HENNEPIN COUNTY
MINNESOTA

Mississippi River Stabilization Project Site Assessment and Summary

Background and Need

City of Brooklyn Park and Hennepin County staff have been developing a partnership over the last year, focused on assisting Mississippi River landowners to address erosion they've been experiencing along their riverbanks. This partnership stems from discussions city staff and elected officials have been having with neighborhood associations and individual landowners, which have been requesting assistance for restoring their riverbanks.

Beginning in Spring 2020, City of Brooklyn Park and Hennepin County staff began in earnest for planning for a large project to restore many properties through a FY21 Clean Water Fund grant. This grant would be leveraged with local dollars from all partners; specifically the city, county, and landowners. Other funding partners may be pursued.

Public input was critical early in project development, and a public meeting was scheduled for June 30, 2020, to present project ideas to landowners and garner interest to participate in the program and allow staff to visit their properties to assess erosion. City of Brooklyn Park staff identified 128 parcels on the riverbank within their city limits with which to mail an invite to the public meeting. From that list, over 50 people attended the meeting. During the meeting, staff provided landowners a Letter of Intent, which landowners could sign and return if they wished to participate in the program. A site visit was completed for any landowner that returned a signed Letter of Intent.

Field Assessment

Hennepin County staff coordinated landowner visits solely based on interactions from, and directly following, the June 30 public meeting for landowners that submitted a signed Letter of Intent. By July 17, the latest date landowner visits were completed, 48 properties were assessed by Hennepin County staff (**Figure 1**). Sites spanned much of the river reach within the City of Brooklyn Park, and included properties above and below the Coon Rapids Dam. All but three properties were privately owned, single-family residential. The three non-single-family residential homes were owned by a commercial business (1), homeowner's association (1), and the Izaak Walton League (1).

Hennepin County Environment and Energy
701 Fourth Avenue South, Suite 700, Minneapolis, MN 55415

environment@hennepin.us

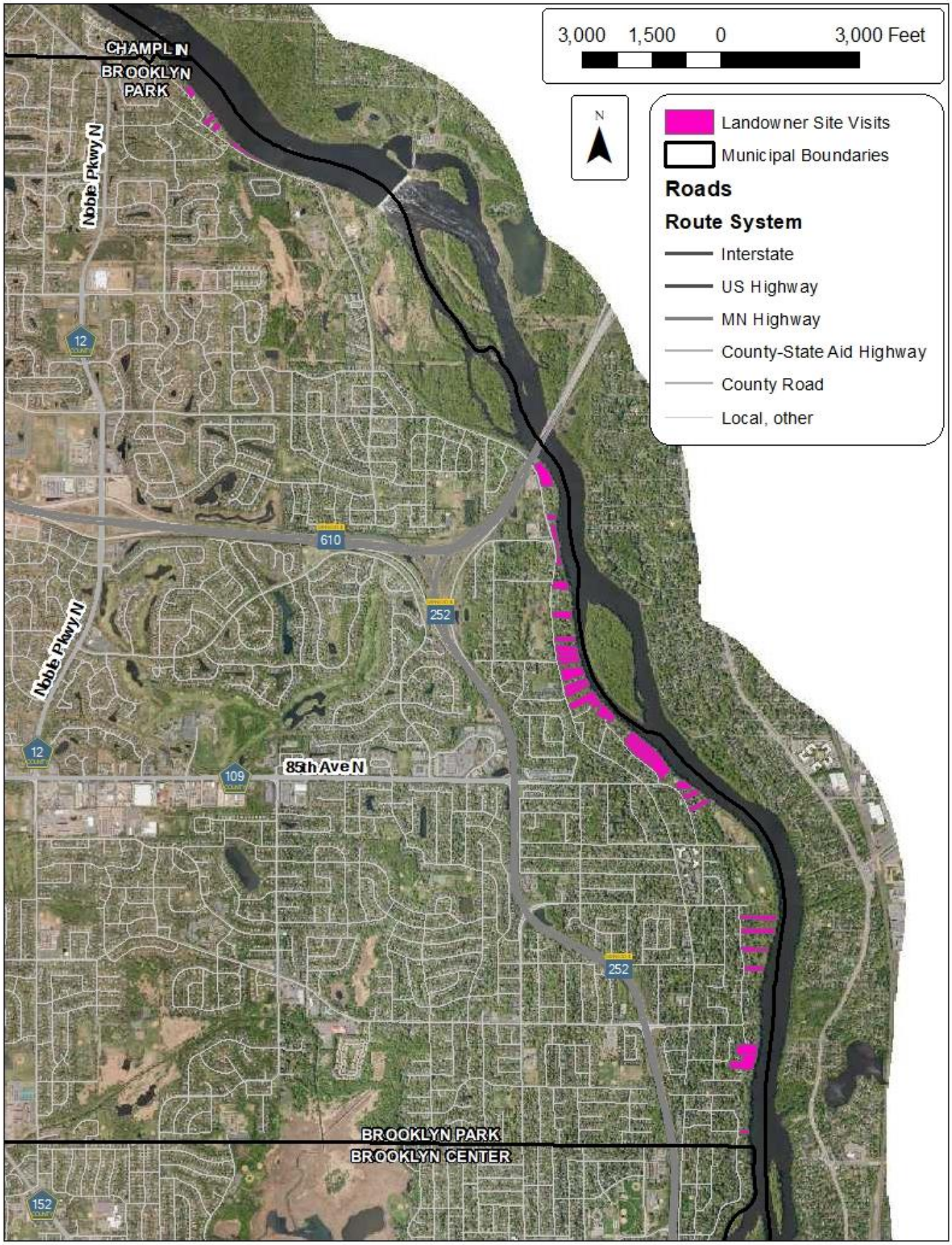


Figure 1: Properties (48) in which landowner site visits were completed in 2020 by Hennepin County staff in the City of Brooklyn Park.

Assessments were scheduled to take up to 45 minutes, and typically included the following:

1) Discussion with the landowner(s), and/or other available representatives, about erosion issues experienced on the property
2) Tour of riverfront with landowner to discuss issues witnessed by landowner and view erosion features in/near bank
3) Measurement and documentation of erosional features for additional analysis
4) Follow-up with landowners on (A) project eligibility and (B) any additional concerns identified onsite

These field assessments were meant primarily to triage properties and to identify those best suited for the FY21 Clean Water Fund grant application the City of Brooklyn Park intends to apply for. Additional site visits, and a more detailed survey(s), will be necessary to acquire the information to develop a riverbank restoration design. The information acquired during this site visit was enough to develop a conceptual understanding of the level of effort to address these shorelines but shouldn't be used for more than that.

Figure 2: Evidence of mass wasting event. PID 1311921230014.

Landowner site visits were completed in 2020 during the weeks of July 6-10 and July 13-17 by Hennepin County staff Kirsten Barta and Kris Guentzel. Field notes and photos gathered during the visits were compiled and used to identify erosion severity, erosion rate, and potential causes. Factors causing erosion are not always clear based on a single site visit, but the following items identified during site visits are typically clear indicators for erosion and often can be clues for various erosion sources:

1) Mass wasting events – sections of bank detaching and sliding down the slope, may be caused by either erosion at the toe of the slope or destabilization within the bank.
2) Scarps – bare and near vertical bluff faces, often found following mass wasting events.
3) Undercutting – usually found at the toe of the bank and caused by scour during high flow events.
4) Exposed roots and overhanging vegetation – most plant root system cannot grow when exposed to air, so exposed roots likely mean erosion occurred recently. Similarly, overhanging vegetation is likely the result of recent bank destabilization and an otherwise vertical (or near vertical) plant falling towards the water surface.

Each of these features were identified during site visits. In some cases all three were found on a given site. **Figures 2-7** illustrate these features.

Figure 3: Seepage flowing through previous mass wasting event. PID 1311921230014.

Figure 4: Evidence of bank sloughing. Top photo from PID 1311921310006. Bottom photo from PID 1311921430005.

Figure 5: Scarp resulting from flow-induced erosion on PID 1211921320015.

Figure 6: Overhanging vegetation within floodplain. Also evidence of flow-induced erosion. Photo from PID 1211921330021.

Figure 7: Banks exhibiting undercutting and exposed roots. Evidence of either (or both) flow-induced and wind/wave erosion. Top photo is from PID 1311921310006. Bottom photo is from PID 1211921320015.

Erosion Severity and Impacts

To assess properties and understand the erosion sources and severity, Hennepin County used the Riverbank Assessment Sheet (MWMO, 2010; **Appendix C**) and other materials in *A Guide to Bank Restoration Options for Large River Systems: Part II Bioengineering Installation Manual*. Results of the assessment can be found in **Tables 4** and **5**.

To estimate lateral bank recession rates, Hennepin County staff applied principals utilized by the Wisconsin Natural Resources Conservation Service (NRCS; **Appendix D**). These techniques are common where *in situ*, measured data may be unavailable or unreliable, and uses erosional characteristics and empirical data to estimate lateral recession rates. Erosion severity categories, and a description of factors defining that category, are shown in **Table 1**. Estimated lateral recession rates varies from 0.05 ft/yr for banks with minor erosion to up to 0.5 ft/yr for banks with severe erosion (**Table 5**). Please see **Appendix D** for a complete description of methods to estimate lateral erosion and **Table 5** for erosion estimates for each property.

Table 1: Wisconsin Natural Resources Conservation Service (NRCS) Bank Erosion Severity Categories and Descriptions.

Lateral Recession Rate (ft/yr)	Category	Description
0.01-0.05	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang. No exposed tree roots.
0.06-0.2	Moderate	Bank is predominantly bare with some rills and vegetative overhang. Some exposed tree roots but no slumps or slips.
0.3-0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross section becomes U-shaped as opposed to V-shaped.
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross section is U-shaped and stream course may be meandering.

Erosional severity categories were applied to properties in the City of Brooklyn Park, with results shown in **Figures 7-9**. These areas are defined as:

1) **Figure 8**: properties north of the Coon Rapids Dam.
2) **Figure 9**: properties between Highway 610 and River Park.
3) **Figure 10**: properties south of River Park.

Many properties north of the Coon Rapids Dam (**Figure 8**) have been experiencing erosion caused primarily by wave action from increased recreational boat traffic. Banks are generally shorter (i.e. < 10 feet in height) then properties downstream of the dam and erosion tends to be concentrated in a 2-3 foot high area where water fluctuates between. Water level is generally consistent based on dam operation (personal communication with landowners, 2020). Six landowners reached out to Hennepin County staff for site visits, and only two landowners had erosion on their property that would quality as minor or moderate. Those without erosion had already stabilized their shore, either through the installation or riprap or railroad ties. The single property with moderate erosion is owned by a homeowner's association and does have significant undercutting and erosion east of the launch and boat marina on the western portion of the property.

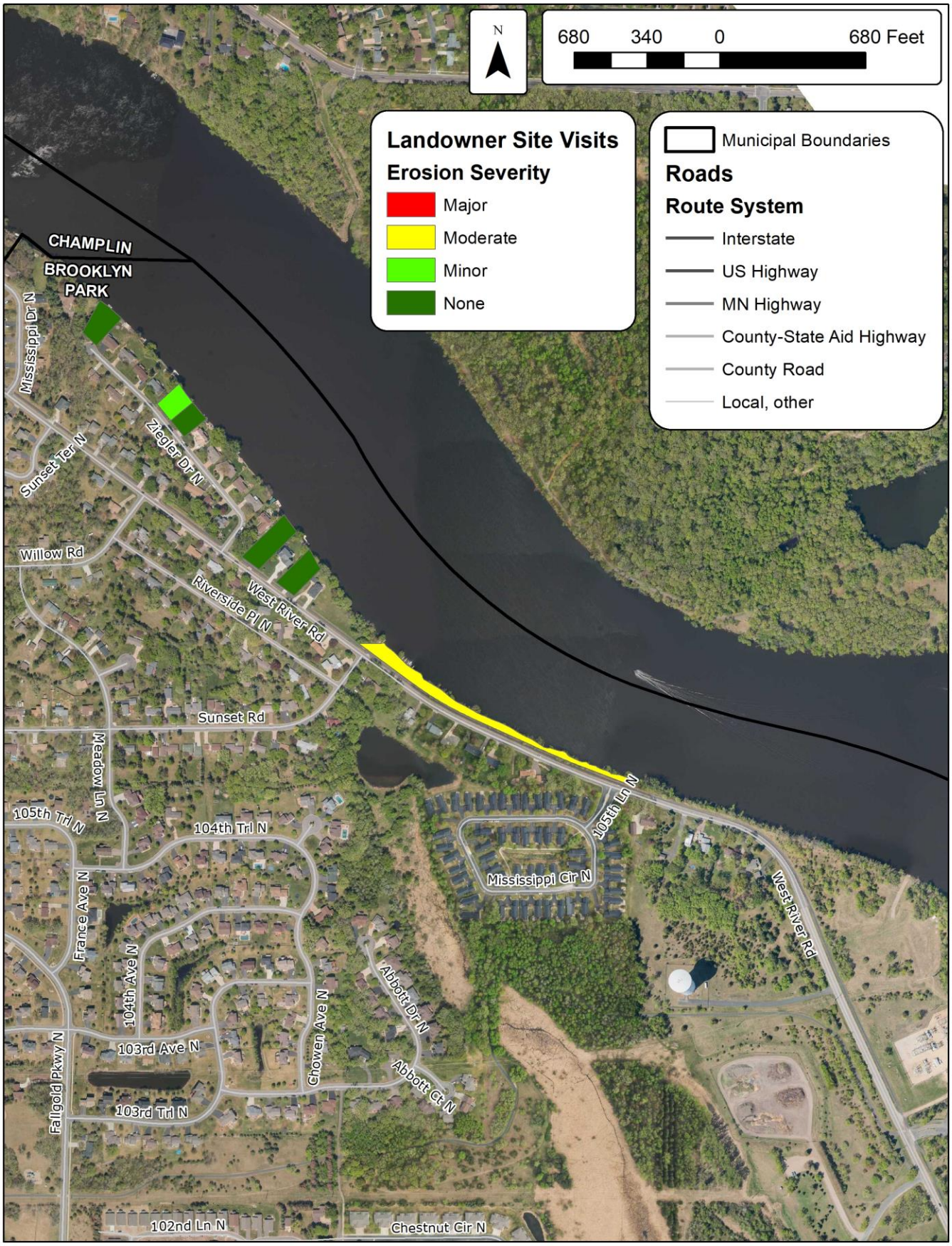


Figure 8: Riverbank erosion severity evaluated during landowner site visits in the City of Brooklyn Park north of the Coon Rapids Dam.

