Creek Restoration Action Strategy

2017 Report

Riley Purgatory Bluff Creek Watershed District

May 2017

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Acknowledgements

This assessment and report were prepared as a joint effort between the Riley-Purgatory-Bluff Creek Watershed District and Barr Engineering. District staff (Josh Maxwell, Michelle Jordan, and Zach Dickhausen) completed the vast majority of the field work necessary to complete this assessment; and Josh Maxwell made significant additional contributions through assisting in the development of the CRAS framework; processing data from field assessments; presenting findings to the District Technical Advisory Committee and Citizen Advisory Committee; and report preparation. This assessment would not have been possible without these key contributions from District staff.

The District and Barr Engineering would like to thank the District Technical Advisory Committee and the Citizen Advisory Committee for reviewing and providing valuable feedbacks on the CRAS. We would also like to also thank District staff and volunteers from the University of Minnesota for all their field work. Finally, the District would like to thank Barr Engineering for working on this project as a team, providing additional training and sharing expertise with our employees. This assessment was funded through the Riley-Purgatory-Bluff Creek Watershed District.

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Certifications

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

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May 25, 2017
Date

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1.0 Introduction

1.1 Background

The Riley Purgatory Bluff Creek Watershed District's (District's) Third Generation Watershed Management Plan (Plan) has identified stream flow (hydrology), erosion, water quality, and aquatic ecosystem biology/habitat as concerns throughout the watershed. The Plan also outlines short- and long-term goals around these themes. The Plan's relevant short- and long-term goals are summarized as follows:

- Coordinate with municipalities and other watershed partners regarding planned expenditures for addressing watershed issues and develop cost-share programs.
- Reduce and manage phosphorus loading to District lakes by determining external, internal, and upstream waters phosphorus loading contributions.
- Improve water quality to fully support designated uses for water bodies and remove water bodies from the Minnesota Pollution Control Agency (MPCA) list of impaired waters.
- Preserve vegetation and habitat important to fish, waterfowl, and other wildlife while also mitigating negative impacts of erosion.

In order to achieve the goals stated above, the District regularly works with cities within the District to address erosion problems along Riley, Purgatory, and Bluff Creeks in order to directly address concerns related to erosion, water quality, and aquatic ecosystem habitat.

Multiple entities, including Minnesota Department of Natural Resources (MNDNR), Minnesota Board of Water and Soil Resources (BWSR), the District's Technical Advisory Committee (TAC) and Citizen's Advisory Committee (CAC), and District residents have inquired about how creek restoration and stabilization projects are prioritized within the District. Multiple locations within the District have been identified as needing restoration; however due to the significant cost of construction projects, it may only be possible to complete a few projects in a given year without significant increases in the tax levy. Working with District staff, this Creek Restoration Action Strategy (CRAS) was developed to prioritize streambank stabilization and restoration projects within the District.

1.2 Objectives

The two primary objectives of the CRAS are:

1) Develop a mechanism to compare stream conditions in the watershed to guide project implementation.
2) Create an adaptive approach to update the CRAS to incorporate new information as it is collected in the future.

Riley, Purgatory, and Bluff Creeks have unique characteristics. The CRAS provides a method to compare the health of each reach throughout the District as a means to guide project implementation. Ultimately, project implementation will depend on other additional factors, such as project cost, coordination with other projects, and/or acute threats to public infrastructure. The reach with the highest score on the CRAS may not necessarily be the first project to be completed; however the CRAS will help guide the District by identifying which reaches would benefit the most by completing a restoration project.

Creeks are dynamic systems that change over time; as such, this process had the additional objective of developing a methodology that can easily be updated as new information about each creek reach is generated. The CRAS is intended to be a “living” document that can be updated on a regular basis.

In order to meet the study’s objectives, District staff worked closely with Barr Engineering staff to complete the following major tasks:

- Reviewed several published methodologies for assessing stream reaches and ultimately selecting a combination of methods to include in the CRAS.
- Identified other key criteria for consideration in prioritization approach.
- Developed scores for reaches and sub-reaches on the three main creeks.
- Met with the TAC and CAC.
- Developed a final-tiered ranking of sub-reaches.
- Identify future work to update and enhance the CRAS.

This report summarizes the methodology used to develop the CRAS, as well as the results of the watershed-wide streambank assessment, and recommendations for future activities based on analysis completed through 2016.

1.3 CRAS Limitations and Assumptions

The CRAS is intended to be a tool used to help compare the condition of streams throughout the District. The assessments used for this study were comprehensive and yet were relatively simple to complete the intended goal. The initial CRAS rankings provided in this report were completed through various assessments described in the following sections. Each of the assessments has certain limitations and assumptions; therefore by extrapolation, the CRAS has certain limitations and assumptions. Many of these limitations are also discussed in further detail in subsequent sections; however the following provides a summary of known assumptions and acknowledged limitations.

- Most assessments required subjective scoring. Different users may develop different scores.
- The majority of sub-reaches within the District were directly assessed by the same District staff; however some sub-reaches were assessed by utilizing photographs from past studies. The photos were not taken with these assessments in mind, so they provide limited ability to accurately assess some variables.
- The assessments did not attempt to identify the cause of deterioration.
- A qualitative infrastructure risk assessment was performed by District and Barr staff. These assessments do not reflect the results of in-depth engineering analyses to determine streambank

stability at each individual location. An in-depth engineering analysis would be needed as part of future feasibility efforts.

- The District monitors water quality by collecting bi-monthly grab samples at 18 monitoring sites. The data available from the monitoring sites were extrapolated upstream from the monitoring sites to generate water quality scores for the 80 sub-reaches scored in this study.
- Water quality data during high flows is only captured at WOMP stations and is not well represented in the grab sample data.
- Potential site specific projects have not been defined, so it is difficult to compare potential projects on two separate reaches.
- Concept designs for potential projects have not been developed, so it is not possible to develop concept design based cost estimates. Instead, cost estimates were based on anticipated costs per foot of stream to be restored and then used to estimate a value for the cost/lb. P/ft. for each reach. Actual restoration costs may be significantly higher or lower depending on the root cause of the problem, specifics of the project design, and other unanticipated variables.
- The City of Eden Prairie has been collecting erosion data by utilizing bank pins for multiple years on some reaches of stream. This data is very valuable, but due to changing soil types within the watershed, it is difficult to accurately extrapolate that data to all sub-reaches.
- For sediment loading, constant erosion rates were applied to constant areas of eroding banks to estimate sediment loads from each sub-reach. The measurement of cost/lb. P/ft. was established for planning purposes only and has been normalized to allow for relative comparison across reaches.
- It was assumed one cubic yard of sediment contains 0.04 pounds of phosphorus for all soil types, which is the average ratio used in the BWSR Water Erosion Pollution Reduction Calculator (MN BWSR, 2010).

2.0 Review of Published Assessment Methods

Dozens of stream assessment methods and prioritization strategies have been published, each having a different set of evaluation criteria to determine stream health. As part of the CRAS development, Barr completed a cursory review of several methodologies to develop a narrowed list of methods to consider. Barr reviewed the following five methods in detail to determine which may be the most suitable to developing a stream restoration prioritization approach that would align with the District's goals and utilizing existing data.

- ***Stream Function Pyramid*** - This method was developed jointly by the Environmental Protection Agency (EPA) and United States Fish and Wildlife Service (USFWS) and divides stream functions into a hierarchy of categories or levels: hydrology (level 1), hydraulic (level 2), geomorphology (level 3), physiochemical (level 4), and biology (level 5) (EPA, 2012).. Higher-level functions are supported by lower-level functions (for example, hydraulic functions cannot occur without hydrologic functions), and this method recommends that all categories be addressed in order to address underlying processes and achieve a successful project. This method is more suitable for establishing restoration goals than for specific assessment and prioritization, and this approach is incompatible with data previously gathered by the District on some reaches; as such, the Stream Function Pyramid was not considered in development of the CRAS.

