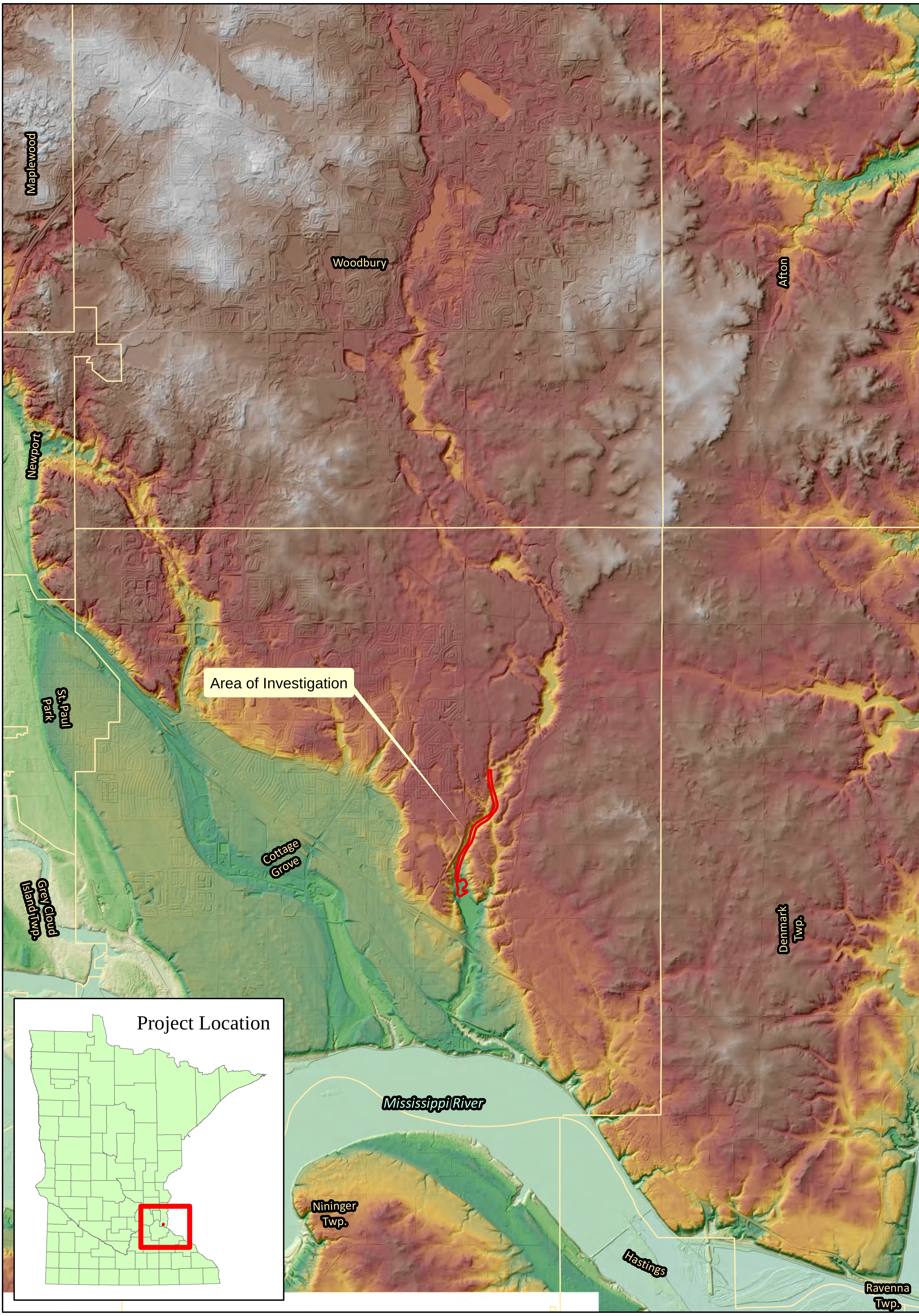
5 Bell, D. T., and E L. Johnson. 1974. [Flood-Caused Tree Mortality Around Illinois Reservoirs.] Trans. Ill. State Acad. Sci. Vol 67 (1): 28-37.

6 Sinclair, Lyon, and Johnson, 1987. Diseases of trees and shrubs, Second edition

7 most individuals survived more than 150 days of flooding during the growing season.

FIGURES

6901 E Fish Lake Rd Ste 140 **Maple Grove** MN 55369 ● Ph. 763.493.4522 ● Fax 763.493.5572



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Legend

Area of Investigation

N

0 3,100 6,200 12,400 Feet

Figure 1: Project Location					
Scale: AS SHOWN	Drawn by: SMW	Checked by: ML	Project No.: 4876-024	Date: 7/22/2013	Sheet: 1 of 1

Houston Engineering Inc.

Maple Grove

P: 763.493.4522
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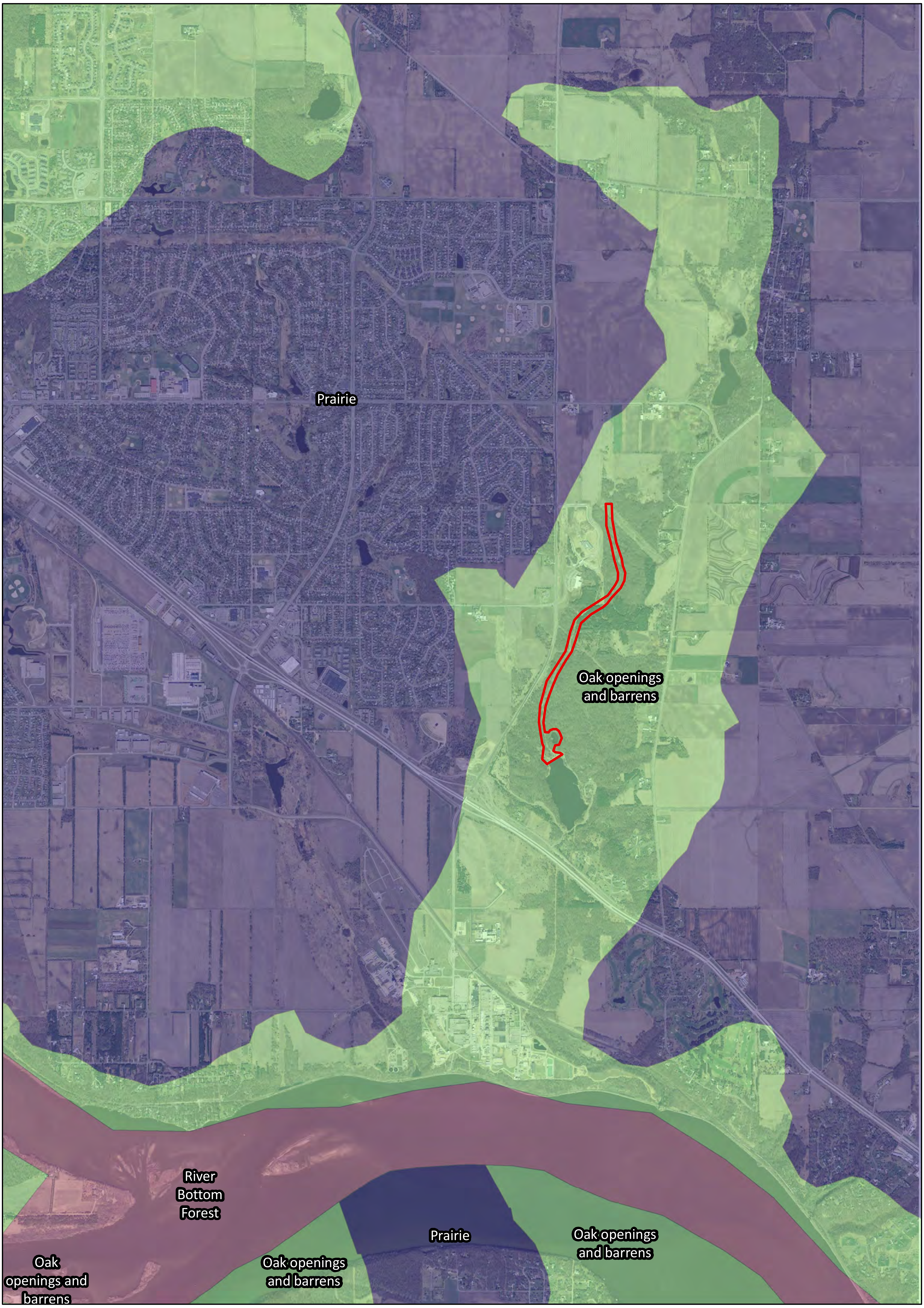

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Imagery: 2012 Twin Cities Aerials
Source: Marschner's Presettlement Vegetation
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Figure 2: Marschner's Map of the Original Vegetation of Minnesota					
Scale: AS SHOWN	Drawn by: SMW	Checked by: ML	Project No.: 4876-024	Date: 7/22/2013	Sheet: 1 of 1

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Area of Investigation

0 1,250 2,500 5,000 Feet

Imagery: 2012 Twin Cities Aerials
Date Saved: 7/26/2013 1:30:46 PM

Legend

- Area of Investigation

Natural Community

- Dry, Open Area
- Dry, Open Area - Clearing
- Dry, Open Area - Utility Clearing
- Pine Plantation
- Wet Mesic Hardwood Forest
- Wetland Area 1
- Wetland Area 2

Figure 3: Natural Communities

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	SMW	ML	4876-024	7/22/2013	1 of 1

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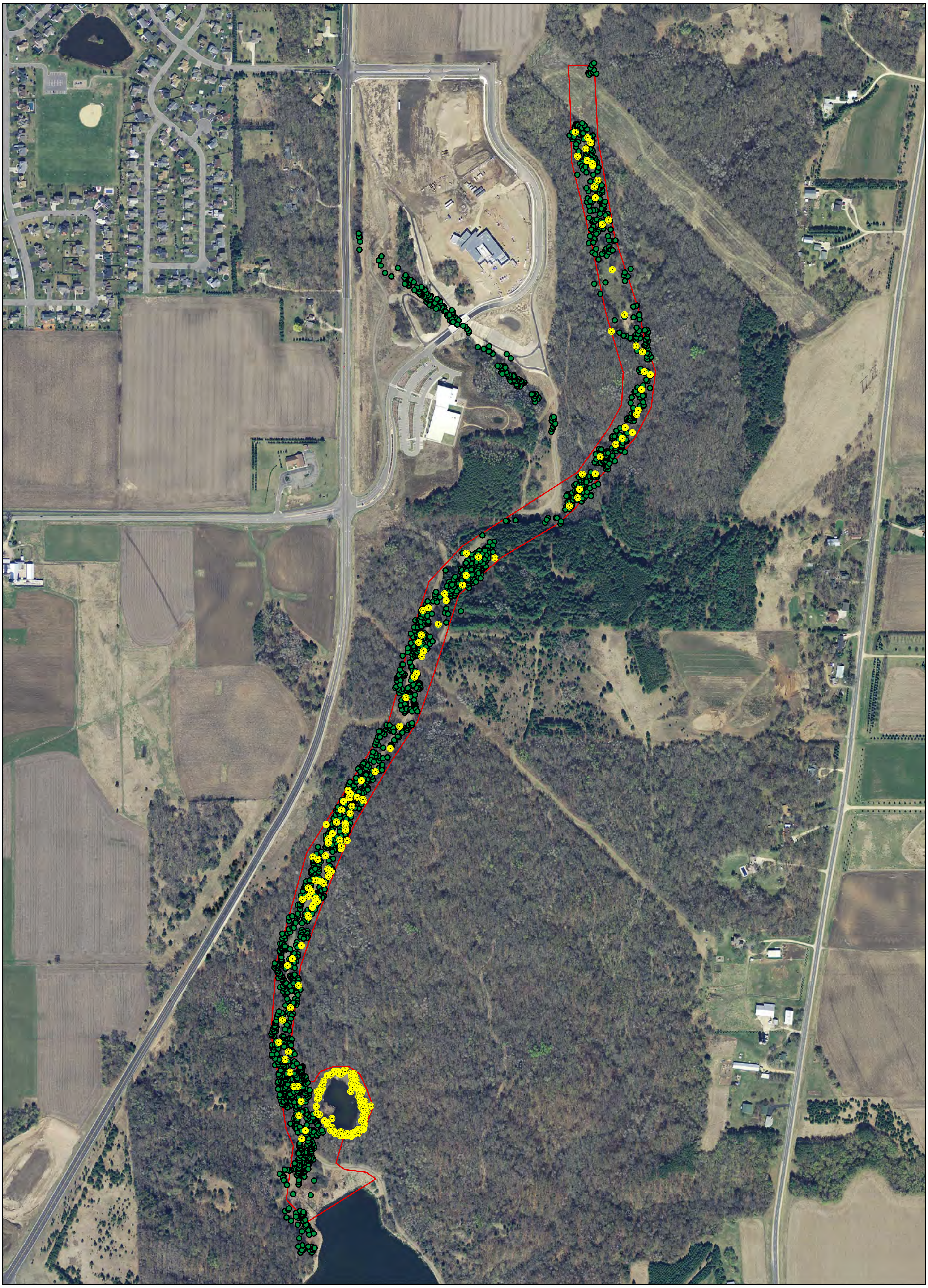

Legend

- Tree Inventory 2013
- Tree Inventory 2002
- Area of Investigation

N

0 265 530 1,060 Feet

Imagery: 2012 Twin Cities Aerials
Date Saved: 7/26/2013 1:31:44 PM

Figure 4: Tree Inventory

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	SMW	ML	4876-024	7/22/2013	1 of 1

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PHOTO LOG

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Photo 1: Wetland Area 1 and wooded buffer. Photo taken from the east facing west across the basin.

Photo 2: Wetland Area 2, rich fen. Photo taken from the north facing south across Ravine Lake.

Photo 3: Representative photo of the forested community, with a thick invasive understory.

Photo 4: Representative photo of the forested community, with a thick invasive understory.

Photo 5: Dry, open area within the northern section of the Area of Investigation.

Photo 6: Representative photo of one of the several maintained dry, open areas. This is a buried pipeline corridor.

Photo 7: Representative photo of the paved trail / pipeline corridor.

APPENDIX B

				100 year, 6.3 inch rainfall event											
		Estimate	Estimate	Existing Conditions				Build Out				Project			
River Sta	Length (ft)	Shear Threshold (lb/sq ft)	Velocity Threshold (ft/sec)	Max Shear (lb/sq ft)	Erosion Potential	Vel Total (ft/s)	Erosion Potential	Max Shear (lb/sq ft)	Erosion Potential	Vel Total (ft/s)	Erosion Potential	Max Shear (lb/sq ft)	Erosion Potential	Vel Total (ft/s)	Erosion Potential
8200	100.0	1.0 - 1.5	1.75 - 3.0	2.475	excessive	1.56	low	2.535	excessive	1.66	low	2.58	excessive	1.72	low
8100	46.4	"	"	1.365	high	1.25	low	1.875	excessive	1.51	low	2.535	excessive	1.82	medium
8054	53.6	"	"	1.395	high	1.25	low	1.995	excessive	1.54	low	2.775	excessive	1.88	medium
8000	45.5	"	"	1.23	medium	1.14	low	1.995	excessive	1.5	low	3.12	excessive	1.95	medium
7954	54.5	"	"	0.555	low	1.21	low	0.735	low	1.55	low	0.99	low	1.95	medium
7900	42.2	"	"	2.1	excessive	1.79	medium	2.415	excessive	2.23	medium	3.03	excessive	2.92	high
7858	57.8	"	"	1.29	high	1.27	low	1.335	high	1.57	low	1.545	excessive	1.91	medium
7800	54.2	"	"	1.215	medium	3.22	excessive	1.74	excessive	3.63	excessive	2.55	excessive	4.34	excessive
7746	45.8	"	"	0.36	low	0.56	low	0.525	low	0.71	low	0.78	low	0.91	low
7700	52.0	"	"	0.345	low	0.57	low	0.795	low	0.87	low	1.605	excessive	1.28	low
7648	48.0	"	"	3.465	excessive	1.91	medium	3.48	excessive	1.91	medium	3.51	excessive	1.92	medium
7600	100.0	1.0 - 1.5	1.75 - 3.0	1.92	excessive	1.89	medium	1.905	excessive	1.89	medium	1.905	excessive	1.89	medium
7500	100.0	1.5 - 2.5	6.0 - 8.0	0.675	low	3.53	low	0.69	low	3.55	low	0.69	low	3.58	low
7400	100.0	"	"	0.48	low	3.42	low	0.48	low	3.41	low	0.465	low	3.4	low
7300	47.6	1.5 - 2.5	6.0 - 8.0	0.06	low	1.35	low	0.06	low	1.35	low	0.06	low	1.35	low
7252	52.4	1.0 - 1.5	1.75 - 3.0	0.06	low	0.66	low	0.06	low	0.66	low	0.06	low	0.66	low
7200	51.0	"	"	0.225	low	0.57	low	0.225	low	0.57	low	0.225	low	0.57	low
7149	49.0	"	"	0.855	low	1.06	low	0.855	low	1.06	low	0.87	low	1.07	low
7100	47.9	"	"	5.505	excessive	2.47	high	5.505	excessive	2.47	high	5.535	excessive	2.48	high
7052	52.1	"	"	3.165	excessive	1.95	medium	3.18	excessive	1.95	medium	3.18	excessive	1.96	medium
7000	47.7	"	"	2.235	excessive	1.68	low	2.25	excessive	1.68	low	2.25	excessive	1.68	low
6952	52.3	"	"	1.695	excessive	1.49	low	1.695	excessive	1.49	low	1.71	excessive	1.49	low
6900	46.6	"	"	1.395	high	1.36	low	1.395	high	1.36	low	1.395	high	1.37	low
6853	53.4	"	"	2.265	excessive	1.71	low	2.25	excessive	1.71	low	2.265	excessive	1.72	low
6800	45.5	"	"	2.625	excessive	1.83	medium	2.595	excessive	1.82	medium	2.625	excessive	1.83	medium
6755	54.5	"	"	2.775	excessive	1.86	medium	2.595	excessive	1.81	medium	2.67	excessive	1.83	medium
6700	100.0	"	"	6.24	excessive	2.57	high	9.165	excessive	3.05	excessive	8.415	excessive	2.94	high
6600	100.0	1.0 - 1.5	1.75 - 3.0	0.135	low	0.44	low	0	low	0.09	low	0	low	0.09	low
6500	100.0	1.5 - 2.5	4.0 - 6.0	0	low	0.06	low	0	low	0.06	low	0	low	0.06	low
6400	100.0	"	"	0	low	0.08	low	0	low	0.08	low	0	low	0.08	low
6300	100.0	"	"	0	low	0.07	low	0	low	0.07	low	0	low	0.07	low
6200	52.8	"	"	0	low	0.11	low	0	low	0.11	low	0	low	0.11	low
6147	47.3	"	"	0	low	0.15	low	0	low	0.14	low	0	low	0.15	low
6100	49.0	"	"	0	low	0.16	low	0	low	0.15	low	0	low	0.15	low
6051	51.0	"	"	0	low	0.16	low	0	low	0.16	low	0	low	0.16	low
6000	53.4	1.5 - 2.5	4.0 - 6.0	0	low	0.17	low	0	low	0.17	low	0	low	0.17	low
5947	46.6	1.0 - 1.5	1.75 - 3.0	0.03	low	0.23	low	0.03	low	0.23	low	0.03	low	0.23	low
5900	54.0	"	"	0.18	low	0.54	low	0.18	low	0.53	low	0.18	low	0.53	low
5846	46.0	"	"	0.39	low	0.78	low	0.375	low	0.76	low	0.375	low	0.76	low
5800	50.7	"	"	1.185	medium	1.28	low	1.11	medium	1.23	low	1.08	medium	1.22	low
5749	49.3	"	"	2.265	excessive	1.73	low	1.965	excessive	1.62	low	1.905	excessive	1.6	low
5700	47.4	"	"	1.14	medium	1.21	low	1.2	medium	1.25	low	1.215	medium	1.26	low
5653	52.6	"	"	1.035	medium	1.17	low	1.11	medium	1.22	low	1.14	medium	1.23	low
5600	100.0	"	"	2.025	excessive	1.6	low	2.145	excessive	1.67	low	2.175	excessive	1.68	low
5500	100.0	"	"	3.315	excessive	2.04	medium	3.465	excessive	2.1	medium	3.51	excessive	2.12	medium
5400	100.0	"	"	3.57	excessive	2.1	medium	3.735	excessive	2.16	medium	3.81	excessive	2.18	medium
5300	100.0	"	"	3.435	excessive	1.92	medium	3.825	excessive	2.04	medium	3.9	excessive	2.07	medium
5200	100.0	"	"	1.08	medium	1.1	low	1.11	medium	1.12	low	1.125	medium	1.14	low
5100	100.0	"	"	0.255	low	0.55	low	0.27	low	0.58	low	0.285	low	0.59	low
5000	100.0	"	"	0.315	low	0.6	low	0.315	low	0.62	low	0.33	low	0.63	low
4900	100.0	"	"	0.36	low	0.62	low	0.345	low	0.61	low	0.36	low	0.63	low
4800	100.0	1.0 - 1.5	1.75 - 3.0	14.325	excessive	3.54	excessive	10.47	excessive	3.34	excessive	10.26	excessive	3.33	excessive
4700	100.0	0.4 - 1.0	1.75 - 2.0	0.57	medium	0.97	low	0.615	medium	1.07	low	0.615	medium	1.09	low
4600	100.0	"	"	0.705	high	4.08	excessive	0.765	high	4.27	excessive	0.78	high	4.3	excessive
4500	100.0	"	"	0.675	medium	1.98	high	0.705	high	2.09	excessive	0.705	high	2.11	excessive
4400	100.0	"	"	1.08	excessive	1.54	low	1.125	excessive	1.68	low	1.125	excessive	1.7	low
4300	100.0	"	"	4.29	excessive	2.49	excessive	4.875	excessive	2.69	excessive	4.965	excessive	2.72	excessive
4200	100.0	"	"	0.825	high	1.31	low	0.9	high	1.4	low	0.915	high	1.41	low
4100	100.0	"	"	1.62	excessive	1.33	low	1.815	excessive	1.42	low	1.845	excessive	1.44	low
4000	100.0	"	"	0.855	high	1.72	low	0.93	high	1.86	medium	0.945	high	1.89	high
3900	100.0	0.4 - 1.0	1.75 - 2.0	2.85	excessive	4.23	excessive	3.21	excessive	4.47	excessive	3.27	excessive	4.51	excessive
3800	100.0	1-2	1.75 - 3.0	0.105	low	1.24	low	0.12	low	1.29	low	0.12	low	1.3	low
3700	100.0	"	"	0.87	low	1.38	low	1.02	medium	1.5	low	1.05	medium	1.52	low
3600	100.0	"	"	5.25	excessive	2.67	high	5.16	excessive	2.77	high	5.13	excessive	2.79	high
3500	100.0	"	"	0.45	low	1.83	medium	0.465	low	1.94	medium	0.465	low	1.96	medium
3400	53.9	"	"	0.09	low	1.52	low	0.105	low	1.64	low	0.105	low	1.66	low
3346	46.1	1-2	1.75 - 3.0	0.06	low	1.18	low	0.06	low	1.31	low	0.075	low	1.33	low
3300	45.4	1-2	1.75 - 3.0	0.03	low	0.93	low	0.045	low	1.03	low	0.045	low	1.05	low
3255	54.6	"	"	0.09	low	1.98	medium	0.105	low	2.15	medium	0.105	low	2.18	medium
3200	42.0	"	"	1.755	excessive	3.19	excessive	2.085	excessive	3.47	excessive	2.145	excessive	3.51	excessive
3158	58.0	"	"	0.945	low	4.83	excessive	1.035	medium	5.09	excessive	1.05	medium	5.13	excessive
3100	50.4	"	"	0.78	low	4.94	excessive	0.78	low	5.12	excessive	0.795	low	5.18	excessive
3050	49.6	"	"	0.825	low	3.89	excessive	0.84	low	3.96	excessive	0.84	low	3.97	excessive
3000	100.0	"	"	0.285	low	1.07	low	0.315	low	1.18	low	0.315	low	1.2	low
2900	100.0	"	"	6.21	excessive	3.91	excessive	6.945	excessive	4.12	excessive	7.125	excessive	4.18	excessive
2800	100.0	"	"	0.48	low	2.51	high	0.495	low	2.59	high	0.495	low	2.59	high
2700	100.0	"	"	1.035	medium	3.05	excessive	1.08	medium	3.16	excessive	1.08	medium	3.16	excessive
2600	100.0	"	"	1.575	excessive	5.4	excessive	1.605	excessive	5.51	excessive	1.605	excessive	5.5	excessive
2500	100.0	"	"	0.78	low	4.7	excessive	0.825	low	4.8	excessive	0.825	low	4.81	excessive
2400	100.0	"	"	0.675	low	5.07	excessive	0.72	low	5.19	excessive	0.72	low	5.19	excessive
2300	100.0	"	"	0.705	low	4.73	excessive	0.735	low	4.82	excessive	0.735	low	4.82	excessive
2200	100.0	"	"	0.495	low	4.19	excessive	0.54	low	4.27	excessive	0.54	low	4.27	excessive
2100	100.0	"	"	0.57	low	4.32	excessive	0.615	low	4.41	excessive	0.615	low	4.41	excessive
2000	100.0	"	"	0.765	low	3.36	excessive	0.915	low	3.51	excessive	0.915	low	3.51	excessive
1900	100.0	"	"	1.155	medium	2.97	high	1.545	excessive	3.32	excessive	1.545	excessive	3.32	excessive
1800	100.0	"	"	0.69	low	1.6	low	0.84	low	1.79	medium	0.84	low	1.79	medium
1700	100.0	"	"	1.23	medium	3.38	excessive	1.425	high	3.6	excessive	1.425	high	3.6	excessive
1600	100.0	"	"	0.69	low	4.31	excessive	0.84	low	4.56	excessive	0.84	low	4.56	excessive
1500	100.0	"	"	0.315	low	3.91	excessive	0.405	low	3.96	excessive	0.405	low	3.96	excessive
1400	100.0	"	"	0.81	low	5.5	excessive	0.855	low	5.45	excessive	0.855	low	5.45	excessive
1300	100.0	"	"	1.62	excessive	2.1	medium	1.605	excessive	1.93	medium	1.605	excessive	1.93	medium
1200	100.0	"	"	4.2	excessive	6.48	excessive	5.34	excessive	6.96	excessive	5.34	excessive	6.96	excessive
1100	100.0	"	"	0.54	low	6.17	excessive	0.63	low	6.68	excessive	0.63	low	6.68	excessive
1000	100.0	"	"	1.305	high	5.08	excessive	1.665	excessive	5.59	excessive	1.665	excessive	5.59	excessive
900	100.0	"	"	0.9	low	4.44	excessive	0.78	low	4.21	excessive	0.78	low	4.21	excessive
800	100.0	"	"	1.17	medium	3.22	excessive	1.38	high	3.42	excessive	1.38	high	3.42	excessive
700	100.0	"	"	1.05	medium	2.47	high	1.11	medium	2.68	high	1.11	medium	2.68	high
600	100.0	"	"	0.465	low	2.01	medium	0.585	low	2.33	medium	0.585	low	2.33	medium
500	100.0	"	"	1.365	high	1.94	medium	1.665	excessive	2.35	medium	1.665	excessive	2.35	medium
400	100.0	"	"	4.875	excessive	3.19	excessive	5.655	excessive	3.82	excessive	5.655	excessive	3.82	excessive
300	100.0	1-2	1.75 - 3.0	0.915	low	2.5	high	1.155	medium	2.76	high	1.155	medium	2.76	high
200	100.0	1.5-2.5	4.0 - 6.0	3.795	excessive	2.35	low	4.17	excessive	2.56	low	4.14	excessive	2.55	low
100	100.0	1.5-2.5	4.0 - 6.0	0.735	low	3.73	low	0.675	low	3.54	low	0.69	low	3.54	low