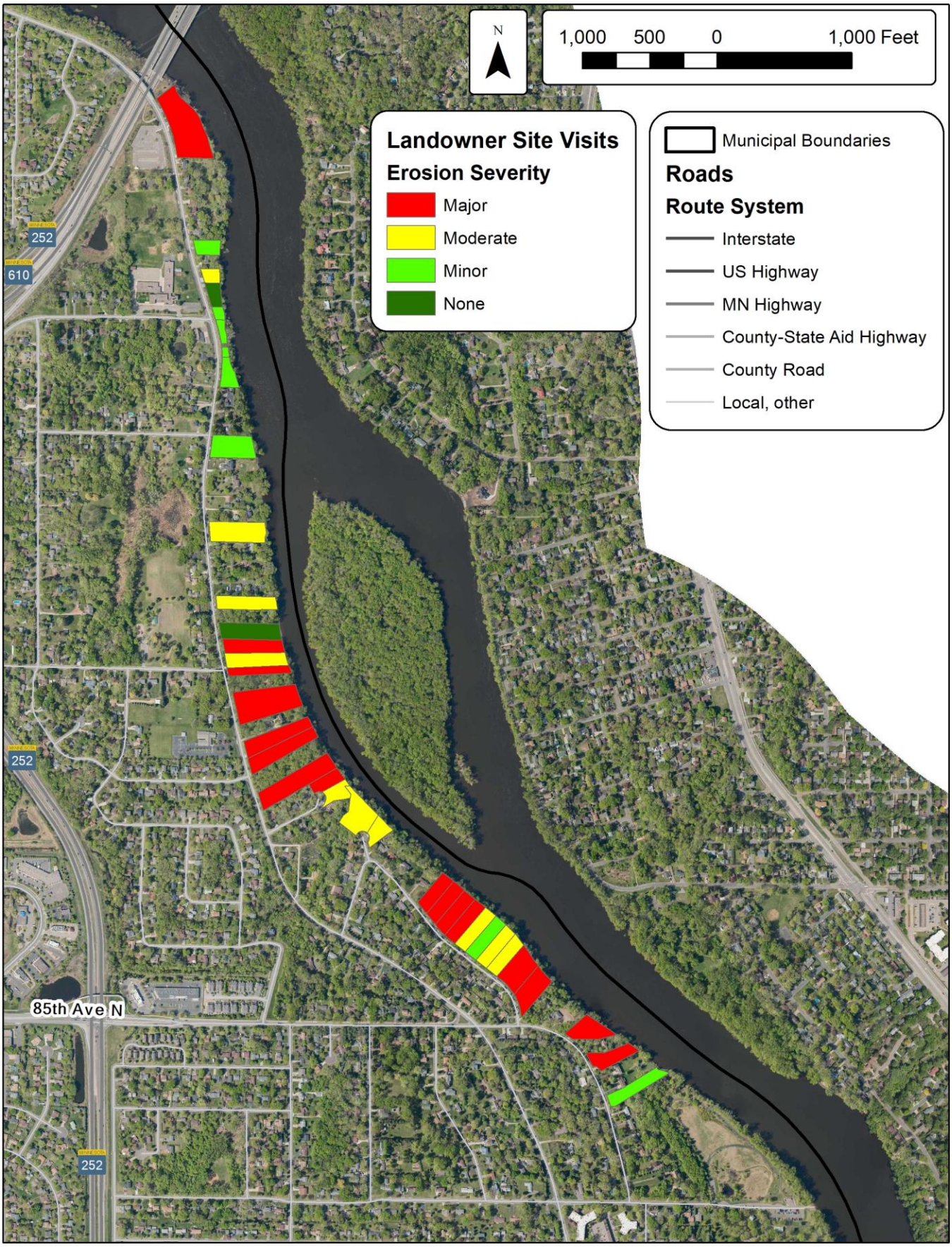


Figure 9: Riverbank erosion severity evaluated during landowner site visits in the City of Brooklyn Park between Highway 610 and the city's River Park.

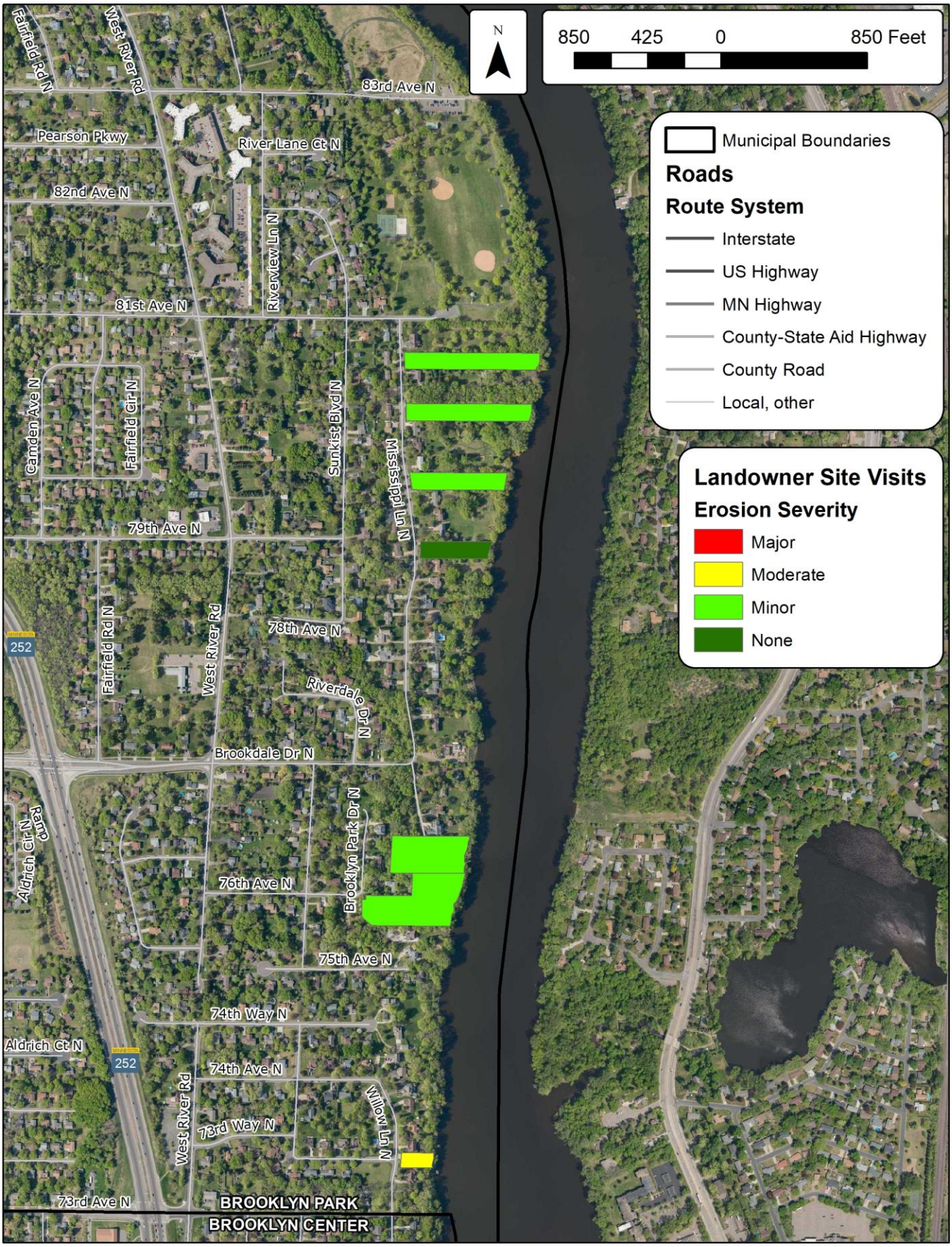


Figure 10: Riverbank erosion severity evaluated during landowner site visits in the City of Brooklyn Park south of the city's River Park.

Similarly, erosion south of River Park (**Figure 10**) was generally minor as erosion forces were limited to generally more minor flow-induced erosion and wave action. Evidence of undercutting and exposed and bare banks were evident, but not common. Erosion categories were mostly minor, with one example of moderate erosion (**Figure 10**).

South of the dam and north of River Park (**Figure 9**), riverbank erosional features (**Figures 2-7**) were consistently found on a majority of the viewed properties. Most properties on West River Road, at and north of 92nd Avenue North, had only minor to moderate erosion caused predominantly by flow-induced forces, such as sheer stress during high flows. The Leopold's Mississippi Gardens property is the exception, as much of the property shows evidence of undercutting and severely eroding banks. The worst example of this is the scarp in **Figure 5**, just east of their parking lot.

South of 92nd Avenue North, for properties on West River Road west of Banfill Island and downstream of Banfill Island on Riverview Lane North, several signatures of erosion were found from a variety of sources. **Figures 2, 3, 4, 6 and 7** were each taken in these areas and are indicative of characteristics found throughout these properties. Of note, was the evidence of active seepages discharging from the banks well above the normal water level. These seepages are caused by groundwater, well above the Mississippi River water level, slowing escaping the banks along the high bluffs in this area. These are naturally occurring (personal communication with residents, 2020) but have increased in their volume and height above the bank of the last 5-10 years. This is consistent with records of increased groundwater levels throughout the county over the last 10 years. These seepages have caused destabilization in many of the banks, which has led to mass wasting events such as those shown in **Figures 2** and **3**. Even in cases where the toe of the slope has been stabilized, such as **Figure 2** with hard armoring through riprap, erosion and downstream sediment loading is still occurring as these events will be washed out during the next high water flood. For properties without toe stabilization, erosion has likely been accelerated through successive events of consistent mid-bank destabilization and mass wasting events paired with semi-regular flood waves which wash out the wasted soils and potentially also remove additional toe soils. Thus, the area that erosion is occurring along these banks is not limited to the toe but extends many feet up the bank, as high as 30-40 feet (**Table 4**) for some properties. In certain cases, overland erosion and wave action (especially for properties south of Banfill Island) also act to intensify erosion rates but were not consistent across all properties in **Figure 9**.

Many of the properties identified as exhibiting 'Major' erosion in **Figure 9** qualify for either the 'Severe' or 'Very Severe' erosion categories in **Table 1.** Across all 48 properties assessed, sediment and total phosphorus (TP) erosion into the Mississippi River has estimated as 1,550 tons/year and 1,434 lbs-TP/year (**Table 5**). Sediment erosion on any given property varied from effectively none (i.e. equal amounts erosion and sedimentation) to 133 tons/year (**Table 5**). Similarly, TP erosion varied from 0-123 lbs-TP/year (**Table 5**). Median sediment erosion for each erosion category were 64.7 tons/year for severe, 21.9 tons/year for moderate, and 1.3 for minor and for TP were 59.8 lbs-TP/year for severe, 20.3 lbs-TP/year for moderate, and 1.2 lbs-TP/year for minor (**Table 5**).

Strategies and Costs to Address Riverbank Erosion

Strategies to restore eroded banks and protect riverbank property vary widely but are generally chosen based on the erosion source(s) and site-specific considerations. The following sources were considered to be significant contributors to the erosion witnessed by Hennepin County staff during their site visits in July 2020 (in no particular order):

1) Flow-induced erosion from the Mississippi River, generally during high flow events
2) Properties within/near cutbanks on the Mississippi River where cutbank is trying to actively migrate downstream
3) Wave action caused by recreational boats and other aquatic vehicles
4) Bank seepage
5) Overland runoff from immediate and adjacent properties

Any site-specific design must incorporate factors that sufficiently address each of these erosion sources. The guidance in **Table 2** is provided for each bank zone (see Table notes) based on the Erosion Severity category applied to each property in **Figures 8-10**. In general, bioengineered practices are strongly encouraged to restore and maintain habitats for aquatic and terrestrial animals.

Table 2: Strategies to address and stabilize riverbanks in the City of Brooklyn Park based on erosion category.

Erosion Category	Evidence of Erosion	Strategies to Address Erosion *
Major	Property has several erosive features, likely caused by multiple erosion sources, including sloughs, scarps, undercutting, overhanging vegetation, exposed roots, and/or fallen trees. Lateral erosion is significant, often as high as a half-foot per year.	**** Toe of Bank**: preference for bioengineering (e.g. cedar tree revetment or rootwads) but likely need to consider hard armoring (e.g. riprap) to fully stabilize bank from forces that caused major erosion. **Bank**: regrading likely necessary to achieve desirable 2:1 or more gradual bank slope, following regrading soil must be protected through erosion control fabric or vegetated mat. Native seeding and/or planting recommended. Within bank forces and factors, such as seeps, must be controlled through drain tile or similar conveyance and protection feature(s). Riprap may be extended into this zone but should be avoided if possible. **Upland**: overland erosion must be controlled and safely diverted to/through restored areas. Drain tile and/or berms can be used to collect and divert water and vegetation used to slow water velocity and increase deep infiltration. **In-channel**: structures may be appropriate which can divert most erosive forces away from the bank (e.g. bendway weirs).
Moderate	Property has no more than a few erosive features, likely caused by one or two erosion sources, including small sloughs, undercutting, overhanging vegetation, exposed roots, and/or fallen trees. Lateral erosion has occurred but isn't consistent and is no more than a few inches per year.	**Toe of Bank**: preference for bioengineering (e.g. cedar tree revetment or rootwads), particularly when erosion is focused on a shorter (i.e. 6 feet or less) bank. Hard armoring should only be considered when necessary. **Bank**: may only need minor regrading to achieve desirable 2:1 or more gradual bank slope. Following regrading soil must be protected through erosion control fabric or vegetated mat. Native seeding and/or planting recommended. Riprap should not extend into this zone. **Upland**: overland erosion must be controlled and safely diverted to/through restored areas. Drain tile and/or berms can be used to collect and divert water and vegetation used to slow water velocity and increase deep infiltration. **In-channel**: structures likely not necessary but may be considered if along a cut bank.
Minor	Property has only one or two erosive features, likely caused by only one erosion source, often limited to undercutting, overhanging vegetation, exposed roots, and/or the very occasional fallen tree.	**Toe of Bank**: Bioengineering (e.g. biologs and live stakes) preferred, particularly when erosion focused on a shorter (i.e. 6 feet or less) bank. Hard armoring should only be considered when necessary. **Bank**: no regrading expected, vegetation should be re-established through seeding and/or planting **Upland**: overland erosion must be controlled and safely diverted to/through restored areas. Deep-rooted vegetation should be employed to promote infiltration away for the bank. A rain garden, rain barrel, or similar practice may suit this purpose. **In-channel**: no activities expected in this zone
None	No erosion features found on the property.	No strategies necessary.