- ***Unified Stream Assessment (USA)*** – The Center for Watershed Protection's Urban Subwatershed Restoration Manual Series (2005) developed the USA method as a rapid technique to locate and evaluate problems and restoration opportunities in urban stream settings. The USA method consists of nine different stream corridor assessments: eight individual impact assessments and a single overall stream reach level assessment. The individual impact assessments cover outfalls, severe erosion, impacted buffer, utilities in the stream corridor, trash and debris in the stream corridor, stream crossing, channel modification, and miscellaneous unusual features or conditions. The reach level assessment considers stream average stability, habitat, vegetation, connectivity, access, flow and substrate across the entire reach. This method does not consider water quality and, also, would not easily be able to incorporate stream stability data already collected by the District; as such, the USA method was not considered in development of the CRAS.

- ***Rosgen Stream Classification System*** – This method was developed by Dave Rosgen and looks at of various stream variables, including channel dimensions, channel slope, valley characteristics, steam bed composition, and channel sinuosity (Rosgen, 1996). The evaluation of these variables is used to classify the stream reach into one of eight different stream types and draw conclusions regarding whether the stream reach is likely in a current state of dynamic equilibrium with its watershed or if it is likely undergoing a morphological change that can lead to system instabilities and water quality deterioration. This method is frequently used by the MNDNR. Barr recommended this method as a component for prioritizing the District's stream restoration projects because it aligns well with past District field investigations and reports for Bluff Creek, Lower Riley Creek, and isolated areas of Purgatory Creek.

- ***Watershed Assessment of River Stability and Sediment Supply (WARSSS)*** – The United States Environmental Protection Agency and Dave Rosgen developed the WARSSS method (Rosgen, 2006). It uses the Rosgen Stream Classification System as one of its components and also examines several other variables from the watershed and the stream to determine the largest sources of sediment loading in the stream and the reach with the greatest instability. The full WARSSS method was more than necessary to prioritize stabilization reaches for the District; however there are useful tools included in this method that can be used to compliment other assessments and data previously collected. A portion of the WARSSS method, specifically the Pfankuch stream stability assessment, was included in the CRAS to assist in prioritizing the stream stabilization efforts in the District because it provides a means to assess and compare stream channel stability.

  As can be seen in the example data sheet in Appendix A, the Pfankuch rating system uses 15 variables related to channel stability, with the variables slope between upper banks/valley walls, lower banks (within the stream channel itself), and the stream bed. The scores from all variables help determine an overall stability score for that reach. This methodology has been a key component in the stream assessment courses taught by Dr. Dave Rosgen around the country and by the MNDNR within the state of Minnesota. It is also included in the RiverMorph software used for stream assessment and design, and is a key component in developing site-specific sediment rating curves. This scoring method was recommended to evaluate channel stability within the watershed because of the robust methodology and the prominence of its use both within MNDNR and throughout the country.

  Additional WARSS assessments, such as the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) may be utilized on specific reaches to help assess risks and estimate sediment loading but was not recommended as part of this original assessment. The BEHI assessment evaluates the potential for bank erosion based on bank height, bank angle, the percent of bank exposed, and the root density within the bank. The NBS assessment examines the most likely cause of erosion and includes considerations of in-stream features that direct flow into banks, the radius of curvature around meanders, mean depth versus bank height, ratios between different water surface slopes in the stream, and shear stress. The effort to complete these assessments on all reaches is not necessary, particularly if the reach is not actively eroding; however these assessments may be useful during in-depth feasibility analysis prior to moving forward with restoration designs.

- ***Stream Habitat Assessment Protocol*** – The Minnesota Pollution Control Agency's (MPCA) Stream Habitat Assessment (MSHA) collects information on watershed land use, riparian quality, bank erosion, stream substrate type and quality, in-stream cover, and several channel morphology characteristics of an identified reach (MPCA, 2014). The reach is assigned a score out of 100 possible points based on these characteristics. This method does not provide enough hydrology, erosion, or water quality information to be considered as a suitable stream prioritization method alone. However, the MSHA Protocol in combination with other methods suitable for prioritizing the District's stream restoration projects is included in the CRAS because it requires minimal time to complete in the field and provides a well-rounded habitat assessment of both the stream and its riparian area.

2.1 Selected Assessment Tools

None of the methods reviewed, either in depth or in summary, contained the necessary components to fully incorporate water quality, stream stability, and stream habitat into a single scoring system. Therefore, a combination of Rosgen Stream Classification System, components from WARSSS (specifically the Pfankuch assessment), and the MSHA Protocol were selected as key components to be included in the CRAS as these methods allowed for extensive use of existing information to help the District prioritize stream restoration projects. Additional considerations were also included, as further described in following sections.

3.0 Methodology and Scoring Criteria

This section outlines methodology and categories evaluated in the CRAS development and the scoring criteria used.

3.1 Key Categories and Basic Scoring System

In addition to the published methods, Barr and District staff identified other key categories that were important to help prioritize restoration efforts. These categories were discussed with the TAC and CAC to solicit their input. District staff and members of the TAC and CAC agreed that the overall assessment should be as comprehensive as possible while also being as straightforward. Discussions, both with TAC and CAC members and internally between District staff and Barr staff, brought up many ideas to consider. Often multiple ideas were reasonably covered within a single evaluation method however additional evaluating criteria were also identified such as public education, infrastructure risk, and partnership opportunities. The following is a list of selected categories included in the CRAS that will be described in more detail in the following sections:

- Infrastructure risk
- Erosion and channel stability (Pfankuch stream stability assessment)
- Ecological benefit (MPCA method)
- Water quality
- Watershed benefits
- Public education
- Partnership opportunities
- Project cost per pound of phosphorus per foot of stream

Scores for each category were necessary to compare reaches and sub-reaches in an objective way. Each category was assigned points based on the severity of the condition. A score of 1, 3, 5, or 7 was given to each category such that a score of 1 was best (i.e., no degradation) and a score of 7 was worst (i.e., significant degradation). Specific scoring criteria are further described in the following sections.

Discussions, both with TAC and CAC members and internally between District staff and Barr staff, considered the pros and cons of weighting each category equally versus weighting one or more categories more than others. The initial discussions with the TAC and CAC members found that there was general consensus that equal weighting of all is most fair given the fact that different stakeholders had different priorities. Additional analysis by District staff and Barr staff following the initial discussions with the TAC and CAC found that a pseudo-weighting system via a tiered system helped to prioritize the typical key drivers of stream projects. The tiered system was endorsed by the TAC and CAC in a subsequent meeting. Additional information about the tiers and TAC and CAC meetings are available in Sections 3.2 and Section 4.0, respectively.

3.1.1 Infrastructure Risk

Infrastructure risk is a critical category in prioritizing stabilization/restoration projects because public safety is a top priority in our communities. Inadequate or aging public infrastructure can also contribute to degraded water quality. For example, aging culverts may be deteriorating, which can result in bank erosion, increasing the risk of a road washout and, thereby, also contributing sediment and phosphorus loading to downstream waters. In this case, infrastructure may include public infrastructure such as roads, bridge, sanitary sewers, or storm sewers. It may also include utilities (gas, electric, etc.) or private infrastructure such as houses and outbuildings. Addressing an acute risk to public infrastructure related to creek erosion also presents an opportunity to take advantage of economies of scale and complete additional restoration in the vicinity or along the access path needed to repair the infrastructure risk.

Table 3-1 summarizes scoring criteria for infrastructure risk. Higher scores indicate more significant threat to infrastructure. It should be noted that the scores and threat levels assigned to infrastructure are based on a quantitative assessment from District and Barr staff and do not reflect the results of in-depth engineering analyses to determine the stability at each individual location. An in-depth engineering analysis would be needed as part of future feasibility efforts.

Table 3-1 Infrastructure Risk Scoring Criteria

Score	Description[1]
1	No threat to infrastructure
3	Long-term threat
5	Medium-term threat
7	Short-term threat

[1] Threat levels do not represent the results of an in-depth engineering analysis regarding the risks of failure at individual sites.

3.1.2 Erosion and Channel Stability

Streams naturally migrate through the landscape, transporting sediment from upstream to downstream. Stable streams are often referred to as being in “dynamic equilibrium” with their respective watersheds. Even with the best efforts to manage stormwater and runoff, development alters hydrology, which disrupts the dynamic equilibrium between the stream and its watershed. Moderate and severe disruptions can cause significant channel and bank instability, contributing to water quality degradation and the amount of sediment and phosphorus entering into the District’s lakes, creeks, and eventually to the Minnesota River.