APPENDIX C

Existing Conditions

River Station	Day 1 Channel Invert El. (ft)	Day 3 Channel Invert El. (ft)	Change in Invert (ft)	Cumulative Mass change (tons)
9300	891.55	887.9708	-3.58	-102
9200	890.29	890.2097	-0.08	-110
9100	889.12	888.881	-0.24	-142
9000	887.74	887.5296	-0.21	-170
8900	886.49	886.1828	-0.31	-186
8800	883.6	882.8418	-0.76	-272
8700	882.17	881.7799	-0.39	-317
8600	879.86	879.6558	-0.20	-323
8500	878.04	878.0642	0.02	-324
8400	876.28	876.3271	0.05	-321
8300	874.57	875.035	0.47	-226
8200	873.16	873.4128	0.25	-190
8100	870.57	870.6508	0.08	-182
8054	869.95	870.0214	0.07	-179
8000	869.69	869.6926	0.00	-179
7954	869.18	869.0391	-0.14	-184
7900	868.35	867.6038	-0.75	-190
7858	867.18	867.3616	0.18	-189
7800	865.04	865.061	0.02	-188
7746	865.32	865.4245	0.10	-185
7700	864.63	863.4893	-1.14	-232
7648	862.71	862.1122	-0.60	-315
7600	861.78	859.7402	-2.04	-624
7500	860.78	859.9673	-0.81	-883
7400	859.58	860.0255	0.45	-749
7300	858.64	858.7651	0.13	-661
7252	857.97	858.6075	0.64	-568
7200	857.44	857.4824	0.04	-560
7149	858.1	858.0249	-0.08	-570
7100	857.8	856.9875	-0.81	-645
7052	856.65	856.5345	-0.12	-657
7000	855.51	855.5907	0.08	-645
6952	854.69	854.7686	0.08	-634
6900	853.73	853.743	0.01	-630
6853	853.15	852.7929	-0.36	-654
6800	852.98	852.0195	-0.96	-697
6755	851.87	851.2957	-0.57	-770
6700	851.48	851.7391	0.26	-772
6600	843.72	843.7599	0.04	-735
6500	841.5	841.6257	0.13	-571
6400	844.68	844.7939	0.11	-421
6300	842.8	842.8583	0.06	-349
6200	844.18	844.2263	0.05	-320
6147	843.96	843.9969	0.04	-308
6100	843.46	843.4925	0.03	-299
6051	843.89	843.9194	0.03	-290
6000	843.28	843.3053	0.03	-282
5947	844.21	844.2289	0.02	-278
5900	846.51	846.5198	0.01	-277
5846	847.6	847.5877	-0.01	-278
5800	848.78	848.5436	-0.24	-300
5749	848.8	848.3211	-0.48	-331
5700	848.51	848.6069	0.10	-322
5653	848.07	847.9154	-0.15	-292
5600	847.11	846.7238	-0.39	-325
5500	846.72	846.1004	-0.62	-395
5400	844.25	842.9587	-1.29	-425
5300	842.76	841.6307	-1.13	-518
5200	841.27	841.114	-0.16	-511
5100	840.14	840.3458	0.21	-467
5000	840.2	840.2485	0.05	-508
4900	840.26	840.1548	-0.11	-549
4800	838.94	837.2153	-1.72	-758
4700	836.54	836.4329	-0.11	-824
4600	836.29	835.8089	-0.48	-923
4500	833.94	834.0002	0.06	-842
4400	832.7	832.9393	0.24	-764
4300	832.09	831.5953	-0.49	-863
4200	830.71	830.7026	-0.01	-861
4100	829.75	828.8453	-0.90	-973
4000	828.54	826.9686	-1.57	-1459
3900	827.21	824.976	-2.23	-1613
3800	825.74	826.1926	0.45	-1428
3700	825.28	825.1793	-0.10	-1461
3600	824.65	823.9733	-0.68	-1583
3500	823.65	823.2019	-0.45	-1707
3400	823.03	822.957	-0.07	-1694
3346	822.45	822.4654	0.02	-1683
3300	822.05	822.026	-0.02	-1669
3255	823.21	820.8627	-2.35	-1890
3200	823.61	821.2471	-2.36	-2060
3158	823.43	820.8342	-2.60	-2212
3100	822.12	819.8188	-2.30	-2400
3050	820.5	820.8032	0.30	-2369
3000	819.41	819.9403	0.53	-2174
2900	820.03	818.9077	-1.12	-2374
2800	818.69	816.0139	-2.68	-2921
2700	817.75	815.2469	-2.50	-3452
2600	817.05	815.6222	-1.43	-3713
2500	815.31	812.8779	-2.43	-4130
2400	813.97	813.9399	-0.03	-4154
2300	812.56	810.4692	-2.09	-4687
2200	810.71	810.045	-0.67	-4759
2100	808.78	808.8456	0.07	-4783
2000	806.62	807.0305	0.41	-4627
1900	805.03	805.7794	0.75	-4153
1800	802.34	802.7546	0.41	-3762
1700	801.07	800.9556	-0.11	-3842
1600	799.65	797.6855	-1.96	-4525
1500	797.66	796.9491	-0.71	-4510
1400	795.4	792.5441	-2.86	-5048
1300	792.99	792.6149	-0.38	-5086
1200	791.42	790.4958	-0.92	-5101
1100	790.84	790.7579	-0.08	-5102
1000	789.4	789.3762	-0.02	-5116
900	787.05	786.1564	-0.89	-5367
800	785.19	785.6056	0.42	-5224
700	783.45	784.9621	1.51	-4897
600	777.44	777.613	0.17	-4824
500	777.45	777.5891	0.14	-4775
400	781.22	781.1241	-0.10	-4852
300	779.11	777.4805	-1.63	-5532
200	776.24	773.823	-2.42	-6106
100	774.12	769.6433	-4.48	-7216
0	771.56	770.3658	-1.19	-7566

Build Out Conditions

River Station	Day 1 Channel Invert El. (ft)	Day 17 Channel Invert El. (ft)	Change in Invert (ft)	Cumulative Mass change (tons)
9300	891.55	886.55	-5.00	-97
9200	890.29	888.2644	-2.03	-291
9100	889.12	886.3084	-2.81	-594
9000	887.74	885.681	-2.06	-849
8900	886.49	883.8862	-2.60	-1089
8800	883.6	881.6288	-1.97	-1178
8700	882.17	881.1688	-1.00	-1285
8600	879.86	878.9082	-0.95	-1306
8500	878.04	877.5322	-0.51	-1347
8400	876.28	877.1124	0.83	-1263
8300	874.57	875.9752	1.41	-920
8200	873.16	874.6939	1.53	-686
8100	870.57	871.3551	0.79	-635
8054	869.95	870.0975	0.15	-618
8000	869.69	869.6171	-0.07	-619
7954	869.18	868.1754	-1.00	-638
7900	868.35	867.9818	-0.37	-648
7858	867.18	868.0831	0.90	-640
7800	865.04	865.0624	0.02	-635
7746	865.32	865.1599	-0.16	-648
7700	864.63	859.63	-5.00	-865
7648	862.71	857.8759	-4.83	-1180
7600	861.78	857.8037	-3.98	-1792
7500	860.78	858.7123	-2.07	-2202
7400	859.58	858.2521	-1.33	-2157
7300	858.64	859.0282	0.39	-2046
7252	857.97	859.1804	1.21	-1829
7200	857.44	858.3833	0.94	-1580
7149	858.1	857.871	-0.23	-1616
7100	857.8	856.5585	-1.24	-1720
7052	856.65	856.5133	-0.14	-1733
7000	855.51	855.2456	-0.26	-1753
6952	854.69	854.4267	-0.26	-1768
6900	853.73	853.2647	-0.47	-1807
6853	853.15	852.8063	-0.34	-1826
6800	852.98	852.071	-0.91	-1905
6755	851.87	852.8193	0.95	-1816
6700	851.48	851.7685	0.29	-1839
6600	843.72	843.8561	0.14	-1781
6500	841.5	842.0471	0.55	-1352
6400	844.68	845.1551	0.48	-948
6300	842.8	843.0362	0.24	-676
6200	844.18	844.2831	0.10	-611
6147	843.96	844.0222	0.06	-592
6100	843.46	843.5134	0.05	-576
6051	843.89	843.9377	0.05	-562
6000	843.28	843.3204	0.04	-550
5947	844.21	844.2394	0.03	-544
5900	846.51	846.5261	0.02	-542
5846	847.6	847.5554	-0.04	-546
5800	848.78	848.4996	-0.28	-571
5749	848.8	848.1965	-0.60	-610
5700	848.51	847.9178	-0.59	-643
5653	848.07	848.1136	0.04	-528
5600	847.11	845.7962	-1.31	-615
5500	846.72	844.6241	-2.10	-807
5400	844.25	843.0112	-1.24	-925
5300	842.76	842.5085	-0.25	-971
5200	841.27	841.3524	0.08	-932
5100	840.14	840.1328	-0.01	-927
5000	840.2	838.8129	-1.39	-1257
4900	840.26	837.9631	-2.30	-1856
4800	838.94	836.0007	-2.94	-2106
4700	836.54	835.9637	-0.58	-2118
4600	836.29	834.6342	-1.66	-2604
4500	833.94	835.1962	1.26	-2128
4400	832.7	832.9032	0.20	-2041
4300	832.09	831.8839	-0.21	-2077
4200	830.71	830.577	-0.13	-2128
4100	829.75	828.8331	-0.92	-2399
4000	828.54	827.2137	-1.33	-2856
3900	827.21	825.1494	-2.06	-3024
3800	825.74	825.7051	-0.03	-2949
3700	825.28	825.0129	-0.27	-3016
3600	824.65	823.3131	-1.34	-3310
3500	823.65	822.1729	-1.48	-3652
3400	823.03	822.2073	-0.82	-3756
3346	822.45	821.2246	-1.23	-3894
3300	822.05	821.9175	-0.13	-3897
3255	823.21	819.4683	-3.74	-4224
3200	823.61	821.1453	-2.46	-4341
3158	823.43	819.0369	-4.39	-4499
3100	822.12	821.0241	-1.10	-4532
3050	820.5	817.0856	-3.41	-4749
3000	819.41	819.1866	-0.22	-4750
2900	820.03	816.1962	-3.83	-5426
2800	818.69	815.9333	-2.76	-6210
2700	817.75	814.367	-3.38	-6871
2600	817.05	813.9348	-3.12	-7123
2500	815.31	811.6713	-3.64	-7155
2400	813.97	813.6458	-0.32	-7247
2300	812.56	808.7339	-3.83	-8212
2200	810.71	808.6796	-2.03	-8739
2100	808.78	808.8802	0.10	-8740
2000	806.62	806.0782	-0.54	-8944
1900	805.03	806.4003	1.37	-7908
1800	802.34	803.2277	0.89	-7214
1700	801.07	800.8037	-0.27	-7309
1600	799.65	796.9134	-2.74	-8214
1500	797.66	797.6152	-0.04	-8219
1400	795.4	790.4014	-5.00	-9009
1300	792.99	788.8535	-4.14	-9599
1200	791.42	789.4585	-1.96	-9768
1100	790.84	787.059	-3.78	-10283
1000	789.4	787.2518	-2.15	-10705
900	787.05	787.0414	-0.01	-10772
800	785.19	784.4576	-0.73	-10992
700	783.45	786.6666	3.22	-10014
600	777.44	778.2698	0.83	-9677
500	777.45	778.1016	0.65	-9448
400	781.22	781.0933	-0.13	-9458
300	779.11	777.3926	-1.72	-10342
200	776.24	774.5573	-1.68	-11349
100	774.12	769.12	-5.00	-14379
0	771.56	766.56	-5.00	-15834

With Project Conditions

River Station	Day 1 Channel Invert El. (ft)	Day 25 Channel Invert El. (ft)	Change in Invert (ft)	Cumulative Mass change (tons)
9300	891.55	886.55	-5.00	-114
9200	890.29	885.29	-5.00	-743
9100	889.12	884.12	-5.00	-1837
9000	887.74	882.74	-5.00	-3092
8900	886.49	881.49	-5.00	-3998
8800	883.6	878.6	-5.00	-4723
8700	882.17	877.17	-5.00	-5373
8600	879.86	874.86	-5.00	-5968
8500	878.04	873.04	-5.00	-6581
8400	876.28	871.2842	-5.00	-7497
8300	874.57	869.5816	-4.99	-8975
8200	873.16	871.2662	-1.89	-9279
8100	870.57	867.9167	-2.65	-9759
8054	869.95	871.0873	1.14	-7992
8000	869.69	867.6263	-2.06	-7901
7954	869.18	867.9384	-1.24	-7728
7900	868.35	866.7273	-1.62	-7783
7858	867.18	868.0366	0.86	-7832
7800	865.04	864.6025	-0.44	-7868
7746	865.32	865.2984	-0.02	-8289
7700	864.63	860.3418	-4.29	-8732
7648	862.71	859.3307	-3.38	-9073
7600	861.78	858.6342	-3.15	-9477
7500	860.78	861.4278	0.65	-9003
7400	859.58	857.3536	-2.23	-9298
7300	858.64	859.6375	1.00	-8689
7252	857.97	858.2382	0.27	-8683
7200	857.44	858.4554	1.02	-8222
7149	858.1	857.8536	-0.25	-8259
7100	857.8	857.4774	-0.32	-8312
7052	856.65	856.4839	-0.17	-8334
7000	855.51	855.7327	0.22	-8314
6952	854.69	854.8655	0.18	-8290
6900	853.73	853.6915	-0.04	-8278
6853	853.15	852.8296	-0.32	-8290
6800	852.98	852.9899	0.01	-8272
6755	851.87	850.561	-1.31	-8414
6700	851.48	852.9427	1.46	-8416
6600	843.72	844.1548	0.43	-8011
6500	841.5	842.9648	1.46	-6281
6400	844.68	846.2039	1.52	-4702
6300	842.8	843.5225	0.72	-3835
6200	844.18	844.7809	0.60	-3463
6147	843.96	844.4258	0.47	-3319
6100	843.46	843.8638	0.40	-3208
6051	843.89	844.2516	0.36	-3103
6000	843.28	843.5799	0.30	-3018
5947	844.21	844.3675	0.16	-2982
5900	846.51	846.4618	-0.05	-2988
5846	847.6	847.3596	-0.24	-3015
5800	848.78	847.3798	-1.40	-3153
5749	848.8	846.9603	-1.84	-3319
5700	848.51	845.6443	-2.87	-3570
5653	848.07	848.1148	0.04	-3477
5600	847.11	842.5468	-4.56	-3744
5500	846.72	841.8751	-4.84	-4345
5400	844.25	841.8577	-2.39	-4638
5300	842.76	841.8431	-0.92	-4859
5200	841.27	841.701	0.43	-4637
5100	840.14	840.5345	0.39	-4384
5000	840.2	839.1977	-1.00	-4629
4900	840.26	837.9633	-2.30	-5181
4800	838.94	833.94	-5.00	-6081
4700	836.54	831.9523	-4.59	-7746
4600	836.29	833.8679	-2.42	-8521
4500	833.94	833.2	-0.74	-8966
4400	832.7	831.5357	-1.16	-9333
4300	832.09	831.4871	-0.60	-9485
4200	830.71	826.4517	-4.26	-11411
4100	829.75	827.5524	-2.20	-12066
4000	828.54	825.3739	-3.17	-12959
3900	827.21	824.2448	-2.97	-13399
3800	825.74	825.4426	-0.30	-12976
3700	825.28	823.0234	-2.26	-13571
3600	824.65	824.9716	0.32	-13573
3500	823.65	819.8773	-3.77	-14621
3400	823.03	824.8877	1.86	-13779
3346	822.45	818.8954	-3.55	-14208
3300	822.05	821.8638	-0.19	-14182
3255	823.21	819.991	-3.22	-13916
3200	823.61	822.2675	-1.34	-13925
3158	823.43	818.7675	-4.66	-14279
3100	822.12	819.2275	-2.89	-14483
3050	820.5	819.4657	-1.03	-14642
3000	819.41	818.77	-0.64	-14817
2900	820.03	819.176	-0.85	-14976
2800	818.69	816.7904	-1.90	-15588
2700	817.75	817.2327	-0.52	-15657
2600	817.05	812.0872	-4.96	-16559
2500	815.31	810.8784	-4.43	-17949
2400	813.97	811.895	-2.08	-18489
2300	812.56	811.7524	-0.81	-18691
2200	810.71	809.9636	-0.75	-18898
2100	808.78	807.7672	-1.01	-19421
2000	806.62	806.2252	-0.39	-19934
1900	805.03	805.5914	0.56	-19861
1800	802.34	801.1367	-1.20	-21361
1700	801.07	799.7173	-1.35	-22218
1600	799.65	794.65	-5.00	-24098
1500	797.66	792.6729	-4.99	-25231
1400	795.4	790.4	-5.00	-25523
1300	792.99	788.8552	-4.13	-25491
1200	791.42	788.9348	-2.49	-25755
1100	790.84	788.7639	-2.08	-25994
1000	789.4	786.2205	-3.18	-26630
900	787.05	787.6906	0.64	-26056
800	785.19	785.4716	0.28	-26021
700	783.45	787.7241	4.27	-22759
600	777.44	779.4528	2.01	-21663
500	777.45	779.1646	1.71	-20967
400	781.22	777.1804	-4.04	-21886
300	779.11	775.1881	-3.92	-23547
200	776.24	771.5833	-4.66	-24990
100	774.12	770.7506	-3.37	-26707
0	771.56	766.56	-5.00	-28190

MEMO

(External Correspondence)

To: John Loomis
Matt Moore

From: Mike Lawrence, P.E.
Anna Dooley, EIT

Date: 3/25/2014

Subject: Lower East Ravine Stabilization

Cc: File 4876-027

I. Introduction and Background

This memorandum's purpose is to develop technical information on Lower East Ravine as it relates to the Central Draw Storage Facility Overflow Project (referred to hereafter as the CDSF Overflow Project). Portions of the ravine are eroding and will erode as the upstream area contributing runoff becomes fully developed. The geomorphic stability of the ravine was identified as a potential impact of the CDSF Overflow Project. The CDSF Overflow Project is being led by the South Washington Watershed District (SWWD) and is comprised of five phases. Phase I of the project is nearly complete; this phase consisted of connecting the CDSF to the Cottage Grove stormwater network and constructing a 72" pipe from the CDSF to another storage area, called CP4-3. Phases II through V consist of providing stabilization to existing channels, updating the lake outlet structure, and constructing a pipe segment. This memorandum is focused on Phase II of the Overflow Project, stabilizing the ravine below Highway 61, and also Phase III updating the lake outlet structure.

The project area (see **Figure 1**) is the open channel of the East Ravine Creek downstream of Ravine Lake from Highway 61 to the Mississippi river. The length of the open channel for this portion of the project is approximately 11,000 feet. The land along the open channel below Highway 61 is owned by Minnesota Mining and Manufacturing (3M).

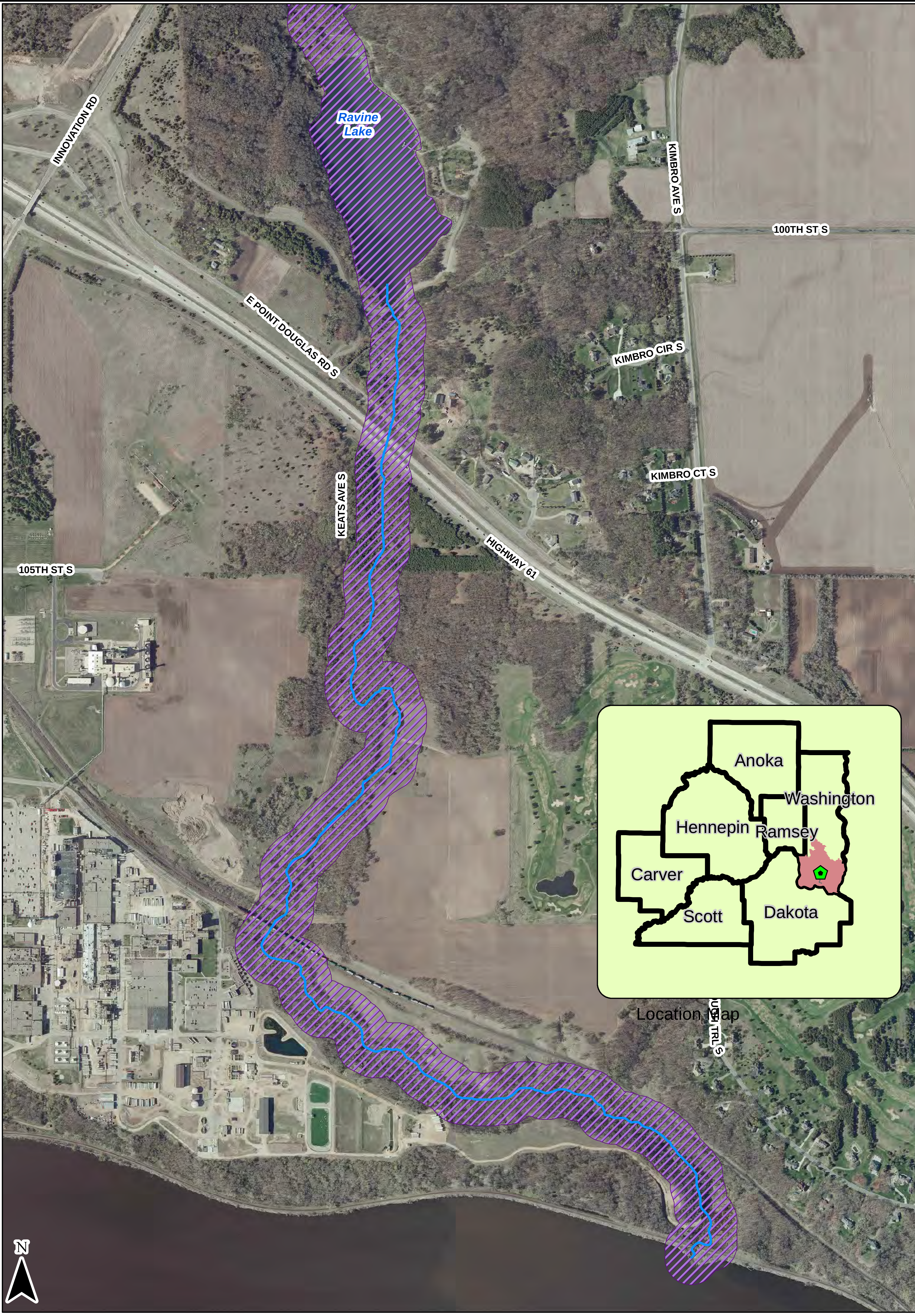
II. Hydrologic Modeling

Extensive hydrologic and hydraulic modeling has been completed to analyze the flow through the watershed to Ravine Lake in addition to the area that contributes runoff to the CDSF Overflow Project. The hydrology used for this memorandum comes from modeling completed by HDR Engineering, Inc.[1] using the XP-SWMM model for three scenarios. The XP-SWMM model has been modified slightly to include updated information. The modeling conditions and assumptions are presented in this section, and the results are presented in Section III.

A. Precipitation

The design precipitation event used for all modeling is a 6.3 inch rainfall event with a 24-hour SCS Type II Distribution. All flows listed in this report are for the 100-year rainfall event. Although the CDSF Overflow Project was designed for the 6.3 inch event, additional modeling has shown that the CDSF Overflow Project can accommodate increase runoff resulting from greater precipitation events (e.g. the new Atlas 14 design event, 7.8" 95% Confidence Interval storm, and back to back design events). Under all of these extreme conditions, outflow from the CDSF Overflow Project is limited by the permitted operation plan for the City of Woodbury's Bailey Lake Lift Station. Therefore the peak runoff rates from the CDSF Overflow Project will not increase even for greater rainfall events, although the local flows are expected increase with development.

[1] HDR Engineering, Inc. "Supplemental Update to the CDSF Outlet Design and Evaluation of Impacts to East Ravine in City of Cottage Grove." October 3, 2013.



0 375 750 1,500 Feet

Stream Centerline

Assessment Area

South Washington WATERSHED District

Sources: SWWD, TLG, MN DOT
Aerial: 2013 Washington County, MN

Figure 1: Location Map

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B. Land Use

Two land use conditions were used in the hydrologic modeling. The existing land use condition is based on 2009 aerial photography and site development plans for government facilities adjacent to the park provided by SWWD. The future land use conditions representing ultimate build out are based on the 2006 Cottage Grove Alternative Urban Area-wide Review (AUAR). This AUAR condition is the planned land use and is considered the ultimate build out condition; no specific timeline is associated with this condition.

C. Modeled Scenarios

The hydrology for three scenarios was evaluated as follows:

Scenario 1. Existing Conditions - This represents the current land use within the contributing drainage area and no stormsewer connection from the CDSF Overflow Project to the East Ravine.

Scenario 2. Build Out Conditions (CDSF not constructed) - This scenario consists of the future (ultimate build out) land use and no stormsewer connection from the CDSF Overflow Project to East Ravine. This scenario provides a sense of the future erosion within the East Ravine, in the absence of the CDSF Overflow Project. This change in the erosion potential as a result of the CDSF Overflow Project is compared to this condition.

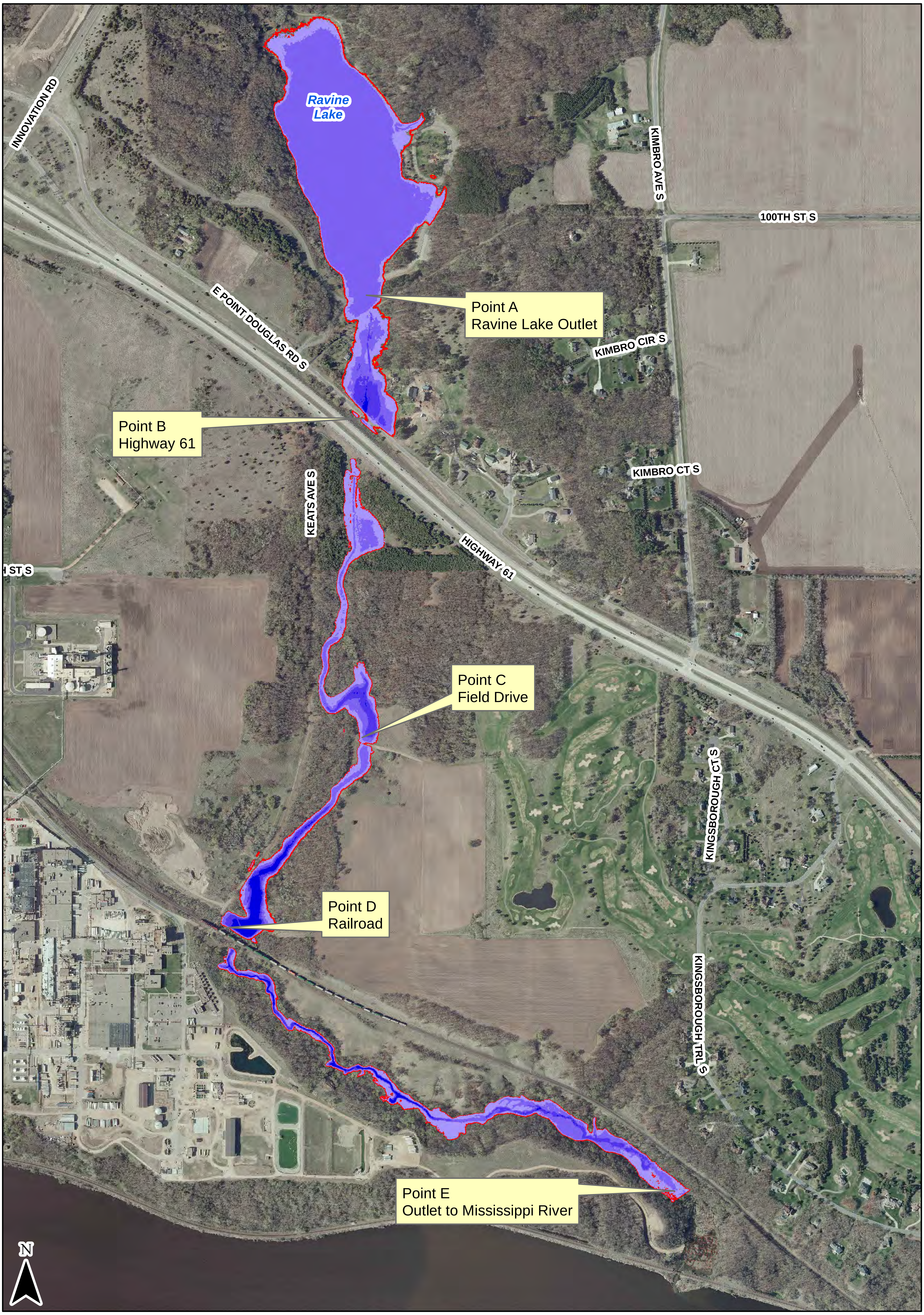
Scenario 3. With Project Conditions (Build-out Conditions with CDSF constructed and gates open) – This represents the future (ultimate build out) land use and an operational CDSF Overflow Project.

III. Flows and Stage through Lower East Ravine

The following section presents results from the XP-SWMM models at 5 reference point locations. **Figure 2** shows the reference point locations as well as the flooding extent for all three scenarios. **Table 2** provides a summary of peak flows and peak stages at each reference points. All results are for the 100 year 24 hour rainfall event. This section also contains a brief discussion on each reference point.