* Strategies are based on bank location and will vary based on site specific considerations. For all erosion categories, a comprehensive survey and design for each site must be developed.

** Toe of Bank is between the low water and normal water levels. The Bank extends from the toe of the bank to bankfull elevation. For this area of the Mississippi River, bankfull elevation can be considered either the top of the bank or the 100-year floodplain elevation, whichever is lower. Upland is all areas above the top of the bank which may impact the top of the bank and is typically only on the landowner's property or adjacent properties. In-channel is any area below the low water level.

In some cases, such as along properties experiencing major erosion from many sources, some level of engineered work (e.g. regrading, hard armoring along the toe of the bank, and drain tile to manage groundwater seepages) will be necessary but should be minimized to the extent practicable.

The riverbank along the Mississippi River is an incredible habitat for several terrestrial, aquatic, and amphibious creatures. **Appendix B**, *Ecological Notes and Wildlife Implications for the Brooklyn Park Mississippi River Stabilization Project*, explores in detail the ecological factors designers should consider as they draft restoration designs. The document introduces design and vegetation management strategies that will sustain existing habitats while mitigating for erosional concerns. It also lists the known species that use the riverbank for their habitat or hunting grounds and must therefore be considered in the design plan to ensure their habitat viability is not hindered through restoration work. Incorporating these will be absolutely necessary to ensure permit approval.

Design and construction costs are a significant factor of any design for riverbank restoration. Its expected that costs for projects identified in the 'Major' erosion category will be even higher due to the very high banks and limitations with site access. A review of similar bank stabilization projects was completed, with a focus on projects recently implemented in the North Metro (**Appendix A**). A couple notable patterns were identified in this review:

A) Projects on banks of 10 feet or more tended to be significantly more expensive on a linear-foot basis, likely due to the added area to be stabilized and the increased complexity often associated with these sites.
B) Design and construction observations costs were generally higher than typical stormwater projects, likely due to increased complexity and factors that need to be considered. Permitting can also extend longer than other stormwater projects as approval from additional state and federal agencies is necessary for these projects.

For the sake of estimating a cost to stabilize each bank, a linear foot cost was established based on the cost bifurcation at around a 10-foot bank height (**Table 3**). Observed and recommended costs are shown for four implementation stages. The notes below the table detail what activities are expected to occur during each stage, as well as any assumptions made. The recommended cost does consider some economy-of-scale savings for bidding out both the design and installation as one large ($0.5-$1M in value) project. Maintenance costs are also provided as there should be some expectation amongst homeowners that over the project lifetime, some elements of the practice may need to be replaced or otherwise maintained. Much of this cost could be provided in-kind, such as time to weed the native vegetation or manually repair or replace some components of the practice. A 25-year practice lifetime was chosen as NRCS guidance recommends streambank and riverbank practice be designed for at least a 20-year lifespan and, as this project will utilizes CIP dollars from the city, BWSR recommends 25-year practice lifetimes in their 2020 Clean Water Fund policy guidance. An estimated cost, and cost-effectiveness to reduce sediment and total phosphorus (TP) loading to the Mississippi River, is shown for each property exhibiting erosion in **Table 6**.

If any particular property wasn't assessed but exhibits similar qualities to a neighboring property which was assessed in **Figure 8-10**, the reader may reasonably presume the same strategy could be recommended but should still seek the guidance of a professional engineer before construction.

Table 3: Observed range of costs, and recommended cost to be used for the MSRP project, based on implementation stage for completed projects reviewed for this report. Additional background and detail can be found in Appendix A.

Cost Category		Administration * ($/ linear-foot)	Design / Oversight ** ($/ linear-foot)	Construction ¥ ($/ linear-foot)	Maintenance £ ($/ linear-foot)
Bank Stabilization less than or equal to 10 feet in bank height	Recommend	$100.00	$125.00	$300.00	15% of Construction
	Observed Range	$1.81 - $125.79	$2.72 - $188.69	$145.58 - $639.81	N/A
Bank Stabilization more 10 feet in bank height	Recommend	$125.00	$210.00	$850.00	15% of Construction
	Observed Range	$17.73 - $174.17	$61.46 – $261.26	$272.83 - $997.99	N/A

* Administration includes the cost, typically for local government unit staff, to coordinate activities amongst landowners, contractors, partners, and funding entities. It may also include cost for outreach and prioritization if not already completed. Used ACD Stem Project with no assumed economy-of-scale savings.
** Typically completed by private engineering firm. Includes cost for comprehensive property survey, design, construction bidding coordination, and construction oversight. Recommended cost assumed some economy-of-scale savings to group restorations in one large project.
¥ Typically completed by private contractor specializing in riverbank restorations. Recommended cost assumed some economy-of-scale savings to group restorations in one large project.
£ Assumed to be 15% of construction costs and includes re-establishment of any non-engineered materials such as vegetated mats, plugs, seed, or erosion control fabric, during the 25-year lifetime of the practice.

Project Funding and Implementation

Considering the strong local support among landowners, county staff, and city staff and elected officials, timing is right to pursue a partnership. Due to the costly nature of these practices, a cost share among multiple entities likely assures the most success, as local partners (and potentially others) gain value in decreased sediment and nutrient loading to the river system and landowners may better protect their property and minimize additional losses.

To achieve cost savings, its recommended restoration projects be grouped based on property proximity. Cost line items like mobilization can be minimized if the contractor doesn't have to traverse long distances with materials and heavy equipment. Transitional work can be minimized if neighboring properties are both restored. This also better ensure longevity of the practices by minimizing breaks in restored shorelines where unrestored areas may be still be eroding and risk endangering stabilization efforts. Properties in **Tables 4-6** have been organized with this grouping in mind. Within each group, properties have been ordered by priority, with severely eroded banks as 'Priority 1' ,moderately eroded banks as 'Priority 2', and banks with only minor erosion as 'Priority 3'. Properties exhibiting no erosion features have no priority number assigned.

Groups A and B have the largest number of properties with severe erosion and are therefore viewed as the most urgent areas for restoration (**Figures 11-12**). Between these two, Group A is viewed as the bigger priority of the two due to the higher potential for sediment and total phosphorus (TP) reductions (**Table 5; Figure 11**) and the cheaper mean cost-effectiveness to keep each of the pollutants from entering the Mississippi River if the area were stabilized (**Table 6**).

Properties in the remaining groups (C, D, and F; **Tables 4-6**) should still be addressed but likely will not achieve much geographical economy-of-scale. Those exhibiting severe erosion should still be considered high priorities, and implementation on these properties should be pursued in the near-term as funding allows.

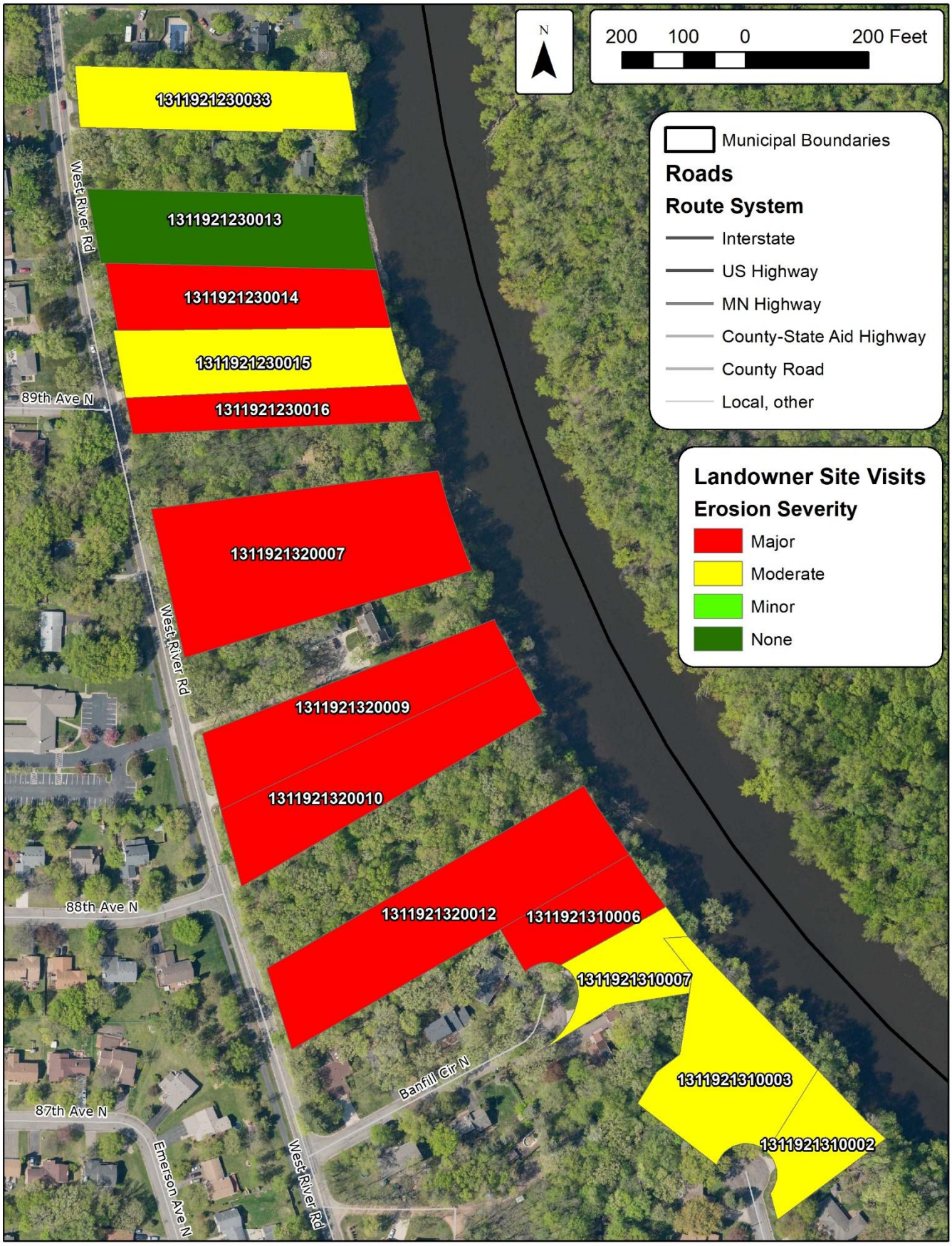


Figure 11: Properties in Group A.

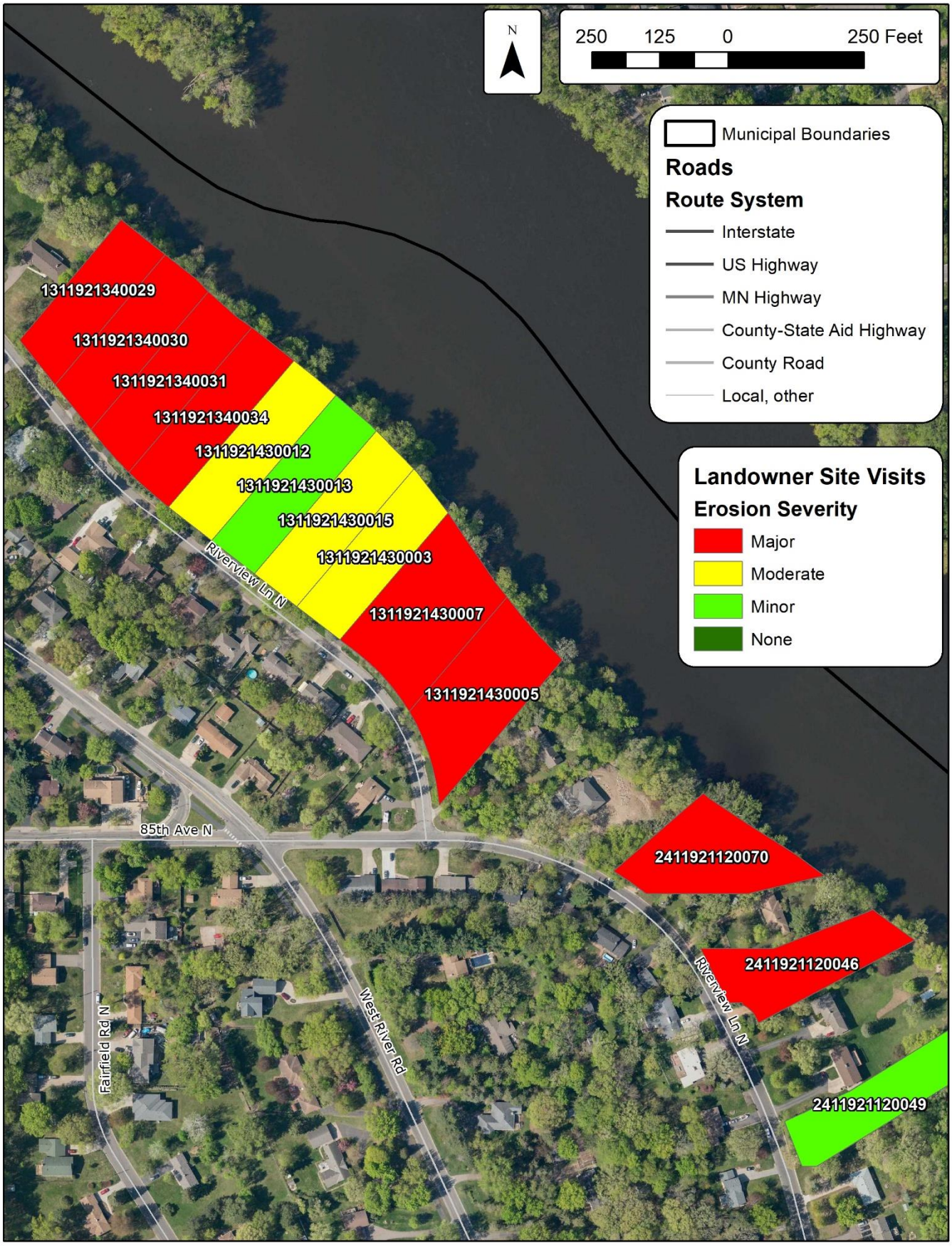


Figure 12: Properties in Group B

Table 4: Results of Landowner Site Visits. Properties sorted and highlighted by priority and group.