The severity of channel erosion and stability was assessed using the Modified Pfankuch Channel Stability Rating Procedure (Pfankuch, 1975). Stream reaches were divided into sub-reaches, as appropriate, and scored using the Pfankuch assessment, which is based on evaluating the upper banks, lower banks, and bed of the stream considering the stream type as identified by the Rosgen Classification System (Rosgen, 1994). A higher Pfankuch score represents a more degraded, less stable stream. Ranges of Pfankuch scores for each stream type were associated with CRAS scoring categories, as shown in Table 3-2. A sample Pfankuch data sheet can be found in Appendix A.

Table 3-2 Erosion and Channel Stability Scoring Criteria

Score	Description	Rosgen Stream Type					
		B-5	C-4/C-5	E-5	E-6	F-4	F-6
1	Very stable	48-57	70-79	50-62	40-51	85-97	80-87
3	Moderately stable	58-68	80-90	63-75	52-63	98-110	88-95
5	Moderately unstable	69-88	91-110	76-96	64-86	111-125	96-110
7	Unstable	89+	111+	97+	87+	126+	111+

3.1.3 Ecological Benefit

Streams are utilized by a variety of organisms that are both important to the ecosystem and provide viewing and educational opportunities for District community members. The MPCA's MSHA was used to score each sub-reach based on a variety of stream habitat characteristics, including both in-stream and riparian features. The lower the habitat rating, the more degraded the habitat was in a particular sub-section, resulting in greater potential benefit that could be gained from a restoration project. Ecological benefit scoring criteria are included in Table 3-3. A sample MSHA data sheet can be found in Appendix A.

Table 3-3 Ecological Benefit Scoring Criteria

Score	MSHA Score	Habitat Quality
1	76-100	Excellent
3	51-75	Good
5	26-50	Fair
7	1-25	Poor

3.1.4 Water Quality

This category uses water quality data from the past five years to assess the status of the water quality within each of the major reaches. Data include but are not limited to: total phosphorus (TP), total suspended solids (TSS), water temperature, dissolved oxygen, pH, chloride, and the MPCA impairment status. Recent water quality data were compared to the river eutrophication standards set by the MPCA in 2014 and scored accordingly. As shown in Table 3-4, the higher the score in this category, the more degraded the water quality.

Table 3-4 Water Quality Scoring Criteria

Score	Description
1	No impairments and water quality parameters are well below set standards
3	No impairments, but water quality parameters are consistently near or infrequently exceed the maximum allowed by the MPCA.
5	On the verge of being impaired with chronic water quality violations.
7	Reach is impaired and has water quality parameters consistently above the MPCA set standards

In locations where a particular reach did not have reach-specific water quality data available, water quality from the closest downstream monitoring location was used.

3.1.5 Watershed Benefits

The District recognizes that some projects have notable benefits that extend beyond the stream reach and across the watershed. For example, a stabilization project completed at a headwater location on a stream may provide greater benefit by directly or indirectly improving or preserving the downstream reaches of a stream.

Watershed benefit was scored based on the percent of the watershed downstream from a reach. As shown in Table 3-5, a higher score in this category corresponds to sites closer to the headwaters of a stream, which may have greater positive effects for the entire watershed if improved. The more potential benefits a project on a particular reach could generate, the higher the score.

Table 3-5 Watershed Benefits Scoring Criteria

Score	Ratio Range	Description
1	<25%	Limited watershed benefits
3	25-49%	Low to middle watershed benefits
5	50-74%	Middle to high watershed benefits
7	75% or greater	Significant watershed benefits, headwater site location

3.1.6 Public Education

Spreading awareness of projects and their benefits to residents and users of the watershed is a key component of the District's Plan. The ability to create conversations and engage the public about how the District is improving water resources has the potential to increase water resource stewardship and implementation of best management practices within the community. The potential for project sites to serve as educational resources to the public (through use of signage and interpretive materials) and increase overall awareness of District efforts is another consideration in prioritizing stabilization and/or restoration efforts.

Public education potential is highest at the most visible and accessible stream reaches, specifically those located on or adjacent to public lands such as parks and trails. As shown in Table 3-6, sites with greater public education potential are ranked higher.

Table 3-6 Public Education Scoring Criteria

Score	Description
1	Stream reach is located entirely on private property and access would be limited almost exclusively to surrounding private residents
3	Stream reach is accessible by private residents with parts of the reach available to the public
5	Stream reach is in a park or other public land but is not easily accessible
7	Stream reach is on public land that is highly visible and accessible by the public (i.e. adjacent to a trail)

3.1.7 Partnership Opportunities

The ability to partner with local groups and agencies within the District is important because it spreads out costs, builds working relationships between different groups, and allows additional resources for larger and more comprehensive projects to be implemented and effectively managed. Partnership scoring criteria are outlined in Table 3-7.

Table 3-7 Partnership Opportunities Scoring Criteria

Score	Partnership Opportunities
1	No partnership
3	Partner
5	Multiple partners
7	Partner(s) with financial support

3.1.8 Project Cost per Pound of Phosphorus per Foot

The cost associated with a project on each reach/sub-reach may vary significantly and is a factor to consider when deciding which projects to implement. Similarly, the volume of erosion occurring on each reach varies significantly. The cost to complete construction in one particular reach may be high; however it may have significant benefits because the sediment loading from that reach is also high. Similarly, a low cost reach may have very low sediment loading. In order to develop a means to compare the costs between reaches, erosion and cost estimates were developed to generate an estimated cost per cubic yard of sediment for each reach. Sections 3.1.8.1 and 3.1.8.2 describe the methods to generate sediment loading and planning level costs for each reach.

The data and information used to generate this score are all estimates, and the following sections describe how these estimates were generated. Each estimate includes a potential for error, so using multiple estimates has the potential to compound estimate errors. Descriptions of future work in Section 6 describe ways to help reduce the error for these variables in the future. The measurement of cost/lb. P/ft. was established for planning purposes only and has been normalized to allow for relative comparison across reaches.

The estimates for sediment loading and costs both include ranges. In order to keep the analysis from being overly complicated, averages from the respective ranges were used to generate a single estimate for this category. It was assumed that the life of a stream restoration project is 20 years; so the sediment loading per foot per year was multiplied by 20 to account for sediment loading prevented through the life of the project. It was also assumed that each cubic yard of sediment contains 0.04 pounds of phosphorus, which is the computed quantity phosphorus from one cubic yard of silt in one year in the Pollution Reduction Estimator spreadsheet from the Minnesota Board of Water and Soil Resources (BWSR) (MN BWSR, 2010). The result of these assumptions and simplifications results in the cost per pound of phosphorus per foot as shown in Table 3-8.

Table 3-8 Project Cost per Pound of Phosphorus per Foot Scoring Criteria

Score	Project Cost
1	High estimated cost per cubic yard of sediment per foot of stream; greater than $100 per pound of phosphorus per foot of stream.
3	Medium-high cost per cubic yard of sediment per foot of stream; $50-$99 per pound of phosphorus per foot of stream.
5	Medium-low cost per cubic yard of sediment per foot of stream; $25-$49 per pound of phosphorus per foot of stream.
7	Low cost per cubic yard of sediment per foot of stream; less than $25 per pound of phosphorus per foot of stream.

3.1.8.1 Sediment Loading Rates

During the assessment of each sub-reach, field staff took notes to document the erosion present on each reach, including bank heights, height of erosion, the percentage of each reach that appeared to be actively eroding, and the dimensions of any mass wasting locations where adjacent hill slopes or tall banks have experienced larger failures that are notably larger than typical bank erosion locations. These estimates provided an area of erosion for each sub-reach.

Table 3-9 shows erosion and channel stability scores from Tier I correlated to estimated erosion rates such that Tier I erosion and channel stability scores of 1, 3, 5, and 7 were given the erosion rates of “slight,” “moderate,” “severe,” and “very severe,” respectively. Erosion rates from Wisconsin NRCS (2003) were modified to be consistent with erosion rates measured by the City of Eden Prairie using bank pins (Wenck, 2014a and 2014b).