Table 1 – Summary of XP-SWMM Model Results, 100 year 24 hour Rainfall

	Point A Ravine Lake		Point B Highway 62		Point C Field Drive		Point D Railroad		Point E Mississippi River	
Conditions	**Peak Flow (cfs)**	**Peak Stage (ft)**	**Peak Flow (cfs)**	**Peak Stage (ft)**	**Peak Flow (cfs)**	**Peak Stage (ft)**	**Peak Flow (cfs)**	**Peak Stage (ft)**	**Peak Flow (cfs)**	**Peak Stage (ft)**
Existing	365	775.07	409	775.07	450	759.07	562	751.31	712	689.79
Build Out	401	775.73	428	775.73	465	759.07	580	751.76	765	689.87
With Project	402	775.75	429	775.75	465	759.07	580	751.75	765	689.86



0 375 750 1,500 Feet

Existing Conditions

Flooded Depth (ft)

- 0
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 12.4

Build Out Conditions

With Project Conditions

Sources: SWWD, TLG, MN DOT
Aerial: 2013 Washington County, MN

South Washington WATERSHED District

Figure 2: Maximum Inundation Area for All Three Scenarios					
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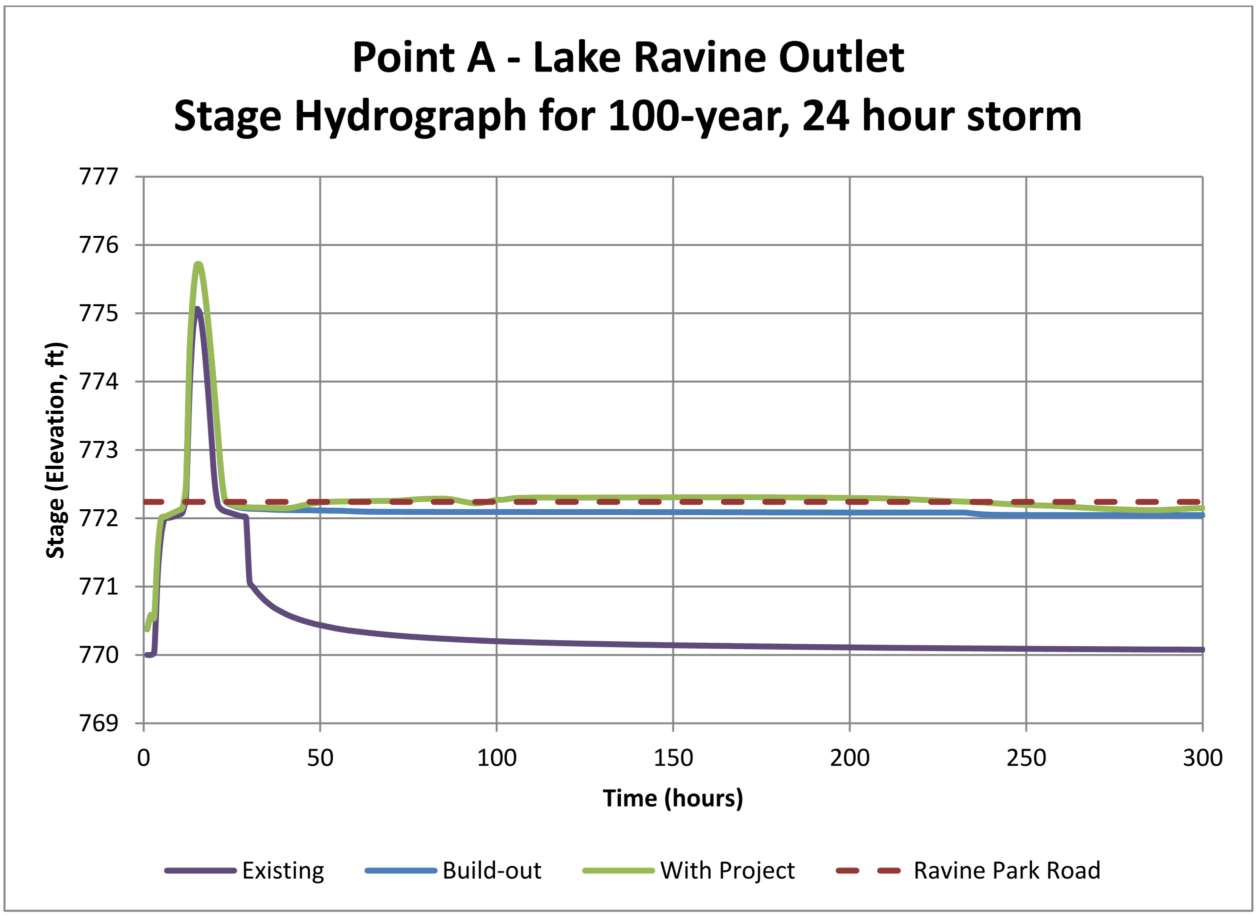
A. POINT A – Ravine Lake Outlet

The current entrance to Cottage Grove Ravine Regional Park crosses through the southern end of Ravine Lake. A 24" HDPE culvert was placed in 2010 under the roadway. There are also two small field roads with 18" CMP culverts; the middle culvert of the three defines the lake runout elevation.

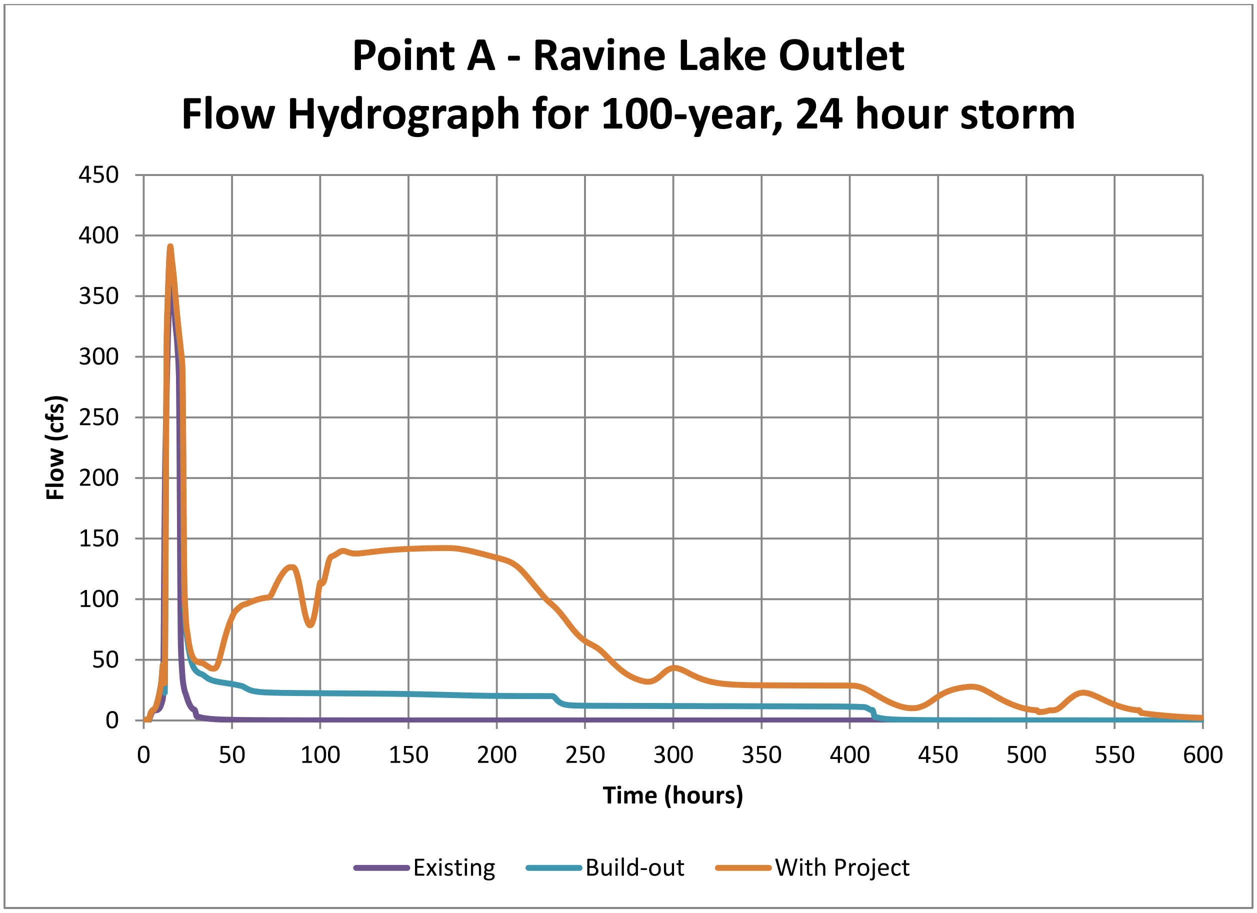
The stage hydrograph for Ravine Lake is presented in **Graph 1**. The Park road is overtopped by two feet or more during the 100 year flood event; the road is overtopped for approximately 13 hours under Existing Conditions. The stage of Ravine Lake is influenced by Highway 61 during the peak flooding, as can be seen in **Table 1**, where the stage is equal for both Point A and B. A flow hydrograph is shown in **Graph 2**. The flows from only the CDSF Overflow project can be seen starting at approximately hour 50 until approximately hour 600, peaking at 142 cfs. The peak flows rates from the local drainage area far exceed the CDSF flows.

The lake outlet is discussed in greater detail in **Section IV**.

Graph 1 – Point A Stage Hydrograph



Graph 2 – Point A Flow Hydrograph



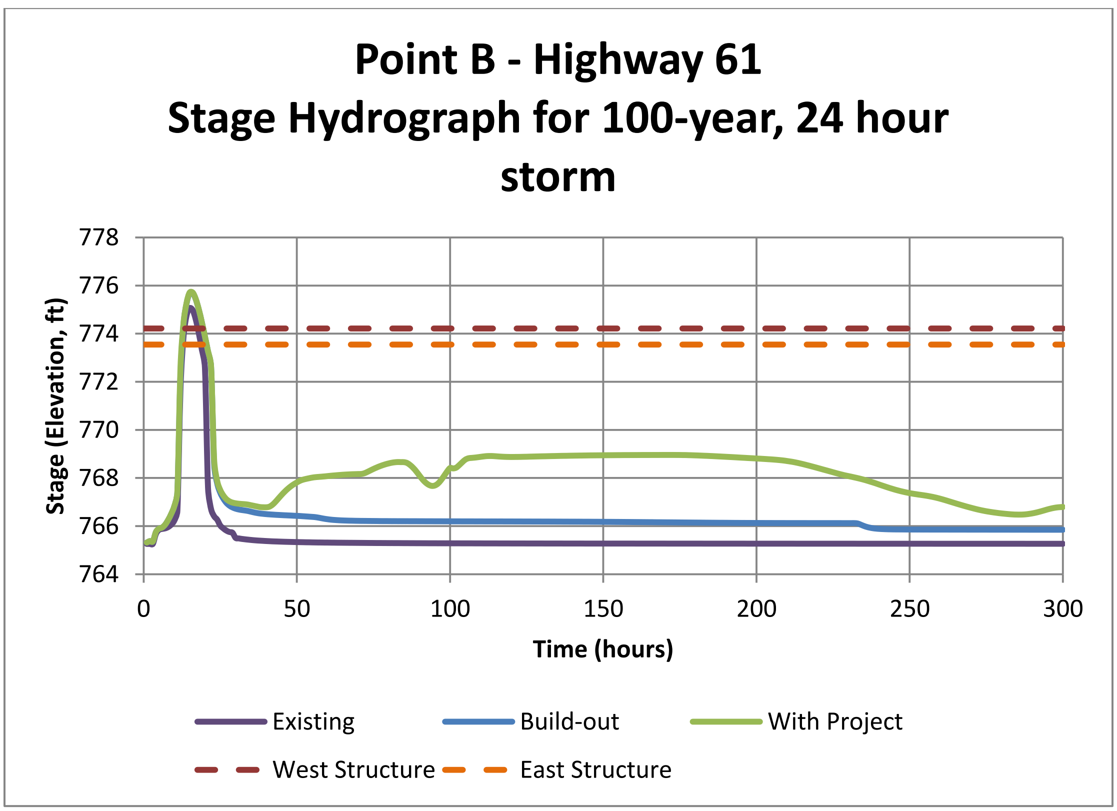
B. POINT B – Highway 61

Highway 61 is located approximately 1000 feet below Ravine Lake. A 6' x 6' Reinforced concrete box culvert (which transitions to a 72" RCP under the roadway) is located under the frontage road and Highway 61. This culvert restricts flow during large events; during the peak of the 100 year event water backs up to Ravine Lake. This can be seen in **Table 1** where the elevation of Point A and B are equal. **Graph 3** presents a stage hydrograph just upstream of Highway 61. Highway 61 has a top of road elevation of approximately 800 feet, so Highway 61 is not overtopped in any of the scenarios. Also shown on this graph is the elevation of two structures which are inundated during the 100 year event. **Graph 4** shows the flow hydrograph through the culvert at Highway 61. The flows from only the CDSF Overflow project can be seen starting at approximately hour 50 until approximately hour 600, peaking at 142 cfs.

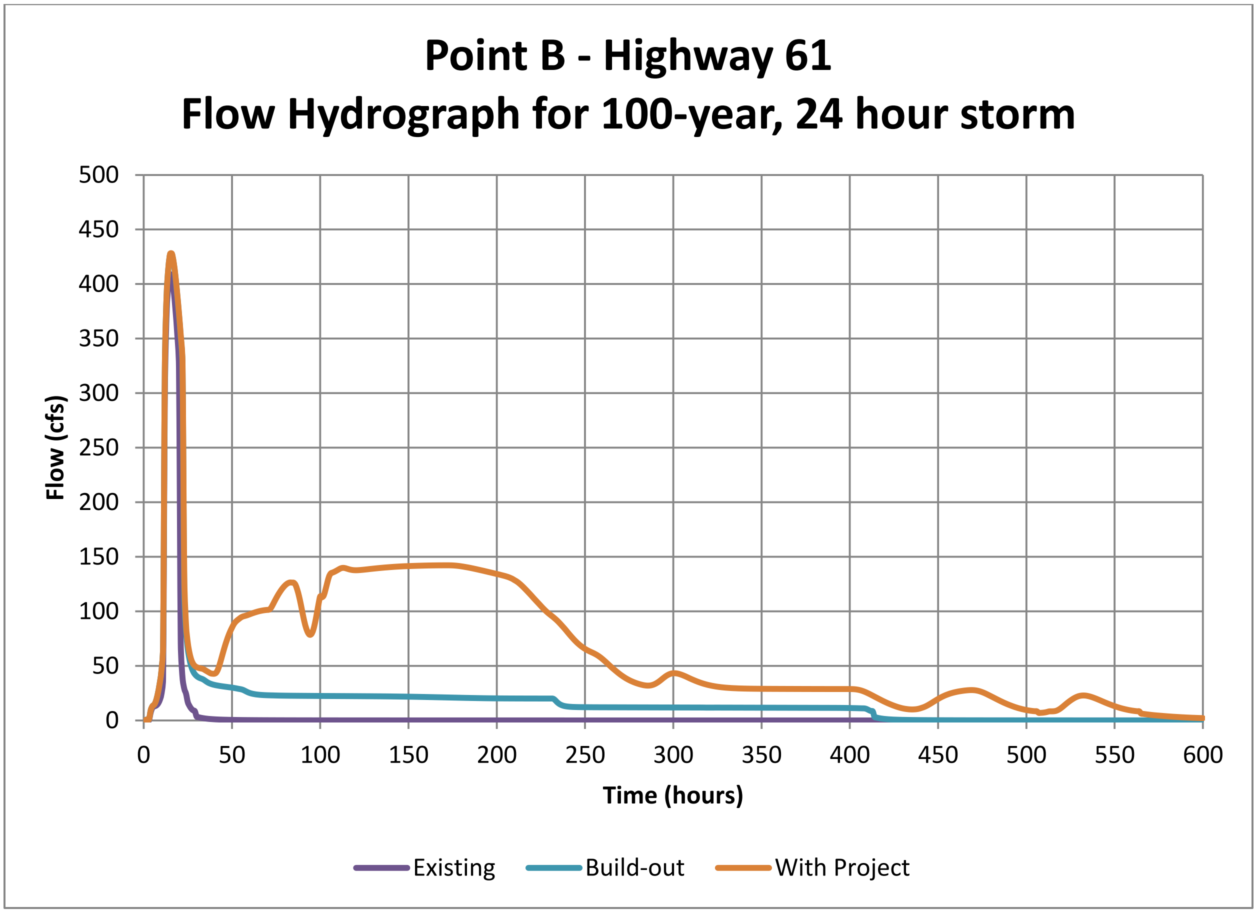
Structures upstream of Highway 61

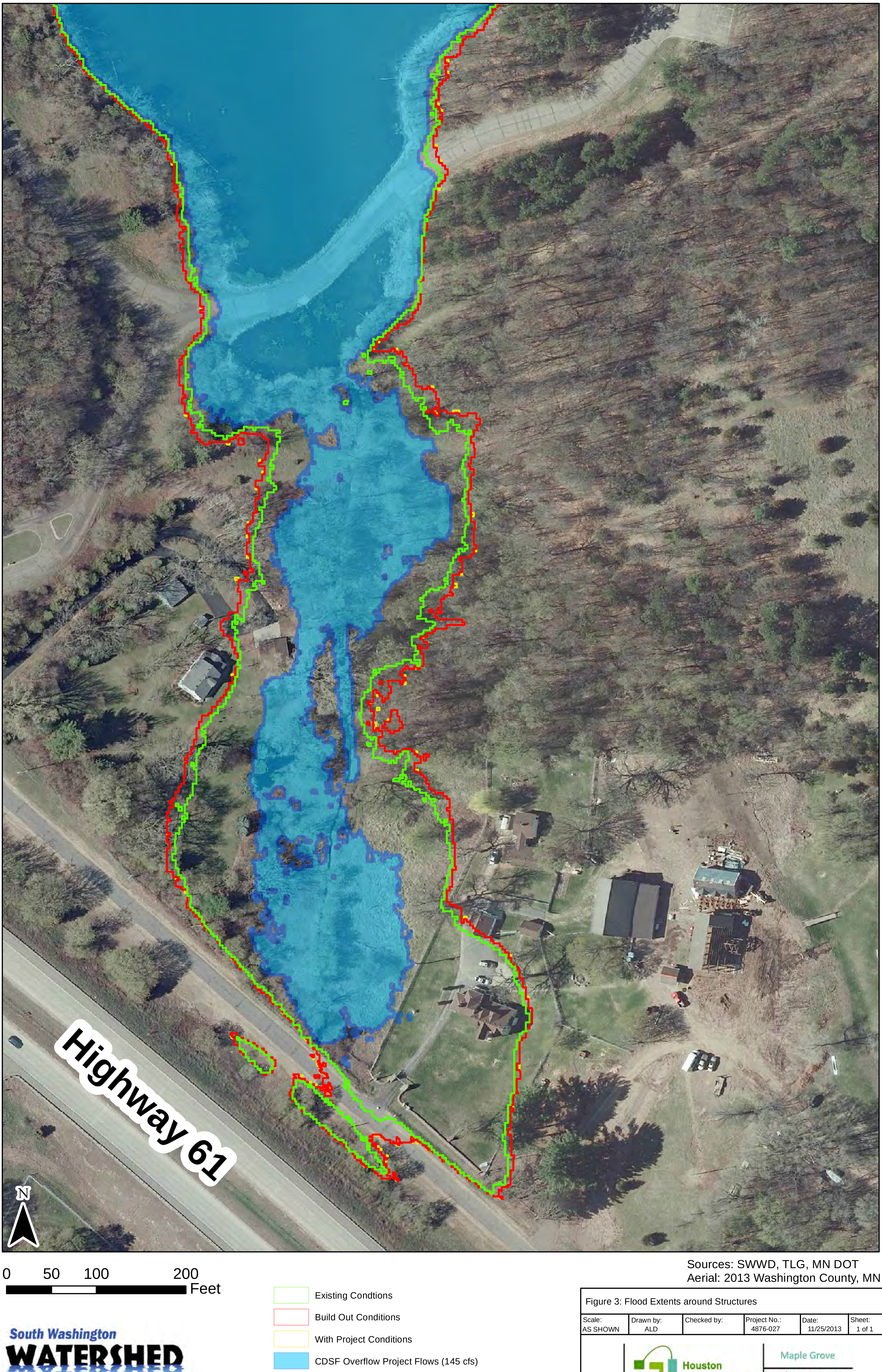
Figure 3 shows a more detailed view of the inundated area above Highway 61. As can be seen in the figure, both structures are inundated under all three scenarios for the 100 year rainfall event. Also shown on the figure is the flooding extent of only the CDSF Overflow project flows at approximately Day 8, at a rate of 142 cfs. The CDSF Overflow Project does not contribute to any increase in stage or duration of the flooding of these two structures. If there is a need to eliminate the flooding of these structures, this will require additional flow capacity through Highway 61 (i.e. another culvert).

Graph 3 – Point B Stage Hydrograph



Graph 4 – Point B Flow Hydrograph





Sources: SWWD, TLG, MN DOT
Aerial: 2013 Washington County, MN

Figure 3: Flood Extents around Structures

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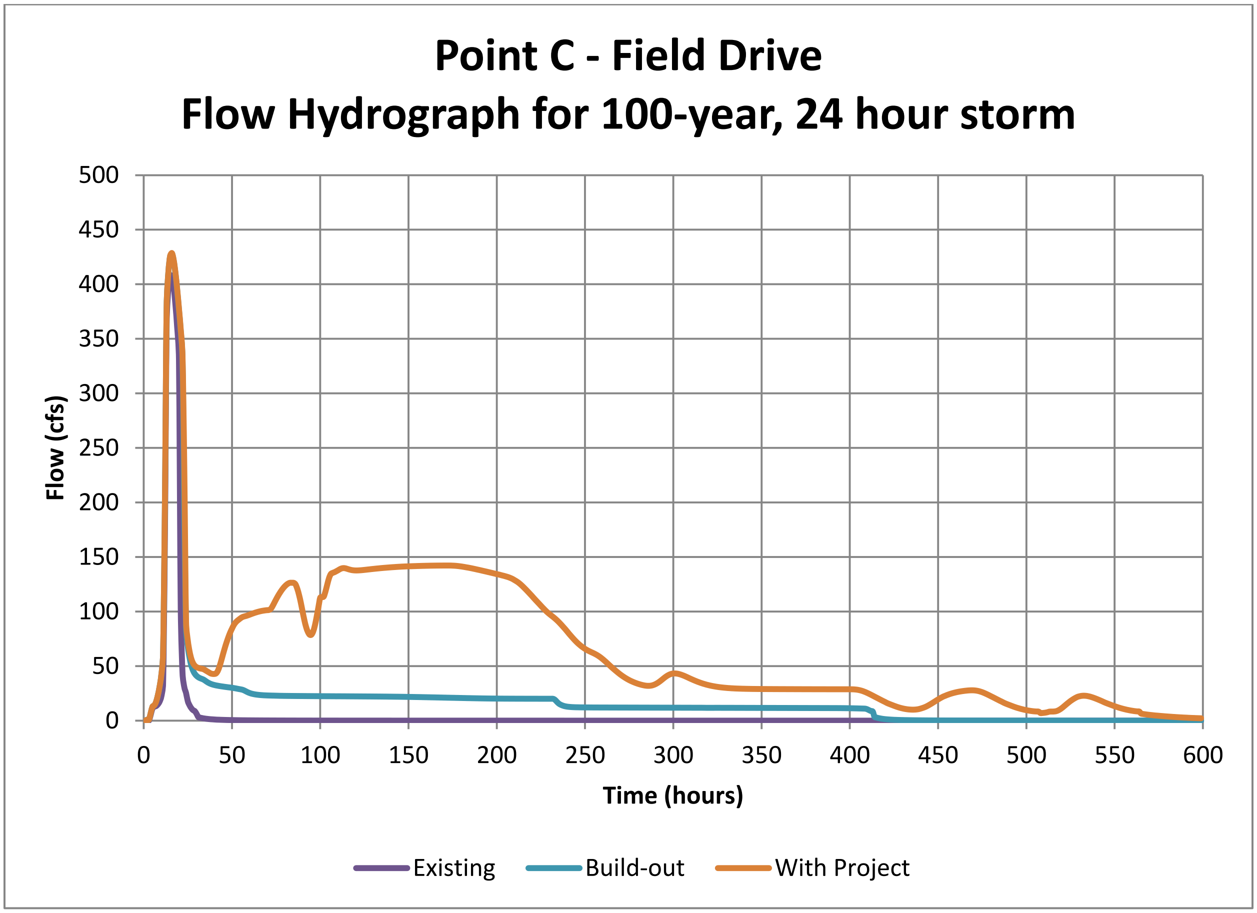
C. POINT C – Field Drive

Located on the 3M property is a small field drive crossing with a 24” CMP. The roadway is quickly overtopped during the 100 year events. The peak flow rate at this structure is 465 cfs for both the Build Out and With Project conditions. The flow hydrograph is shown in **Graph 5**.

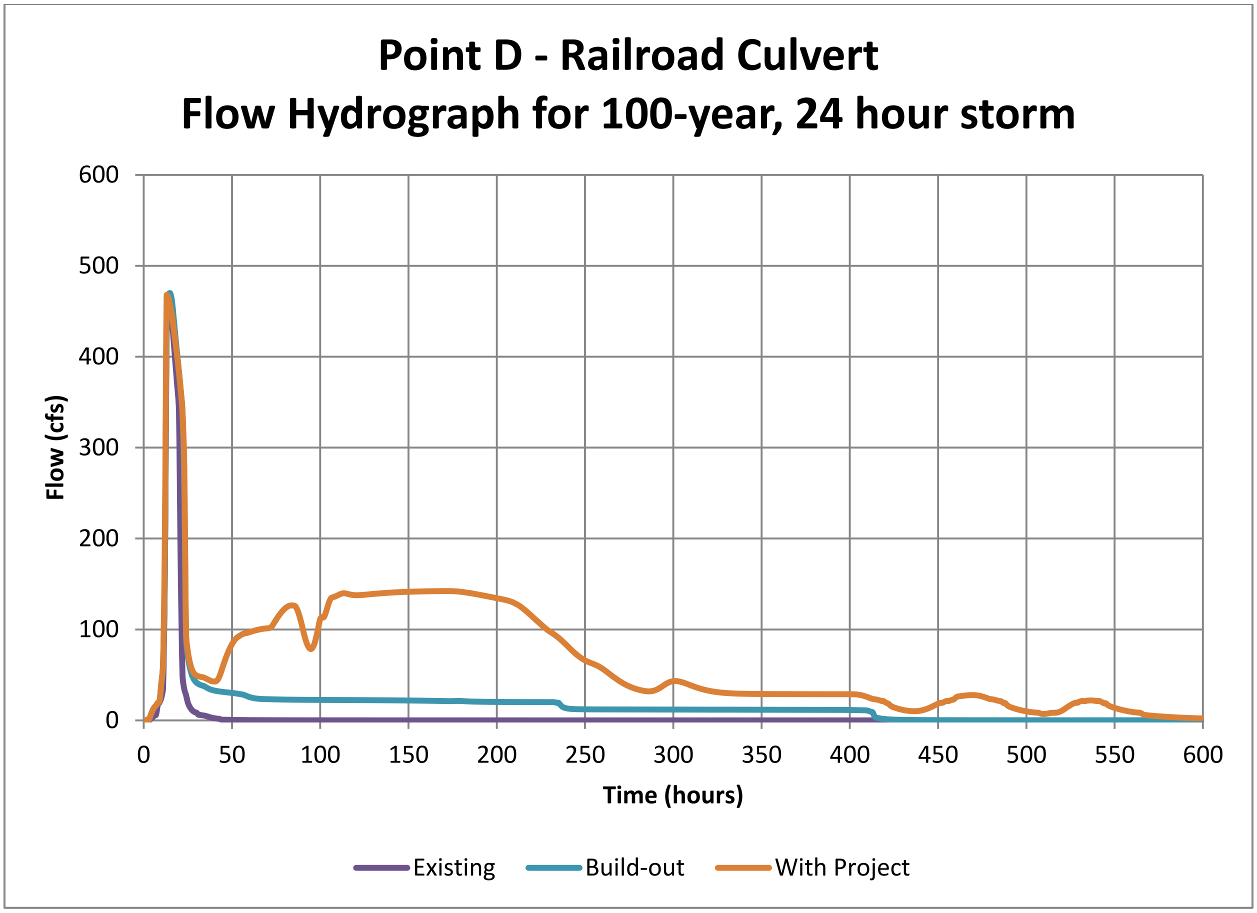
Graph 5 – Point C Flow Hydrograph



D. POINT D – Railroad

Also located on the 3M property is a railroad crossing which has an existing stone arch culvert. This culvert was modeled in the XP-SWMM model as a 6' x 8' box culvert. The peak flow through the structure is 580 cfs for the Build Out and With Project conditions. The flow hydrograph is shown in **Graph 6**.