									Erosion on Bank Heights > 10ft			Erosion on Bank Heights <= 10 ft			Total
Property Grouping	**Street Address**	**Property Type**	**PID**	**Contract Name(s)**	**Evidence of Spring?**	**Impact of Spring**	**Significant Erosion Sources**	**Candidate for Restoration?**	**Bank Length (ft)**	**Bank Height (ft)**	**Eroding Area (sq-ft)**	**Bank Length (ft)**	**Bank Height (ft)**	**Eroding Area (sq-ft)**	**Eroding Area (sq-ft)**
Group A, Priority 1	8840 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1311921320007	Barbara Franklin	Yes	Major	bank seepage, flow induced erosion	Yes	168	30	5,040	0	0	0	5,040
Group A, Priority 1	8822 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1311921320010	Jim and Judith Arnold	Yes	Major	bank seepage, flow induced erosion	Yes	85	30	2,550	0	0	0	2,550
Group A, Priority 1	8904 WEST RIVER RD	SEASONAL-RESIDENTIAL REC	1311921230014	Linda Nathan (for owner Better Berg)	Yes	Major	bank seepage, flow induced erosion	Yes	93	30	2,790	0	0	0	2,790
Group A, Priority 1	1232 BANFILL CIR N	RESIDENTIAL LAKE SHORE	1311921310006	Marlys Carls-Steiskal & David Steiskal	Yes	Major	bank seepage, flow induced erosion	Yes	102	30	3,060	0	0	0	3,060
Group A, Priority 1	8848 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1311921230016	Samuel Goff	Unable to Access	N/A	bank seepage and overland runoff	Yes	62	30	1,860	0	0	0	1,860
Group A, Priority 1	8830 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1311921320009	Bradley & Kathy Larson	Yes	Moderate	Flow induced erosion, springs	Yes	85	30	2550	0	0	0	2,550
Group A, Priority 1	8816 WEST RIVER RD	COMMERCIAL-PREFERRED	1311921320012	Jim Arnold, Joe Klohs, & Steve Schaust	Yes	Moderate	Springs and flow induced erosion	Yes	135	30	4050	0	0	0	4,050
Group A, Priority 2	8900 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1311921230015	Joe and Judy Klohs	No	N/A	N/A	Yes	95	15	1,425	0	0	0	1,425
Group A, Priority 2	1224 BANFILL CIR N	RESIDENTIAL LAKE SHORE	1311921310007	David & Charlotte Jensen	No	N/A	flow induced erosion	Yes	60	30	1,800	0	0	0	1,800
Group A, Priority 2	8672 MATTSON BROOK LA N	RESIDENTIAL LAKE SHORE	1311921310002	Chlo Walensky	No	N/A	flow induced erosion, overland runoff	Yes	150	10	1,500	0	0	0	1,500
Group A, Priority 2	9000 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1311921230033	Laura-Lee and Dan Brown	Yes	Moderate	bank seepage, flow induced erosion, runoff	Yes	95	30	2,850	0	0	0	2,850
Group A, Priority 2	8657 MATTSON BROOK LA N	RESIDENTIAL LAKE SHORE	1311921310003	Mark Clements & Daphne Koop	No	N/A	flow induced erosion, overland runoff	Yes	0	0	0	300	10	3,000	3,000
Group B, Priority 1	8616 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	1311921340030	Brett & Zoe Hildreth	Yes	Major	bank seepage, flow induced erosion, wave action	Yes	105	25	2,625	0	0	0	2,625
Group B, Priority 1	8624 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	1311921340029	Brian & Esther Hammer	Yes	Moderate	bank seepage, flow induced erosion, runoff	Yes	100	20	2,000	0	0	0	2,000
Group B, Priority 1	8600 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	1311921340034	Darnel & Theresa Mitchell	No	N/A	Flow induced erosion	Yes	95	25	2375	0	0	0	2,375
Group B, Priority 1	8450 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	2411921120070	Peter Lacey	Yes	Minor	Flow induced erosion, wave action, drain tile	Yes	266	20	5320	0	0	0	5,320
Group B, Priority 1	8608 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	1311921340031	Rex & Jaci Hale	Yes	Major	bank seepage, flow induced erosion, runoff	Yes	104	20	2,080	0	0	0	2,080
Group B, Priority 1	8508 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	1311921430005	Brian Gross	Yes	Major	bank seepage, flow induced erosion, runoff	Yes	158	30	4,740	0	0	0	4,740
Group B, Priority 1	8518 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	1311921430007	Bruce & Sally Wojahn	Yes	Minor	Flow induced erosion	Yes	80	30	2400	0	0	0	2,400
Group B, Priority 1	8436 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	2411921120046	Daniel Malecha & Darcy Futrell	No	N/A	Flow induced erosion, eddy action	Yes	95	25	2375	0	0	0	2,375
Group B, Priority 2	8534 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	1311921430012	Jon & Rachel Hagel	Yes	Moderate	small scarp, exposed roots, overhanging vegetation	Yes	99	25	2,475	0	0	0	2,475
Group B, Priority 2	8522 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	1311921430003	Robert & Cynthia Taft	Yes	Minor	flow induced erosion, wave action	Yes	0	0	0	100	8	800	800
Group B, Priority 2	8524 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	1311921430015	Sasha Demarre and Michael Howard	Yes	Minor	Flow induced erosion	Yes	0	0	0	96	8	768	768
Group B, Priority 3	8530 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	1311921430013	Mike & Susan Schmitz	No	N/A	N/A	No	0	0	0	99	8	792	792
Group B, Priority 3	8408 RIVERVIEW LA N	RESIDENTIAL LAKE SHORE	2411921120049	Nick Kerstegen	No	N/A	N/A	No	0	0	0	105	4	420	420
Group C, Priority 3	8000 MISSISSIPPI LA N	RESIDENTIAL LAKE SHORE	2411921410048	Chris & Tiffany Nguyen	No	N/A	Flow induced erosion	No	0	0	0	102	4	408	408
Group C, Priority 3	8040 MISSISSIPPI LA N	RESIDENTIAL LAKE SHORE	2411921410059	John & Marlene Wexler	No	N/A	N/A	No	0	0	0	105	4	420	420
Group C, Priority 3	1 76TH AVE N	RESIDENTIAL LAKE SHORE	2511921110059	Maureen Steinwall & Mike Lavelle	No	N/A	N/A	No	0	0	0	318	4	1,272	1,272
Group C, Priority 3	7924 MISSISSIPPI LA N	RESIDENTIAL LAKE SHORE	2411921410012	Rebecca Risler	No	N/A	N/A	No	0	0	0	102	4	408	408
Group C, Priority 3	7624 MISSISSIPPI LA N	RESIDENTIAL LAKE SHORE	2511921110043	Michael Hanson	No	N/A	Flow induced erosion	Yes	0	0	0	205	4	820	820

Property Grouping	Street Address	Property Type	PID	Contract Name(s)	Evidence of Spring?	Impact of Spring	Significant Erosion Sources	Candidate for Restoration?	Erosion on Bank Heights > 10ft			Erosion on Bank Heights <= 10 ft			Total Eroding Area (sq-ft)
									Bank Length (ft)	Bank Height (ft)	Eroding Area (sq-ft)	Bank Length (ft)	Bank Height (ft)	Eroding Area (sq-ft)	
Group C, Priority 3	7326 WILLOW LA N	RESIDENTIAL LAKE SHORE	2511921140054	Christy and Steve Sandberg	No	N/A	Flow induced erosion	Yes	80	20	1600	0	0	0	1,600
Group D, Priority 1	9500 WEST RIVER RD	COMMERCIAL-PREFERRED	1211921320015	Jordan and Jamie Leopold	Yes	Minor	Flow induced erosion, wave action, bank seepage	Yes	80	20	1,600	435	6	2,610	4,210
Group D, Priority 2	9110 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1311921230006	Mark Laberda	Yes	Moderate	bank seepage and flow induced erosion	Yes	74	15	1,110	0	0	0	1,110
Group D, Priority 2	48 ADDRESS UNASSIGNED	VACANT LAND-LAKESHORE	311921140011	Rob Freeman	No	N/A	wave action	Yes	0	0	0	112	6	672	672
Group D, Priority 2	9308 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1211921330021	Terry Williams	No	N/A	Flow induced erosion, wave action	Yes	0	0	0	105	6	630	630
Group D, Priority 3	9140 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1311921220050	Andrew & Kathryn Shell	Yes	Minor	flow induced erosion	No	0	0	0	168	3	504	504
Group D, Priority 3	48 ADDRESS UNASSIGNED	VACANT LAND-LAKESHORE	1311921220001	Deb & Dave Novak	No	N/A	flow induced erosion	No	0	0	0	177	4	708	708
Group D, Priority 3	9216 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1311921220012	Deb & Dave Novak	No	N/A	flow induced erosion	No	0	0	0	309	3	927	927
Group D, Priority 3	9324 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1211921330017	Kathleen Hyatt	No	N/A	Flow induced erosion	No	0	0	0	102	6	612	612
Group D, Priority 3	48 ADDRESS UNASSIGNED	VACANT LAND-LAKESHORE	1211921330009	Mona Geeting	None	N/A	Flow induced erosion		0	0	0	100	5	500	500
Group E, Priority 3	10748 ZIEGLER DR N	RESIDENTIAL LAKE SHORE	311921120008	Susan and Michael Shasky	No	N/A	wave action		0	0	0	35	6	210	210
No Project Necessary	8908 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1311921230013	Eric & Mary Jo Duncan	Yes	Major	bank seepage and flow induced erosion	No	0	0	0	0	0	0	0
No Project Necessary	9300 WEST RIVER RD	RESIDENTIAL LAKE SHORE	1211921330008	Mona Geeting	None	N/A	N/A		0	0	0	0	0	0	0
No Project Necessary	10620 WEST RIVER RD	RESIDENTIAL LAKE SHORE	311921130002	Seth Bork	None	N/A	Wave action	No	0	0	0	0	0	0	0
No Project Necessary	10816 ZIEGLER DR N	RESIDENTIAL LAKE SHORE	311921120003	Steve Beyer	None	N/A	Wave action	No	0	0	0	0	0	0	0
No Project Necessary	10740 ZIEGLER DR N	RESIDENTIAL LAKE SHORE	311921120009	Susan & Patrick Ledray	None	N/A	Wave action	No	0	0	0	0	0	0	0
No Project Necessary	10616 WEST RIVER RD	RESIDENTIAL LAKE SHORE	311921130004	Thomas McShane	No	N/A	N/A	No	0	0	0	0	0	0	0
No Project Necessary	7878 MISSISSIPPI LA N	RESIDENTIAL LAKE SHORE	2411921440001	Tim Snell	No	N/A	N/A	No	0	0	0	0	0	0	0

Table 5: Estimated sediment and total phosphorus (TP) erosion occurring annually on assessed properties. Properties sorted and highlighted by priority and group. A sum of relevant columns is shown for each group at the bottom of the table.