Table 3-9 Correlation between Erosion and Channel Stability and Erosion Rates

Erosion Category	Erosion and Channel Stability Score	Erosion Rate Range (ft./yr.)[1]	Description
Slight	1	0.01 – 0.05	Some bare banks, but little active erosion is apparent
Moderate	3	0.035 – 0.1	Banks mostly bare with some rills and vegetative overhang. Some exposed tree roots
Severe	5	0.075 – 0.25	Banks are bare with rills and severe vegetative overhang. Exposed tree roots and some fallen trees.
Very Severe	7	0.1 – 0.5	Banks are bare with gullies and severe vegetative overhang. Many fallen trees. Obvious bank erosion is common.

[1] Assumed erosion rates based on limited bank pin data (Wenck 2014a and 2014b) and published rates from WI NRCS (2003).

3.1.8.2 Screening Level Cost Estimates

Screening level cost estimates were developed for the sub-reaches assessed in the CRAS. The cost estimates are an anticipated cost per foot of stream stabilization/restoration and include design, permitting, construction, and construction management in 2017 US dollars. The cost per foot is based on Barr's project experience and guidelines in ASTM (2006) and AACE (2005). The key considerations include:

- Site access
- Bank height
- Riparian vegetation
- Floodplain topography
- Infrastructure risks/components
- Potential for significant geotechnical input and solutions.

The screening costs were developed on a per foot basis because specific potential project extents have not yet been defined. Furthermore, sub-reaches in the CRAS are not of uniform length, so a cost per foot basis the most appropriate way to compare costs between sub-reaches within RPBCWD.

Costs associated with Base Planning Engineering and Design (PED) are based on percentages of estimated construction cost and are within a range similar to those used in past projects designed by Barr. Costs associated with Construction Management (CM) are based on estimated costs to manage the construction process, based on Barr's experience with similar projects, but may change depending on the services that are provided during construction. The cost estimates also include percentage-based costs for permitting and regulatory approvals, which are intended to account for additional planning, coordination, and mitigation costs that are likely to be incurred as the project is permitted with environmental agencies.

The screening costs include tasks and items related to engineering and design, permitting, constructing each conceptual design, and vegetation monitoring. The opinions of cost do not include other tasks following construction of each alternative presented such as operations and maintenance, or other forms of monitoring.

Industry resources for cost estimating (*AACE International Recommended Practice No. 18R-97, and ASTM E2516-06 Standard Classification for Cost Estimate Classification System*) provide guidance on cost uncertainty, depending on the level of project design developed. The screening costs for the CRAS generally corresponds to a Class 5 estimate characterized by completion of limited engineering and use of deterministic estimating methods. As the level of design detail increases, the level of uncertainty is reduced. Figure 3-1 provides a graphic representation of how uncertainty (or accuracy) of cost estimates can be expected to improve as more detailed design is developed.

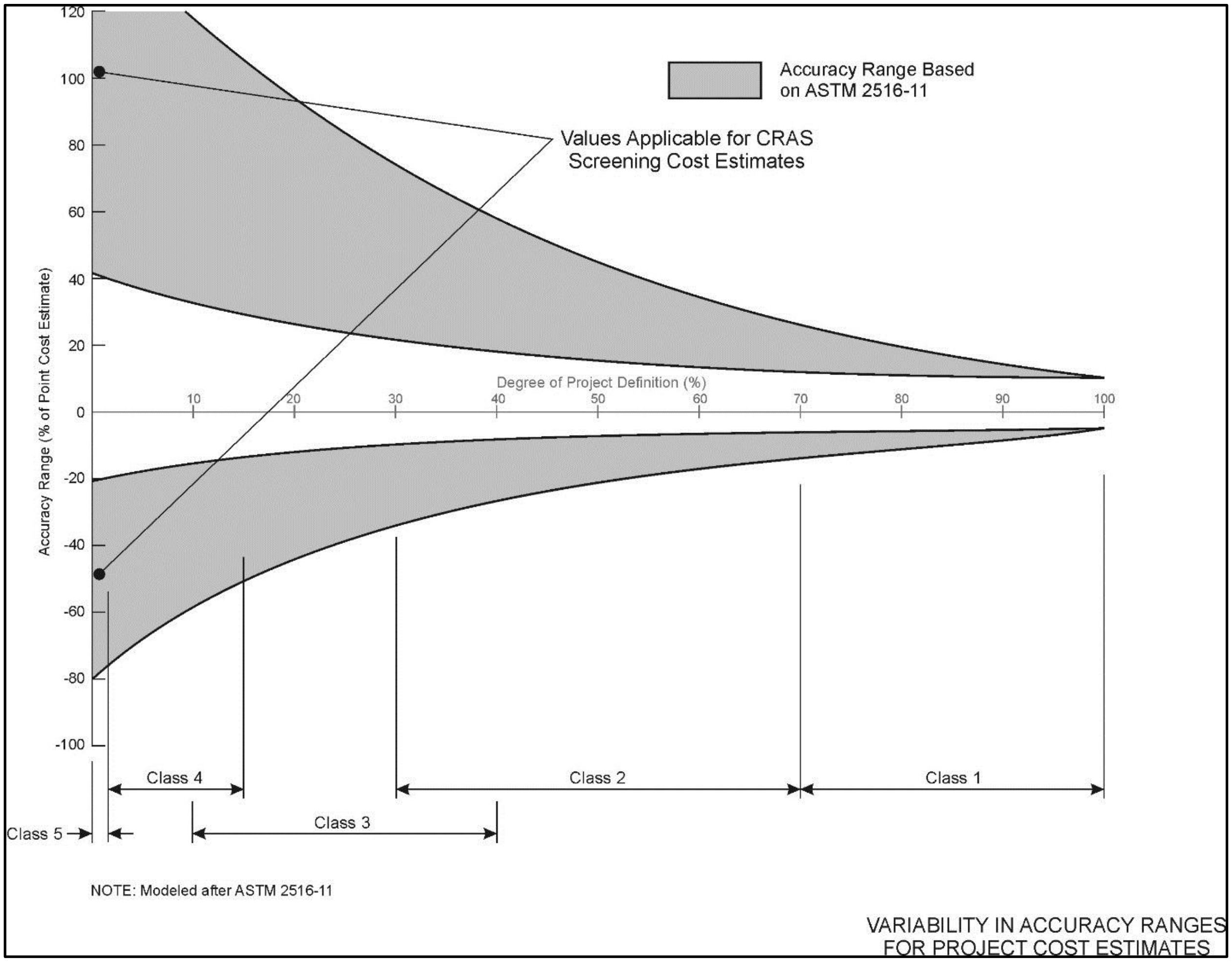

Figure 3-1 Relationship between Cost Accuracy and Degree of Project Definition

At this early stage of design, the range of uncertainty of total project cost is very high. Due to the early stage of design, it is standard practice to place a broad accuracy range around the point cost estimate.

The accuracy range is based on professional judgment considering the level of design completed, the complexity of the project, and the uncertainties in the project scope; the accuracy range does not include costs for future scope changes that are not part of the project as currently defined or risk contingency. The estimated accuracy range for this point estimate is -50% to +100%.

The screening level cost estimate per foot of stream (Table 3-10) is made on the basis of Barr Engineering's experience and qualifications and represents our best judgment as experienced and qualified professionals familiar with similar projects. The screening level cost estimate may change as more information becomes available and further design is completed. In addition, because Barr Engineering has no control over the eventual cost of labor, materials, equipment or services furnished by others, or over the contractor's methods of determining prices, or over competitive bidding or market conditions, Barr Engineering cannot and does not guarantee that proposals, bids, or actual costs will not vary from the screening level cost estimates in this report. Adding greater assurances as to the probable cost would require more time and effort. It was determined that a high level evaluation fit the needs of this study and that more detailed estimated could be done as necessarily.