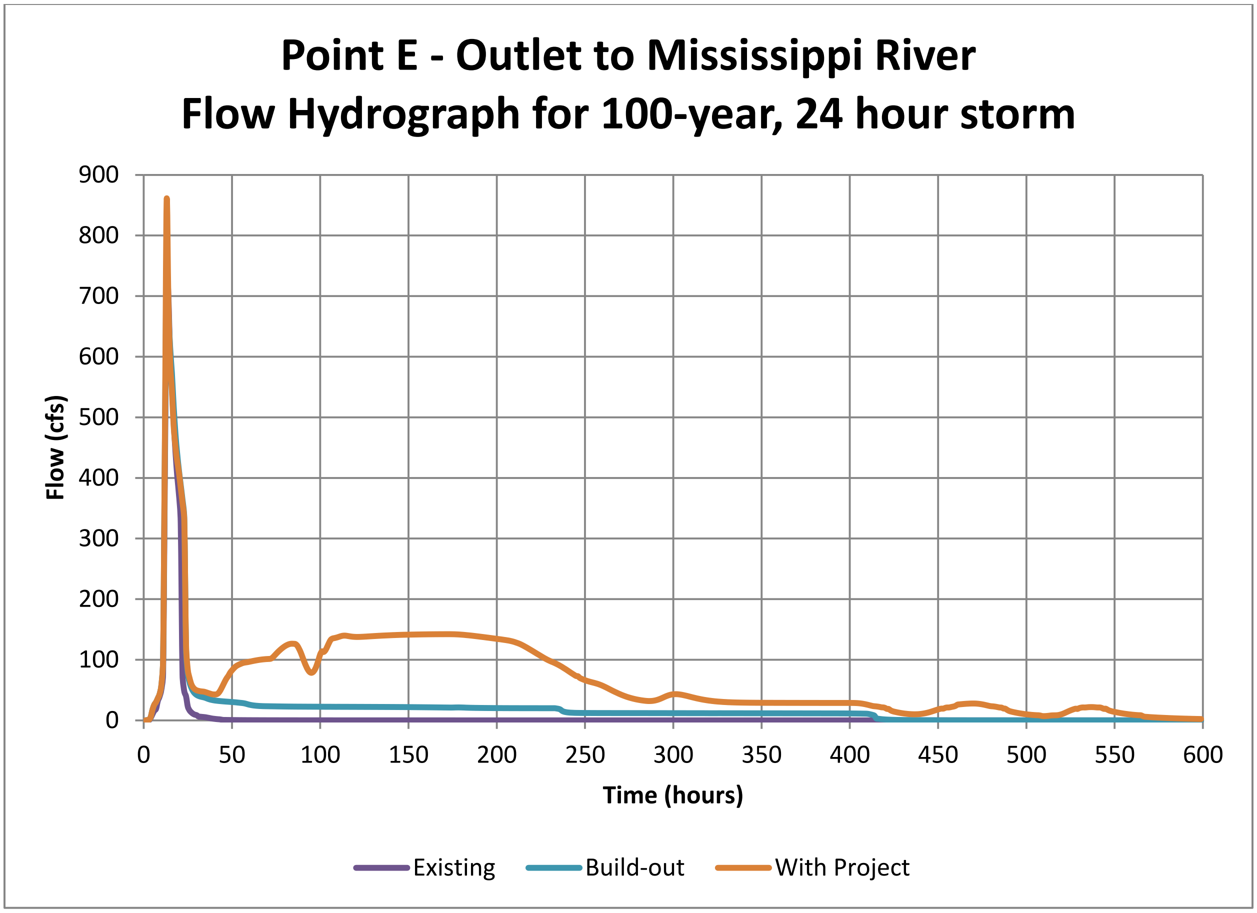
Graph 5 – Point D Flow Hydrograph



E. POINT E – Outlet to Mississippi River

The reach outlets to the Mississippi river under a large railroad bridge. The bridge was not explicitly modeled, but the approximately 70 foot long bridge would not restrict flow even if explicitly modeled. The peak flow at this point is 765 cfs. The flow hydrograph is shown in **Graph 7**.

Graph 5 – Point E Flow Hydrograph



IV. Ravine Lake Outlet Considerations

The outlet to Ravine Lake has been presented an ongoing flooding issue at the entrance to the park. This ongoing problem was discussed in memorandum prepared by HR Green to Washington County[2]. At that time it was determined the 18” CMP culvert under the roadway was crushed and was replaced in 2010 by a 24” HDPE. The memorandum stated that the 24” pipe is not adequate to convey the existing 2-year flow, and the 24” culvert provided an intermediate solution while a long term solution was determined.

Washington County currently has plans to modify the entrance to the park and upgrade the roadways within the park[3]. The County is also proposing to possibly move the park access road to the South and remove the roadway from passing through Ravine Lake.

Providing an updated outlet and park access road is planned during Washington County’s upgrades to the Park; these upgrades will accommodate both the flows from the local area under build out conditions and flows from the CDSF Overflow Project. The new outlet configuration would be designed to maintain current lake levels and minimize bounce during large rainfall events.

If the current park access road is not moved, the road would need to be raised 1 to 3 feet and a large culvert placed under the road with a control structure downstream. The control structure would likely be a two stage weir configuration; with a small weir length to maintain normal pool conditions and a large weir length at a higher elevation to accommodate larger flows. If the road is moved to the south a large culvert would be placed under the roadway, and the control structure could be above or below the roadway. The control structure would again have a two stage weir configuration.

While not required for a new lake outlet and park access, additional capacity under Highway 61 would help reduce the peak elevation of the 100 year flood event on Ravine Lake.

[2] HR Green. “Ravine Park Flooding Memo.” March 25, 2010.
[3] Cottage Grove Ravine Regional Park Master Plan. May 2007.

V. Erosion Potential

An erosion analysis was completed by Houston Engineering for upstream of Ravine lake[4]. The same methodology used in that analysis was also used in the analysis for this memorandum. A HEC-RAS model was created for the reach and peak flows from the XP-SWMM model for the three scenarios were used. **Figure 4** shows the cross section locations of the HEC-RAS model along with the stationing along the reach which is referenced in this section.

A. SHEAR STRESS AND VELOCITY THRESHOLDS

Shear stress and velocity thresholds indicative of the potential to erode the ground surface were set based on plant cover and soil descriptions. These thresholds were assigned over areas of similar composition longitudinally along the east ravine. All soils were sandy loam, causing plant cover to be the differentiating factor. The table of permissible shear values from Fisch Engineering[5] that was used in the original shear stress analysis was also used as a basis for determining the allowable shear stresses in this analysis. A description of the cross sections and the assigned thresholds are in **Table 2**.

Table 2 – Summary Shear and Velocity Thresholds

Cross Section Station Range	Existing Vegetative Cover	Estimated Shear Threshold (lb/sf)	Estimated Velocity Threshold (fps)
0 - 5140	Wooded forest. Medium density underbrush. Medium tree density.	1.0 - 1.5	1.75 - 3.0
5293 - 6259	Wooded forest. Medium density underbrush. Medium tree density.	1.0 - 1.5	1.75 - 3.0
6583 - 7255	Wetland. High grass.	1.5 - 2.5	4.0 - 6.0
7543 - 9710	Wooded forest. Medium density underbrush. Medium tree density.	1.0 - 1.5	1.75 - 3.0
10129 - 10326	Grass cover. Few trees.	1.5 - 2.5	6.0 - 8.0
10431 - 10701	Wooded forest. Medium density underbrush. Medium tree density.	1.0 - 1.5	1.75 - 3.0
10742 - 10838	Grass cover. Few trees.	1.5 - 2.5	6.0 - 8.0
10886 - 11074	South end of Ravine Lake.	1.5 - 2.5	4.0 - 6.0

4 Houston Engineering, Inc. "Cottage Grove Ravine Regional Park Erosion Analysis, Draft Report." December 11, 2013.
5 EOR 2002. "Erosion Potential by Shear Stress Analysis of Cottage Grove Ravine Regional Park." January 28, 2002.

B. EROSION POTENTIAL DETERMINATION

The following process was used to determine the erosion potential for each portion of the ravine.

1. Scenario maximum shear stress occurring in the channel was determined by multiplying the shear stress calculated in the HEC-RAS model by 1.5 to account for local variations in velocity and accelerations.

2. Erosion potential was determined by comparing the maximum shear stress occurring in each cross section to the corresponding shear stress threshold and the modeled velocity to the velocity threshold listed in **Table 2**. The erosion potential at each cross section was classified by maximum shear stress or velocity within the following ranges for each classification. The sections are defined as the downstream area below each cross section.

   a. Low — Below the lower limit of the threshold range
   b. Medium — Between the lower limit and midpoint of the threshold range
   c. High — Between the midpoint and upper limit of the threshold range
   d. Excessive — Above the upper limit of the shear stress threshold range

C. Results

The erosion potential classification for each cross section was calculated for all three scenarios based on the peak flow rates. The erosion potential classifications based on both shear stress and velocity were computed and tabulated. These results are shown spatially in **Figure 5**, **6**, and **7**; the shear stress value is shown for each section in all of the figures. The highest erosion potential areas fall south of the railroad. **Table 3** provides a summary of the lengths of the ravine that are classified as high or excessive. Sections classified as high or excessive in either the shear or velocity, are areas that will most likely see erosion and may require stabilization. The table shows that very little additional area is classified as high or excessive for the With Project Condition when compared to the Existing Conditions. When comparing the With Project Condition to the Build Out condition there is no additional area.

Table 3 – Summary of Reach Lengths with High and Excessive Erosion Potential

	Scenario 1: Existing Conditions	Scenario 2: Build Out	Scenario 3: With Project
Length with High and Excessive Erosion Potential (ft)	11,075	11,075	11,075
Total Length of Reach (ft)	6,440	6,500	6,500
Percent of Total Length	58.1%	58.7%	58.7%

0 375 750 1,500
Feet

Cross Section Stations

Stream Centerline

South Washington WATERSHED District

Sources: SWWD, TLG, MN DOT
Aerial: 2013 Washington County, MN

Figure 4: Existing Conditions 100 Year Flood Extent and Flow Rates

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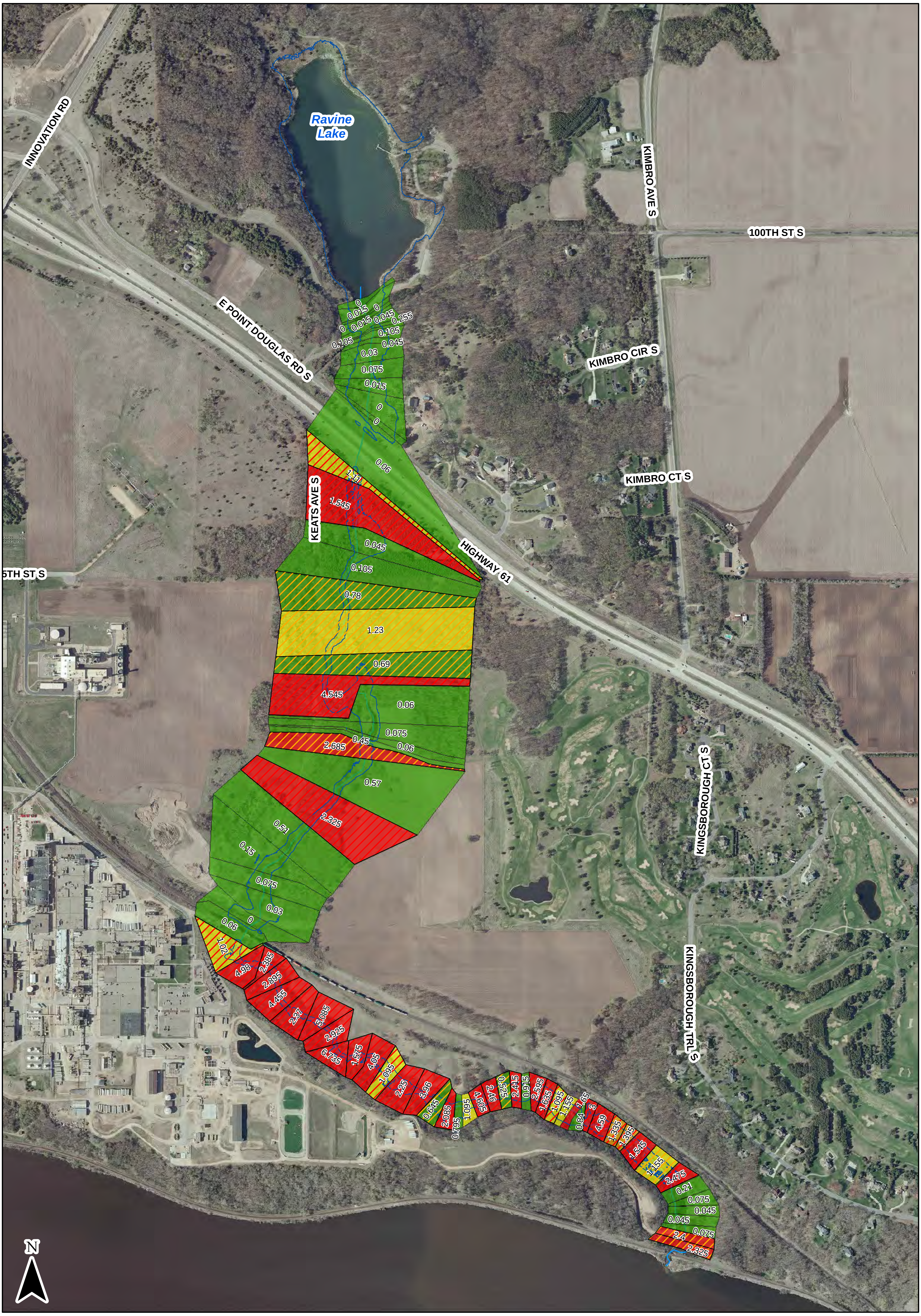

0 375 750 1,500 Feet

Erosion Potential

Shear

- Excessive
- High
- Medium
- Low

Velocity

- Excessive
- High
- Stream Centerline
- 100 year flood extent under existing conditions

Sources: SWWD, TLG, MN DOT
Aerial: 2013 Washington County, MN

Figure 5: Existing Conditions Erosion Potential

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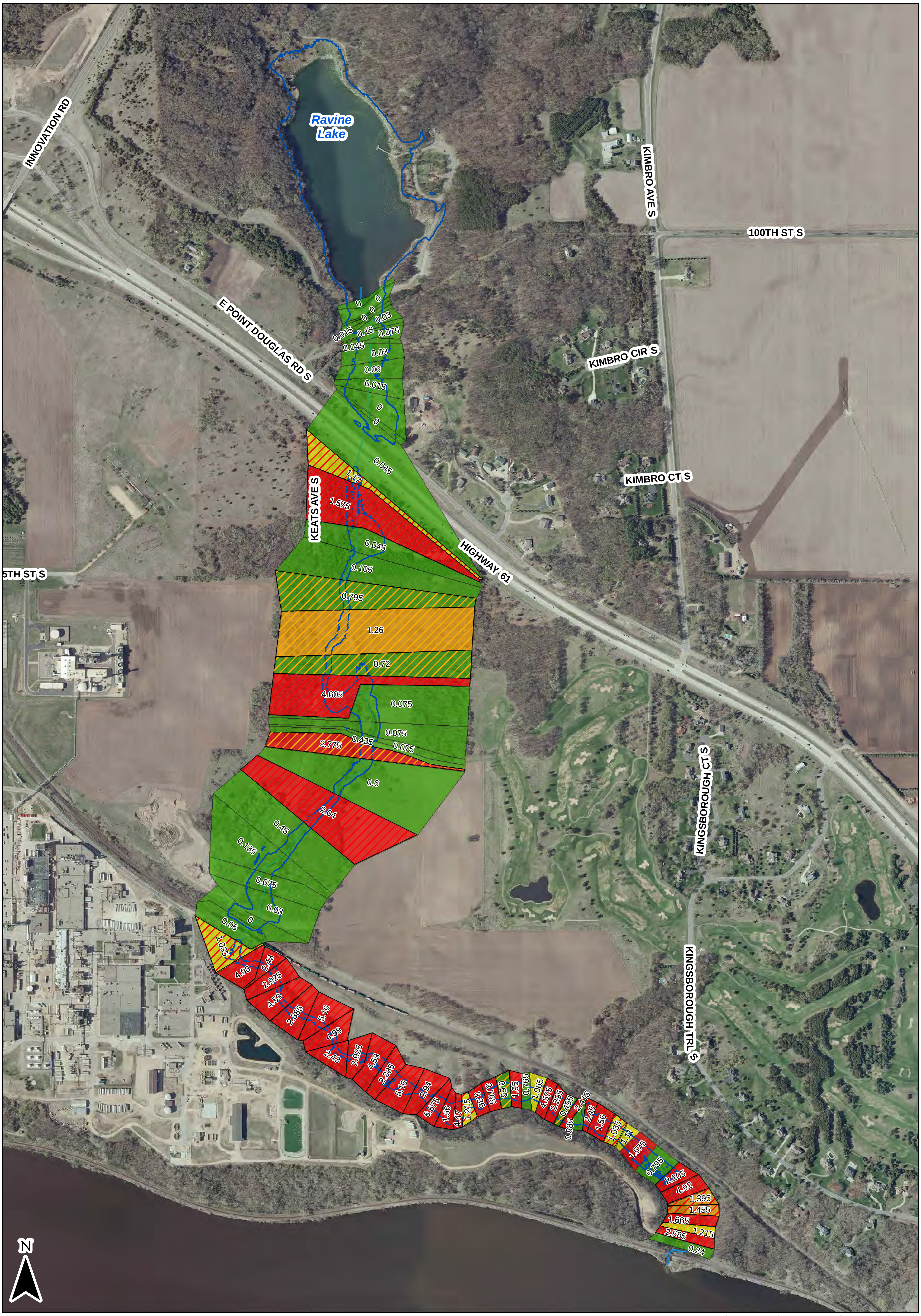


0 375 750 1,500 Feet

Erosion Potential

Shear
- Excessive
- High
- Medium
- Low

Velocity
- Excessive
- High
- 100 year flood extent under build out conditions
- Stream Centerline

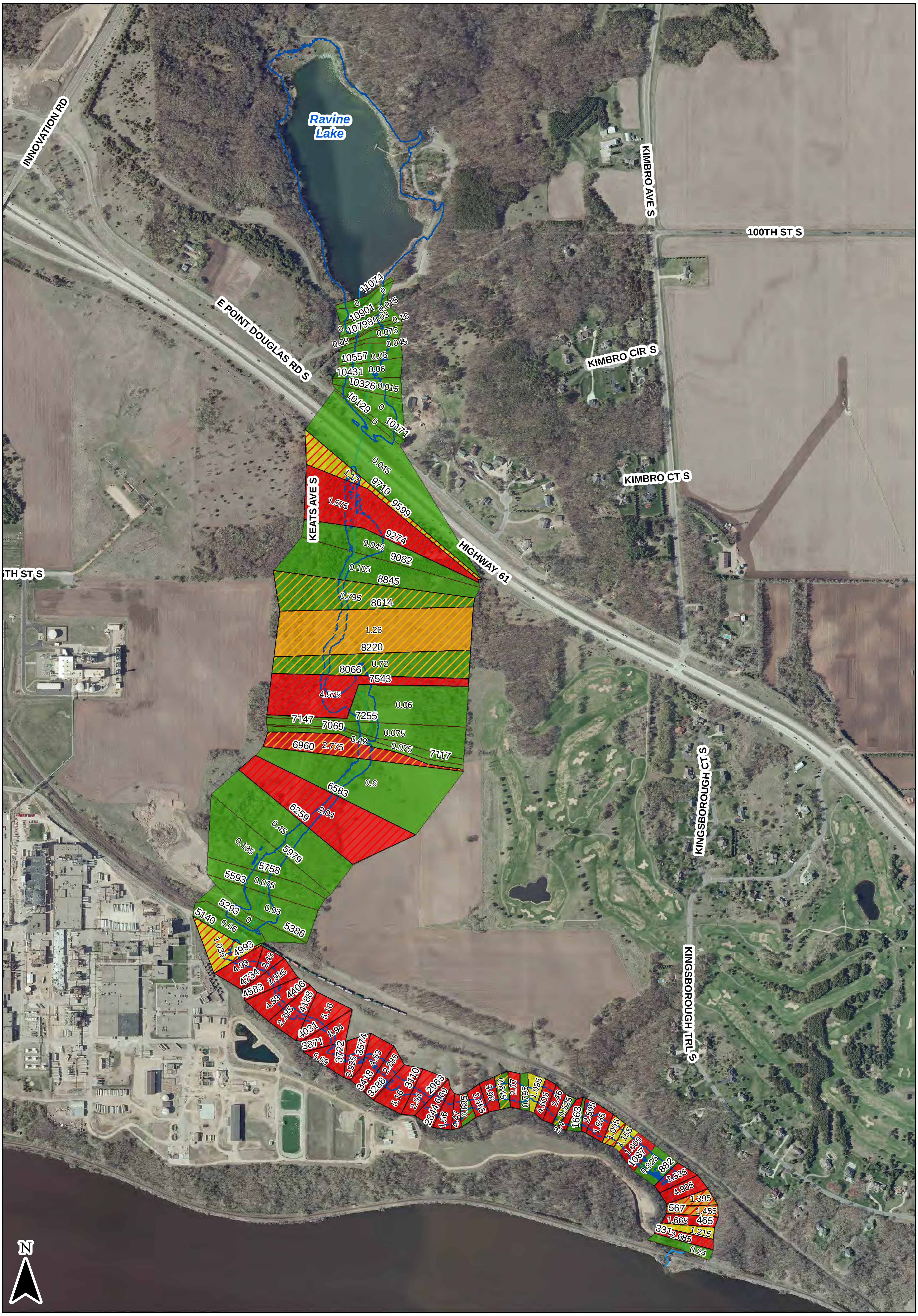
Sources: SWWD, TLG, MN DOT
Aerial: 2013 Washington County, MN

Figure 6: Build Out Erosion Potential

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	ALD		4876-027	11/25/2013	1 of 1

South Washington WATERSHED District

Houston Engineering Inc.
Maple Grove
P: 763.493.4522
F: 763.493.5572



0 375 750 1,500 Feet

Erosion Potential

Shear

- Excessive
- High
- Medium
- Low

Velocity

- Excessive
- High
- 100 year flood extent under project conditions
- Stream Centerline

Sources: SWWD, TLG, MN DOT
Aerial: 2013 Washington County, MN

South Washington WATERSHED District

Figure 7: Build Out With Project Erosion Potential

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	ALD		4876-027	11/25/2013	1 of 1

Houston Engineering Inc.

Maple Grove
P: 763.493.4522
F: 763.493.5572

VI. Stabilization Technique Alternatives

Based on the erosion potential rating of each section, stabilization measures will be selected. Potential stabilization measures include vegetation management, constructed lined channel, lined existing channel, and check dams. **Table 4** provides a summary of the stabilization measures with the maximum allowable shear stress. These are the same techniques and thresholds used in the analysis through Cottage Grove Ravine Regional Park.

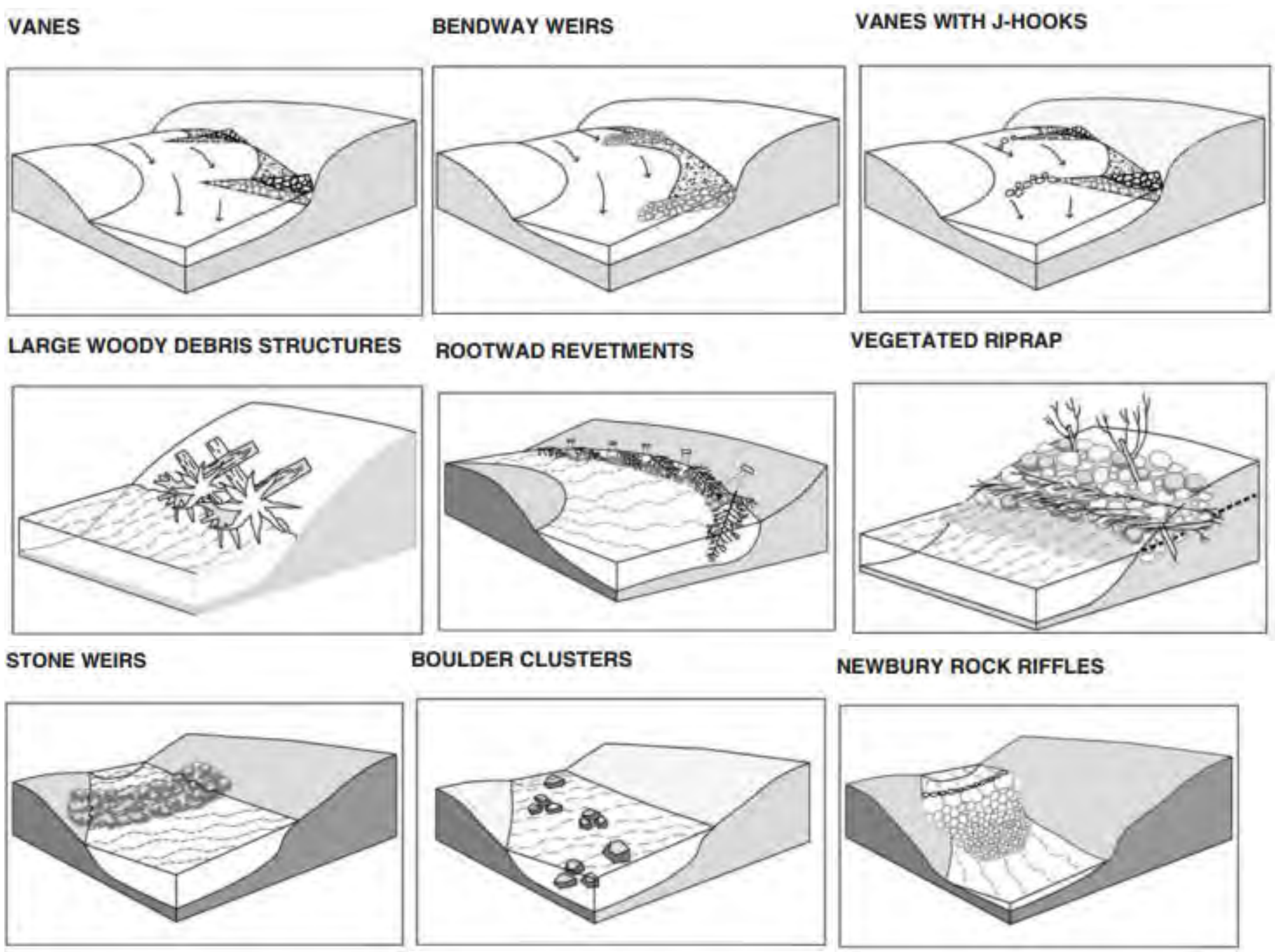
Table 4 – Stabilization Measure Shear Stress Threshold

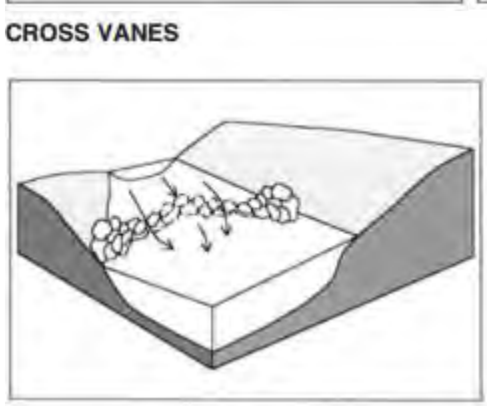
Stabilization Technique		Maximum Shear Stress (lb/sq. ft.)
None		0.4 - 2.5
Vegetation Management, Native Grasses		1.5
Constructed Channel Lining	Turf Reinforced Mat	3 - 8
	High Performance Turf Reinforced Mat	4 - 10
	9" D_{50} Riprap Lining	3.8
	12" D_{50} Riprap Lining	5.1
Line Existing Channel	9" D_{50} Riprap Lining	3.8
	12" D_{50} Riprap Lining	5.1
Check Dams		3-20

The upper half of the reach below Ravine Lake is similar to the previous study area through Cottage Grove Ravine Regional Park, and the same stabilization measures apply. However, below the Railroad crossing at approximately station 5200, the channel becomes more incised and prevalent. At approximately station 3200, 3M discharges water into the channel from their facility. This discharge provides a baseflow to the reach. Because of the more prevalent channel and the baseflow, stabilization work through this area will utilize additional stabilization techniques more consistent with a streambank stabilization and stream restoration project. **Figure 8** shows the variety of techniques that may be utilized in this lower portion of the reach[6]. The design will be consistent with methodologies by the MN DNR and Rosgen[7]. Potential stabilization techniques include stabilizing outside bends with rock vanes, woody debris, rootwads, and vegetated riprap. A riffle-pool design will be utilized; the riffles will be constructed from rock using multiple techniques. These techniques are similar to one another with just slight variations of height, length, width and density of rock placement. The stabilization measures ultimately selected will take into account effectiveness at stabilizing the reach, cost effectiveness, and the needs of the 3M.

[6] McCullah, John and Gray, Donald. "Environmentally Sensitive Channel- and Bank-Protection Measures". NCHRP Report 5544. 2005.
[7] Rosgen, Dave. "Applied River Morphology." 1996.