Property Grouping	Street Address	PID	Contract Name(s)	Total Eroding Area (sq-ft)	Erosion Category	Estimated Lateral Recession Rate (ft/yr)	Predominant Soil Texture	Volume-Weight Ratio (lbs/cu-ft)	Sediment Erosion (lbs/yr)	Sediment Erosion (tons/yr)	TP Erosion (lbs/yr)
Group A, Priority 1	8840 WEST RIVER RD	1311921320007	Barbara Franklin	5040	Severe	0.5	Sandy Loam	100	252,000	126.0	116.6
Group A, Priority 1	8822 WEST RIVER RD	1311921320010	Jim and Judith Arnold	2550	Severe	0.5	Sandy Loam	100	127,500	63.8	59.0
Group A, Priority 1	8904 WEST RIVER RD	1311921230014	Linda Nathan (for owner Better Berg)	2790	Severe	0.5	Sandy Loam	100	139,500	69.8	64.5
Group A, Priority 1	1232 BANFILL CIR N	1311921310006	Marlys Carls-Steiskal & David Steiskal	3060	Severe	0.5	Sandy Loam	100	153,000	76.5	70.8
Group A, Priority 1	8848 WEST RIVER RD	1311921230016	Samuel Goff	1860	Severe	0.5	Sandy Loam	100	93,000	46.5	43.0
Group A, Priority 1	8830 WEST RIVER RD	1311921320009	Bradley & Kathy Larson	2550	Severe	0.5	Sandy Loam	100	127,500	63.8	59.0
Group A, Priority 1	8816 WEST RIVER RD	1311921320012	Jim Arnold, Joe Klohs, & Steve Schaust	4050	Severe	0.5	Sandy Loam	100	202,500	101.3	93.7
Group A, Priority 2	8900 WEST RIVER RD	1311921230015	Joe and Judy Klohs	1425	Moderate	0.3	Sandy Loam	100	42,750	21.4	19.8
Group A, Priority 2	1224 BANFILL CIR N	1311921310007	David & Charlotte Jensen	1800	Moderate	0.3	Sandy Loam	100	54,000	27.0	25.0
Group A, Priority 2	8672 MATTSON BROOK LA N	1311921310002	Chlo Walensky	1500	Moderate	0.3	Sandy Loam	100	45,000	22.5	20.8
Group A, Priority 2	9000 WEST RIVER RD	1311921230033	Laura-Lee and Dan Brown	2,850	Moderate	0.3	Sandy Loam	100	85,500	42.8	39.5
Group A, Priority 2	8657 MATTSON BROOK LA N	1311921310003	Mark Clements & Daphne Koop	3,000	Moderate	0.3	Sandy Loam	100	90,000	45.0	41.6
Group B, Priority 1	8616 RIVERVIEW LA N	1311921340030	Brett & Zoe Hildreth	2,625	Severe	0.5	Sandy Loam	100	131,250	65.6	60.7
Group B, Priority 1	8624 RIVERVIEW LA N	1311921340029	Brian & Esther Hammer	2,000	Severe	0.5	Sandy Loam	100	100,000	50.0	46.3
Group B, Priority 1	8600 RIVERVIEW LA N	1311921340034	Darnel & Theresa Mitchell	2,375	Severe	0.5	Sandy Loam	100	118,750	59.4	54.9
Group B, Priority 1	8450 RIVERVIEW LA N	2411921120070	Peter Lacey	5,320	Severe	0.5	Sandy Loam	100	266,000	133.0	123.0
Group B, Priority 1	8608 RIVERVIEW LA N	1311921340031	Rex & Jaci Hale	2,080	Severe	0.5	Sandy Loam	100	104,000	52.0	48.1
Group B, Priority 1	8508 RIVERVIEW LA N	1311921430005	Brian Gross	4,740	Severe	0.5	Sandy Loam	100	237,000	118.5	109.6
Group B, Priority 1	8518 RIVERVIEW LA N	1311921430007	Bruce & Sally Wojahn	2,400	Severe	0.5	Sandy Loam	100	120,000	60.0	55.5
Group B, Priority 1	8436 RIVERVIEW LA N	2411921120046	Daniel Malecha & Darcy Futrell	2,375	Severe	0.5	Sandy Loam	100	118,750	59.4	54.9
Group B, Priority 2	8534 RIVERVIEW LA N	1311921430012	Jon & Rachel Hagel	2,475	Moderate	0.3	Sandy Loam	100	74,250	37.1	34.3
Group B, Priority 2	8522 RIVERVIEW LA N	1311921430003	Robert & Cynthia Taft	800	Moderate	0.3	Sandy Loam	100	24,000	12.0	11.1
Group B, Priority 2	8524 RIVERVIEW LA N	1311921430015	Sasha Demarre and Michael Howard	768	Moderate	0.3	Sandy Loam	100	23,040	11.5	10.7
Group B, Priority 3	8530 RIVERVIEW LA N	1311921430013	Mike & Susan Schmitz	792	Minor	0.05	Sandy Loam	100	3,960	2.0	1.8
Group B, Priority 3	8408 RIVERVIEW LA N	2411921120049	Nick Kerstegen	420	Minor	0.05	Sandy Loam	100	2,100	1.1	1.0
Group C, Priority 3	8000 MISSISSIPPI LA N	2411921410048	Chris & Tiffany Nguyen	408	Minor	0.05	Sandy Loam	100	2,040	1.0	0.9
Group C, Priority 3	8040 MISSISSIPPI LA N	2411921410059	John & Marlene Wexler	420	Minor	0.05	Sandy Loam	100	2,100	1.1	1.0
Group C, Priority 3	1 76TH AVE N	2511921110059	Maureen Steinwall & Mike Lavelle	1,272	Minor	0.05	Sandy Loam	100	6,360	3.2	2.9
Group C, Priority 3	7924 MISSISSIPPI LA N	2411921410012	Rebecca Risler	408	Minor	0.05	Sandy Loam	100	2,040	1.0	0.9
Group C, Priority 3	7624 MISSISSIPPI LA N	2511921110043	Michael Hanson	820	Minor	0.05	Sandy Loam	100	4,100	2.1	1.9
Group C, Priority 3	7326 WILLOW LA N	2511921140054	Christy and Steve Sandberg	1,600	Moderate	0.3	Sandy Loam	100	48,000	24.0	22.2
Group D, Priority 1	9500 WEST RIVER RD	1211921320015	Jordan and Jamie Leopold	4,210	Severe	0.5	Sandy Loam	100	210,500	105.3	97.4
Group D, Priority 2	9110 WEST RIVER RD	1311921230006	Mark Laberda	1,110	Moderate	0.3	Sandy Loam	100	33,300	16.7	15.4
Group D, Priority 2	48 ADDRESS UNASSIGNED	311921140011	Rob Freeman	672	Moderate	0.3	Sandy Loam	100	20,160	10.1	9.3
Group D, Priority 2	9308 WEST RIVER RD	1211921330021	Terry Williams	630	Moderate	0.3	Sandy Loam	100	18,900	9.5	8.7
Group D, Priority 3	9140 WEST RIVER RD	1311921220050	Andrew & Kathryn Shell	504	Minor	0.05	Sandy Loam	100	2,520	1.3	1.2
Group D, Priority 3	48 ADDRESS UNASSIGNED	1311921220001	Deb & Dave Novak	708	Minor	0.05	Sandy Loam	100	3,540	1.8	1.6
Group D, Priority 3	9216 WEST RIVER RD	1311921220012	Deb & Dave Novak	927	Minor	0.05	Sandy Loam	100	4,635	2.3	2.1
Group D, Priority 3	9324 WEST RIVER RD	1211921330017	Kathleen Hyatt	612	Minor	0.05	Sandy Loam	100	3,060	1.5	1.4
Group D, Priority 3	48 ADDRESS UNASSIGNED	1211921330009	Mona Geeting	500	Minor	0.05	Sandy Loam	100	2,500	1.3	1.2
Group E, Priority 3	10748 ZIEGLER DR N	311921120008	Susan and Michael Shasky	210	Minor	0.05	Sandy Loam	100	1,050	0.5	0.5
No Project Necessary	8908 WEST RIVER RD	1311921230013	Eric & Mary Jo Duncan	0	None	0	Sandy Loam	100	0	0.0	0.0

Property Grouping	Street Address	PID	Contract Name(s)	Total Eroding Area (sq-ft)	Erosion Category	Estimated Lateral Recession Rate (ft/yr)	Predominant Soil Texture	Volume-Weight Ratio (lbs/cu-ft)	Sediment Erosion (lbs/yr)	Sediment Erosion (tons/yr)	TP Erosion (lbs/yr)
No Project Necessary	9300 WEST RIVER RD	1211921330008	Mona Geeting	0	None	0	Sandy Loam	100	0	0.0	0.0
No Project Necessary	10620 WEST RIVER RD	311921130002	Seth Bork	0	None	0	Sandy Loam	100	0	0.0	0.0
No Project Necessary	10816 ZIEGLER DR N	311921120003	Steve Beyer	0	None	0	Sandy Loam	100	0	0.0	0.0
No Project Necessary	10740 ZIEGLER DR N	311921120009	Susan & Patrick Ledray	0	None	0	Sandy Loam	100	0	0.0	0.0
No Project Necessary	10616 WEST RIVER RD	311921130004	Thomas McShane	0	None	0	Sandy Loam	100	0	0.0	0.0
No Project Necessary	7878 MISSISSIPPI LA N	2411921440001	Tim Snell	0	None	0	Sandy Loam	100	0	0.0	0.0
Group A (SUM)				32,475					1,412,250	706.1	653.2
Group B (SUM)				29,170					1,323,100	661.6	611.9
Group C (SUM)				4,928					64,640	32.3	29.9
Group D (SUM)				9,873					299,115	149.6	138.3
Group E (SUM)				210					1,050	0.5	0.5

Table 6: Cost benefit for riverbank restoration practices. Properties not requiring restoration practices are not shown. Properties sorted and highlighted by priority and group. A sum of relevant columns is shown for each group at the bottom of the table.

Property Grouping	Street Address	PID	Contract Name(s)	Construction Cost ($)	Design + Construction ($)	Practice Lifetime	Maintenance Cost over Lifetime ($)	Total Cost Over Lifetime ($)	Sediment Reduction Over Lifetime (tons)	TP Reduction Over Lifetime (lbs)	Lifetime Cost-Effectiveness for Sediment ($/ton)	Lifetime Cost-Effectiveness for TP ($/lb)
Group A, Priority 1	8840 WEST RIVER RD	1311921320007	Barbara Franklin	$ 142,800	$ 178,080	25	$ 26,712	$ 204,792	3,150.0	2,913.8	$ 65.01	$ 70.28
Group A, Priority 1	8822 WEST RIVER RD	1311921320010	Jim and Judith Arnold	$ 72,250	$ 90,100	25	$ 13,515	$ 103,615	1,593.8	1,474.2	$ 65.01	$ 70.28
Group A, Priority 1	8904 WEST RIVER RD	1311921230014	Linda Nathan (for owner Better Berg)	$ 79,050	$ 98,580	25	$ 14,787	$ 113,367	1,743.8	1,613.0	$ 65.01	$ 70.28
Group A, Priority 1	1232 BANFILL CIR N	1311921310006	Marlys Carls-Steiskal & David Steiskal	$ 86,700	$ 108,120	25	$ 16,218	$ 124,338	1,912.5	1,769.1	$ 65.01	$ 70.28
Group A, Priority 1	8848 WEST RIVER RD	1311921230016	Samuel Goff	$ 52,700	$ 65,720	25	$ 9,858	$ 75,578	1,162.5	1,075.3	$ 65.01	$ 70.28
Group A, Priority 1	8830 WEST RIVER RD	1311921320009	Bradley & Kathy Larson	$ 72,250	$ 90,100	25	$ 13,515	$ 103,615	1,593.8	1,474.2	$ 65.01	$ 70.28
Group A, Priority 1	8816 WEST RIVER RD	1311921320012	Jim Arnold, Joe Klohs, & Steve Schaust	$ 114,750	$ 143,100	25	$ 21,465	$ 164,565	2,531.3	2,341.4	$ 65.01	$ 70.28
Group A, Priority 2	8900 WEST RIVER RD	1311921230015	Joe and Judy Klohs	$ 80,750	$ 100,700	25	$ 15,105	$ 115,805	534.4	494.3	$ 216.71	$ 234.28
Group A, Priority 2	1224 BANFILL CIR N	1311921310007	David & Charlotte Jensen	$ 51,000	$ 63,600	25	$ 9,540	$ 73,140	675.0	624.4	$ 108.36	$ 117.14
Group A, Priority 2	8672 MATTSON BROOK LA N	1311921310002	Chlo Walensky	$ 127,500	$ 159,000	25	$ 23,850	$ 182,850	562.5	520.3	$ 325.07	$ 351.42
Group A, Priority 2	9000 WEST RIVER RD	1311921230033	Laura-Lee and Dan Brown	$ 80,750	$ 100,700	25	$ 15,105	$ 115,805	1,068.8	988.6	$ 108.36	$ 117.14
Group A, Priority 2	8657 MATTSON BROOK LA N	1311921310003	Mark Clements & Daphne Koop	$ 90,000	$ 127,500	25	$ 19,125	$ 146,625	1,125.0	1,040.6	$ 130.33	$ 140.90
Group B, Priority 1	8616 RIVERVIEW LA N	1311921340030	Brett & Zoe Hildreth	$ 89,250	$ 111,300	25	$ 16,695	$ 127,995	1,640.6	1,517.6	$ 78.02	$ 84.34
Group B, Priority 1	8624 RIVERVIEW LA N	1311921340029	Brian & Esther Hammer	$ 85,000	$ 106,000	25	$ 15,900	$ 121,900	1,250.0	1,156.3	$ 97.52	$ 105.43
Group B, Priority 1	8600 RIVERVIEW LA N	1311921340034	Darnel & Theresa Mitchell	$ 80,750	$ 100,700	25	$ 15,105	$ 115,805	1,484.4	1,373.0	$ 78.02	$ 84.34
Group B, Priority 1	8450 RIVERVIEW LA N	2411921120070	Peter Lacey	$ 226,100	$ 281,960	25	$ 42,294	$ 324,254	3,325.0	3,075.6	$ 97.52	$ 105.43
Group B, Priority 1	8608 RIVERVIEW LA N	1311921340031	Rex & Jaci Hale	$ 88,400	$ 110,240	25	$ 16,536	$ 126,776	1,300.0	1,202.5	$ 97.52	$ 105.43
Group B, Priority 1	8508 RIVERVIEW LA N	1311921430005	Brian Gross	$ 134,300	$ 167,480	25	$ 25,122	$ 192,602	2,962.5	2,740.3	$ 65.01	$ 70.28
Group B, Priority 1	8518 RIVERVIEW LA N	1311921430007	Bruce & Sally Wojahn	$ 68,000	$ 84,800	25	$ 12,720	$ 97,520	1,500.0	1,387.5	$ 65.01	$ 70.28
Group B, Priority 1	8436 RIVERVIEW LA N	2411921120046	Daniel Malecha & Darcy Futrell	$ 80,750	$ 100,700	25	$ 15,105	$ 115,805	1,484.4	1,373.0	$ 78.02	$ 84.34
Group B, Priority 2	8534 RIVERVIEW LA N	1311921430012	Jon & Rachel Hagel	$ 84,150	$ 104,940	25	$ 15,741	$ 120,681	928.1	858.5	$ 130.03	$ 140.57
Group B, Priority 2	8522 RIVERVIEW LA N	1311921430003	Robert & Cynthia Taft	$ 30,000	$ 42,500	25	$ 6,375	$ 48,875	300.0	277.5	$ 162.92	$ 176.13
Group B, Priority 2	8524 RIVERVIEW LA N	1311921430015	Sasha Demarre and Michael Howard	$ 28,800	$ 40,800	25	$ 6,120	$ 46,920	288.0	266.4	$ 162.92	$ 176.13
Group B, Priority 3	8530 RIVERVIEW LA N	1311921430013	Mike & Susan Schmitz	$ 29,700	$ 42,075	25	$ 6,311	$ 48,386	49.5	45.8	$ 977.50	$ 1,056.76
Group B, Priority 3	8408 RIVERVIEW LA N	2411921120049	Nick Kerstegen	$ 31,500	$ 44,625	25	$ 6,694	$ 51,319	26.3	24.3	$ 1,955.00	$ 2,113.51
Group C, Priority 3	8000 MISSISSIPPI LA N	2411921410048	Chris & Tiffany Nguyen	$ 30,600	$ 43,350	25	$ 6,503	$ 49,853	25.5	23.6	$ 1,955.00	$ 2,113.51
Group C, Priority 3	8040 MISSISSIPPI LA N	2411921410059	John & Marlene Wexler	$ 31,500	$ 44,625	25	$ 6,694	$ 51,319	26.3	24.3	$ 1,955.00	$ 2,113.51
Group C, Priority 3	1 76TH AVE N	2511921110059	Maureen Steinwall & Mike Lavelle	$ 95,400	$ 135,150	25	$ 20,273	$ 155,423	79.5	73.5	$ 1,955.00	$ 2,113.51
Group C, Priority 3	7924 MISSISSIPPI LA N	2411921410012	Rebecca Risler	$ 30,600	$ 43,350	25	$ 6,503	$ 49,853	25.5	23.6	$ 1,955.00	$ 2,113.51
Group C, Priority 3	7624 MISSISSIPPI LA N	2511921110043	Michael Hanson	$ 61,500	$ 87,125	25	$ 13,069	$ 100,194	51.3	47.4	$ 1,955.00	$ 2,113.51
Group C, Priority 3	7326 WILLOW LA N	2511921140054	Christy and Steve Sandberg	$ 68,000	$ 84,800	25	$ 12,720	$ 97,520	600.0	555.0	$ 162.53	$ 175.71
Group D, Priority 1	9500 WEST RIVER RD	1211921320015	Jordan and Jamie Leopold	$ 198,500	$ 269,675	25	$ 40,451	$ 310,126	2,631.3	2,433.9	$ 117.86	$ 127.42
Group D, Priority 2	9110 WEST RIVER RD	1311921230006	Mark Laberda	$ 62,900	$ 78,440	25	$ 11,766	$ 90,206	416.3	385.0	$ 216.71	$ 234.28
Group D, Priority 2	48 ADDRESS UNASSIGNED	311921140011	Rob Freeman	$ 33,600	$ 47,600	25	$ 7,140	$ 54,740	252.0	233.1	$ 217.22	$ 234.83
Group D, Priority 2	9308 WEST RIVER RD	1211921330021	Terry Williams	$ 31,500	$ 44,625	25	$ 6,694	$ 51,319	236.3	218.5	$ 217.22	$ 234.83
Group D, Priority 3	9140 WEST RIVER RD	1311921220050	Andrew & Kathryn Shell	$ 50,400	$ 71,400	25	$ 10,710	$ 82,110	31.5	29.1	$ 2,606.67	$ 2,818.02
Group D, Priority 3	48 ADDRESS UNASSIGNED	1311921220001	Deb & Dave Novak	$ 53,100	$ 75,225	25	$ 11,284	$ 86,509	44.3	40.9	$ 1,955.00	$ 2,113.51
Group D, Priority 3	9216 WEST RIVER RD	1311921220012	Deb & Dave Novak	$ 92,700	$ 131,325	25	$ 19,699	$ 151,024	57.9	53.6	$ 2,606.67	$ 2,818.02
Group D, Priority 3	9324 WEST RIVER RD	1211921330017	Kathleen Hyatt	$ 30,600	$ 43,350	25	$ 6,503	$ 49,853	38.3	35.4	$ 1,303.33	$ 1,409.01
Group D, Priority 3	48 ADDRESS UNASSIGNED	1211921330009	Mona Geeting	$ 30,000	$ 42,500	25	$ 6,375	$ 48,875	31.3	28.9	$ 1,564.00	$ 1,690.81
Group E, Priority 3	10748 ZIEGLER DR N	311921120008	Susan and Michael Shasky	$ 10,500	$ 14,875	25	$ 2,231	$ 17,106	13.1	12.1	$ 1,303.33	$ 1,409.01
Group A (SUM)				$ 1,050,500	$ 1,325,300		$ $198,795	$ 1,524,095	17,653.1	16,329.1		