Table 3-10 Ranges of Cost Estimates per Foot for Stream Restoration Projects

Cost Range per foot	Considerations
$200-250	Uncomplicated project, low eroded bank heights, easy access.
$250-300	Uncomplicated project, low to medium eroded bank heights, easy to moderate access difficulty
$300-350	Medium effort for design and/or construction, minor geotechnical or other technical considerations, medium to high eroded bank heights, moderate to difficult access
>$350	High effort for design or construction, major geotechnical or other technical considerations, medium to high eroded bank heights, difficult access

3.2 Evaluation Levels

During the first TAC and CAC meetings, much of the discussion centered on the categories to be used in the CRAS and the relative values of such categories. The basic questions fueling the discussion were "Should category X be included and, if so, should it get the same weight or value as category Y?" Different stakeholders had differing opinions about which category(s) should be weighted more than others. Ultimately there was a general consensus that each category should maintain the same scoring system. As discussed earlier, additional analysis by District staff and Barr staff following the initial discussions with the TAC and CAC found that a pseudo-weighting system via a tiered system helped to prioritize the typical key drivers of stream projects. The tiered system was endorsed by the TAC and CAC in a subsequent meeting. Additional information about the tiers and TAC and CAC meetings is available in Section 4.0.

The discussions with the TAC and CAC helped identify the categories that appeared to be most important to most TAC and CAC members. With that input and with consideration of District goals, a tiered scoring system was developed with the CRAS categories as described in the following sections.

3.2.1 Tier I Categories and Scoring

Tier I categories are those factors that affect public health and safety, align with goals in the District's Plan, and represent the key reasons why stream restoration projects are undertaken. These categories include:

- infrastructure risk
- erosion and channel stability
- ecological benefit
- water quality

Tier I categories were considered for all stream reaches evaluated and assessed based on a combination of desktop review of existing data and field evaluations. Each category in Tier I was assigned points based on the severity of degradation or the importance of the individual category to either the public or the District.

The goal of the Tier I scoring was to determine which sub-reaches are most degraded and in need of stabilization and/or restoration using scientific assessment and identifying infrastructure vulnerabilities. The results of the scoring generated a list of sub-reaches that can be divided in to low, medium, high, and severe levels of need to complete a stabilization and/or restoration project. Higher scores corresponded to either greater risk of degradation if left unrestored or greater benefit (i.e., reduced degradation) if restored. Tier I category scores were combined into a total score, allowing reaches to be grouped and ranked according to four prioritization classes, as shown in Table 3-11.

Table 3-11 Tier I Scoring Summary

Score	Priority Class	Description
≤12	Low	Lowest priority reach, no restoration efforts needed; less than 50% of possible points
13-17	Medium	Low priority reach, possible benefit from restoration in scattered sub-reaches of main reach; 50-74% of possible points
18-21	High	Restoration needed and could notably reduce infrastructure risk or improve stream health; 75-90% of possible points
≥22	Severe	Highest priority reach, immediate stabilization and/or restoration project needed; > 90 % of possible points

3.2.2 Tier II Categories and Scoring

Tier I categories are those that are primary drivers of why restoration projects are typically done. However, there are a number of factors that provide supporting benefits to a project. This study identified factors that provide supporting benefit as Tier II categories. If several reaches receive the same score in the Tier I process, Tier II category scores may be used to provide a finer level of differentiation.

Once higher priority stream reaches were identified by the Tier I process, Tier II categories were used to apply additional considerations for prioritization, allowing a finer level of detail to differentiate between stream reaches of similar priority level. Tier II categories include:

- watershed benefits
- public education,
- partnership opportunities
- project cost per pound of phosphorus

District and Barr staff reviewed many different combinations of arithmetic with Tier I and Tier II scores, and it was concluded that the simple addition of the Tier II scores with all categories weighted equally provided the most clear and simple means of incorporating all categories.

Tier II score = (Total Tier I score) + public education + watershed benefits + partnerships + project cost per pound of phosphorus

As described above, Tier II scores were used to apply additional considerations for prioritization within the severity levels determined in Tier I. The Tier I scores are used to determine “severe,” “high,” “moderate,” and “low” priority reaches for stabilization. The Tier II categories are used to reprioritize the reaches within each of the categories. Therefore, all reaches classified as “severe” reaches will remain as top priority reaches, and it will not be possible for reaches in the “high” or even “moderate” categories to jump into a “severe” reach because they score particularly well on the Tier II categories.

The results of the scoring are shown in detail in Section 5.0.

4.0 TAC and CAC Meetings

4.1 TAC Meetings

The CRAS project approach was presented at the Technical Advisory Committee (TAC) meeting on February 18, 2015. The TAC members included city representatives from our community as well as from the Minnesota Department of Natural Resources, BWSR, Hennepin County and Lower Minnesota Watershed District. The objectives of this meeting were to solicit feedback from the TAC on the proposed scoring criteria and to request information about additional sources of information available from TAC members that could be used to develop CRAS scoring. During this meeting, the CRAS project was introduced, prioritization categories and strategy were presented, and there was the opportunity for questions and feedback. Suggestions from the TAC were incorporated into the final CRAS approach. The most significant change included the addition of a "Watershed Benefits" prioritization category, which would allow the CRAS to factor in the importance of certain projects that will be more beneficial to the watershed as a whole, meaning that projects occurring farther upstream will have more benefit to the water bodies within the watershed than projects occurring farther downstream. Discussion also occurred about the potential for a weighted scoring methodology for certain categories; however, it was determined that weighting all prioritization categories equally would be most appropriate. Overall the TAC was supportive of the CRAS study, and members emphasized the importance of continuing with the project into the future with diligent updating in order for the study to remain effective.

A second meeting was held on June 10, 2015 with the purpose of soliciting feedback from the TAC in regards to the preliminary findings of the CRAS. The CRAS assessment criteria was briefly reviewed, changes made within Tier II were explained, results of both Tier I/Tier II including a summary table and associated figures were presented, and future work associated with the further development of the CRAS was discussed. TAC discussion involved the combination and coordination of both Tier I and Tier II rankings instead of one Tier having a final ranking over the other. Additionally, the TAC suggested looking into more measurable benefits caused by the implementation of projects. Overall the TAC was supportive of the CRAS findings and recognized the CRAS as an effective tool for applying for grants in the future.

4.2 CAC Meetings

The CRAS project was also presented at the March 16, 2015 Citizen Advisory Committee (CAC) meeting. The purpose of this meeting was to solicit feedback from the CAC on the development of the CRAS. The CRAS project was introduced, prioritization categories were explained, and an example applying a stream reach to the CRAS scoring categories was presented. CAC members were also invited to ask questions regarding the CRAS goals and development. Discussion points included different options of weighted scoring methodology similar to ideas brought up by the TAC, the emphasis of the importance of protecting the "good" stream sub-reaches identified, and the possibility of volunteers to assist with the stream walks. Additionally, the CAC expressed interest in creating a similar tool for lakes within the Watershed District. Through the discussion it was again determined that weighting all prioritization categories equally was most appropriate. The CAC was very supportive of the CRAS methodology.

A second meeting was held on June 15, 2015 with the purpose of soliciting feedback from the CAC in regards to the preliminary findings of the CRAS. During the meeting, the CRAS assessment criteria was briefly reviewed, changes made within Tier II were explained, results of both Tier I/Tier II including a summary table and associated figures were presented, and future work associated with the further development of the CRAS was discussed. Overall the CAC was supportive of the study and highlighted the importance of having such an analysis of streams within the Watershed District. Limited discussion occurred after the presentation and mainly focused on how the CRAS would be incorporated into the District's Plan in the future.

5.0 Results

5.1 Field Assessments

District staff completed walks of most reaches of the three major creeks between the fall of 2013 and the fall of 2016, with most of the assessments completed in the fall of 2014 and spring of 2015. Additional assessments were completed in 2016 to fill in gaps or update scores originally developed from past photographs. Figure 5-1 shows the reaches that were walked and directly assessed between 2013 and 2016.