Figure 8 – Potential Stabilization Techniques downstream of Railroad (Station 5200)





*This figure reproduced from McCullah and Gray, 2005.

VII. Summary

The hydrologic modeling shows that the peak flows from the local runoff far exceed the CDSF Overflow Project flows for the reach below Ravine Lake. Peak flooding does not increase with the CDSF Overflow Project. The two structures that are currently flooded under the 100 year rainfall event just upstream of Highway 61 do not experience an increase in stage or duration of flooding from the CDSF Overflow Project.

The erosion potential analysis used for the reach below Ravine Lake is consistent with the approach used through Cottage Grove Ravine Regional Park. The stabilization measures that will be utilized are also consistent, with the exception of the area downstream from the Railroad crossing. In this area stabilization measures will be more consistent with streambank stabilization and stream restoration projects.

Appendix A

Baseline						6.3 inch event														
						Existing Conditions					Build Out					Project				
Section	River Sta	Length (ft)	Invert Slope	Estimate Shear Threshold (lb/sq ft)	Estimate Velocity Threshold (ft/sec)	Shear Total (lb/sq ft)	Max Shear (lb/sq ft)	Erosion Potential	Vel Total (ft/s)	Erosion Potential	Shear Total (lb/sq ft)	Max Shear (lb/sq ft)	Erosion Potential	Vel Total (ft/s)	Erosion Potential	Shear Total (lb/sq ft)	Max Shear (lb/sq ft)	Erosion Potential	Vel Total (ft/s)	Erosion Potential
81	11074	61.3	0.0000	1.5 - 2.5	4.0 - 6.0	0	0	low	0.16	low	0	0	low	0.17	low	0	0	low	0.17	low
80	11012	72.2	0.0047	"	"	0.01	0.015	low	0.34	low	0	0	low	0.32	low	0	0	low	0.32	low
79	10940	12.0	-0.0025	"	"	0	0	low	0.17	low	0	0	low	0.17	low	0	0	low	0.17	low
78	10928	27.7	-0.0007	"	"	0	0	low	0.19	low	0	0	low	0.19	low	0	0	low	0.19	low
77	10901	14.8	0.0067	"	"	0.01	0.015	low	0.38	low	0.01	0.015	low	0.35	low	0.01	0.015	low	0.35	low
76	10886	48.2	0.0106	1.5 - 2.5	4.0 - 6.0	0.03	0.045	low	0.67	low	0.02	0.03	low	0.57	low	0.02	0.03	low	0.57	low
75	10838	22.0	0.0032	1.5 - 2.5	1.75 - 3.0	0.17	0.255	low	1.06	low	0.12	0.18	low	0.87	low	0.12	0.18	low	0.87	low
74	10816	17.7	0.0074	"	"	0.07	0.105	low	0.81	low	0.06	0.09	low	0.7	low	0.06	0.09	low	0.7	low
73	10798	56.1	0.0059	"	"	0.07	0.105	low	0.84	low	0.05	0.075	low	0.71	low	0.05	0.075	low	0.71	low
72	10742	40.6	-0.0059	1.5 - 2.5	1.75 - 3.0	0.03	0.045	low	0.48	low	0.03	0.045	low	0.45	low	0.03	0.045	low	0.45	low
71	10701	144.3	0.0034	1.0 - 1.5	1.75 - 3.0	0.02	0.03	low	0.41	low	0.02	0.03	low	0.39	low	0.02	0.03	low	0.39	low
70	10557	125.9	0.0010	"	"	0.05	0.075	low	0.58	low	0.04	0.06	low	0.52	low	0.04	0.06	low	0.52	low
69	10431	105.4	0.0083	1.0 - 1.5	1.75 - 3.0	0.01	0.015	low	0.52	low	0.01	0.015	low	0.48	low	0.01	0.015	low	0.48	low
68	10326	154.5	0.0151	1.5 - 2.5	6.0 - 8.0	0	0	low	0.26	low	0	0	low	0.25	low	0	0	low	0.25	low
67	10171	41.9	-0.0055	"	"	0	0	low	0.15	low	0	0	low	0.15	low	0	0	low	0.15	low
66	10129	419.1	0.0008	1.5 - 2.5	6.0 - 8.0	0.04	0.06	low	1.13	low	0.03	0.045	low	1.11	low	0.03	0.045	low	1.11	low
65	9710	110.7	0.0143	1.0 - 1.5	1.75 - 3.0	0.74	1.11	medium	3.8	excessive	0.78	1.17	medium	3.9	excessive	0.78	1.17	medium	3.9	excessive
64	9599	325.6	0.0051	"	"	1.03	1.545	excessive	4.72	excessive	1.05	1.575	excessive	4.79	excessive	1.05	1.575	excessive	4.79	excessive
63	9274	191.7	0.0015	"	"	0.03	0.045	low	0.67	low	0.03	0.045	low	0.67	low	0.03	0.045	low	0.67	low
62	9082	237.2	0.0047	"	"	0.07	0.105	low	1.06	low	0.07	0.105	low	1.06	low	0.07	0.105	low	1.06	low
61	8845	230.7	0.0009	"	"	0.52	0.78	low	2.79	high	0.53	0.795	low	2.82	high	0.53	0.795	low	2.82	high
60	8614	394.4	0.0064	"	"	0.82	1.23	medium	2.97	high	0.84	1.26	high	2.98	high	0.84	1.26	high	2.98	high
59	8220	154.4	0.0060	"	"	0.46	0.69	low	2.95	high	0.48	0.72	low	3	high	0.48	0.72	low	3	high
58	8066	522.4	0.0074	"	"	3.03	4.545	excessive	6.58	excessive	3.07	4.605	excessive	6.63	excessive	3.05	4.575	excessive	6.63	excessive
57	7543	288.3	0.0008	1.0 - 1.5	1.75 - 3.0	0.04	0.06	low	0.91	low	0.05	0.075	low	0.94	low	0.04	0.06	low	0.94	low
56	7255	108.1	-0.0004	1.5 - 2.5	4.0 - 6.0	0.05	0.075	low	1.1	low	0.05	0.075	low	1.14	low	0.05	0.075	low	1.14	low
55	7147	29.9	0.0027	"	"	0.04	0.06	low	1.04	low	0.05	0.075	low	1.08	low	0.05	0.075	low	1.08	low
54	7117	47.9	0.0196	"	"	0.3	0.45	low	2.34	low	0.29	0.435	low	2.3	low	0.32	0.48	low	2.3	low
53	7069	109.3	0.0102	"	"	1.79	2.685	excessive	5.66	high	1.85	2.775	excessive	5.76	high	1.85	2.775	excessive	5.76	high
52	6960	376.8	0.0079	1.5 - 2.5	4.0 - 6.0	0.38	0.57	low	2.93	low	0.4	0.6	low	3.01	low	0.4	0.6	low	3.01	low
51	6583	323.8	0.0106	1.0 - 1.5	1.75 - 3.0	1.55	2.325	excessive	5.11	excessive	1.36	2.04	excessive	4.79	excessive	1.36	2.04	excessive	4.79	excessive
50	6259	280.1	0.0029	"	"	0.34	0.51	low	2.23	medium	0.3	0.45	low	2.07	medium	0.3	0.45	low	2.07	medium
49	5979	220.7	0.0016	"	"	0.1	0.15	low	1.36	low	0.09	0.135	low	1.28	low	0.09	0.135	low	1.28	low
48	5758	165.1	0.0136	"	"	0.05	0.075	low	0.79	low	0.05	0.075	low	0.75	low	0.05	0.075	low	0.75	low
47	5593	206.7	0.0073	"	"	0.02	0.03	low	0.5	low	0.02	0.03	low	0.48	low	0.02	0.03	low	0.48	low
46	5386	93.3	0.0190	"	"	0	0	low	0.31	low	0	0	low	0.3	low	0	0	low	0.3	low
45	5293	152.7	0.0056	"	"	0.04	0.06	low	1.14	low	0.04	0.06	low	1.14	low	0.04	0.06	low	1.14	low
44	5140	147.5	0.0154	"	"	0.68	1.02	medium	4.39	excessive	0.69	1.035	medium	4.44	excessive	0.69	1.035	medium	4.44	excessive
43	4993	165.9	0.0271	"	"	3.32	4.98	excessive	5.6	excessive	3.32	4.98	excessive	5.58	excessive	3.32	4.98	excessive	5.58	excessive
42	4827	93.3	0.0198	"	"	1.59	2.385	excessive	4.95	excessive	1.62	2.43	excessive	4.97	excessive	1.62	2.43	excessive	4.97	excessive
41	4734	150.3	0.0126	"	"	1.93	2.895	excessive	4.4	excessive	1.95	2.925	excessive	4.4	excessive	1.95	2.925	excessive	4.4	excessive
40	4583	177.6	0.0160	"	"	2.97	4.455	excessive	6.74	excessive	3.02	4.53	excessive	6.74	excessive	3.02	4.53	excessive	6.74	excessive
39	4406	217.7	0.0184	"	"	1.58	2.37	excessive	5.31	excessive	1.59	2.385	excessive	5.32	excessive	1.59	2.385	excessive	5.32	excessive
38	4188	157.1	0.0104	"	"	3.39	5.085	excessive	7.05	excessive	3.44	5.16	excessive	4.44	excessive	3.44	5.16	excessive	7.05	excessive
37	4031	160.3	0.0114	"	"	1.95	2.925	excessive	5.75	excessive	3.32	4.98	excessive	5.58	excessive	1.96	2.94	excessive	5.74	excessive
36	3871	149.3	0.0142	"	"	4.49	6.735	excessive	8.94	excessive	1.62	2.43	excessive	4.97	excessive	4.46	6.69	excessive	8.98	excessive
35	3722	147.7	0.0202	"	"	1.05	1.575	excessive	3.87	excessive	1.95	2.925	excessive	4.4	excessive	1.95	2.925	excessive	3.84	excessive
34	3574	156.2	0.0110	"	"	2.7	4.05	excessive	6.78	excessive	3.02	4.53	excessive	6.74	excessive	3.02	4.53	excessive	6.74	excessive
33	3418	130.0	0.0112	"	"	0.73	1.095	medium	4.49	excessive	1.59	2.385	excessive	5.32	excessive	1.59	2.385	excessive	5.32	excessive
32	3288	177.8	0.0058	"	"	1.5	2.25	excessive	5	excessive	3.44	5.16	excessive	7.05	excessive	3.44	5.16	excessive	7.05	excessive
31	3110	146.7	0.0071	"	"	2.64	3.96	excessive	8.31	excessive	1.96	2.94	excessive	5.74	excessive	1.96	2.94	excessive	5.74	excessive
30	2963	118.9	-0.0115	"	"	0.43	0.645	low	2.94	high	4.45	6.675	excessive	8.98	excessive	4.46	6.69	excessive	8.98	excessive
29	2844	83.7	0.0213	"	"	1.39	2.085	excessive	3.42	excessive	1.04	1.56	excessive	3.84	excessive	1.04	1.56	excessive	3.84	excessive
28	2761	52.4	-0.0168	"	"	0.53	0.795	low	1.78	medium	2.98	4.47	excessive	7.11	excessive	2.98	4.47	excessive	7.11	excessive
27	2708	85.5	0.0138	"	"	0.73	1.095	medium	2.25	medium	0.81	1.215	medium	4.73	excessive	0.59	0.885	low	4.73	excessive
26	2623	111.4	0.0232	"	"	3.07	4.605	excessive	5.63	excessive	2.24	3.36	excessive	5.74	excessive	1.71	2.565	excessive	5.74	excessive
25	2511	110.9	0.0218	"	"	1.64	2.46	excessive	4.98	excessive	2.51	3.765	excessive	8.06	excessive	2.64	3.96	excessive	8.06	excessive
24	2400	96.2	0.0078	"	"	0.35	0.525	low	2.44	high	0.42	0.63	low	2.93	high	0.43	0.645	low	2.93	high
23	2304	81.5	0.0179	"	"	1.61	2.415	excessive	3.25	excessive	1.3	1.95	excessive	3.35	excessive	1.38	2.07	excessive	3.35	excessive
22	2223	71.2	-0.0003	"	"	0.61	0.915	low	2.03	medium	0.51	0.765	low	1.77	medium	0.53	0.795	low	1.77	medium
21	2151	81.0	0.0061	"	"	1.73	2.595	excessive	4.16	excessive	0.71	1.065	medium	2.25	medium	0.73	1.095	medium	2.25	medium
20	2071	86.9	0.0091	"	"	1.09	1.635	excessive	3.74	excessive	3.05	4.575	excessive	5.63	excessive	3.07	4.605	excessive	5.63	excessive
19	1984	94.1	0.0121	"	"	0.73	1.095	medium	3.24	excessive	1.53	2.295	excessive	4.89	excessive	1.64	2.46	excessive	4.89	excessive
18	1890	75.9	-0.0034	"	"	0.77	1.155	medium	2.21	medium	0.33	0.495	low	2.4	high	0.35	0.525	low	2.4	high
17	1814	51.6	0.0174	"	"	1.1	1.65	excessive	2.32	medium	1.61	2.415	excessive	3.32	excessive	1.6	2.4	excessive	3.32	excessive
16	1762	99.2	0.0071	"	"	0.56	0.84	low	1.93	medium	0.59	0.885	low	2.01	medium	0.61	0.915	low	2.01	medium
15	1663	53.4	-0.0015	"	"	2	3	excessive	6.63	excessive	1.64	2.46	excessive	4.11	excessive	1.73	2.595	excessive	4.11	excessive
14	1609	150.4	0.0178	"	"	3.06	4.59	excessive	7.34	excessive	1.04	1.56	excessive	3.75	excessive	1.09	1.635	excessive	3.75	excessive
13	1459	109.5	0.0096	"	"	0.89	1.335	high	3.27	excessive	0.69	1.035	medium	3.22	excessive	0.73	1.095	medium	3.22	excessive
12	1349	89.9	0.0087	"	"	0.93	1.395	high	3.69	excessive	0.74	1.11	medium	2.17	medium	0.77	1.155	medium	2.17	medium
11	1260	173.0	0.0105	"	"	1.03	1.545	excessive	4.3	excessive	1.05	1.575	excessive	2.27	medium	1.07	1.605	excessive	2.27	medium
10	1087	204.9	0.0051	"	"	0.77	1.155	medium	2.42	high	0.53	0.795	low	1.87	medium	0.55	0.825	low	1.87	medium
9	882	111.4	0.0017	"	"	1.65	2.475	excessive	3.21	excessive	1.47	2.205	excessive	5.54	excessive	1.69	2.535	excessive	5.54	excessive
8	770	107.1	0.0001	"	"	0.14	0.21	low	1.31	low	3.28	4.92	excessive	7.61	excessive	3.27	4.905	excessive	7.61	excessive
7	663	35.6	0.0210	"	"	0.05	0.075	low	0.98	low	0.93	1.395	high	3.25	excessive	0.93	1.395	high	3.25	excessive
6	628	60.3	-0.0066	"	"	0.03	0.045	low	0.76	low	0.97	1.455	high	3.74	excessive	0.97	1.455	high	3.74	excessive
5	567	102.7	-0.0046	"	"	0.03	0.045	low	0.79	low	1.11	1.665	excessive	4.3	excessive	1.11	1.665	excessive	4.3	excessive
4	465	61.4	-0.0070	"	"	0.05	0.075	low	0.98	low	0.81	1.215	medium	2.45	high	0.81	1.215	medium	2.45	high
3	403	72.1	0.0189	"	"	1.6	2.4	excessive	2.44	high	1.79	2.685	excessive	3.31	excessive	1.79	2.685	excessive	3.31	excessive
2	331	71.5	0.0011	"	"	1.55	2.325	excessive	2.52	high	0.16	0.24	low	1.38	low	0.16	0.24	low	1.38	low
1	260	0.0	0.0000	"	"	0.34	0.51	low	2.12	medium	0.05	0.075	low	1.02	low	0.05	0.075	low	1.02	low

Minnesota Unique Well No.

233573

County: Washington
Quad: St Paul Park
Quad ID: 102C

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

Entry Date: 06/13/1989
Update Date: 03/06/2002
Received Date:

Well Name 3M CHEMOLITE OB. NO.7

Township	Range	Dir	Section	Subsections	Elevation	
27	21	W	27	ADDDDD	791 ft.	Elevation Method: 7.5 minute topographic map (+/- 5 feet)

Well Depth: 146 ft.
Depth Completed: 146 ft.
Date Well Completed:

Drilling Method --

Well Address

COTTAGE GROVE MN

Drilling Fluid --

Well Hydrofractured? ☐ Yes ☐ No
From Ft. to Ft.

Use Observation well

Geological Material	Color	Hardness	From	To
DRIFT			0	38
PRAIRIE DU CHIEN DOLOMITE			38	50
PRAIRIE DU CHIEN DOLOMITE			50	90
JORDAN SANDSTONE			90	100
JORDAN SANDSTONE			100	146

Casing Type Joint No Information Drive Shoe? ☐ Yes ☐ No Above/Below ft.

Casing Diameter	Weight	Hole Diameter

Open Hole from ft. to ft.

Screen Make Type

Diameter	Slot/Gauze	Length	Set Between

Static Water Level
67.8 ft. from Land surface Date Measured 06/09/1989

PUMPING LEVEL (below land surface)
ft. after hrs. pumping g.p.m.

Well Head Completion
Pitless adapter manufacturer Model
☐ Casing Protection ☐ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

R E M A R K S
27-21-27 ADDDDD
ELEV 790-+6
102-C

Grouting Information Well Grouted? ☐ Yes ☐ No

Located by: Minnesota Geological Survey
Method: Digitized - scale 1:24,000 or larger (Digitizing Table)
Unique Number Verification: Information from owner
Input Date: 01/01/1990
System: UTM - Nad83, Zone15, Meters
X: 507614 Y: 4960449

Nearest Known Source of Contamination
_feet _direction _type

Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name Model number __ HP _ Volts
Length of drop Pipe _ft. Capacity _g.p.m Type Material

Abandoned Wells Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No

Variance Was a variance granted from the MDH for this well? ☐ Yes ☐ No

Well Contractor Certification

First Bedrock Prairie Du Chien Group
Last Strat Jordan Sandstone
Aquifer
Depth to Bedrock 38 ft.

Minnesota Geological Survey	MGS	
License Business Name	Lic. Or Reg. No.	Name of Driller

County Well Index Online Report

233573

Printed 1/24/2014
HE-01205-07

Haliaeetus leucocephalus **(Linnaeus, 1766)** **Bald Eagle**

MN Status:

special concern

Federal Status:
none

CITES:
yes

USFS:
yes

Group:

bird

Class:
Aves

Order:
Accipitriformes

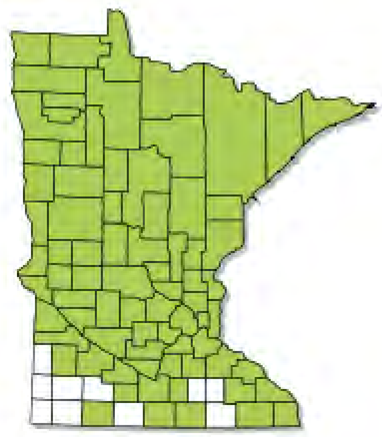
Family:
Accipitridae

Habitats:
Fire Dependent Forest, Mesic Hardwood Forest, Lake Shore, River Shore, Floodplain Forest, Wet Forest, Small Rivers and Streams, Medium Rivers and Streams, Large Rivers, Littoral Zone of Lake, Deep Water Zone of Lake, Savanna

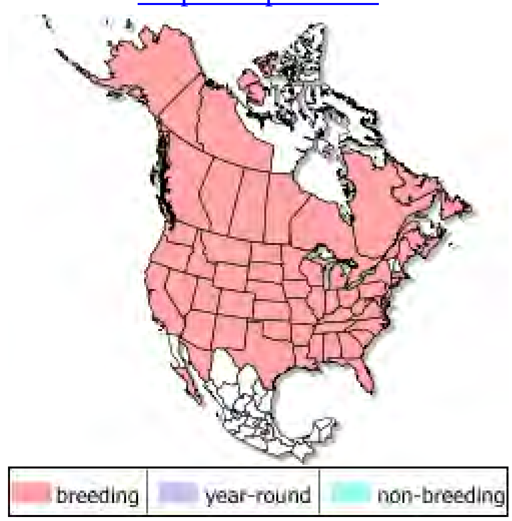
(Mouse over a habitat for definition)

Basis for Listing

The bald eagle is widespread throughout Canada and portions of the United States, and two races are recognized. The northern race ranges throughout Alaska, most of Canada (except the Archipelago and Hudson Bay lowlands), and across the northern United States from the Pacific Northwest to the Great Lakes and Maine coast. The southern race is found from the Delaware Bay south to Florida and west along the Gulf Coast. Formerly, the bald eagle also ranged across southern California and the southwestern United States. The decline of the bald eagle over its entire range in the contiguous 48 states has been well documented. Environmental contamination by DDT was the primary cause of the decline, and the mechanism was the accumulation of DDT residues in fish, the major food of bald eagles. Since the banning of DDT in the United States in 1972, bald eagle populations have increased nationwide.

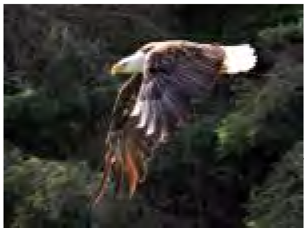
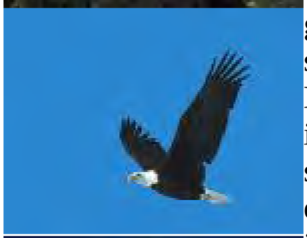


Map Interpretation



Map Interpretation

In presettlement times, the bald eagle nested throughout Minnesota,

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including along large prairie rivers and bigger lakes in the southern half of the state. In recognition of the pre-1972 population decline, the bald eagle was listed as threatened in Minnesota when the first state endangered species list was created in 1984. The species had already been added to the federal list of threatened and endangered species in 1978. The Northern States Bald Eagle Recovery Plan established a goal of 300 occupied breeding territories in Minnesota. This goal was surpassed in 1987 when 350 occupied breeding areas were documented. Both the numbers and the range of bald eagles have continued to expand in Minnesota. By 1994, the number of known occupied territories in the states was 615. Consequently, the status of bald eagles under the state endangered species law was changed from threatened to special concern in 1996. Although the majority of bald eagles are found in the forested northern half of the state and along the St. Croix and Lower Mississippi rivers, the species has begun to reoccupy much of its former range in the southern half of Minnesota in recent years. A statewide Known Nest Survey in 2005 located 872 active nests. By combining the results of the Known Nest Survey with data from a survey of random plots, an estimate of 1,312 (± 220) active nests was derived (Baker and Monstad 2005). Among the 50 states, Minnesota has the third largest bald eagle breeding population, following Alaska and Florida. Data from the 2005 surveys provided support for a U.S. Fish and Wildlife Service proposal to remove the bald eagle from the federal list of threatened and endangered species. The bald eagle was subsequently delisted on August 9, 2007. However, bald eagles and their nests are still protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act.

Description

The bald eagle is the second largest bird of prey, with a wingspan of 1.7-2.4 m (5.6-7.9 ft.) (Buehler 2000). The white head and tail and contrasting dark brown body of adult bald eagles are diagnostic of this species. Immature and subadult bald eagles are more difficult to identify, as their head and tail are brown or mottled brown and white. Blotchy white coloration on the underside of the wings and tail of young bald eagles help distinguish them from young golden eagles (*Aquila chrysaetos*), which have a more sharply defined white pattern. Bald eagles attain full adult plumage is their fourth or fifth year. In flight, bald eagles can be confused with turkey vultures (*Cathartes aura*), but the former can be distinguished by their tendency to soar on flat, board-like wings. Turkey vultures fly with their wings in a v-shape.

Habitat

Bald eagles select nest sites near lakes and rivers in forested areas where tall, large diameter trees are available for nesting (Grier and Guinn 2003).

Nest trees are usually within 0.8 km (.5 mi.) of water. In Minnesota, red pines (*Pinus resinosa*), white pines (*Pinus strobes*), large eastern cottonwoods (*Populus deltoides*), and aspen (*Populus* spp.) are most often selected for nesting. Eagles have also been known to nest on artificial structures such as powerline poles and osprey (*Pandion haliaetus*) nest platforms, but this is not common.

Biology / Life History

Breeding bald eagles defend territories of variable size, averaging 1-2 km^2 (0.4-0.8 $mi.^2$). The average distance between nests along a shoreline is 0.2-3.1 km (0.1-1.9 mi.) (Buehler 2000). Bald eagle pairs are monogamous and may mate for life. There is evidence that mates may winter together and maintain a pair bond. Each spring, pairs perform spectacular aerial courtship displays. In the cartwheel display, for example, the pair flys to great altitude, locks talons, and tumbles back toward the ground, breaking away at the last moment to avoid collision. Other displays include chases, rolls, and dives from great heights (Buehler 2000).

Nests are built in large, strong trees, often in the supercanopy, that have a view of the surrounding area and provide easy access for the adults. Once built, the nest may be reused and added to in subsequent years. Alternate nest sites are common in many territories. The female lays a clutch of 1-3 eggs, which she incubates immediately, resulting in asynchronous hatching after 35 days. Sibling competition exists among nestlings, with the first to hatch having the advantage. The female generally incubates and broods the young, but both sexes participate in feeding. Young typically leave the nest after 8-14 weeks, although they may become grounded earlier in the event of unsuccessful flight attempts. In most cases, adults will still feed grounded young birds. Immature birds stay with adults for many weeks post-fledging and may be fed by adults up to 6 weeks after leaving the nest (Kussman 1977). Their dependence on adults gradually decreases as the young begin to hunt on their own, until they finally disperse. Although breeding may be attempted at earlier ages with limited success, bald eagles are typically capable of breeding after 4 or 5 years of age (Buehler 2000).

Not all bald eagles migrate in the fall. Eagles in warm climates, such as Florida, may remain on or near their nesting territories year-round. Bald eagles in cooler climates will migrate if food becomes difficult to find, with adults and juveniles migrating separately. As most bald eagles prefer fish, migration may occur as lakes and rivers freeze over, but the blad eagle is also an opportunistic feeder that forages on fish, bird, and mammal carrion (Buehler 2000).

Bald eagle wintering grounds typically contain open water, ample food, limited human disturbance, and protective roosting sites. Preferred roosts are coniferous or deciduous super-canopy trees. Stopover habitat is similar to wintering habitat, with food supply being the most important factor. Bald eagles migrate alone but may gather by the hundreds at communal feeding sites and roosts. In Minnesota, bald eagles congregate around areas of open water in winter, particularly along the Mississippi River south of Red Wing. Bald eagles return to their breeding territories in late winter, as soon as a food source is available (Buehler 2000). In central Minnesota, bald eagles are typically back at their nest sites by the end of the first week of February.

Conservation / Management

Human activity is the biggest threat to the bald eagle. Although DDT is no longer a risk factor in the United States, organophosphates, heavy metals, and other pollutants continue to cause sickness or death in bald eagles. Lead poisoning is also a significant cause of mortality, and oil spills threaten eagles in coastal areas. Bald eagles are occasionally still shot or intentionally poisoned. Additionally, collisions with vehicles and power lines are a growing threat as more land is developed (Buehler 2000). Vehicle collisions have also become more frequent as the bald eagle population has increased in Minnesota, due to their habit of feeding on deer carcasses along roads. Land development in wilderness areas and along shorelines destroys breeding habitat and winter roost sites, and increased human activity may cause bald eagles to abandon nesting or winter roosting sites. However, the fact that bald eagles are now successfully nesting in proximity to humans, even in the Twin Cities metropolitan area, indicates that some bald eagles may become habituated to humans if they are not persecuted (Buehler 2000; Grier and Guinn 2003). The U.S. Fish and Wildlife Service has prepared National Bald Eagle Management Guidelines to help landowners, land managers, and others avoid disturbing bald eagles. Preservation of large diameter white pine trees, or other large diameter, tall trees in the vicinity of lakes will ensure continued nesting habitat availability for bald eagles.

Conservation Efforts in Minnesota

After state listing in 1984, the Minnesota DNR's Nongame Wildlife Program (NWP) prepared management plans for nesting areas to insure that human activities did not interfere with successful nesting. As a result, annual surveys by the NWP documented a steady population increase in the state. NWP staff have also provided technical assistance on a case-by-case when human activities threatened nesting, roosting, or wintering bald eagles, and they have facilitated the capture and transport of injured birds to The Raptor Center at the University of Minnesota. In 2005, the

DNR cooperated with the U.S. Fish and Wildlife Service (USFWS) and the U.S. Geological Survey to conduct a scientifically rigorous statewide bald eagle population survey. Another survey led by the USFWS is planned for 2010.