Property Grouping	Street Address	PID	Contract Name(s)	Construction Cost ($)	Design + Construction ($)	Practice Lifetime	Maintenance Cost over Lifetime ($)	Total Cost Over Lifetime ($)	Sediment Reduction Over Lifetime (tons)	TP Reduction Over Lifetime (lbs)	Lifetime Cost-Effectiveness for Sediment ($/ton)	Lifetime Cost-Effectiveness for TP ($/lb)
Group B (SUM)				$ 1,056,700	$ 1,338,120		$ 200,718	$ 1,538,838	16,635.8	15,298.3		
Group C (SUM)				$ 317,600	$ 438,400		$ 65,760	$ 504,160	808.0	747.4		
Group D (SUM)				$ 583,300	$ 804,140		$ 120,621	$ 924,761	3,738.9	3,458.5		
Group E (SUM)				$ 10,500	$ 14,875		$ 2,231	$ 17,106	13.1	12.1		

Appendix A

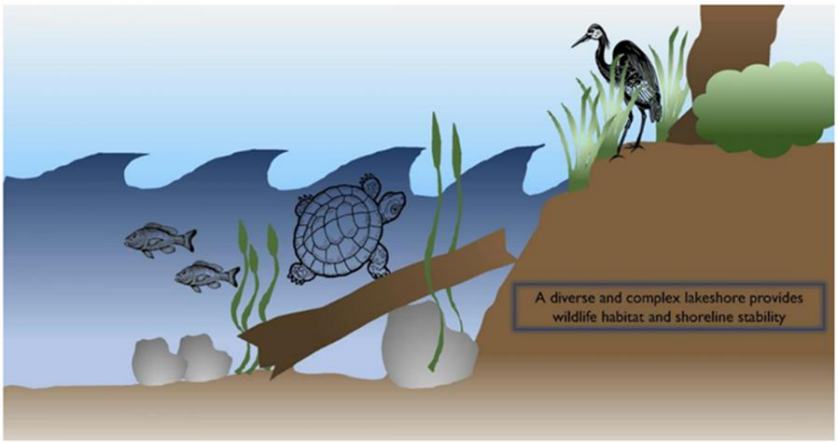
Table A1: Recently completed projects used to estimate unit cost for administration, design, and construction.

		Restoration Dimensions and Characteristics							Pollutant Retention		Cost Factors										Cost-Benefit	
Organization	**Project Name**	**Height (ft)**	**Length (ft)**	**Surface Area (sq-ft)**	**Estimated Lateral Erosion (ft/yr)**	**Erosion Volume (cu-ft/yr)**	**Date Installed**	**Restoration Characteristics**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**Admin. ***	**Admin / Outreach**	**Design / Oversight**	**Construction**	**Total**	**Total Linear Cost ($/ft)**	**Linear Cost for Construction ($/ft)**	**Linear Cost for Admin / Outreach ($/ft)**	**Linear Cost for Design /Oversight ($/ft)**	**Total Areal Cost (sq-ft)**	**TSS ($/lb)**	**TP ($/lb)**
Anoka Conser-vation District (ACD)	Rainbow	9	180	1,620	0.5	810	2019	Riprap for toe, VRSS and natives above	117,719	58.9	$56,606.09	$ 22,642.44	$33,963.65	$115,165.00	$171,771.09	$ 954.28	$ 639.81	$ 125.79	$ 188.69	0.59	$ 1.46	$ 2,916.32
	Stem	25	130	3,250	0.7	2275	2019	Regrading, riprap for toe, RSS using geogrid, natives seeded throughout	268,874	134.4	$56,606.09	$ 22,642.44	$33,963.65	$129,738.75	$186,344.84	$ 1,433.42	$ 997.99	$ 174.17	$ 261.26	0.44	$ 0.69	$ 1,386.49
	Rum River Central Site 4	7	310	2,170	0.5	1085	2019	Minor regrading, riprap for toe, erosion control blanket, natives seeding	220,870	93.9	$30,837.72	$ 12,335.09	$18,502.63	$61,359.00	$92,196.72	$ 297.41	$ 197.93	$ 39.79	$ 59.69	0.14	$ 0.42	$ 981.86
	Rum River Central Regional Park	8.25	324	2,676	0.5	1206	2015	Minor regrading, erosion mats along toe, erosion control fabric, cedar tree revetments, natives seeding	124,200	83.8	$ 1,470.00	$ 588.00	$ 882.00	$47,169.31	$48,639.31	$ 150.12	$ 145.58	$ 1.81	$ 2.72	0.06	$ 0.39	$ 580.42
	Cedar Creek Conservation Area	10	490	4,900	0.5	2450	2015	Regrading, riprap interplanted with willow stakes for toe, natives seeding, bendway weirs	245,000	165.4	$14,246.31	$ 6,958.90	$ 7,287.41	$122,023.00	$136,269.31	$ 278.10	$ 249.03	$ 14.20	$ 14.87	0.06	$ 0.56	$ 823.88
	Oak Glen Creek Corridor	25	1,400	35,000			2013-2014	in-channel: rock vanes on-bank: riprap, brush bundles, revetments, live stakes, seeding	633,600	507.0	$139,738			$381,963.00	$521,701.00	$ 372.64	$ 272.83	$ -	$ -	0.01	$ 0.82	$ 1,029.00
	Geldaker	15	100	1,500			2014	Riprap, erosion control blankets, percussion anchors, native seeding	120,000		$3,807.01	$ 4,085.50	$ 9,721.50	$30,278.49	$44,085.50	$ 440.86	$ 302.78	$ 40.86	$ 97.22	0.29	$ 0.37	#DIV/0!
	Swenson	20	160	3,200			2014	Riprap, erosion control blankets, stabilization mats, native seeding	57,600		$12,612.44	$ 2,779.50	$ 9,832.94	$64,072.00	$76,684.44	$ 479.28	$ 400.45	$ 17.37	$ 61.46	0.15	$ 1.33	#DIV/0!
Hennepin County	Eric Duncan	21	120	2,520			2013	Regrading, terracing, drain tile, riprap along toe of slope, erosion control blanket, native seeding						$110,340.00	$110,340.00	$ 919.50	$ 919.50	$ -	$ -	0.36	#DIV/0!	#DIV/0!
	Eric Duncan (w/ 10% inflation)	21	120	2,520			2020 (proposed)	Regrading, terracing, drain tile, riprap along toe of slope, erosion control blanket, native seeding						$121,374.00	$121,374.00	$ 1,011.45	$ 1,011.45	$ -	$ -	0.40	#DIV/0!	#DIV/0!

Appendix B

Ecological Notes and Wildlife Implications For the Brooklyn Park Mississippi River Stabilization Project

Mitigation Considerations



As identified in a following section, many species rely on the banks, slopes, shoreline, and open water areas of the Mississippi for nesting, foraging, cover, and hibernation. Techniques to stabilize banks along the river corridor should consider the various habitat needs of existing wildlife. Timing of restoration and stabilization work should also mitigate potential impacts to wildlife. The following section discusses general considerations for stabilization efforts that may mitigate negative impacts and support positive habitat and wildlife outcomes.

For instance, turtle species likely to occupy the project extent predominately rely on soft sediment bottoms, sandy and vegetated shorelines, and woody debris under and on top of the water. Considering stabilization techniques that will maximize opportunity for maintaining and restoring native substrate and vegetative conditions will improve nesting and terrestrial foraging habitat. In addition, use of woody debris and logs for stabilization and habitat structure will provide important hibernation and basking locations. Like turtles, frogs and snakes would also benefit from vegetative cover on the banks as well as soft substrates along shore and in the water. Furthermore, use of exclusively hard armoring and riprap is likely to pose movement challenges for these groups. Timing of stabilization work should also attempt avoidance of spring mating, summer nesting, and fall young emergence for most of the amphibians and reptiles like to occupy the project area; especially if nest sites are suspected.

In addition, many of the bird groups which inhabit the project area rely on woody overhangs for perching and hunting, soft-bottoms and gentle slopes, and vegetated shorelines for wadding and hunting. Trees and taller shrubs further up slope are also important nesting, perching, and overwintering habitat for many raptors. Some birds may even utilize exposed bank for excavating nesting cavities. As such, stabilization techniques should avoid impacts to existing colonies and should strive to reduce impacts to bird habitat during nesting season. In addition, stabilization focused on enhancement and creation of emergent sandbar habitat, enhance native shrub and tree growth, and gentle slopes where possible would be highly beneficial to avifauna.

Fish and mammals are more mixed in likely response to riprap. Many fish species know to occupy the Mississippi River in the metro utilize a variety of habitat space such as sand, gravel, woody debris, and open water. Due to the variation in habitat use throughout the year and for different age classes of the same species, it is likely that localized riprap will have limited effect on fish populations. That said, diversity in habitat structure created from riprap, woody materials, and vegetation could provide larger water quality benefits, improved habitat for invertebrates; resulting in healthier fish communities in the river. Increases in insects are likely to also benefit birds, bats, and frogs. Other mammals like mink, racoons, squirrels, and chipmunks are also likely to benefit from natural shorelines and native vegetation as a result of improved cover, burrow locations, and foraging potential.

Potential Stabilization Techniques and Plant Suggestions

The following section outlines potential stabilization techniques and planting designs that will be considered. Project considerations are aimed at maximizing both water quality benefits and supporting wildlife.

Vegetation enhancement, fiber blankets, root wads, live staking, fiber core rolls, encapsulated soil lifts and native seeding have been used in locations along large rivers in many other states as well as along the Mississippi in Minnesota to achieve bank stabilization. In areas with high shear stress, combinations of techniques or vegetated riprap alternated with lengths of non-riprap areas have proven successful. In addition to providing stabilization these techniques offering more beneficial habitat, they offer greater water quality filtration, carbon sequestration, and long-term cost-effectiveness. Often time riprap projects due to settling and sedimentation need to be amended or replaced at fairly high cost.