For those reaches not walked, available photos from past studies and inventories were used to complete initial scoring for all reaches except sub-reaches B2B, B4B, and B4E. These reaches flow through grassy and marshy areas; so it is assumed that the risk of erosion along these reaches is relatively minor. The Bluff Creek Total Maximum Daily Load (TMDL) study was used to evaluate Bluff Creek Reach 1, and the Riley Creek Lower Valley study was used to evaluate Reaches 1 and 2 on Riley Creek. All reaches not evaluated in the field between 2013 and 2016 are high priorities for field evaluations over the next year.

In the process of walking and evaluating the creeks, District staff divided the major reaches into sub-reaches in order to provide more accurate summaries of the relative condition of different segments of each creek. A total of 93 sub-reaches were defined through this process, as shown on Figure 5-2, with scores developed for the 88 reaches that were fully assessed. The boundaries of a sub-reach were defined in multiple ways, including but not limited to the following:

- Stream crossings,
- Obvious changes to the characteristics of the stream and surrounding area, with respect to channel shape, valley shape, or surrounding vegetation,
- Observed locations where erosion issues begin or end.

Some sub-reaches are quite long when the creek may go through a lengthy stretch of consistent characteristics; however in some places the sub-reaches can be comparatively short. Short sub-reaches most often occurred when there were frequent changes to the stream either through crossings or moving into or out of wetland complexes.

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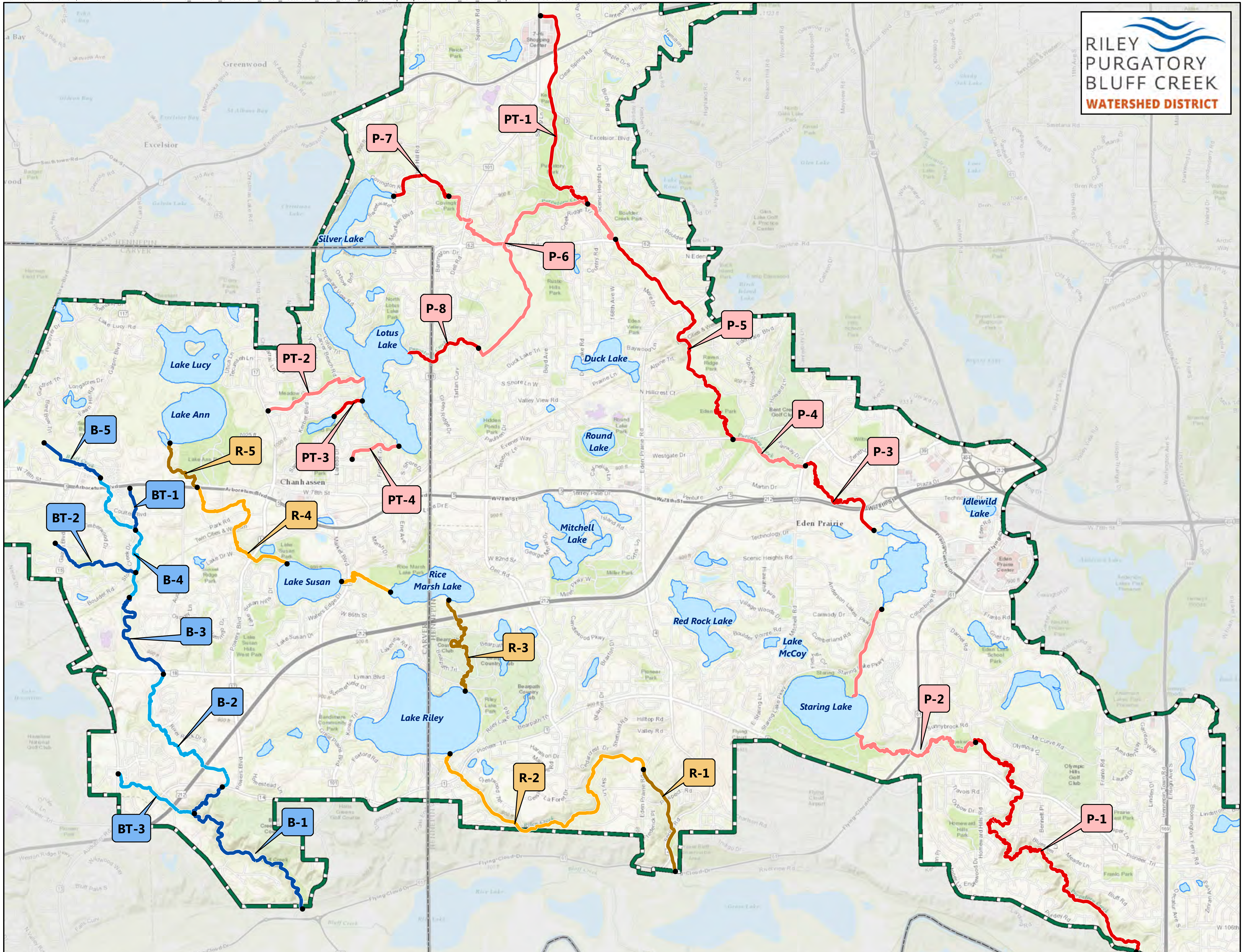

LEGEND

Reaches Directly Assessed in 2013 - 2016

- Bluff Creek
- Purgatory Creek
- Riley Creek
- Lakes
- Watershed District Boundary

N

Feet

4,000 0 4,000

Meters

1,200 0 1,200

Figure 5-1 REACHES ASSESSED : 2013-2016

Creek Restoration Action Strategy
Riley Purgatory Bluff Creek
Watershed District

5.2 Tier I Results

The Tier I scoring described in Section 3.0 was applied to all reaches with available data. The majority of the reaches had overall Tier I scores within the moderate/low and poor/high rating, meaning notable benefits could be derived stream improvements in these locations. Table 5-1 provides a summary of the number and percentages of sub-reaches rating within each category.

Table 5-1 Summary of Tier I Results by Category and Total Score

Rating	Infrastructure Risk	Erosion and Channel Stability	Ecological Benefit	Water Quality	Tier I Score
Good/Low	64 (70%)	21 (24%)	4 (4%)	1 (1%)	20 (23%)
Moderate/Low	18 (20%)	18 (21%)	18 (21%)	11 (12%)	33 (38%)
Poor/High	6 (6%)	27 (31%)	60 (68%)	40 (44%)	25 (28%)
Severe	4 (4%)	22 (25%)	6 (7%)	38 (42%)	10 (12%)

Scores for each sub-reach evaluated are tabulated in Table 5-2 on the following page. As shown above in Table 5-2 and Figures 5-2 through 5-5 on following pages, ten sub-reaches qualify for the severe classification. Brief summaries of each of these nine reaches are included in Appendix B.