In 2007, after the federal delisting, the USFWS prepared National Bald Eagle Management Guidelines. The guidelines are intended to help landowners, land managers, and others avoid disturbing bald eagles and comply with the intent of the Bald Eagle Protection Act. NWP staff are available to assist the public in applying the federal guidelines to their activities, but any questions regarding interpretation of the guidelines should be directed to the USFWS at (612) 725-3548. Given the recovery of bald eagles in Minnesota, site-specific management plans and annual surveys are no longer being conducted by the DNR.

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Ligumia recta **(Lamarck, 1819)** **Black Sandshell**

MN Status:

special concern

Federal Status:

none

CITES:

none

USFS:

yes

Group:

mussel

Class:

Bivalvia

Order:

Unionoida

Family:

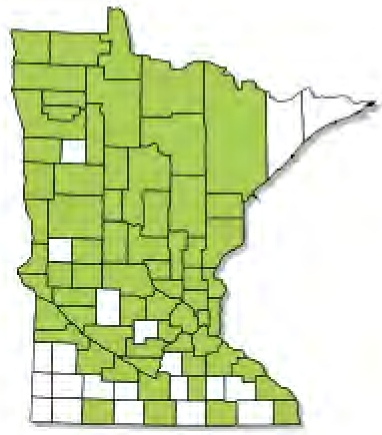
Unionidae

Habitats:

Medium Rivers and Streams, Large Rivers

(Mouse over a habitat for definition)

Click to enlarge



Map Interpretation

Map Interpretation

Basis for Listing

The black sandshell was once common in all but the smallest rivers in Minnesota (Dawley 1947). Although Bright et al. (1990) found dead specimens at 18 sampling points on the Minnesota River, indicating the former broad range of the species, only 1 live specimen was collected. Thiel (1981) cited evidence of declining numbers in Pools 3-9 of the Mississippi River. Bright et al. (1994) found the black sandshell live or recently dead at each of 24 sampling stations in the Mississippi and Crow Wing rivers upstream of Little Falls, Minnesota. The species is apparently still doing well in the Chippewa River where 56 live specimens were found at 12 sites, and evidence of recruitment was observed (Bright et al. 1995). The black sandshell has also been recently reported from several northern rivers. The St. Croix, Cloquet, and Whiteface rivers appear to be the last strongholds for this species in the state (Doolittle 1988). Given its decline and the degreadtion of its habitat, the black sandshell was listed as a special concern species in Minnesota in 1996.

Description

The shell of the black sandshell is elongate, moderately thick, and up to 20 cm (8 in.) long. The outside of the shell is smooth, shiny, greenish or black, and often rayed. The beak sculpture has a few faint double loops that are usually unnoticeable. This species is sexually dimorphic, with females having a more truncate posterior and males having a more pointed posterior. The pseudocardinal and lateral teeth are well developed, and the inside of the shell is white, purple, or a combination of both colors. The black sandsell is larger and more elongate than the pondmussel (*Liguma subrostrata*), and darker than the yellow sandshell (*Lampsilis teres*). It can be distinguished from the spectaclecase (*Cumberlandia monodonta*) and the spike (*Elliptio dilatata*) mussel by its smooth, shiny, rayed outer shell. The black sandshell's obscure beak sculpture also helps distinguish it from similar species.

Habitat

The black sandshell is usually found in the riffle and run areas of medium to large rivers in areas dominated by sand or gravel.

Biology / Life History

Mussels are long-lived animals. Members of many species may live for several decades and in some instances, a century or more. They spend most of their lives buried in the bottom sediments of permanent water bodies, and often live in multi-species communities called mussel beds (Sietman 2003).

Mussels are primarily sedentary, but they can move around with the use of their foot, which is a hatchet shaped muscle that can be extended out between the valves (shells). A mussel will burrow its foot into the sediment and then contract it to pull itself slowly along the bottom of its aquatic habitat (Sietman 2003).

Mussels eat by filtering bacteria, protozoans, algae, and other organic matter out of the water. They draw water into their body through their incurrent siphon, remove food and oxygen with their gills, and then expel the filtered water through their excurrent siphon. Food particles are carried to the mussel's mouth by tiny hairlike cilia located on the gills. Waste is expelled through the excurrent siphon (Sietman 2003).

Mussels have a complex and distinctive reproductive cycle. Males release sperm into the water, which are drawn in by females through their incurrent siphon. Fertilized eggs are brooded in the female's gills, where they develop into tiny larvae called glochidia. The black sandshell is bradytictic, with females brooding their young long-term from August through July before they are released as glochidia (Ortmann 1919). Once the glochidia are expelled from the female's gills, they attach to fish gills or fins by clamping onto them with their valves. The glochidia live as parasites on the host fish until they develop into juvenile mussels, at which point they detach from the fish and fall to the streambed as free-living mussels. Host fish for the glochidia of the black sandshell include the bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), sauger (*Stizostedion canadense*), and white crappie (*Pomoxis annularis*) (Watters 1994).

Conservation / Management

Degradation of mussel habitat in streams throughout the black sandshell's known range is a continuing threat to this species. Declines in habitat conditions are associated with management of the Mississippi River as a navigational canal, and with non-point source water pollution and sediment pollution. Dams, channelization, and dredging increase siltation, physically alter habitat conditions, and block the movement of fish hosts. The black sandshell is also being impacted by the infestation of non-native zebra mussels (*Dreissena polymorpha*) in the Mississippi River and its tributaries. Zebra mussels can attach themselves in large numbers to the shells of native mussels, eventually causing death by suffocation. Further survey work in rivers where the black sandshell was formerly documented is needed to verify its status in the remainder of its historical range.

Conservation Efforts in Minnesota

A 10-year statewide mussel survey initiated by the Minnesota DNR in 1999 resulted in a better understanding of the black sandshell's ecology and current status in Minnesota. Additionally, over 500 black sandshells were collected from zebra mussel infested habitats in the Mississippi River in 2000 and translocated into areas of the Mississippi River south of the Twin Cities, where habitats were devoid of zebra mussels.

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Endangered, Threatened, and Special Concern Species of Minnesota

Blanding's Turtle
(*Emydoidea blandingii*)

Minnesota Status:	Threatened	State Rank[1]:	S2
Federal Status:	none	Global Rank[1]:	G4

HABITAT USE

Blanding's turtles need both wetland and upland habitats to complete their life cycle. The types of wetlands used include ponds, marshes, shrub swamps, bogs, and ditches and streams with slow-moving water. In Minnesota, Blanding's turtles are primarily marsh and pond inhabitants. Calm, shallow water bodies (Type 1-3 wetlands) with mud bottoms and abundant aquatic vegetation (e.g., cattails, water lilies) are preferred, and extensive marshes bordering rivers provide excellent habitat. Small temporary wetlands (those that dry up in the late summer or fall) are frequently used in spring and summer -- these fishless pools are amphibian and invertebrate breeding habitat, which provides an important food source for Blanding's turtles. Also, the warmer water of these shallower areas probably aids in the development of eggs within the female turtle. Nesting occurs in open (grassy or brushy) sandy uplands, often some distance from water bodies. Frequently, nesting occurs in traditional nesting grounds on undeveloped land. Blanding's turtles have also been known to nest successfully on residential property (especially in low density housing situations), and to utilize disturbed areas such as farm fields, gardens, under power lines, and road shoulders (especially of dirt roads). Although Blanding's turtles may travel through woodlots during their seasonal movements, shady areas (including forests and lawns with shade trees) are not used for nesting. Wetlands with deeper water are needed in times of drought, and during the winter. Blanding's turtles overwinter in the muddy bottoms of deeper marshes and ponds, or other water bodies where they are protected from freezing.

LIFE HISTORY

Individuals emerge from overwintering and begin basking in late March or early April on warm, sunny days. The increase in body temperature which occurs during basking is necessary for egg development within the female turtle. Nesting in Minnesota typically occurs during June, and females are most active in late afternoon and at dusk. Nesting can occur as much as a mile from wetlands. The nest is dug by the female in an open sandy area and 6-15 eggs are laid. The female turtle returns to the marsh within 24 hours of laying eggs. After a development period of approximately two months, hatchlings leave the nest from mid-August through early-October. Nesting females and hatchlings are often at risk of being killed while crossing roads between wetlands and nesting areas. In addition to movements associated with nesting, all ages and both sexes move between wetlands from April through November. These movements peak in June and July and again in September and October as turtles move to and from overwintering sites. In late autumn (typically November), Blanding′s turtles bury themselves in the substrate (the mud at the bottom) of deeper wetlands to overwinter.

IMPACTS / THREATS / CAUSES OF DECLINE

- loss of wetland habitat through drainage or flooding (converting wetlands into ponds or lakes)
- loss of upland habitat through development or conversion to agriculture
- human disturbance, including collection for the pet trade* and road kills during seasonal movements
- increase in predator populations (skunks, racoons, etc.) which prey on nests and young

*It is illegal to possess this threatened species.

RECOMMENDATIONS FOR AVOIDING AND MINIMIZING IMPACTS

These recommendations apply to typical construction projects and general land use within Blanding's turtle habitat, and are provided to help local governments, developers, contractors, and homeowners minimize or avoid detrimental impacts to Blanding's turtle populations. **List 1** describes minimum measures which we recommend to prevent harm to Blanding's turtles during construction or other work within Blanding's turtle habitat. **List 2** contains recommendations which offer even greater protection for Blanding's turtles populations; this list should be used *in addition to the first list* in areas which are known to be of state-wide importance to Blanding's turtles (contact the DNR's Natural Heritage and Nongame Research Program if you wish to determine if your project or home is in one of these areas), or in any other area where greater protection for Blanding's turtles is desired.

List 1. Recommendations for all areas inhabited by Blanding's turtles.	**List 2.** ***Additional*** **recommendations for areas known to be of state-wide importance to Blanding's turtles.**
GENERAL	
A flyer with an illustration of a Blanding's turtle should be given to all contractors working in the area. Homeowners should also be informed of the presence of Blanding's turtles in the area.	Turtle crossing signs can be installed adjacent to road-crossing areas used by Blanding's turtles to increase public awareness and reduce road kills.
Turtles which are in imminent danger should be moved, by hand, out of harms way. Turtles which are not in imminent danger should be left undisturbed.	Workers in the area should be aware that Blanding's turtles nest in June, generally after 4pm, and should be advised to minimize disturbance if turtles are seen.
If a Blanding's turtle nests in your yard, do not disturb the nest.	If you would like to provide more protection for a Blanding's turtle nest on your property, see "Protecting Blanding's Turtle Nests" on page 3 of this fact sheet.
Silt fencing should be set up to keep turtles out of construction areas. It is <u>critical</u> that silt fencing be removed after the area has been revegetated.	Construction in potential nesting areas should be limited to the period between September 15 and June 1 (this is the time when activity of adults and hatchlings in upland areas is at a minimum).
WETLANDS	
Small, vegetated temporary wetlands (Types 2 & 3) should not be dredged, deepened, filled, or converted to storm water retention basins (these wetlands provide important habitat during spring and summer).	Shallow portions of wetlands should not be disturbed during prime basking time (mid morning to mid- afternoon in May and June). A wide buffer should be left along the shore to minimize human activity near wetlands (basking Blanding's turtles are more easily disturbed than other turtle species).
Wetlands should be protected from pollution; use of fertilizers and pesticides should be avoided, and run-off from lawns and streets should be controlled. Erosion should be prevented to keep sediment from reaching wetlands and lakes.	Wetlands should be protected from road, lawn, and other chemical run-off by a vegetated buffer strip at least 50' wide. This area should be left unmowed and in a natural condition.
ROADS	
Roads should be kept to minimum standards on widths and lanes (this reduces road kills by slowing traffic and reducing the distance turtles need to cross).	Tunnels should be considered in areas with concentrations of turtle crossings (more than 10 turtles per year per 100 meters of road), and in areas of lower density if the level of road use would make a safe crossing impossible for turtles. Contact your DNR Regional Nongame Specialist for further information on wildlife tunnels.
Roads should be ditched, not curbed or below grade. If curbs must be used, 4 inch high curbs at a 3:1 slope are preferred (Blanding's turtles have great difficulty climbing traditional curbs; curbs and below grade roads trap turtles on the road and can cause road kills).	Roads should be ditched, not curbed or below grade.

ROADS cont.	
Culverts between wetland areas, or between wetland areas and nesting areas, should be 36 inches or greater in diameter, and elliptical or flat-bottomed.	Road placement should avoid separating wetlands from adjacent upland nesting sites, or these roads should be fenced to prevent turtles from attempting to cross them (contact your DNR Nongame Specialist for details).
Wetland crossings should be bridged, or include raised roadways with culverts which are 36 in or greater in diameter and flat-bottomed or elliptical (raised roadways discourage turtles from leaving the wetland to bask on roads).	Road placement should avoid bisecting wetlands, or these roads should be fenced to prevent turtles from attempting to cross them (contact your DNR Nongame Specialist for details). This is especially important for roads with more than 2 lanes.
Culverts under roads crossing streams should be oversized (at least twice as wide as the normal width of open water) and flat-bottomed or elliptical.	Roads crossing streams should be bridged.
UTILITIES	
Utility access and maintenance roads should be kept to a minimum (this reduces road-kill potential).	
Because trenches can trap turtles, trenches should be checked for turtles prior to being backfilled and the sites should be returned to original grade.	
LANDSCAPING AND VEGETATION MANAGEMENT	
Terrain should be left with as much natural contour as possible.	As much natural landscape as possible should be preserved (installation of sod or wood chips, paving, and planting of trees within nesting habitat can make that habitat unusable to nesting Blanding's turtles).
Graded areas should be revegetated with native grasses and forbs (some non-natives form dense patches through which it is difficult for turtles to travel).	Open space should include some areas at higher elevations for nesting. These areas should be retained in native vegetation, and should be connected to wetlands by a wide corridor of native vegetation.
Vegetation management in infrequently mowed areas -- such as in ditches, along utility access roads, and under power lines -- should be done mechanically (chemicals should not be used). Work should occur fall through spring (after October 1st and before June 1st).	Ditches and utility access roads should not be mowed or managed through use of chemicals. If vegetation management is required, it should be done mechanically, as infrequently as possible, and fall through spring (mowing can kill turtles present during mowing, and makes it easier for predators to locate turtles crossing roads).

Protecting Blanding's Turtle Nests: Most predation on turtle nests occurs within 48 hours after the eggs are laid. After this time, the scent is gone from the nest and it is more difficult for predators to locate the nest. Nests more than a week old probably do not need additional protection, unless they are in a particularly vulnerable spot, such as a yard where pets may disturb the nest. Turtle nests can be protected from predators and other disturbance by covering them with a piece of wire fencing (such as chicken wire), secured to the ground with stakes or rocks. The piece of fencing should measure at least 2 ft. x 2 ft., and should be of medium sized mesh (openings should be about 2 in. x 2 in.). It is ***very important*** that the fencing be **removed before August 1st** so the young turtles can escape from the nest when they hatch!

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Ellipsaria lineolata (Rafinesque, 1820) Butterfly

MN Status:

threatened

Federal Status:

none

CITES:

none

USFS:

none

Group:

mussel

Class:

Bivalvia

Order:

Unionoida

Family:

Unionidae

Habitats:

Large Rivers

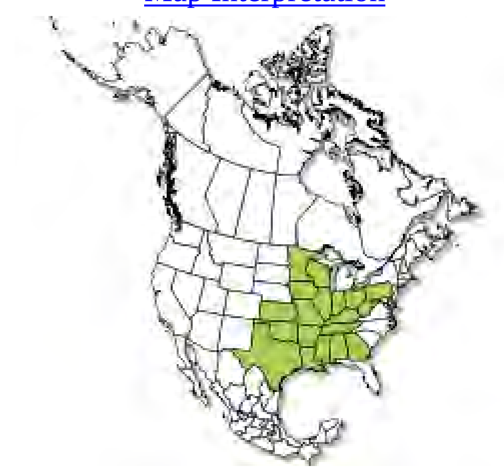
(Mouse over a habitat for definition)

Synonyms

Plagiola lineolata

Basis for Listing

Map Interpretation



Map Interpretation

Based on the presence of old shells, the butterfly was once present in the Minnesota, St. Croix, and Mississippi rivers, but was comparatively rare, even in the 1900s (Coker 1919; Bright et al. 1990). The butterfly mussel is now uncommon in the St. Croix River, where it was found by Doolittle (1988) at only 2 sampling points. Hornbach et al. (1995) quantified it as less than 1% of all the mussel fauna in the St. Croix River. The butterfly is also rare in the lower reaches of the Mississippi River in southeastern Minnesota (Fuller 1985). In a 1995 survey of Mississippi River Pool 7, only 1 live butterfly mussel was found out of the more than 2,000 specimens examined (Davis and Hart 1995). The butterfly has apparently been extirpated from the Minnesota River (Bright et al. 1990). Given its low numbers and the vulnerability of its habitat, the butterfly mussel was listed as a threatened species in Minnesota in 1996.

Description

The shell of the butterfly mussel is somewhat triangular, with rounded dorsal, anterior, and ventral margins. The shells of male butterfly mussels are compressed, while those of females are modestly inflated. The shell of both sexes is thick and up to 12.7 cm (5 in.) long. The outside of the shell has numerous interrupted brown rays and is generally yellowish, but can be brown in old specimens. The hinge ligament is sometimes dark green. The beak is turned forward and the beak sculpture consists of a few fine, double-looped lines, which are usually obscure. The pseudocardinal and lateral teeth are well developed and the inside of the shell is white. The butterfly does not closely resemble any other Minnesota mussel species.

Habitat

The butterfly mussel usually inhabits areas of large rivers with swift currents in sand or gravel substrates. However, it appears that the butterfly has adapted to life in reservoirs in some southern states, where it is found in water depths up to 6 m (20 ft). (Parmalee and Bogan 1998).

Biology / Life History

Mussels are long-lived animals. Members of many species may live for several decades and in some instances, a century or more. They spend most of their lives buried in the bottom sediments of permanent water bodies, and often live in multi-species communities called mussel beds (Sietman 2003).

Mussels are primarily sedentary, but they can move around with the use of their foot, which is a hatchet shaped muscle that can be extended out between the valves (shells). A mussel will burrow its foot into the sediment and then contract it to pull itself slowly along the bottom of its aquatic habitat (Sietman 2003).

Mussels eat by filtering bacteria, protozoans, algae, and other organic matter out of the water. They draw water into their body through their incurrent siphon, remove food and oxygen with their gills, and then expel the filtered water through their excurrent siphon. Food particles are carried to the mussel's mouth by tiny hairlike cilia located on the gills. Waste is expelled through the excurrent siphon (Sietman 2003).

Mussels have a complex and distinctive reproductive cycle. Males release sperm into the water, which are drawn in by females through their incurrent siphon. Fertilized eggs are brooded in the female's gills, where they develop into tiny larvae called glochidia. The butterfly mussel is bradytictic, with females brooding their young long-term from August through July before they are released as glochidia (Baker 1928). Once the glochidia are expelled from the female's gills, they attach to fish gills or fins by clamping onto them with their valves. The glochidia live as parasites on the host fish until they develop into juvenile mussels, at which point they detach from the fish and fall to the streambed as free-living mussels. Known fish hosts for the glochidia of the butterfly mussel include sunfish (*Lepomis* spp.), sauger (*Stizostedion canadense*), and drum (*Aplodinotus grunnieus*) (Fuller 1978).

Conservation / Management

The viability of remaining butterfly mussel populations in the Mississippi River is jeopardized by the continuing decline in habitat conditions associated with the river's management as a navigation canal, and with non-point and point source water and sediment pollution. Dams, channelization, and dredging increase siltation, physically alter habitat conditions, and block the movement of fish hosts. The butterfly is also being impacted by the infestation of non-native zebra mussels (*Dreissena polymorpha*) in the Mississippi River and its tributaries. Zebra mussels can attach in large numbers to the shells of native mussels, eventually causing death by suffocation. Historically the butterfly mussel was harvested for use in the pearl button industry (Baker 1928), and today it is harvested in some portions of its North American range for use in the cultured pearl industry (Oesch 1984). If observed trends cannot be reversed, the butterfly mussel may become endangered within Minnesota in the future.

Conservation Efforts in Minnesota

A 10-year statewide mussel survey initiated by the Minnesota DNR in 1999 resulted in a better understanding of the butterfly mussel's ecology and current status in Minnesota. Additionally, over 500 butterfly mussels were collected from zebra mussel infested habitats in the Mississippi River in 2000 and translocated into areas devoid of zebra mussels south of the Twin Cities.

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Fusconaia ebena (I. Lea, 1831) Ebonyshell

MN Status:

endangered

Federal Status:

none

CITES:

none

USFS:

none

Group:

mussel

Class:

Bivalvia

Order:

Unionoida

Family:

Unionidae

Habitats:

Large Rivers

(Mouse over a habitat for definition)

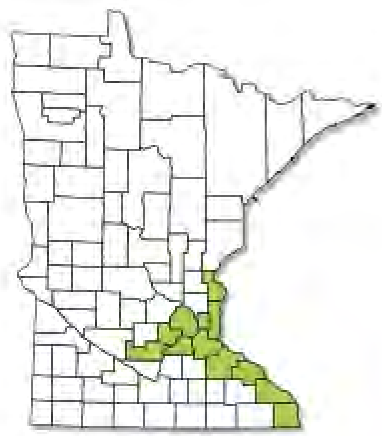
Click to enlarge

Synonyms

Fusconaia ebenus

Basis for Listing

Historically the most abundant mussel in the upper Mississippi River, the ebonyshell was prized by button makers for its thick white shell (Coker 1919). Populations in Minnesota occurred in the lower Minnesota, lower St. Croix, and Mississippi rivers. The ebonyshell is presently restricted to the lower St. Croix River above Lakeland and at Prescott, where less than 40 individuals have been found in recent decades (Kelner and Sietman 2000), and it is on the verge of extirpation from Minnesota. Overharvest during the pearl button era, pollution, and dams, which block the migration of its primary host fish, skipjack herring (*Alosa chrysochloris*), are the reasons for the species' demise. Its extreme rarity and narrow distribution make it vulnerable to catastrophic events. The ebonyshell was originally listed as a special concern species in Minnesota in 1984, but given continued habitat degradation and concerns over the



Map Interpretation

Map Interpretation

availability of its host fish, it was reclassified as an endangered species in 1996.

Description

The ebonyshell has a round, heavy shell with a beak that curves forward. The shell is brown to black in color, and can reach up to 10 cm (4 in.) long. The teeth of the ebonyshell are well developed, with the pseudocardinal teeth parallel to the lateral teeth. The beak cavity is deep, and the inner shell is white. Similar species include the Wabash pigtoe (*Fusconaia flava*), rouhd pigtoe (*Pleurobema sintoxia*), and hickorynut (*Obovaria olivaria*), but the combination of the ebonyshell's round shape, forward curved beak, deep beak cavity, and parallel pseudocardinal and lateral teeth, distinguish it from all of these species.

Habitat

The ebonyshell mussel primarily inhabits large rivers in sand or gravel (Cummings and Mayer 1992).

Biology / Life History

Mussels are long-lived animals. Members of many species may live for several decades and in some instances, a century or more. They spend most of their lives buried in the bottom sediments of permanent water bodies, and often live in multi-species communities called mussel beds (Sietman 2003).

Mussels are primarily sedentary, but they can move around with the use of their "foot", which is a hatchet shaped muscle that can be extended out between the valves (shells). A mussel will burrow its foot into the sediment and then contract it to pull itself slowly along the bottom of its aquatic habitat (Sietman 2003).

Mussels eat by filtering bacteria, protozoans, algae, and other organic matter out of the water. They draw water into their body through their incurrent siphon, remove food and oxygen with their gills, and then expel the filtered water through their excurrent siphon. Food particles are carried to the mussel's mouth by tiny hairlike cilia located on the gills. Waste is expelled through the excurrent siphon (Sietman 2003).

Mussels have a complex and distinctive reproductive cycle. Males release sperm into the water, which are drawn in by females through their incurrent siphon. Fertilized eggs are brooded in the female's gills, where they develop into tiny larvae called glochidia. The ebonyshell mussel is tachytictic, with females brooding their young short-term, from May to early fall, before they are released as glochidia (Parmalee and Bogan 1998). Once the glochidia are expelled from the female's gills, they attach to fish gills or fins by clamping onto them with their valves. The glochidia live as parasites on the host fish until they develop into juvenile mussels, at which point they detach from the fish and fall to the streambed as free-living mussels. The primary host fish for the ebonyshell is the skipjack herring (Watters 1994).

Conservation / Management

The primary threats to the continued persistence of the ebonyshell in Minnesota are the blockage of its migratory host fish, the skipjack herring, by dams (Kelner and Sietman 2000), and the species' small population size. The ebonyshell is also threatened by the continuing decline in habitat conditions on the Mississippi River, which are associated with its management as a navigation canal, and by non-point and point source water and sediment pollution. Dams, channelization, and dredging increase siltation and physically alter habitat conditions. The ebonyshell is also being impacted by the infestation of non-native zebra mussels (*Dreissena polymorpha*) in the Mississippi River and its tributaries. Zebra mussels can attach themselves in large numbers to the shells of native mussels, eventually causing death by suffocation.

Conservation Efforts in Minnesota

A 10-year statewide mussel survey initiated by the Minnesota DNR in 1999 resulted in a better understanding of the ebonyshell mussel's ecology and current status in Minnesota. Efforts are also underway to propagate juveniles for restocking into areas where habitat conditions have improved.

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Obovaria olivaria (Rafinesque, 1820) Hickorynut

MN Status:

special concern

Federal Status:
none

CITES:
none

USFS:
none

Group:

mussel

Class:
Bivalvia

Order:
Unionoida

Family:
Unionidae

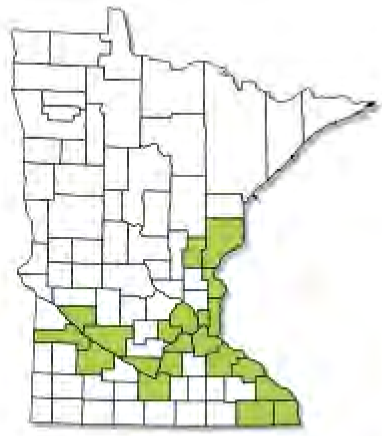
Habitats:
Medium Rivers and Streams, Large Rivers

(Mouse over a habitat for definition)

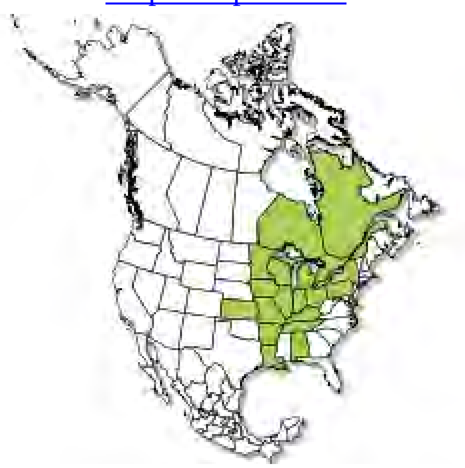
Click to enlarge

Basis for Listing

The hickorynut was historically found in the Minnesota and St. Croix rivers and the Mississippi River below St. Anthony Falls (van der Schalie and van der Schalie 1950), but it is now absent from the Minnesota River (Bright et al. 1990), rare in the St. Croix River (Doolittle 1988; Hornbach et al. 1995), and uncommon and scattered in the Mississippi River (Heath 1989). The range and abundance of this species and its host fish species have been reduced. For these reasons, the hickorynut was listed as a special conern species in Minnesota in 1996.



Map Interpretation



Map Interpretation

Description

The shell of the hickorynut is round or oval, thick, usually inflated, and up to 10 cm (4 in.) long. The beak is turned forward, and the beak sculpture consists of a few very fine, double-looped lines that are only visible on young mussels. The outside of the shell is greenish, tan, or brown, often with fine green rays. The pseudocardinal and lateral teeth are well developed. The left valve (shell) has 2 heavy, triangular-shaped pseudocardinal teeth, while the right valve has only 1 (Parmalee and Bogan 1998). The inside of the shell is white with a shallow beak cavity. Some individual hickorynuts may be confused with male Higgins eye (*Lampsilis higginsii*) specimens, but can be differentiated by the shape and alignment of the pseudocardinal teeth.

Habitat

The hickorynut most often inhabits large rivers and is rarely found in smaller streams (Cummings and Mayer 1992). It is most often found in sand and gravel substrates in water depths that generally exceed 1.5-1.8 m (5-6 ft.) (Parmalee and Bogan 1998).

Biology / Life History

Mussels are long-lived animals. Members of many species may live for several decades and in some instances, a century or more. They spend most of their lives buried in the bottom sediments of permanent water bodies, and often live in multi-species communities called mussel beds (Sietman 2003).

Mussels are primarily sedentary, but they can move around with the use of their "foot", which is a hatchet shaped muscle that can be extended out between the valves (shells). A mussel will burrow its foot into the sediment and then contract it to pull itself slowly along the bottom of its aquatic habitat (Sietman 2003).