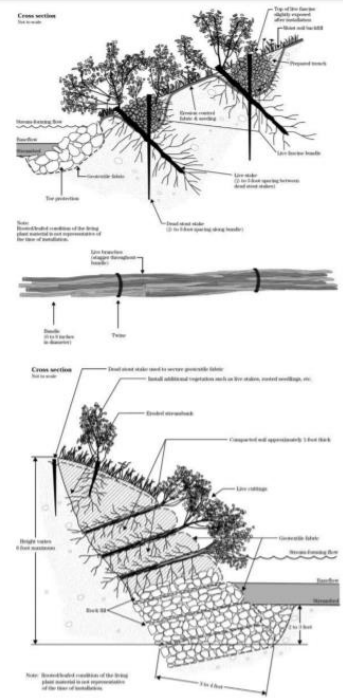
Below are some images from primary literature and completed projects describing a variety of bioengineered approaches for bank stabilization along rivers. Some combination of these techniques could function to adequately enhance shorelines while also supporting important wildlife habitat and movement.

Table 4. Generalized environmental impact of selected streambank stabilization measures on aquatic and terrestrial habitat elements compared with bare or eroding streambanks. Note: impacts represent typical applications – actual performance may be enhanced through good design and construction practices.

Ecological Performance Factor	Vegetation Temporary RECP (ECB)	Bioengineering – brush layers, VRSS, log crib	Ordinary / Advanced TRM	HPTRM / ARVS	Riprap	ACB	Hard Armor – gabions concrete, sheet pile
Wildlife access	🙂	😐/🙂	😐/🙂	😐/🙂	😐/☹	😐/☹	☹
Aquatic habitat complexity	😐/🙂	😐/🙂	😐	😐	😐/🙂	😐/☹	☹
Riparian / veg. habitat complexity	🙂	😐/🙂	😐/🙂	😐/🙂	😐/☹	😐/☹	☹
Shade, temperature	😐/🙂	😐/🙂	😐	😐	😐/☹	😐/☹	☹
Cover, refugia	😐/🙂	😐/🙂	😐/☹	😐/☹	😐/🙂	😐/☹	😐/☹
Nutrient cycling	🙂	🙂	😐/🙂	😐/🙂	☹	☹	☹
Surface-groundwater connection	😐	😐	😐	😐	😐	😐/☹	☹
Water quality – pollutant removal	🙂	🙂	🙂	🙂	😐/☹	😐/☹	😐/☹
Water quality – overland sed. capture	🙂	🙂	😐/🙂	😐/🙂	😐/🙂	😐/☹	😐/☹
Soil development	🙂	😐/🙂	🙂	😐	☹	☹	☹
Construction impacts	😐	😐/☹	😐	😐	😐/☹	☹	☹
Maintenance impacts	😐	😐	😐	😐	😐/☹	😐/☹	😐/☹

🙂	Beneficial
😐/🙂	Neutral to Beneficial
😐	Neutral
😐/☹	Neutral to Detrimental
☹	Detrimental

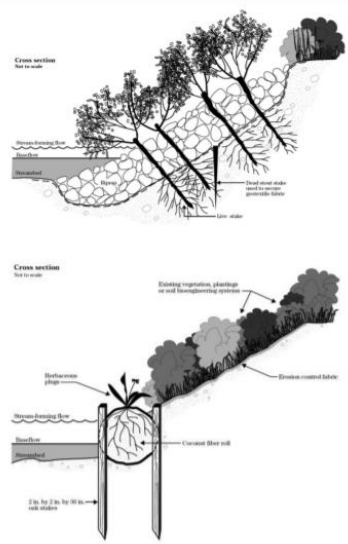
Figure 4.5 Qualitative ranking of environmental impacts for various streambank stabilization techniques according to Miller et al. (2012).



b) live fascines

c) vegetated geogrid (also known as or similar to soil lifts, vegetated mechanically stabilized earth (VSME), vegetated reinforced soil slope (VRSS))

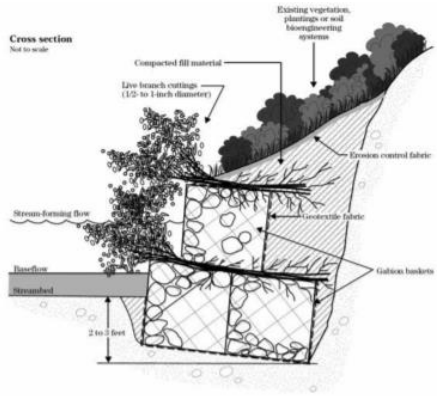
Figure B.1 (Continued).



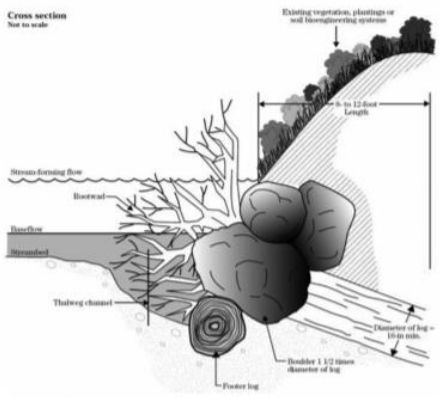
d) joint planting

e) coconut fiber rolls (also termed coir logs, or bio-logs)

Figure B.1 (Continued).

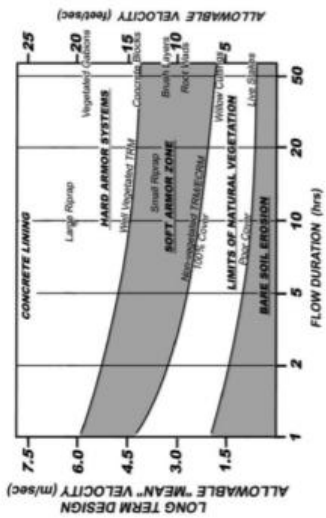


f) vegetated gabions



g) root wads (with boulders and footer log)

Figure B.1 (Continued).



NOTES:
1. **Hard Armor** - includes Concrete, Riprap, Gabions, Concrete Blocks, etc.
2. **Soft Armor** - includes Turf Reinforcement Mats (**TRM**), Erosion Control Revegetation Mats (**ECRM**), Vegetated Geocells, and many Biotechnical Treatments.
3. Available data shows considerable variability in limit velocities.

Adapted from Thiesen (1988) (used with permission of Synthetic Industries, Inc.; Fischenich and Allen (2003); McCullah and Gray (2005) (NCSU-WP-164)

Figure 4.6 Variation of permissible velocities with flow duration according to Miller et al. (2012).

Targeted Mississippi River Bank Stabilization Focused on Bioengineering – Round 2

Project Background

- The Mississippi River is impaired for TSS and turbidity.
- A full inventory of shoreline conditions was completed by ACD in 2016 and 2012 along a 13.3-mile stretch of the Mississippi River in the cities of Anoka, Coon Rapids, and Ramsey. These inventories identified 12,569 linear feet of riverbank with severe to very severe erosion.
- Promotion efforts to date for ACD's FY 2017 CWF grant have resulted in interest from 31 properties, and at most, five properties will receive assistance with currently available funds.

Project Benefits

- For this grant request of $236,000 with $59,000 in local match, up to five river banks will be stabilized delivering reductions of up to 2,000,000 lbs-TSS and 1,000 lbs-TP over the 10-year expected lifespan of the projects.
- Stabilization is highly cost-effective with a 100% pollutant delivery ratio and removal costs for TSS of $0.15/lb and for TP of $295/lb over the project life.

Potential Mississippi River Stabilization Sites

Site Information	Ownership	Erosion Length (ft) Severe/Very Severe	Height (ft)	Depth (ft)	Slope (H:V)	Soil Loss (tons/yr)
	Private	589	8 - 22	12 - 33	1.5 - 1.9	653.5

Examples of Bioengineered Riverbank Stabilization Projects

Stearns County Mississippi River Park

Streambank Stabilization

The project at Mississippi River Park was many years in the making. The project came together because of the involvement from many partners to restore the river bank and associated habitat. The Stearns County Parks Department has shown outstanding commitment to this project along the Mississippi River. – Greg Berg, Stearns SWCD Lakeshed Specialist

Before Project Streambank Erosion

Before Project Streambank Erosion

During Project Construction

During Project Construction

Project Site Prior To Final Planting

Funding:

State Funds*	$148,218
Landowner (Match)	$ 13,751

* Administered by Stearns SWCD

All programs and services are available without the regard to race, color, national origin, sex, religion, age, disability, political beliefs, and marital or family status.

City of St. Cloud – Whitney Park Project

Dam Removal & Souk River Streambank Stabilization

"The coordination on this project to solve a major water resource concern was outstanding. Removing the dam to assist with a resource issue is no easy task" – Greg Berg, Stearns County SWCD Lakeshed Specialist

Before Project – Failing Slope

Before Project – Habitat Degradation

During Streambank Stabilization

After Streambank Stabilization

After Streambank Stabilization

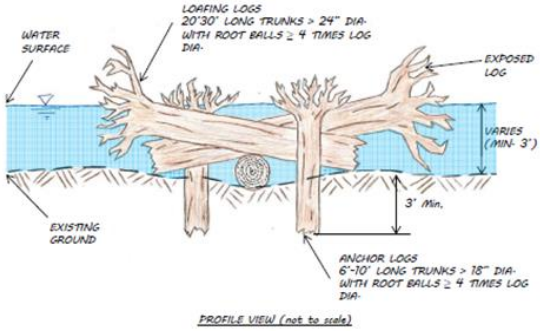
Funding:

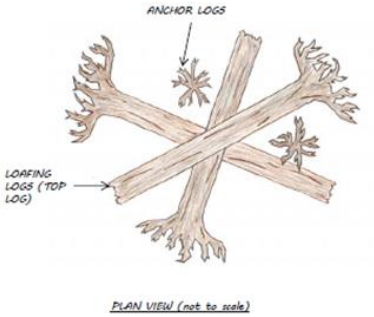
State Funds*	$ 337,999
City of St. Cloud (In-kind)	$ 15,813

* Administered by the City of St. Cloud, Stearns County SWCD and Souk River Watershed District
BWSR Clean Water Fund and DNR CPL

All programs and services are available without the regard to race, color, national origin, sex, religion, age, disability, political beliefs, and marital or family status.

Cross Log Habitat Structure





OBJECTIVE

- Provide shallow water and loafing habitat in wetlands and near-shore areas

MATERIALS/INSTALLATION

- Cross logs consist of a minimum of three logs, 24" dia., 20'-30' long, with root balls ≥ 4 times log dia., placed horizontally
- Anchor logs are typically 12"- 18" dia., 6'-10' long, with root ball ≥ 4 times log dia., placed in the gaps of horizontally placed logs, with a minimum of two anchor logs per structure
- Cross log structures are placed in areas protected from wave action
- Structure installed using barge crane or floating excavator

BENEFITS

- Low cost structure
- Provides near-shore and shallow water lake/wetland habitat for fish (all life stages), herpitiles, amphibians and birds
- Provides waterfowl nesting habitat

PHOTO - CROSS LOG STRUCTURE

SEEPS

Seeps along the slopes add additional complication to slope stability. Groundwater seeps create additional and often ongoing moisture to surficial soils. This moisture can cause reduced soil cohesion and bank stability, especially when coupled with rain events and overland flow. However, seeps are important micro habitats for a variety of plants, insects, and frogs. Maintaining this natural hydrology is important for continued existence of these micro communities. Slope stabilization techniques should consider opportunities to re-route surface flows from up-slope and avoided tiling of seepage areas, to the extent practicable. This will mitigate additional moisture stress from stormwater flows while maintaining the natural groundwater flow and plant community conditions. Options such as a catch basin coupled with a chimney drain can route surface flows from top of bank to outlet near OWH of the river.

Potential Wildlife

The following section outlines various wildlife species that likely utilize the Mississippi River corridor associated with Brooklyn Park, MN and may be sensitive to bank armoring and/or benefit from stabilization. This section outlines habitat needs and natural history traits of various species groups.

TURTLES

There are six species of turtles in MN which have potential to occupy the Mississippi River in the proposed project area. This includes snapping turtles, smooth and spiny softshell turtles, false and northern map turtles, and painted turtles.

Snapping Turtles

Snapping turtles often inhabit large rivers with muddy bottoms like the Mississippi. They rely on sandy riverbanks, lawns, and road embankments for nest locations. And will hide under submerged logs, rocks, and vegetation during the day. They prefer areas with abundant aquatic vegetation. They feed almost exclusively underwater and eat a variety of snails, fish, frogs, eggs, invertebrates, birds, small mammals, snakes, and plants. They often hibernate in holes in riverbanks or wedge under submerged logs. Egg Laying occurs May-June and hatchlings emerge July-September.

Painted Turtle

Require loose soil or sand for nesting. Prefer permanent waterbodies and do inhabit larger rivers with rocky shorelines. Basking sites are very important. They Hibernate in mud and water under ice and huddled against submerged logs. They eat small fish, invertebrates, and plants. Nesting occurs May-July (mostly June) and hatching occurs in late august through the fall but, hatchlings may remain in nest until following spring.

Smooth Softshell Turtle

They inhabit large rivers and occur in the Mississippi river. Although smooth softshell turtles are uncommon in MN however, NPS has indicated observations near to/within the project area. They prefer sand and mud bottoms and avoid areas with rocks and lots of vegetation. These turtles tend to overwinter burrowed in sediments of the river bottom and like basking on sandbars along the shoreline. They eat frogs, invertebrates, and fish. Nesting occurs in June and July on sandbars with good sunlight. Hatchlings emerge late August -early October.

Spiny Softshell Turtles

Spiny softshell turtles are found in major MN rivers like the Mississippi and require very similar habitat to and natural history as smooth softshell turtles but are much more common.