Table 5-2 Tier I Scores

Reach	Subreach	Rank	Location	Infrastructure Risk	Pfankuch Summary	MSHA Summary	Water Quality Summary	Tier I Scores
B1	B1D	1	475 feet Upstream of Great Plains Boulevard to Great Plains Boulevard	7	7	5	7	26
R2	R2E	2	Middle Third between Dell Road and Eden Prairie Road	7	7	5	7	26
B5	B5C	3	Galpin Boulevard to West 78th Street	5	7	5	7	24
P1	P1E	4	1,350 feet Downstream of Pioneer Trail to Burr Ridge Lane	7	7	3	5	22
BT3	BT3A	5	Audubon Road to Pioneer Trail	3	7	5	7	22
R2	R2D	6	Upper Third between Dell Road and Eden Prairie Road	3	7	5	7	22
B3	B3A	7	750 feet Downstream of Railroad to 860 feet Downstream of Railroad	1	7	7	7	22
B5	B5B	8	985 feet Upstream of Galpin Boulevard to Galpin Boulevard	1	7	7	7	22
P7	P7E	9	Covington Road to Pond in Covington Park	7	5	5	5	22
B3	B3C	10	1,675 feet Upstream of Audubon Road to Lyman Boulevard	3	5	7	7	22
R4	R4D	11	Railroad Bridge to Powers Boulevard	5	7	5	3	20
P1	P1F	12	Burr Ridge Lane to 1,250 feet Upstream of Riverview Road	3	7	5	5	20
B1	B1B	13	2,150 feet Downstream of Pioneer Trail to 300 feet Upstream of Bluff Creek Park	1	7	5	7	20
BT3	BT3C	14	Bluff Creek Drive to Bluff Creek	1	7	5	7	20
R1	R1B	15	1,700 feet Downstream of Eden Prairie Road to Spring Road	1	7	5	7	20
R1	R1C	16	Spring Road to Flying Cloud Drive	1	7	5	7	20
R2	R2C	17	720 feet Upstream of Dell Trail to Dell Road	1	7	5	7	20
R2	R2F	18	Lower Third between Dell Road and Eden Prairie Road	3	5	5	7	20
BT1	BT1A	19	Arboretum Boulevard to Bluff Creek	1	5	7	7	20
B1	B1C	20	300 feet Upstream of Bluff Creek Park to 475 feet Upstream of Great Plains Boulevard	1	7	3	7	18
P1	P1B	21	380 meters Downstream of Homeward Hills Road to Pioneer Trail	3	7	3	5	18
R4	R4E	22	Powers Boulevard to Lake Susan	3	7	5	3	18
P4	P4B	23	Bent Creek Golf Club to Mitchell Road	1	7	5	5	18
R4	R4A	24	Highway 5 to Park Drive	5	5	5	3	18
R4	R4C	25	Park Road to Railroad Bridge	5	5	5	3	18
BT2	BT2B	26	Gaplin Boulevard to Bluff Creek	3	5	3	7	18
B2	B2A	27	Lyman Boulevard to Bluff Creek Boulevard	1	5	5	7	18
B3	B3B	28	860 feet Downstream of Railroad to 1,675 feet Upstream of Audubon Road	1	5	5	7	18
B4	B4D	29	350 feet Downstream of Stone Creek Drive to 950 feet Downstream of Stone Creek Drive	1	5	5	7	18
B4	B4F	30	530 feet Upstream of Railroad to 750 feet Downstream of Railroad	1	5	5	7	18
R1	R1A	31	Eden Prairie Road to 1,700 feet Downstream of Eden Prairie Road	1	5	5	7	18
R2	R2A	32	Lake Riley to 3,000 feet downstream of Lake Riley	1	5	5	7	18
R2	R2B	33	3,000 feet downstream of Lake Riley to 720 feet upstream of Dell Road	1	5	5	7	18
R3	R3A	34	Rice Marsh to Northern Portion of Bearpath Country Club	1	5	5	7	18
BT3	BT3B	35	Pioneer Trail to Bluff Creek Drive	3	3	5	7	18
P1	P1D	36	2,950 feet Downstream of Pioneer Trail to 1,350 feet Downstream of Pioneer Trail	1	7	3	5	16
P2	P2A	37	Purgatory Creek Conservation Area to Staring Lake	1	7	5	3	16
P1	P1C	38	Pioneer Trail to 2,950 feet Downstream of Pioneer Trail	3	5	3	5	16
P3	P3A	39	Mitchell Road to 1,375 feet upstream of Highway 212	3	5	3	5	16
P1	P1G	40	1,250 feet Upstream of Riverview Road to Riverview Road	1	5	5	5	16
P8	P8C	41	Tartan Curve to Duck Lake Trail	1	5	5	5	16
PT2	PT2C	42	Kerber Boulevard to Carver Beach Road	1	5	5	5	16
R3	R3D	43	Lake Riley to 250 feet Downstream of Bearpath Trail Bridge	3	3	3	7	16
B1	B1A	44	Pioneer Trail to 2,150 feet Downstream of Pioneer Trail	1	5	3	7	16
BT2	BT2A	45	380 feet Upstream of Galpin Road to Galpin Boulevard	1	3	5	7	16
R3	R3B	46	Northern Portion of Bearpath Country Club to 260 feet Upstream of Bearpath Trail Bridge	1	3	5	7	16
R3	R3C	47	260 feet Upstream of Bearpath Trail Bridge to 250 feet Downstream of Bearpath Trail Bridge	1	3	5	7	16
P7	P7C	48	220 feet Upstream of Vine Hill Road to Vine Hill Road	5	1	5	5	16
B2	B2E	49	830 feet Downstream of Highway 212 to Pioneer Trail	3	1	5	7	16
B4	B4C	50	Stone Creek Drive to 350 feet Downstream of Stone Creek Drive	1	1	7	7	16
B5	B5A	51	Ridgeview Road Recreational Trail to 985 feet Upstream of Galpin Boulevard	1	1	7	7	16
P2	P2B	52	Staring Lake to Flying Cloud Drive	1	7	3	3	14
P1	P1A	53	Homeward Hills Road to 380 meters Downstream of Homeward Hills Road	1	5	3	5	14
P3	P3B	54	1,375 feet Upstream of Highway 212 to Purgatory Creek Conservation Area	1	5	3	5	14
P2	P2C	55	Flying Cloud Drive to Creek Knoll Road	1	5	5	3	14
P6	P6C	56	175 feet Downstream of Highway 101 to Highway 62	3	3	3	5	14
P6	P6E	57	Highway 62 to 985 feet Upstream of Scenic Heights Drive	3	3	3	5	14
R4	R4B	58	Park Drive to Park Road	3	3	5	3	14
P4	P4A	59	Valley View Road to Bent Creek Golf Club	1	3	5	5	14
P5	P5D	60	1500 feet Downstream of Railroad to 3550 feet Downstream	1	3	5	5	14
P8	P8B	61	Chanhassen Road to Tartan Curve	1	3	5	5	14
PT1	PT1A	62	Highway 101 to 430 feet Downstream of Highway 7	1	3	5	5	14
PT1	PT1B	63	430 feet Downstream of Highway 7 to North Portion of Purgatory Park	1	3	5	5	14
PT1	PT1C	64	North Portion of Purgatory Park to Stadola Road	1	3	5	5	14
PT1	PT1D	65	Stadola Road to Purgatory Creek	1	3	5	5	14
B2	B2D	66	Highway 212 to 830 feet Downstream of Highway 212	3	1	3	7	14
B2	B2C	67	1,750 feet Upstream of Highway 212 to Highway 212	1	1	5	7	14
B4	B4A	68	West 78th Street to 485 feet Downstream of Highway 5	1	1	5	7	14
PT2	PT2A	69	Powers Boulevard to 1,000 feet Downstream of Powers Boulevard	1	5	1	5	12
PT2	PT2B	70	1,000 feet Downstream of Powers Boulevard to Kerber Boulevard	1	5	1	5	12
P2	P2D	71	Creek Knoll Road to 1,725 feet Downstream of Creek Knoll Road	1	5	3	3	12
P2	P2E	72	1,725 feet Downstream of Creek Knoll Road to Homeward Hills Road	1	3	5	3	12
R4	R4F	73	Lake Susan to Rice Marsh Lake	1	3	5	3	12
P5	P5A	74	Highway 62 to Eden Prairie Road	1	1	5	5	12
P5	P5B	75	Eden Prarie Road to Railroad	1	1	5	5	12
P5	P5C	76	Railroad to 1500 feet Downstream	1	1	5	5	12
P5	P5E	77	3550 feet Downstream of Railroad to Valley View Road	1	1	5	5	12
P6	P6B	78	190 feet Upstream of Highway 101 to 175 feet Downstream of Highway 101	1	1	5	5	12
P6	P6F	79	985 feet Upstream of Scenic Heights Drive to Highway 62	1	1	5	5	12
P7	P7A	80	Silver Lake to Covington Road	1	1	5	5	12
P7	P7D	81	Vine Hill Road to Covington Road	1	1	5	5	12
P8	P8A	82	Lotus Lake to Chanhassen Road	1	1	5	5	12
P8	P8D	83	Duck Lake Trail to Dell Road	1	1	5	5	12
PT2	PT2D	84	Carver Beach Road to Lotus Lake	1	1	5	5	12
R5	R5	85	Lake Ann to Highway 5	3	3	3	1	10
P6	P6D	86	Dell Road to CR 62	1	1	3	5	10
PT3	PT3A	87	Kerber Pond to Lotus Lake	1	1	1	5	8
PT4	PT4A	88	Santa Fe Trail to Lotus Lake	1	1	1	5	8