Mussels eat by filtering bacteria, protozoans, algae, and other organic matter out of the water. They draw water into their body through their incurrent siphon, remove food and oxygen with their gills, and then expel the filtered water through their excurrent siphon. Food particles are carried to the mussel's mouth by tiny hairlike cilia located on the gills. Waste is expelled through the excurrent siphon (Sietman 2003).

Mussels have a complex and distinctive reproductive cycle. Males release sperm into the water, which are drawn in by females through their incurrent siphon. Fertilized eggs are brooded in the female's gills, where they develop into tiny larvae called glochidia. The hickorynut is bradytictic, with females brooding their young long-term, from August through June, before they are released as glochidia (Baker 1928). Once the glochidia are expelled from the female's gills, they attach to fish gills or fins by clamping onto them with their valves. The glochidia live as parasites on the host fish until they develop into juvenile mussels, at which point they detach from the fish and fall to the streambed as free-living mussels. The shovelnose sturgeon (*Scaphirhynchus platorynchus*) is a known fish host for the hickorynut's glochidia (Watters 1994).

Conservation / Management

The hickorynut in Minnesota is vulnerable to further declines from the hydrologic alteration of streams and their watersheds; the continuing decline in habitat conditions on the Mississippi River associated with its management as a navigation canal; and non-point and point source water and sediment pollution. Dams, channelization, and dredging increase siltation, physically alter habitat conditions, and block the movement of fish hosts. The hickorynut is also being impacted by the infestation of non-native zebra mussels (*Dreissena polymorpha*) in the Mississippi River and its tributaries. Zebra mussels can attach themselves in large numbers to the shells of native mussels, eventually causing death by suffocation.

Conservation Efforts in Minnesota

A 10-year statewide mussel survey initiated by the Minnesota DNR in 1999 resulted in a better understanding of the hickorynut's ecology and current status in Minnesota. Additionally, 148 hickorynuts were collected from zebra mussel infested habitats in the Mississippi River in 2000 and translocated into areas of the Mississippi River south of the Twin Cities, where habitats were devoid of zebra mussels.

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van der Schalie, H., and A. van der Schalie. 1950. The mussels of the Mississippi River. American Midland Naturalist 44:448-464.

Lampsilis higginsii (I. Lea, 1857) Higgins Eye

MN Status:

endangered
Federal Status:
endangered
CITES:
yes
USFS:
none

Group:

mussel
Class:
Bivalvia
Order:
Unionoida
Family:
Unionidae
Habitats:
Large Rivers

(Mouse over a habitat for definition)

Click to enlarge

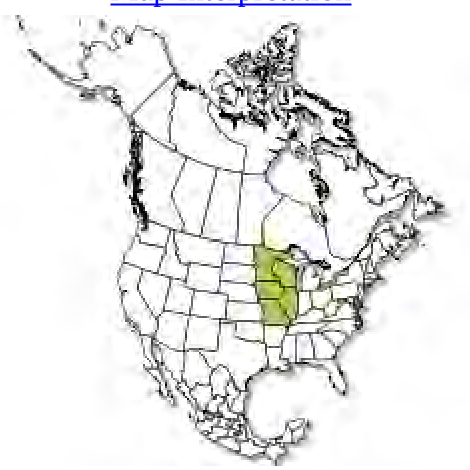
Synonyms

Lampsilis higginsii, Lampsilis higginsi

Basis for Listing

The Higgins eye was the first freshwater mussel to receive federal protection, which took effect in 1972. Degradation of the Mississippi River in the form of navigation improvements and pollution severely restricted the range of this species. Today, the lower St. Croix River has one of the largest remaining Higgins eye populations throughout the species' range. It has been extirpated from the Minnesota River, and is rare in the Mississippi River. The Higgins eye was afforded state endangered stauts in 1984.

Map Interpretation



Map Interpretation

Description

The shell of the Higgens eye is up to 15 cm (6 in.) long, and is inflated, with thick valves and a beak that is pointed forward. The outside of the shell is yellow, greenish, reddish, or brown, often with green rays. This species is sexually dimorphic, with the females having a shell that is rounded and truncate posteriorly, while the males have a shell that is oval. The beak sculpture in both sexes is obscure, and the pseudocardinal and lateral teeth are well developed. The inside of the shell is white, and sometimes pink or salmon in the beak cavity. The Higgens eye resembles the hickorynut (*Obovaria olivaria*), mucket (*Actinonaias ligamentina*), and plain pocketbook (*Lampsilis cardium*) mussels.

Habitat

The Higgins eye occurs only in the Mississippi River and the lower portion of some of its large tributaries (Havlik 1980). It occupies stable substrates that vary from sand to boulders, but not firmly packed clay, flocculent silt, organic material, bedrock, concrete or unstable sand. Water velocities should be less than 1 m/s (3.3 ft./s) during periods of low discharge. The species is usually found in mussel beds that contain at least 15 other species at densities greater than 0.01 individual/m^2 (U.S. Fish and Wildlife Service 2004).

Biology / Life History

Mussels are long-lived animals. Members of many species may live for several decades and in some instances a century or more. They spend most of their lives buried in the bottom sediments of permanent water bodies, and often live in multi-species communities called mussel beds (Sietman 2003).

Mussels are primarily sedentary, but they can move around with the use of their foot, which is a hatchet shaped muscle that can be extended out between the valves. A mussel will burrow its foot into the sediment and then contract it to pull itself slowly along the bottom of its aquatic habitat (Sietman 2003).

Mussels eat by filtering out bacteria, protozoans, algae, and other organic matter out of the water. They draw water into their body through their incurrent siphon, remove food and oxygen with their gills, and expel the water through their excurrent siphon. Food particles are carried to the mussel's mouth by tiny hairlike cilia located on the gills. Waste is expelled through the excurrent siphon (Sietman 2003).

Mussels have a complex and distinctive reproductive cycle. Males release sperm into the water, which are drawn in by females through their incurrent siphon. Fertilized eggs are brooded in the female's gills, where they develop into tiny larvae called glochidia. Baker (1928) reports that the Higgins eye is bradytictic, with females brooding their young long-term before they are released as glochidia . They are gravid in May and September. Once the glochidia are expelled from the female's gills, they attach to fish gills or fins by clamping onto them with their valves. The glochidia live as parasites on the host fish until they develop into juvenile mussels, at which point they detach from the fish and fall to the streambed as free-living mussels. The bluegill (*Lepomis macrochirus*), freshwater drum (*Aplodinotus grunniens*), green sunfish (*Lepomis cyanellus*), largemouth bass (*Micropterus salmoides*), northern pike (*Esox lucius*), sauger (*Sander canadense*), smallmouth bass (*Micropterus dolomieu*), walleye (*Sander vitreus*), and yellow perch (*Perca flavescens*) have been reported to be viable host fish species for the glochidia of the Higgins eye mussel (Waller and Holland-Bartels 1988; Watters 1994).

Conservation / Management

The Higgins eye is rare or extirpated throughout most of its former range. The viability of remaining populations in the Mississippi River is jeopardized by the continuing decline in habitat conditions associated with management of the river as a navigation canal; with non-point and point source water and sediment pollution; and by the infestation of non-native zebra mussels (*Dreissena polymorpha*) in the Mississippi River and its tributaries. Zebra mussels can attach themselves in large numbers to the shells of native mussels, eventually causing death by suffocation.

Conservation Efforts in Minnesota

In the early 1980s, a recovey team consisting of biologists from the U.S. Fish and Wildlife Service, Minnesota and Wisconsin DNRs, the U.S. Geological Survey, U.S. Army corps of Engineers, University of Minnesota, Macalaster College, and Western Wisconsin Technical College drafted the first Higgins Eye recovery plan. The plan identified actions necessary for the recovery of this rare mussel species (U. S. Fish and Wildlife Service 1983). The recovery team subsequently reconvened in the early 2000s to review all Higgins eye research conducted since 1980, and to review the status of the species. A revised recovery plan, taking into account new information and threats, such as the infestation of zebra mussels, was completed in 2004 (U. S. Fish and Wildlife Service 2004).

An intensive multi-state program is underway to propagate juvenile Higgins eye and reintroduce them into areas where the species occurred historically, with the hope of establishing new viable populations. As of 2004, 2 new populations of juveniles had been reintroduced into suitable habitat in Pools 3 and 4 of the Mississippi River. In addition, a population of adult Higgins eye were salvaged from a severely zebra mussel infested area of the Mississippi River and relocated to an area of the Mississippi River near the Twin Cities, where native mussels are recovering.

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Quadrula metanevra **(Rafinesque, 1820)** **Monkeyface**

MN Status:

threatened

Federal Status:
none

CITES:
none

USFS:
none

Group:

mussel

Class:
Bivalvia

Order:
Unionoida

Family:
Unionidae

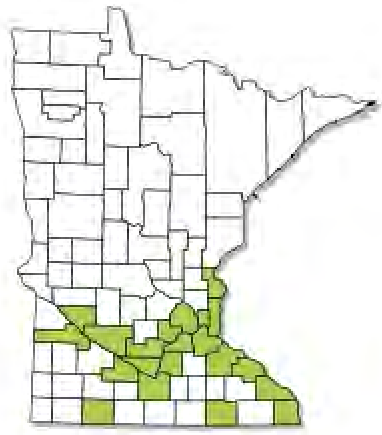
Habitats:
Medium Rivers and Streams, Large Rivers

(Mouse over a habitat for definition)

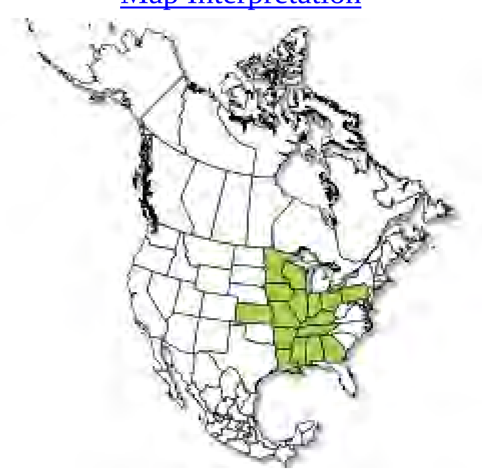
Click to enlarge

Basis for Listing

Monkeyface mussels were once widely distributed in the larger streams of the Mississippi basin, although they were among the less common mussels where they occurred (Fuller 1978). They are no longer found in the Minnesota River (Bright et al. 1990) and are very rare in the Mississippi River (Thiel 1981; M. Davis, Minnesota DNR, pers. comm.). Only the St. Croix River appears to still support a viable monkeyface population (Doolittle 1988; Heath 1990), where Hornbach et al. (1995) found it comprised 3% of the specimens they collected. The monkeyface was listed as a threatened species in Minnesota in 1996.



Map Interpretation



Map Interpretation

Description

The shell of the monkeyface can reach up to 12.7 cm (5 in.) long. It is squarish in shape with thick valves and a prominent posterior ridge, which often has a series of large knobs surrounded by scattered pustules (bumps). The posterior slope of the shell is flattened, appearing winged, often with a series of small ridges that curve upward. The posterior shell margin is indented. The outside of the shell is yellowish, greenish or brown, and usually marked with green chevrons (V-shaped markings). The pseudocardinal and lateral teeth are heavy, and the inside of the shell is white. The monkeyface resembles the mapleleaf (*Quadrula quadrula*), pimpleback (*Q. pustulosa*), purple wartyback (*Cyclonaias tuberculata*), wartyback (*Q. nodulata*), and winged mapleleaf (*Q. fragosa*) mussels, but can be distinguished from all of these species by its large, knobbed posterior ridge and green V-shaped markings.

Habitat

Hornbach et al. (1996) reported that densities of the monkeyface mussels in the St. Croix River peaked in habitats dominated by stable substrates in water over 2 m (6.6 ft) deep.

Biology / Life History

Mussels are long-lived animals. Members of many species may live for several decades and in some instances, a century or more. They spend most of their lives buried in the bottom sediments of permanent water bodies, and often live in multi-species communities called mussel beds (Sietman 2003).

Mussels are primarily sedentary, but they can move around with the use of their foot, which is a hatchet shaped muscle that can be extended out between the valves (shells). A mussel will burrow its foot into the sediment and then contract it to pull itself slowly along the bottom of its aquatic habitat (Sietman 2003).

Mussels eat by filtering bacteria, protozoans, algae, and other organic matter out of the water. They draw water into their body through their incurrent siphon, remove food and oxygen with their gills, and then expel the filtered water through their excurrent siphon. Food particles are carried to the mussel's mouth by tiny hairlike cilia located on the gills. Waste is expelled through the excurrent siphon (Sietman 2003).

Mussels have a complex and distinctive reproductive cycle. Males release sperm into the water, which are drawn in by females through their incurrent siphon. Fertilized eggs are brooded in the female's gills, where they develop into tiny larvae called glochidia. The monkeyface is a short-term breeder, and females may contain glochidia in their gills from May to July (Parmalee and Bogan 1998). Once the glochidia are expelled from the female's gills, they attach to fish gills or fins by clamping onto them with their valves. The glochidia live as parasites on the host fish until they develop into juvenile mussels, at which point they detach from the fish and fall to the streambed as free-living mussels. Fish hosts for the glochidia of the monkeyface are known to include sunfish (*Lepomis* spp.), bluegill (*L. macrochirus*), and sauger (*Stizostedion canadense*)

(Parmalee and Bogan 1998).

Conservation / Management

The monkeyface is declining or extirpated throughout most of its former range. The viability of remaining populations is jeopardized by the continuing decline in habitat conditions on the Mississippi River associated with its management as a navigation canal, and from non-point and point source water and sediment pollution. Dams, channelization, and dredging increase siltation, physically alter habitat conditions, and block the movement of fish hosts. The monkeyface is also being impacted by the infestation of non-native zebra mussels (*Dreissena polymorpha*) in the Mississippi River and its tributaries. Zebra mussels can attach in large numbers to the shells of native mussels, eventually causing death by suffocation. If observed trends cannot be reversed, the monkeyface will likely become endangered in the future.

Conservation Efforts in Minnesota

A 10-year statewide mussel survey initiated by the Minnesota DNR in 1999 resulted in a better understanding of the monkeyface's ecology and current status in Minnesota. Additionally, 40 monkeyface mussels were collected from zebra mussel infested habitats in the Mississippi River in 2000 and translocated into areas of the Mississippi River south of the Twin Cities, where habitats were devoid of zebra mussels.

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Polyodon spathula **(Walbaum, 1792)**

Paddlefish

MN Status:

threatened

Federal Status:
none

CITES:
yes

USFS:
none

Group:

fish

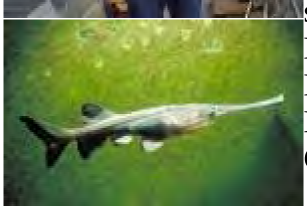
Class:
Actinopterygii

Order:
Acipenseriformes

Family:
Polyodontidae

Habitats:
Large Rivers

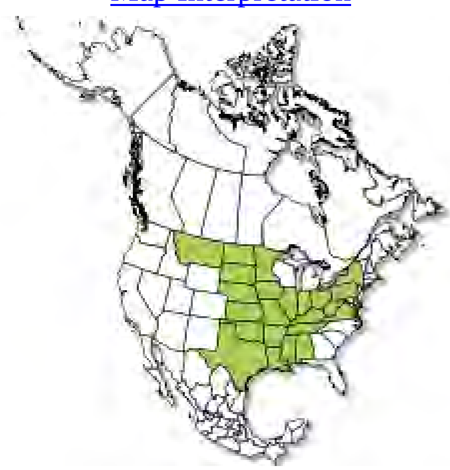
(Mouse over a habitat for definition)



Basis for Listing

The paddlefish is native to the Mississippi River basin, requiring large expanses of free-flowing river in which to complete its life cycle. Throughout its range, the paddlefish has experienced declines in abundance and distribution (Becker 1983). In Minnesota, paddlefish historically occurred in the Minnesota River to Granite Falls, in the Mississippi River to St. Anthony Falls, and in the St. Croix River to Taylors Falls (Cox 1897). Today, Minnesota's paddlefish are limited to small populations in the St. Croix and Mississippi rivers, including Lake St. Croix and Lake Pepin (Hatch et al. in preparation), with occasional reports from other waters. For example, in the early 1990s there were two angling reports of this species from the Minnesota River at Mankato and St. Peter. Minnesota DNR fisheries crews sampled a paddlefish in May 2004 near Granite Falls, an exceptional reappearance of this species.

Map Interpretation



Map Interpretation

The paddlefish's decline is probably due to habitat loss and degradation, overharvest, alterations to natural river flow regimes, and the construction of navigation dams on the Mississippi River, which limit or eliminate spawning migrations. The paddlefish was originally listed as a special concern species in Minnesota in 1984, but given evidence of long-term declines in abundance and distribution and the continued deterioration of habitat, the species was afforded threatened status in 1996. As a result of these protections, the paddlefish is now exhibiting a slow but significant recovery.

Description

The paddlefish has a long, paddle-like snout, small eyes that are set far forward, and a shark-like tail. It is blue-black or gray in color on the back, and white below. Its body is scaleless except for small patches of scales on the throat, pectoral girdle, and caudal (tail) fin. Small, paired barbels are present on the under surface of the paddle near the mouth. As adults, paddlefish reach a maximum size of 2.2 m (7.3 ft.) in total length and can weigh over 23 kg (50 lbs) (Page and Burr 1991). Historically, paddlefish have been reported to be over 91 kg (200 lbs.). A more recent record of a paddlefish taken from the lower Chippewa River in western Wisconsin in 1998 measured 1.8 m (5.9 ft.) long and weighed 39.4 kg (86.9 lbs.).

Habitat

Paddlefish occur in open waters of large rivers and river lakes (such as Lake Pepin and Lake St. Croix), oxbow lakes, and backwaters. In the upper Mississippi River drainage, they have been associated with areas of deep water and low current velocities (Zigler et al. 2003). Paddlefish need waters rich in zooplankton, on which they feed (Becker 1983), and free-flowing rivers with gravel bars that are inundated in spring floods for spawning.

Biology / Life History

Paddlefish are one of the few true large river species found in Minnesota. Spawning occurs in early spring over gravel bars in temporarily flooded tributaries when water temperatures reach about 10°C (50°F) (Purkett 1961). Zigler et al. (2003) found the linear range of paddlefish in the upper Mississippi River and 2 tributaries to be significantly larger during the spring compared to other seasons, suggesting a possible correlation with the onset of spawning activity. Paddlefish eggs hatch in 7 days or less at 18°C-21°C (65°F-70°F) (Purkett 1961) and newly hatched larvae average 8.5 mm (0.3 in.) long (Hatch et al. in preparation). Most male paddlefish mature at 7-9 years and most females mature at 9-12 years. Mature adults probably do not spawn every year. Paddlefish are long-lived species, surviving for at least 20 years, and females grow larger and live longer than males. Adults are filter feeders, swimming with their mouths open to pass water over their gills and trap zooplankton on the gill rakers. Their snouts have thousands of sensory pits, which may help in the detection of food (Hatch et al. in preparation).

Conservation / Management

Construction of dams and flood impoundment structures on large rivers has eliminated much of the paddlefish's spawning grounds and interfered with migration. Dredging, overfishing, and pollution have also been implicated in the species' decline since the start of the 20th Century. Some river construction projects have helped paddlefish populations temporarily, but the long-term effects have been negative (Sparrowe 1986; Unkenholz 1986). Injuries and death from propeller strikes on pleasure crafts in Lake Pepin are increasing and pose a significant threat to the slowly recovering paddlefish population. Additionally, paddlefish can be heavily parasitized by lampreys, which can weaken the fish and cause death (J. T. Hatch, University of Minnesota, pers. comm.).

Zigler et al. (2003) concluded that general area types (for example, channels, tailwaters, or impoundments) based on gross geomorphological features may be inadequate for describing paddlefish habitat and therefore making management recommendations. Rather, microhabitat characteristics (depth, current velocity, and water temperature) appear to be more important factors in habitat selection by paddlefish. The ability of paddlefish to pass through dams and move freely between spawning and non-spawning habitats will be critical for their population recovery. Zigler et al. (2004) found that strong flood pulse (high discharge), low dam head (0.3 m; 12 in. or less), and reduced current velocities positively influenced paddlefish passage through navigation dams in the upper Mississippi River. To effectively manage for this rare species, additional research on paddlefish reproductive and recruitment success is needed. Locating specific spawning areas and evaluating lock chambers as possible avenues for fish passage of navigation dams will be important components of any future studies.

Other common names for the paddlefish include spoonbill cat, duckbill cat, boneless cat, and spadefish.

Conservation Efforts in Minnesota

Tagging and radio telemetry studies of 71 paddlefish in the Upper Mississippi River drainage conducted by the Upper Midwest Environmental Sciences Center of the U.S. Geological Survey in collaboration with the U.S. Fish and Wildlife Service from 1994-1997 provided greater insight into the habitat use, long-term movement patterns, and dam passage of this species in Minnesota (Zigler et al. 2003, 2004). Additional paddlefish surveys were conducted in 2004 by the Minnesota DNR Section of Fisheries on the Minnesota River and by the Minnesota DNR Division of Ecological Services on the Minnesota, Mississippi, and St. Croix rivers. The Minnesota DNR Division of Ecological Services also received a State Wildlife Grant to conduct surveys for rare fish species in the Mississippi River from the Twin Cities to the Iowa border. These surveys were conducted from 2006-2008 (Schmidt and Proulx 2009), and the paddlefish was a targeted species.

The continued recovery of paddlefish to historic habitats and abundance is dependent on the removal or retrofitting of dams with fish passage features such ladders or lifts. This will include dams on the Mississippi River from Minneapolis to the Iowa border, and the Minnesota River from Granite Falls to Big Stone Lake. Long-term monitoring of paddlefish populations is essential and can be achieved through non-standardized and non-lethal survey techniques such as snagging and short duration gill net sets during the fall, winter, and spring. Another avenue that is being pursued on a limited basis is the funding of on-board fish biologists who observe and gather data on the incidental catches of commercial operators. The commercial nets, catch methods, and seasonal timing of commercial operations have proven to be far more effective on paddlefish and other rare, large river fish species than the standard gear and methods fish biologists typically utilize. Further paddlefish research needs include mortality frequency of propeller strikes from large recreational watercraft and basic life history to identify the critical spawning, rearing, and seasonally-utilized habitats.

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Arcidens confragosus (Say, 1829) — Rock Pocketbook

MN Status:
endangered
Federal Status:
none
CITES:
none
USFS:
none

Group:
mussel
Class:
Bivalvia
Order:
Unionoida
Family:
Unionidae
Habitats:
Large Rivers

(Mouse over a habitat for definition)

Click to enlarge

Basis for Listing

Historically a resident of the Mississippi River and its largest tributaries, where Dawley (1947) characterized it as "not common", the rock pocketbook was apparently both more common and more widely distributed in Minnesota in the past than it is today. Van der Schalie and van der Schalie (1950), reporting on survey work done by Ellis in the early 1930s, characterized the species as having a wide range, but seldom found in large numbers. Evidence of the rock pocketbook's past distribution can be found in turn-of-the-century shell middens left by pearl hunters near Red Wing, where the species is no longer found (M. Davis, Minnesota DNR, pers. comm.), and by relict shells found along the Minnesota River (Bright et al. 1990). The rock pocketbook continues to be rare in Minnesota waters, but recent surveys have found it to be repopulating portions of Pools 2 and 3 of the Mississippi River (Kelner and Davis 2002). It has never been reported from the St. Croix River, one of the last stable habitats for large river mussel fauna in the Upper Midwest. The rock pocketbook was listed as an endangered species in Minnesota in 1996.

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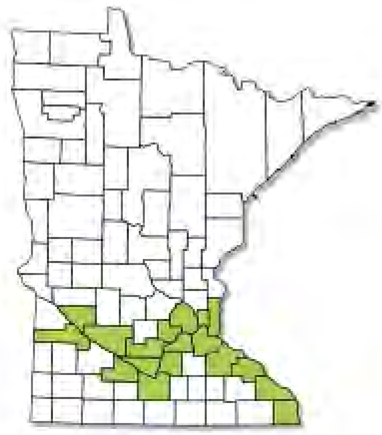

Map Interpretation

Map Interpretation

Description

The rock pocketbook is a fairly thin-shelled mussel species, which can be up to 15 cm (6 in.) long. The outside of its shell is green to dark brown, and it is heavily sculptured. The beak sculpture consists of 2 rows of large knobs or heavy, double-looped ridges, which become irregular folds or ridges as the individual matures. The pseudocardinal teeth are present, the lateral teeth are poorly developed, and the inner shell is white. The rock pocketbook resembles the threeridge (*Amblema plicata*) and the washboard (*Megalonaias nervosa*), but is distinguishable from them by its distinct coarse beak sculpture, thin shell, and reduced lateral teeth.

Habitat

The rock pocketbook inhabits medium to large rivers. It may be found in fine substrates such as silt or sand in slow current areas (Parmalee and Bogan 1998).

Biology / Life History

Mussels are long-lived animals. Members of many species may live for several decades and in some instances, a century or more. They spend most of their lives buried in the bottom sediments of permanent water bodies, and often live in multi-species communities called mussel beds (Sietman 2003). Because the rock pocketbook is a rare species in Minnesota, its populations consist of a few individuals scattered through its habitat.

Mussels are primarily sedentary, but they can move around with the use of their foot, which is a hatchet shaped muscle that can be extended out between the valves (shells). A mussel will burrow its foot into the sediment and then contract it to pull itself slowly along the bottom of its aquatic habitat (Sietman 2003).

Mussels eat by filtering bacteria, protozoans, algae, and other organic matter out of the water. They draw water into their body through their incurrent siphon, remove food and oxygen with their gills, and then expel the filtered water through their excurrent siphon. Food particles are carried to the mussel's mouth by tiny hairlike cilia located on the gills. Waste is expelled through the excurrent siphon (Sietman 2003).

Mussels have a complex and distinctive reproductive cycle. Males release sperm into the water, which are drawn in by females through their incurrent siphon. Fertilized eggs are brooded in the female's gills, where they develop into tiny larvae called glochidia. Fuller (1978) reports that the rock pocketbook is bradytictic, with females brooding their young long-term, from September through June, before they are released as glochidia. Once the glochidia are expelled from the female's gills, they attach to fish gills or fins by clamping onto them with their valves. The glochidia live as parasites on the host fish until they develop into juvenile mussels, at which point they detach from the fish and fall to the streambed as free-living mussels. The freshwater drum (*Aplodinotus grunniens*), rockbass (*Ambloplites rupestris*), and white crappie (*Pomoxis annularis*) have been reported to be viable host fish species for the glochidia of the rock pocketbook (Fuller 1978).

Conservation / Management

The viability of remaining rock pocketbook populations in Minnesota is jeopardized by the continuing decline in habitat conditions on the Mississippi River associated with its management as a navigation canal, and with non-point and point source water and sediment pollution. Dams, channelization, and dredging increase siltation, physically alter habitat conditions, and block the movement of fish hosts. The rock pocketbook is also being impacted by the infestation of non-native zebra mussels (*Dreissena polymorpha*) in the Mississippi River and its tributaries. Zebra mussels can attach themselves in large numbers to the shells of native mussels, eventually causing death by suffocation. The rock pocketbook is a thin-shelled species making it especially vulnerable to zebra mussel mortality. It is not considered commercially valuable to the cultured pearl industry, therefore the threats of poaching are thought to be minimal.

Conservation Efforts in Minnesota

A 10-year statewide mussel survey initiated by the Minnesota DNR in 1999 resulted in a better understanding of the rock pocketbook's ecology and current status in Minnesota. Additionally, 88 rock pocketbooks were collected from zebra mussel infested habitats in the Mississippi River in 2000 and translocated into areas of the Mississippi River south of the Twin Cities, where habitats were devoid of zebra mussels.

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Pleurobema sintoxia (Rafinesque, 1820) Round Pigtoe

MN Status:

threatened

Federal Status:
none

CITES:
none

USFS:
none

Group:

mussel

Class:
Bivalvia

Order:
Unionoida

Family:
Unionidae

Habitats:
Small Rivers and Streams, Medium Rivers and Streams, Large Rivers

(Mouse over a habitat for definition)

Click to enlarge

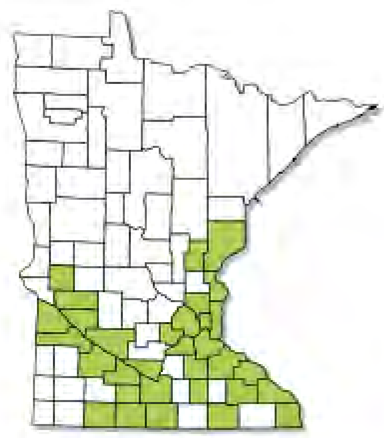
Synonyms

Pleurobema coccineum

Basis for Listing

The round pigtoe was historically found in the Zumbro, Cannon, Minnesota, and St. Croix rivers, as well as the Mississippi River below St. Anthony Falls (Doolittle 1988; Bright et al. 1988, 1990; Davis 1987). However, Dawley (1947) considered the species not to be abundant anywhere in the state. Today, the round pigtoe is apparently extirpated from the Minnesota River (Bright et al. 1990), extremely rare in the Cannon and Zumbro rivers (Bright et al. 1988; Davis 1987), rare in the Mississippi River, and common only in the St. Croix River (Doolittle 1988; Heath 1990). Hornbach et al. (1995) reported that the round pigtoe comprised only 3% of the specimens they collected from the St. Croix River. It has recently been found alive in only a small number of drainages, making it vulnerable to catastrophic events. Given its limited distribution and degradation of its habitat, the round pigtoe was listed as a threatened species in Minnesota in 1996.