False Map Turtle

False map turtles inhabit big rivers and are occupants of the Mississippi River in the south and south-central portions of MN. Hibernate on downstream sides of submerged rock and logs. These turtles prefer soft bottoms, abundant vegetation, and strong currents. Basking sites away from the shore are very important. False map turtles primarily eat plants but also consume invertebrates, and fish. Egg laying occurs May-early July and hatchling emerge late summer through early fall or in the following spring.

Northern Map Turtle

Northern map turtles are found in large and mid-sized rivers and are commonly distributed along the Mississippi, Minnesota, and St. Croix Rivers; slow water, backchannels, and oxbows are preferred. Basking sites are very important. They prefer soft substrates and hibernate under rocks and logs under the ice. They forage river bottoms for invertebrates and fish. Egg Laying occurs June-July. Hatchlings emerge in September or May-June of the following year.

SNAKES

Common Water Snake

Common water snakes inhabit the Mississippi River and are frequently in the water or observed on basking sites like logs, rocks, and ground vegetation. They feed primarily on fish and amphibians. These snakes give birth to live snake litters in august and early September.

Western Fox Snake

This snake is found along the Mississippi River Valley in forested areas and along shores. They lay eggs in May and June and they typically hatch June-August. Eggs are often laid under logs in damp soil.

Eastern Hog-nosed snakes

These snakes occupy the sand beaches and forested areas along the Mississippi River and are also commonly observed swimming. They require soft substrates for burrowing below the frost line for hibernation and for nests. Eggs are laid in May-July and emerge July-September.

FROGS

There are few frogs likely to utilize the Mississippi River in the project area. However, Leopard and green frogs have potential to inhabit shoreline and in water areas. They primarily feed on toads.

Northern Leopard Frog and Chorus Frog

Northern leopard and chorus frogs are unlikely to inhabit the river but may be found along the shoreline or in vegetated areas with adequate moisture.

Green Frog

Green Frogs inhabit permanent waters including rivers and associated seeps and backwaters. They commonly use waters edge habitat and breed from May to mid-August. Green frogs eat invertebrates and small fish and prefer shorelines with vegetation. Negative impacts have been documented in areas of shoreline development.

FISH

Fish in the Mississippi River north of the St. Anthony Dam and south of the Coon Rapids Dam likely include species such as catfish, smallmouth and largemouth bass, bluegill, crappie, bluegill, sauger, yellow perch, freshwater drum, and carp. Some of these species lay eggs in open water or over sand/gravel and some require woody debris like hollow logs or vegetation for nesting and egg-laying. Research suggests that catfish, bluegill, drum, bass, and larval fishes may respond positively to riprap depending on size and configuration of the material.

BIRDS

The Mississippi River is a very important migratory flyway for all orders of birds and is considered an important bird area. The river and associated banks and floodplains offer cover and important stopover and habitat for birds during migration and year-round.

Specifically, bank and northern roughed-winged swallows and belted kingfishers may currently use exposed banks are to establish nests by excavating small burrows. Swallows, Kingfishers, flycatchers, and night hawks use the shoreline and open water corridor for hunting bugs from the near the water surface and in the air. Egrets and herons may also be found along the shoreline hunting for frogs and fish. Egrets and herons both benefit from soft shorelines with vegetation and overhanging branches, this habitat structure offers good stalking and perching conditions. In addition, herons are likely to benefit from gentle slopes into the river for wading and stalking.

Birds of prey and waterfowl are also likely the use and occupy the Mississippi within the project area. Osprey and bald eagles use the river for hunting fish and nesting. Broad-winged hawks, cooper hawks, red-tailed hawks, red-shouldered hawks, peregrine falcons, Great horned owls, barred owls, eastern screech owls, and turkey vultures are likely to utilize the wooded slopes for perching and hunting other birds and animals found along the river corridor. Mallards, swans, diving ducks, geese, are all likely to utilize the main channel for stopover habitat, especially during spring migration when rivers offer some of the only open water. Although armoring is not likely to have direct impacts on the aforementioned bird groups and species, tree canopy and improved habitat for other species will offer indirect benefits for their migration and mating success.

MAMMALS

Mink, muskrat, racoons, river otter, stripped skunk, squirrels, chipmunks, beaver, bats, and a variety of smaller mammals such as mice and voles are likely to visit or inhabit the areas along the project corridor. Manny of these animals rely on negative herbaceous and woody vegetation for hiding and foraging, trees and shrubs for nesting, and downed trees and soft sediment for burrows and savaging. In addition, beaver, mink, muskrat, and bats are likely to use open water areas for foraging and movement between habitat areas. Some mammals mentioned here also have stout legs and long bodies, resulting in a shuffling/waddling gate. As a result, large boulders may cause challenges for movement. Generally, mammals are not likely to be significantly impacted by hard armoring techniques, however, most mammals would benefit from naturalization and soft armoring of banks and slopes due to the improved

cover and potential for prey and forage. Project techniques should strive to better habitat to the extent practicable and avoid impacts to dens and nest.

Appendix C

Riverbank Classification Assessment Worksheet

Reach ID#		Evaluator	
Date/Time		Zone	☐ Toe/Splash (skip slope questions) ☐ Bank ☐ Upland
Bank	☐ East ☐ West		
Transect Features (once per reach)		Other Modifiers	☐ Unnatural ☐ Floodplain ☐ Woody debris (< 5 logs > 6" dia. & 6' long) ☐ Debris jam (5 or more logs > 6" dia. & 6' long) ☐ Root wad ☐ Culvert - drain outlet ☐ Island ☐ Outer bend ☐ Depositional areas ☐ Undercut bank ☐ Altered area ☐ Scarp Scarp height (in feet)_____
Bank height (top-of-toe to top-of-bank)	☐ 0' - 5' ☐ 6' - 10' ☐ 11' - 15' ☐ 16' - 20' ☐ > 20'		
Upland condition	☐ Gradual (level to 4:1) ☐ Moderate (4:1 to 2:1) ☐ Steep (2:1 to vertical) ☐ Overhanging		
Average bank slope (top-of-toe to top-of-bank)	☐ Gradual (level to 4:1) ☐ Moderate (4:1 to 2:1) ☐ Steep (2:1 to vertical) ☐ Overhanging	*Erosion / Deposition Features (for each zone)*	
Zone Features (for each zone)		Engineered surface or structure	☐ None ☐ Poured concrete ☐ Wood ☐ Metal ☐ Riprap ☐ Gabion ☐ Landscaped earth ☐ Other: (describe)
Land use	☐ Commercial ☐ Industrial ☐ Residential ☐ Park ☐ Roadway ☐ Vacant ☐ Other (describe):		
Vegetative cover (primary)	☐ Bare ☐ Herbaceous/Shrub ☐ Forest ☐ Aquatic	Effect of engineered surface or structure on erosion or stability	☐ Not applicable ☐ Stabilizing bank ☐ Causing erosion ☐ No apparent effect
Vegetative cover (secondary)	☐ Bare ☐ Herbaceous/Shrub ☐ Forest ☐ Aquatic	Evidence of erosion (all that apply)	☐ None ☐ Undercutting ☐ Overhanging vegetation ☐ Cracking / mass wasting / sloughing ☐ Presence of a scarp ☐ Exposed roots ☐ Tipping / fallen trees ☐ Other (describe):
Vegetative density	☐ 0 - 9% (Bedrock and levy walls only) ☐ 10 - 25% cover ☐ 26% - 50% cover ☐ 51% - 75% cover ☐ 76% - 100% cover		
Substrate	☐ Organic (peat or organic soil) ☐ Silt ☐ Clay ☐ Sand (0.003" - 0.19") ☐ Gravel (0.19" to 2.9") ☐ Cobble (2.9" to 11.8") ☐ Boulder (> 11.8") ☐ Bedrock	*Causative Processes (for each zone)*	
Depth of Surficial Soil	☐ 0" - 5" ☐ 6" - 11" ☐ 12" - 17" ☐ 18" - 23" ☐ 24" - 29" ☐ 30" - 35" ☐ > 36"	Potential cause of erosion (all that apply)	☐ Obstruction in river ☐ Cutbank at bend in river ☐ Flow induced erosion ☐ Dam operations ☐ Wetting / drying ☐ Bank seepage ☐ Concentrated sheetflow ☐ Gully from side channel or outfall ☐ Erosion around structure on bank ☐ Recreational or foot traffic ☐ Human encroachment (buildings, etc.) ☐ Other: (describe)

Riverbank Classification Assessment Worksheet

Photo Log		*Notes*
3 digit ID = Reach. side of river. photo# IE: 12.E.156		
ID	Description/Orientation	
	Transect	
	Upstream	
	Downstream	

Appendix D

Streambank Erosion

Field Measurement Procedure

The best way to quantify streambank erosion is to measure it directly in the field. The basic procedure in measuring streambank erosion is to survey, flag, or in some way fix a “before" image of the channel you are evaluating. This establishes the baseline condition. Changes due to erosion can then be monitored over time by going back to the study area and re-measuring from your fixed reference points.

Channel cross-sections can be surveyed and plotted on a periodic basis to monitor change. Stakes or pins can be driven into channel banks flush with the surface. The amount of stake or pin exposed due to erosion is the amount of change at the streambank erosion site between your times of observation.

Field Estimate Procedure (Direct Volume Method)

The field measurement procedure is the most accurate way to measure streambank erosion. However, the time involved in monitoring your site, in wet years and dry years, often precludes this method of data collection. The Direct Volume Method can be used to estimate streambank erosion at your site. The Direct Volume Method is summarized in the following equation:

$$\frac{\text{(eroding area)}\ \text{(lateral recession rate)}\ \text{(density)}}{\text{2000 lbs/ton}} = \text{erosion in tons/year}$$

The eroding area is in square feet, the lateral recession rate is in feet/year, and density is in pounds/cubic feet (pcf).

Determining Eroding Area

Eroding areas are channel banks that are bare, rilled or gullied. They generally have sloughed soil at their bases. A grassed bank or rock bank is considered to be non-eroding. The actual eroding area is defined by multiplying the height and the length to obtain square feet of eroding area. The height is measured on the bank surface as the slope height; not the vertical height.

Average Annual Lateral Recession Rate

The average annual recession rate is the thickness of soil eroded from a bank surface (perpendicular to the face) in an average year. Recession rates are measured in feet per year. Channel erosion often occurs as chunk or blowout type erosion. A channel bank may not erode for a period of years when no major runoff events occur. When a major storm does occur, the bank may be cut back tens of feet for short distances. It is necessary to assign recession rates to banks with such a process in mind. When a bank is observed after a flood and ten feet of bank has been eroded, that ten feet must be averaged with the years when no erosion occurred. This will result in a much lower average annual recession rate than a recession rate for one storm.

Selecting the average annual lateral recession rate is the most critical step in estimating channel erosion using the direct volume method. A historical perspective is needed in many instances. Old photographs, old survey records, and any other information that helps to determine the bank condition at known times in the past are very useful data. In most instances, such information is lacking and field observations and judgement are needed to estimate recession rates.

Cultural features are often helpful in determining recession rates. Exposed bridge piers, suspended outfalls or culverts, suspended fence lines are all possible indicators of lateral recession. Discoloration on the bridge piers may show the original channel bottom elevation. Given the date of the bridge installation, a recession rate can be calculated for that reach of stream. Culverts are generally installed flush with a bank surface. The amount of culvert exposed and age of the culvert allows for the calculation of a recession rate.

Exposed tree root is probably the most common field evidence of lateral recession. Roots will not grow towards a well-drained, exposed, eroding channel bank. The amount of root exposed should be increased by at least a factor of two to account for

soil that was in the bank and that the root was growing in. By dividing the length of root exposed and the thickness of soil around the root by the age of the tree, a recession rate can be estimated.

Much experience and professional judgement are required to estimate channel recession rates. It is often not possible to directly measure recession rates in the field. Therefore, the following table has been included which relates recession rates to narrative descriptions of banks eroding at different rates.

Lateral Recession Rate (ft/yr)	Category	Description
0.01-0.05	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang. No exposed tree roots.
0.06-0.2	Moderate	Bank is predominantly bare with some rills and vegetative overhang. Some exposed tree roots but no slumps or slips.
0.3-0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross section becomes U-shaped as opposed to V-shaped.
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross section is U-shaped and stream course may be meandering.

Volume Weight Conversions

The volume (cubic feet) of eroded material is obtained by multiplying eroding areas by a lateral recession rate. To convert this volume of eroded material to a weight, the dry density of the soil must be known. The following table lists soil textures with corresponding volume weights.

Soil Texture	Volume-Weight
Gravel	110
Sand	105
Fine Sandy Loam	100
Loamy Sand	100
Sandy Loam	100
Loam	90
Sandy Clay Loam	90
Clay Loam	85
Silt Loam	85
Silty Clay	85
Silty Clay Loam	85
Silt	80
Clay	65
Organic	22

Example

Farmer Brown's cattle have access to the stream running through his pasture. On the south side of the stream, 700 feet of bank is bare with rills and overhanging vegetation. Exposed tree roots are evident with many fallen trees and slumps. Bank height is 8 feet measured along the bank. Soil type is predominantly sandy loam. On the north side of the stream, 300 feet of bank is predominantly bare with some rills and vegetative overhang. There are some exposed tree roots but no slumps are evident. Bank height is 10 feet and the soil texture is a loam.

Annual erosion at the site using the Direct Volume Method:

$$\frac{\text{(eroding area) (lateral recession rate) (density)}}{\text{2000 lbs/ton}} = \text{erosion in tons/year}$$

South bank:

$$\frac{\text{700 ft x 8 ft x 0.4 ft/yr x 100 pcf}}{\text{2000 lbs/ton}} = \text{112 t/yr}$$

North bank:

$$\frac{\text{300 ft x 10 ft x 0.1 ft/yr x 90 pcf}}{\text{2000 lbs/ton}} = \text{13.5 t/yr}$$

112 t/yr + 13.5 t/yr = 125.5 tons/year eroding at the site.

Hennepin County Environment and Energy
701 Fourth Avenue South, Suite 700, Minneapolis, MN 55415

environment@hennepin.us