Description



Map Interpretation

Map Interpretation

The shape of the round pigtoe's shell is highly variable depending on habitat. The shell can be triangular (large river form) or rounded (small stream form), compressed or inflated, with valves that are moderately thick to heavy. The shell reaches up to 13 cm (5 in.) long and the outside is chestnut to dark brown, sometimes with fine green rays. The beak sculpture consists of 2 or 3 small ridges, which are visible only in young specimens. The pseudocardinal and lateral teeth are heavy, and the beak cavity is moderately shallow. The inside of the shell is usually white, but it can occasionally be pink or salmon colored. The round pigtoe resembles several other Minnesota mussels. The ebonyshell (*Fusconaia ebena*) can be distinguished by its more circular shape, forward curved beak, and parallel pseudocardinal and lateral teeth. The sheepnose (*Plethobasus cyphyus*) can be distinguished by its row of low, broad knobs that extend down the center of the valve. The Wabash pigtoe (*F. flava*) can be distinguished by its distinct posterior ridge and deep beak cavity.

Habitat

The round pigtoe is found primarily in medium to large rivers but occasionally occurs in smaller rivers. Preferred habitats include fast current areas dominated by coarse sand and gravel substrates. Round pigtoes can be found in waters 0.9 m (3 ft.) to greater than 6.1 m (20 ft.) deep (Parmalee and Bogan 1998).

Biology / Life History

Mussels are long-lived animals. Members of many species may live for several decades and in some instances, a century or more. They spend most of their lives buried in the bottom sediments of permanent water bodies, and often live in multi-species communities called mussel beds (Sietman 2003).

Mussels are primarily sedentary, but they can move around with the use of their foot, which is a hatchet shaped muscle that can be extended out between the valves (shells). A mussel will burrow its foot into the sediment and then contract it to pull itself slowly along the bottom of its aquatic habitat (Sietman 2003).

Mussels eat by filtering bacteria, protozoans, algae, and other organic matter out of the water. They draw water into their body through their incurrent siphon, remove food and oxygen with their gills, and then expel the filtered water through their excurrent siphon. Food particles are carried to the mussel's mouth by tiny hairlike cilia located on the gills. Waste is expelled through the excurrent siphon (Sietman 2003).

Mussels have a complex and distinctive reproductive cycle. Males release sperm into the water, which are drawn in by females through their incurrent siphon. Fertilized eggs are brooded in the female's gills, where they develop into tiny larvae called glochidia. The round pigtoe is tachytictic, with females brooding their young short-term, from mid-May through July, before they are released as glochidia (Baker 1928). Once the glochidia are expelled from the female's gills, they attach to fish gills or fins by clamping onto them with their valves. The glochidia live as parasites on the host fish until they develop into juvenile mussels, at which point they detach from the fish and fall to the streambed as free-living mussels. The bluegill (*Lepomis macrochirus*) and several species of minnows are suitable fish hosts for the glochidia of the round pigtoe (Coker et al. 1921; Hove 1995).

Conservation / Management

The round pigtoe is jeopardized by the continuing decline of habitat conditions associated with the management of the Mississippi River as a navigational canal, and from non-point and point source water and sediment pollution. Dams, channelization, and dredging increase siltation, physically alter habitat conditions, and block the movement of fish hosts. The round pigtoe is also being impacted by the infestation of non-native zebra mussels (*Dreissena polymorpha*) in the Mississippi River and its tributaries. Zebra mussels can attach in large numbers to the shells of native mussels, eventually causing death by suffocation. Continued survey work in rivers where the round pigtoe was formerly documented is needed to verify its status in that former range.

Conservation Efforts in Minnesota

A 10-year statewide mussel survey initiated by the Minnesota DNR in 1999 resulted in a better understanding of the round pigtoe's ecology and current status in Minnesota. Additionally, over 50 round pigtoes were collected from zebra mussel infested habitats in the Mississippi River in 2000 and translocated into areas of the Mississippi River south of the Twin Cities, where habitats were devoid of zebra mussels.

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Sietman, B. E. 2003. Field guide to the freshwater mussels of Minnesota. Minnesota Department of Natural Resources, St. Paul, Minnesota. 144 pp.

Elliptio dilatata (Rafinesque, 1820) — Spike

MN Status:

special concern

Federal Status:
none

CITES:
none

USFS:
none

Group:

mussel

Class:
Bivalvia

Order:
Unionoida

Family:
Unionidae

Habitats:
Small Rivers and Streams, Medium Rivers and Streams, Large Rivers, Littoral Zone of Lake

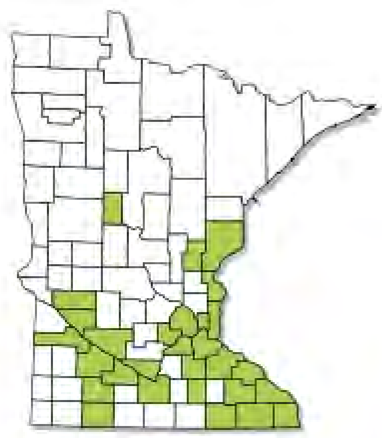
(Mouse over a habitat for definition)

Synonyms

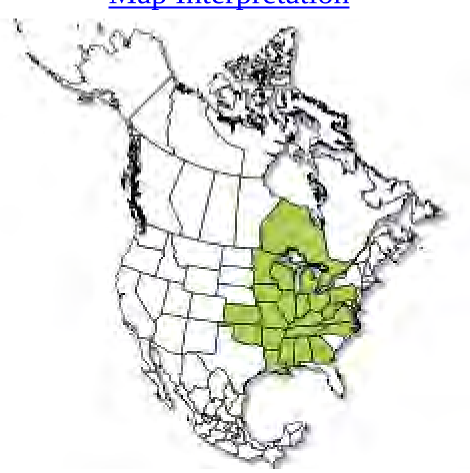
Elliptio dilatatus

Basis for Listing

Historically widespread and locally abundant in Minnesota (Dawley 1947), the spike, also known as the lady finger, is now common only in the St. Croix River and its tributaries (Doolittle 1988; Havlik 1993), Rose Creek, and at the outlet of Lake Pepin on the Mississippi River (Hart 1999). Occasional specimens are collected from tributaries to the Mississippi River (Davis 1987), but it is apparently extirpated in the mainstem of the Minnesota River and its tributaries, despite ample habitat (Bright et al. 1990; Minnesota DNR, unpublished data). It has recently been found alive in only a small number of drainages, and degradation of its stream habitat is a continuing threat. For these reasons, the spike was listed as a special concern species in Minnesota in 1996.



Map Interpretation



Map Interpretation

Description

The shell of the spike is elongate, moderately thick to heavy, compressed or slightly inflated, and up to 15 cm (6 in.) long. The outside of the shell is brown to black, occasionally with green rays. The beak sculpture consists of coarse loops raised slightly in the center. The pseudocardinal and lateral teeth are well-developed, and the inner shell is usually purple, sometimes white or orange, or a combination. The black sandshell (*Ligumia recta*) is similar, but is often heavily rayed and lacks beak sculpture.

Habitat

Spike mussels are usually found in small to large rivers, but they are also known to inhabit reservoirs and lakes. Whether in rivers or lakes, they are most often found in sand and gravel substrates in depths ranging from 0.6-7.3 m (2-24 ft.) (Parmalee and Bogan 1998). When spike mussels do inhabit lakes or reservoirs, they are usually associated with outlet habitats dominated by swift currents.

Biology / Life History

Mussels are long-lived animals. Members of many species may live for several decades and in some instances, a century or more. Survival rates for populations of spike mussels, much like other long-lived organisms, are high. Hart et al. (2001) reported that spike mussels have mean annual survival rates greater than 90%. These survival rates were measured in habitats colonized by zebra mussels (*Dreissena polymorpha*), and the survival rates in habitats without zebra mussels would most likely be even higher.

Mussels spend most of their lives buried in the bottom sediments of permanent water bodies, and often live in multi-species communities called mussel beds. They are primarily sedentary, but they can move around with the use of their foot, which is a hatchet shaped muscle that can be extended out between the valves (shells). A mussel will burrow its foot into the sediment and then contract it to pull itself slowly along the bottom of its aquatic habitat (Sietman 2003).

Mussels eat by filtering bacteria, protozoans, algae, and other organic matter out of the water. They draw water into their body through their incurrent siphon, remove food and oxygen with their gills, and then expel the filtered water through their excurrent siphon. Food particles are carried to the mussel's mouth by tiny hairlike cilia located on the gills. Waste is expelled through the excurrent siphon (Sietman 2003).

Mussels have a complex and distinctive reproductive cycle. Males release sperm into the water, which are drawn in by females through their incurrent siphon. Fertilized eggs are brooded in the female's gills, where they develop into tiny larvae called glochidia. The spike is a tachytictic breeder, with females brooding their young short-term, from May through August, before they are released as glochidia (Baker 1928). Once the glochidia are expelled from the female's gills, they attach to fish gills or fins by clamping onto them with their valves. The glochidia live as parasites on the host fish until they develop into juvenile mussels, at which point they detach from the fish and fall to the streambed as free-living mussels. Fish hosts for the glochidia of the spike mussel include the gizzard shad (*Dorosoma cepedianum*), flathead catfish (*Pylodictis olivaris*), white crappie (*Pomoxis annularis*), black crappie (*P. nigromaculatus*), and yellow perch (*Perca flavescens*) (Fuller 1974).

Conservation / Management

Degradation of mussel habitat in streams throughout the spike's known range is a continuing threat. Spike populations in Minnesota are vulnerable to further decline because of hydrologic alteration of streams and their watersheds; the continuing decline in habitat conditions on the Mississippi River associated with its management as a navigation canal; and non-point and point source water pollution and sedimentation. Dams, channelization, and dredging increase siltation, physically alter habitat conditions, and block the movement of fish hosts. The spike mussel is also being impacted by the infestation of non-native zebra mussels in the Mississippi River and its tributaries. Zebra mussels can attach themselves in large numbers to the shells of native mussels, eventually causing death by suffocation. If current trends cannot be reversed, the spike may become threatened in the future. Further survey work in rivers where the spike mussel was formerly documented is needed to verify its status in that former range.

Conservation Efforts in Minnesota

A 10-year statewide mussel survey initiated by the Minnesota DNR in 1999 resulted in a better understanding of the spike mussel's ecology and current status in Minnesota. A research project designed to measure the survival rate of a population of spike mussels is also ongoing in the Mississippi River (Hart 1999; Hart et al. 2001). Additionally, a small number of spikes were collected from zebra mussel infested habitats in the Mississippi River in 2000 and translocated into areas of the Mississippi River south of the Twin Cities, where habitats were devoid of zebra mussels.

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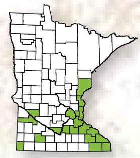
Sietman, B. E. 2003. Field guide to the freshwater mussels of Minnesota. Minnesota Department of Natural Resources, St. Paul, Minnesota. 144 pp.

WESTERN FOXSNAKE

(Pantherophis vulpinus)



Status:	Not listed, Species in Greatest Conservation Need
Size:	36 - 54 inches
Active season:	Late April through October
Scales:	Weakly keeled, divided anal plate
Description:	This snake has a yellowish tan to gray background color with brown to black mid-dorsal blotches and a row of alternating smaller blotches along each side. Blotches are outlined in black. The head is a solid copper or brown color. The belly is pale yellow with brown or black markings. Young Foxsnakes typically have a lighter background color, and a dark bar between their eyes, extending to the corner of the mouth on each side.
Diet:	Rodents, ground-nesting birds and their eggs
Habitat:	Often found in riparian (river) areas, upland hardwood forests, pine barrens and prairies; typically near a river or stream. They overwinter below the frost line in rock crevices, mammal burrows, wells and stone foundations.
Hunting:	Constrictor
Reproduction:	Egg layer, clutch size is 7 – 29 eggs, with an average of 14.
Other name(s):	Pine Snake, Copperhead
Notes:	This snake is frequently encountered in people's homes, especially homes with stone foundations. The previous scientific name for this snake was *Elaphe vulpina*.


MNDNR-Barb Perry

Adult Western Foxsnake.


Christopher E. Smith

Juvenile Western Foxsnake. Juveniles of this species have different coloration than adults.

Source: Minnesota Department of Natural Resources. 2010. **Snakes and Lizards of Minnesota**. Nongame Wildlife Program, Minnesota Department of Natural Resources, St. Paul, Minnesota. 67 pp.

Quadrula nodulata **(Rafinesque, 1820)** **Wartyback**

MN Status:

endangered

Federal Status:
none

CITES:
none

USFS:
none

Group:

mussel

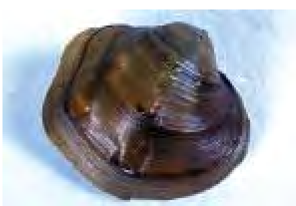
Class:
Bivalvia

Order:
Unionoida

Family:
Unionidae

Habitats:
Large Rivers

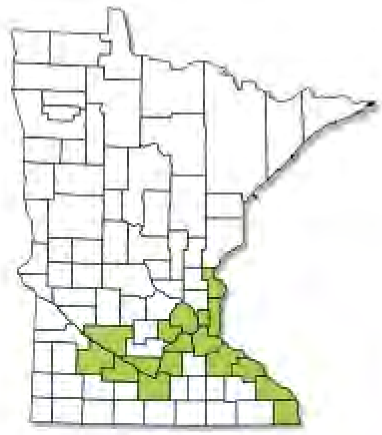
(Mouse over a habitat for definition)



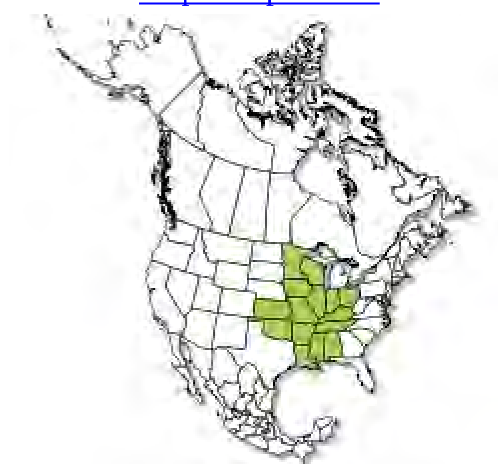
Click to enlarge

Basis for Listing

The wartyback historically occurred in the Minnesota and Mississippi rivers in Minnesota (Dawley 1947; van der Schalie and van der Schlalie 1950), where populations have since declined. Bright et al. (1990) found only 7 live individulas at 4 sites in the Minnesota River. The species is still rare and sporadically distributed in the Mississippi River, although there is recent evidence of some recovery in the Twin Cities area (Kelner and Davis 2002). Given the wartyback's restricted range and the small number of recent live specimens, it was listed as an endangered species in Minnesota in 1996.



Map Interpretation



Map Interpretation

Description

The shell of the wartyback is rounded, thick, truncated posteriorly, moderately inflated, and up to 8 cm (3 in.) long. The outside of the shell is straw colored to brown, and rayless. The shell has large pustules that are usually paired, but are sometimes single, forming 2 rows that extend from the beak to the ventral margin. The shell also has a small posterior wing that is usually present, and an obscure beak sculpture. The pseudocardinal and lateral teeth are well-developed, and the inside of the shell is white. The wartyback is similar to the purple wartyback (*Cyclonaias* *tuberculata*), the winged mapleleaf (*Quadrula fragosa*), the pimpleback (*Q. pustulosa*), and the mapleleaf (*Q. quadrula*), but its 2 rows of large pustules, lack of green rays, and straw color distinguish it from these species.

Habitat

The wartyback is found in large rivers in Minnesota, and it can be found in fine or coarse substrates in areas of slow or moderate current.

Biology / Life History

Mussels are long-lived animals. Members of many species may live for several decades and in some instances, a century or more. They spend most of their lives buried in the bottom sediments of permanent water bodies, and often live in multi-species communities called mussel beds (Sietman 2003).

Mussels are primarily sedentary, but they can move around with the use of their foot, which is a hatchet shaped muscle that can be extended out between the valves (shells). A mussel will burrow its foot into the sediment and then contract it to pull itself slowly along the bottom of its aquatic habitat (Sietman 2003).

Mussels eat by filtering bacteria, protozoans, algae, and other organic matter out of the water. They draw water into their body through their incurrent siphon, remove food and oxygen with their gills, and then expel the filtered water through their excurrent siphon. Food particles are carried to the mussel's mouth by tiny hairlike cilia located on the gills. Waste is expelled through the excurrent siphon (Sietman 2003).

Mussels have a complex and distinctive reproductive cycle. Males release sperm into the water, which are drawn in by females through their incurrent siphon. Fertilized eggs are brooded in the female's gills, where they develop into tiny larvae called glochidia. The wartyback is tachytictic, with females brooding their young short-term before they are released as glochidia. Female wartybacks may be gravid in June and July (Parmalee and Bogan 1998). Once the glochidia are expelled from the female's gills, they attach to fish gills or fins by clamping onto them with their valves. The glochidia live as parasites on the host fish until they develop into juvenile mussels, at which point they detach from the fish and fall to the streambed as free-living mussels. Fish hosts for the glochidia of the wartyback include black crappie (*Pomoxis nigromaculatus*), white crappie (*P. annularis*), bluegill (*Lepomis macrochirus*), channel catfish (*Ictalurus punctatus*), and largemouth bass (*Micropterus salmoides*) (Watters 1994).

Conservation / Management

Degradation of mussel habitat in streams throughout the wartyback's known range is a continuing threat to this species. Populations in Minnesota are vulnerable to further decline because of hydrologic alteration of streams and their watersheds; the continuing decline in habitat conditions on the Minnesota and Mississippi rivers; non-point and point source water and sediment pollution; and the infestation of non-native zebra mussels (*Dreissena polymorpha*) in the Mississippi River and its tributaries. Zebra mussels can attach themselves in large numbers to the shells of native mussels, eventually causing death by suffocation. Further survey work in rivers where the wartyback was formerly documented is needed to verify its status in that former range.

Conservation Efforts in Minnesota

A 10-year statewide mussel survey initiated by the Minnesota DNR in 1999 resulted in a better understanding of the wartyback mussel's ecology and current status in Minnesota.

References

Bright, R. C., C. Gatenby, D. Olson, and E. Plummer. 1990. A survey of the mussels of the Minnesota River, 1989. Final report submitted to the Natural Heritage and Nongame Research Program, Minnesota Department of Natural Resources. 106 pp.

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From:	Thomas Cinadr
To:	Katherine Lind
Subject:	Re: FW: Request for a Review of Archaeological/Historic database
Date:	Thursday, February 06, 2014 8:58:39 AM
Attachments:	Archaeology.rtf Historic.rtf

THIS EMAIL IS NOT A PROJECT CLEARANCE.

This message simply reports the results of the cultural resources database search you requested. The database search produced results for only previously known archaeological sites and historic properties. Please read the note below carefully.

Archaeological sites and historic properties were identified in a search of the Minnesota Archaeological Inventory and Historic Structures Inventory for the search area requested. **Reports containing the results of the search are attached.**

The result of this database search provides a listing of recorded archaeological sites and historic architectural properties that are included in the current SHPO databases. Because the majority of archaeological sites in the state and many historic architectural properties have not been recorded, important sites or structures may exist within the search area and may be affected by development projects within that area. Additional research, including field survey, may be necessary to adequately assess the area's potential to contain historic properties.

If you require a comprehensive assessment of a project's potential to impact archaeological sites or historic architectural properties, you may need to hire a qualified archaeologist and/or historian. If you need assistance with a project review, please contact Kelly Gragg-Johnson in Review and Compliance @ 651-259-3455 or by email at kelly.graggjohnson@mnhs.org.

The Minnesota SHPO Survey Manuals and Database Metadata and Contractor Lists can be found at **http://www.mnhs.org/shpo/survey/inventories.htm**

SHPO research hours are 8:00 AM – 4:00 PM Tuesday-Friday.

The Office is closed on Mondays.

Tom Cinadr
Survey and Information Management Coordinator
Minnesota State Historic Preservation Office
Minnesota Historical Society
345 Kellogg Blvd. West
St. Paul, MN 55102

651-259-3453

On Tue, Feb 4, 2014 at 12:47 PM, Katherine Lind <klind@houstoneng.com> wrote:

Good day Mr. Cinadr,

Please find the attached letter for the request of a review of the archaeological and historic database for a site in Washington County, Minnesota. Please give me a call if you have any questions or concerns.

Regards,

Katherine

Katherine Lind

Research Analyst
O 763.493.4522 | **D** 763.493.6992 | **F** 763.493.5572

6901 E Fish Lake Rd. , Suite 140 • Maple Grove, MN • 55369

www.houstoneng.com

History/Architecture Inventory

COUNTY: Washington

CITY/TOWNSHIP: Cottage Grove

PROPERTY NAME	ADDRESS	Twp	Range	Sec	Quarters	USGS	Report	NRHP	CEF	DOE	Inventory Number
3M Chemolite Plant	xxx Chemolite Rd.	27	21	34	NW	St. Paul Park					WA-CGC-019
Healy-Hope Glen Farmstead, Mackintosh-Healy House	10276 Pt. Douglas Rd.	27	21	26	SE-NW-NW	St. Paul Park	WA-94-5H				WA-CGC-024
Cottage Grove Cemetery, Lyceum Hall	SE corner 70th St. S. & Lamar Ave. S.	27	21	11	NE-NE	St. Paul Park	WA-91-1H				WA-CGC-033
Thompson Barn	10768 80th St. S.	27	21	14	NW-NW-	St. Paul Park	WA-2001-1H				WA-CGC-043
Thompson Barn		27	21	14	NW-NW-	St. Paul Park	WA-89-2H				WA-CGC-043
Thompson-Tank Farmstead	10052 80th St. S.	27	21	11	SW-SW-SW	St. Paul Park	WA-89-2H				WA-CGC-055
Thompson-Tank Farmstead		27	21	11	SW-SW-SW	St. Paul Park	WA-2001-1H				WA-CGC-055
O-Keene-Gramse Farmstead	10478 80th St. S.	27	21	11	SE-SE-SW	St. Paul Park	WA-89-2H				WA-CGC-056
N.H. Van Slyke Farmstead	9016 Kimbro Ave. S.	27	21	23	NW-NW-NE	St. Paul Park	WA-90-2H				WA-CGC-061
James Sheridan Barn (razed)	9866 Kimbro Ave. S.	27	21	23	SE-SE-SW	St. Paul Park	WA-89-2H				WA-CGC-064
Robens House	10701 80th St. S.	27	21	11	SE-SW-SE	St. Paul Park	WA-88-2H				WA-CGC-091
Jansen Barn	9649 90th St. S.	27	21	22	NW-NW-NE	St. Paul Park	WA-89-2H				WA-CGC-092
Jansen Barn		27	21	22	NW-NW-NE	St. Paul Park	WA-2001-1H				WA-CGC-092
Ruona House	8782 96th St. S.	27	21	14	SW-NE-NE	St. Paul Park	WA-85-1H				WA-CGC-093
John Bailey Farmstead	7333 Keats Ave. S.	27	21	11	NW-SW-NW	St. Paul Park	WA-89-2H				WA-CGC-111
Ludwig Wolf Barn	9056 Kimbro Ave. S.	27	21	23	SW-NW-NE	St. Paul Park	WA-89-2H				WA-CGC-112
Miller House, Nieman House	7737 Lamar Ave. S.	27	21	11	NE-SE-SE	St. Paul Park	WA-88-2H				WA-CGC-132
Kemp Barn	9430 Pt. Douglas Rd.	27	21	22	NE-SE-SW	St. Paul Park	WA-89-2H				WA-CGC-155
Pommerening Barn	9826 Pt. Douglas Rd.	27	21	27	NW-NE-NE	St. Paul Park	WA-89-2H				WA-CGC-156
Heldman House	10176 Pt. Douglas Rd.	27	21	26	SW-NW-NW	St. Paul Park	WA-88-2H				WA-CGC-157
Hale Barn	10532 Pt. Douglas Rd.	27	21	26	NE-NE-SW	St. Paul Park	WA-89-2H				WA-CGC-158

PROPERTY NAME	ADDRESS	Twp	Range	Sec	Quarters	USGS	Report	NRHP	CEF	DOE	Inventory Number

COUNTY: Washington

CITY/TOWNSHIP: Cottage Grove

PROPERTY NAME	ADDRESS	Twp	Range	Sec	Quarters	USGS	Report	NRHP	CEF	DOE	Inventory Number
Biscoe Barn	10473 80th St. S.	27	21	14	NE-NE-NW	St. Paul Park	WA-89-2H				WA-CGC-167
Smallidge Barn	10992 Pt. Douglas Rd.	27	21	26	SE-SE-SE	St. Paul Park	WA-89-2H				WA-CGC-177
Fort Ripley Military Rd. - Cottage Grove Segment	Lehigh Rd., Lamar Ave., 70th St., Military Rd.	27	21	11		St. Paul Park	WA-91-1H				WA-CGC-186
Fort Ripley Military Rd. - Cottage Grove Segment		27	21	23		St. Paul Park	WA-91-1H				WA-CGC-186
Cottage Grove Cemetery	xxx 70th St.	27	21	11	NE-NE-NE	St. Paul Park					WA-CGC-196
Cottage Grove Ravine	off U.S. Hwy. 10	27	21	11	E-E	St. Paul Park	WA-91-1H				WA-CGC-209
Cottage Grove Ravine		27	21	14	SW	St. Paul Park	WA-91-1H				WA-CGC-209
Cottage Grove Ravine		27	21	14	NE	St. Paul Park	WA-91-1H				WA-CGC-209
Cottage Grove Ravine		27	21	22	E-E	St. Paul Park	WA-91-1H				WA-CGC-209
Cottage Grove Ravine		27	21	23	W	St. Paul Park	WA-91-1H				WA-CGC-209
Cottage Grove Ravine		27	21	26	NW	St. Paul Park	WA-91-1H				WA-CGC-209
Cottage Grove Ravine		27	21	27	NE-NE	St. Paul Park	WA-91-1H				WA-CGC-209
Pt. Douglas Rd.- Cottage Grove Segment	Pt. Douglas Rd.	27	21	26		St. Paul Park	WA-91-1H				WA-CGC-210
Pt. Douglas Rd.- Cottage Grove Segment		27	21	27	SW	St. Paul Park	WA-91-1H				WA-CGC-210
Chicago Burlington & Quincy Railroad Line		27	21	34	N	St. Paul Park	WA-91-1H				WA-CGC-212
Chicago Burlington & Quincy Railroad Line		27	21	35	E	St. Paul Park	WA-91-1H				WA-CGC-212
Glacial River Channel	off U.S. Hwy. 10	27	21	34	NW	St. Paul Park	WA-91-1H				WA-CGC-214
Bedrock Knob	off Military Rd.	27	21	11	C-NW	St. Paul Park	WA-91-1H				WA-CGC-219
Grey Cloud, Cottage Grove and Stillwater Road		27	21	11		St. Paul Park					WA-CGC-224
Pt. Douglas Road Wayside Rest Area	East Pt. Douglas Rd. .2 mi west of Kimbro Ave.	27	21	26	NW-NW-SE	St. Paul Park					WA-CGC-225
Cottage View Drive-In	9338 E. Pt. Douglas Rd.	27	21	22	NW-SW	St. Paul Park	WA-2000-2H				WA-CGC-229
Bridge 9071	CSAH 19 3.1 mi NW of Jct. TH 95	27	21	22	SE-SW	Saint Paul Park					WA-CGC-237

COUNTY: Washington

CITY/TOWNSHIP: Cottage Grove

Archaeological Site Locations

Site Number	Site Name	Twp.	Range	Sec.	Quarter Sections	Acres	Phase	Site Description	Tradition	Context	Reports	NR	CEF	DOE
County:	**Washington**													
21WA0056	River Oaks	27	21	35	NE-NE-SE, SE-NE-SE	5	1	SR			WA-88-01			
	River Oaks	27	21	35	NE-NE-SE, SE-NE-SE	5	1	SR			WA-87-01			
21WA0079		27	21	14	E-SW-SW-NW	0.1	1	SA	A-2		WA-90-01			
21WA0080		27	21	14	E-NW-NE-NW	2	1	LS			WA-90-01			