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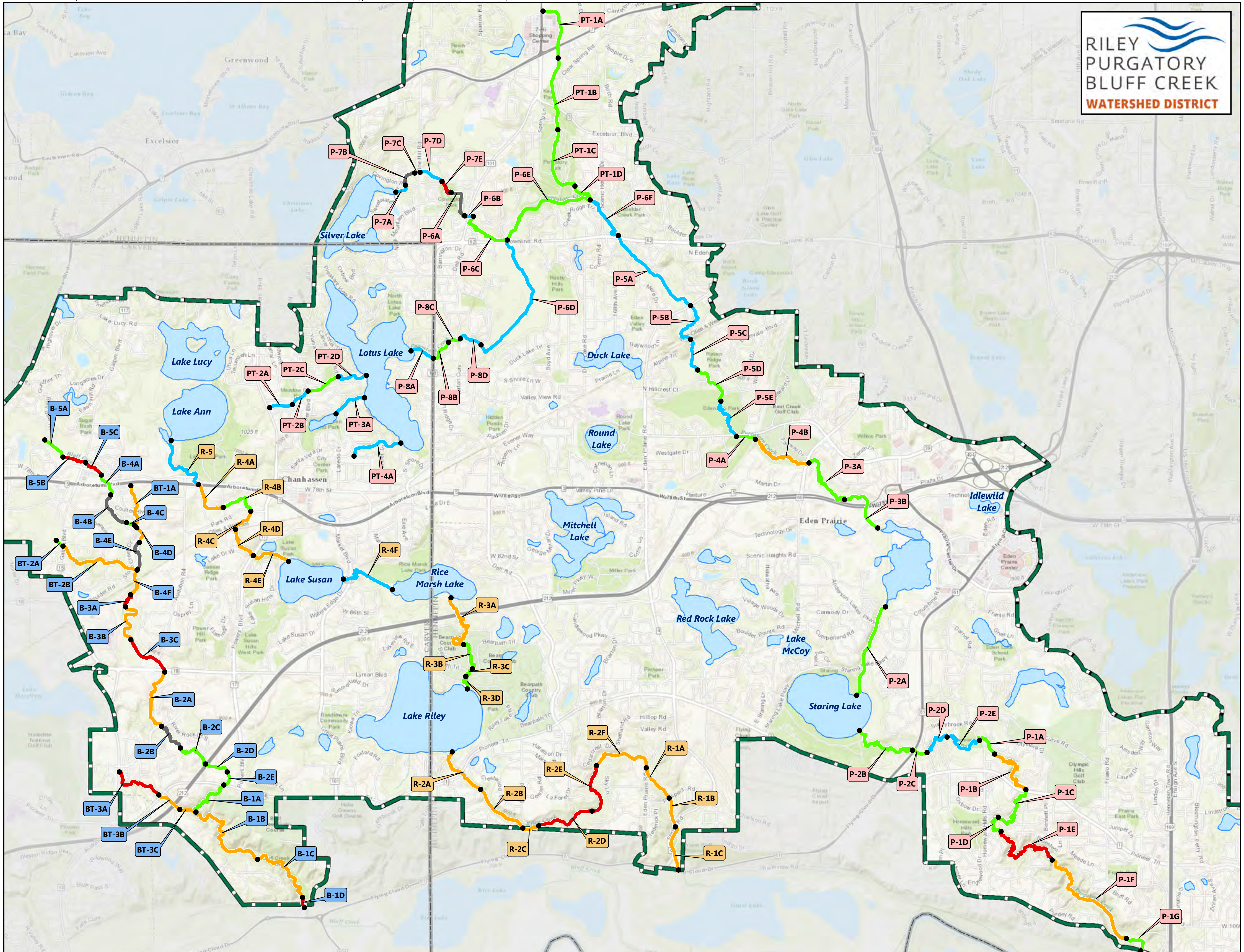

FIGURE 5-2 TIER 1 SCORES
Creek Restoration Action Strategy
Riley Purgatory Bluff Creek
Watershed District

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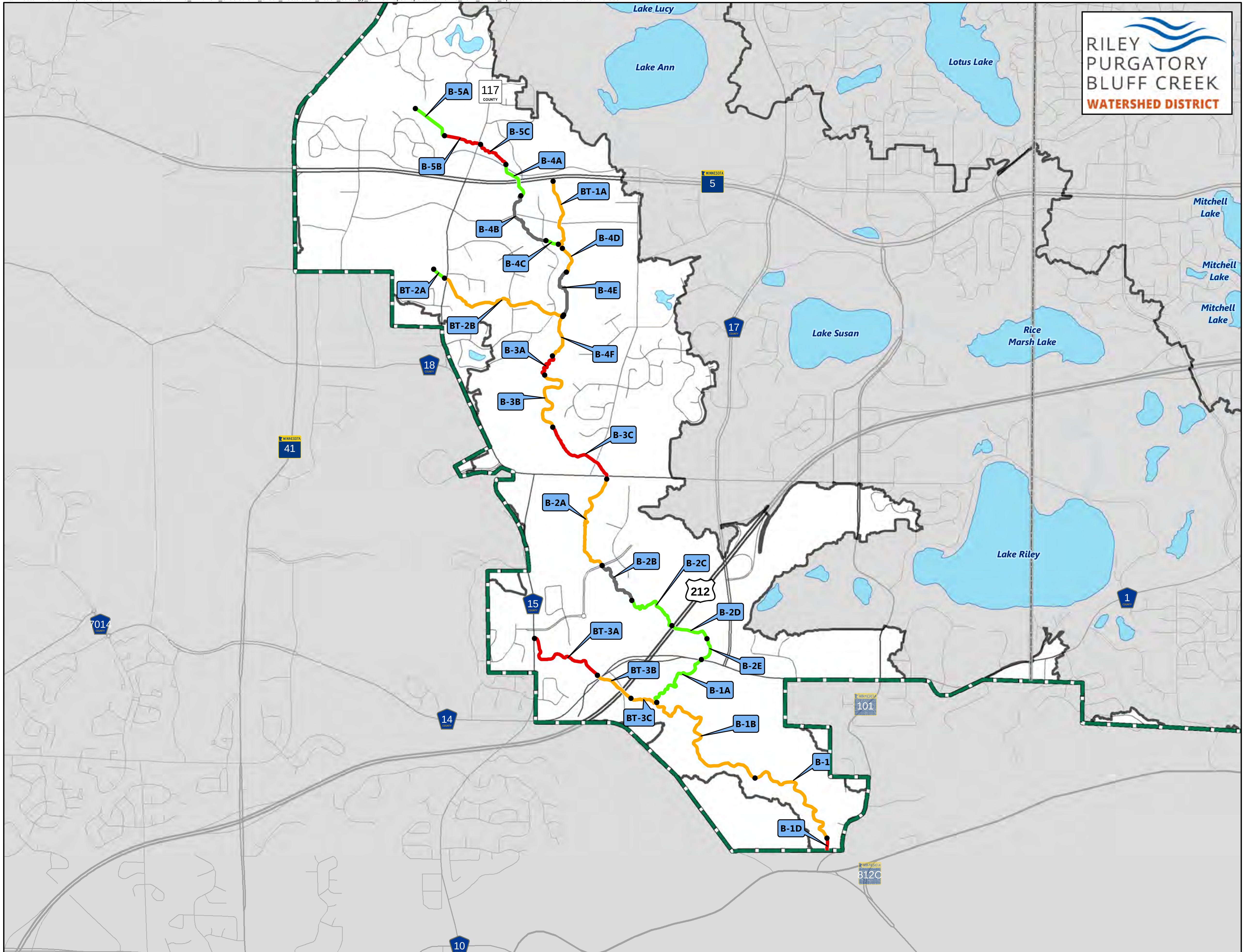

LEGEND

Stream Reaches - Tier 1 Score
- 13 - 17
- 18 - 21
- >= 22 (Worst)
- Unsurveyed Stream Reach
- Lakes
- Watershed District Boundary

Feet
2,500 0 2,500

Meters
750 0 750

FIGURE 5-3 TIER 1 SCORE - BLUFF CREEK
Creek Restoration Action Strategy
Riley Purgatory Bluff Creek
Watershed District

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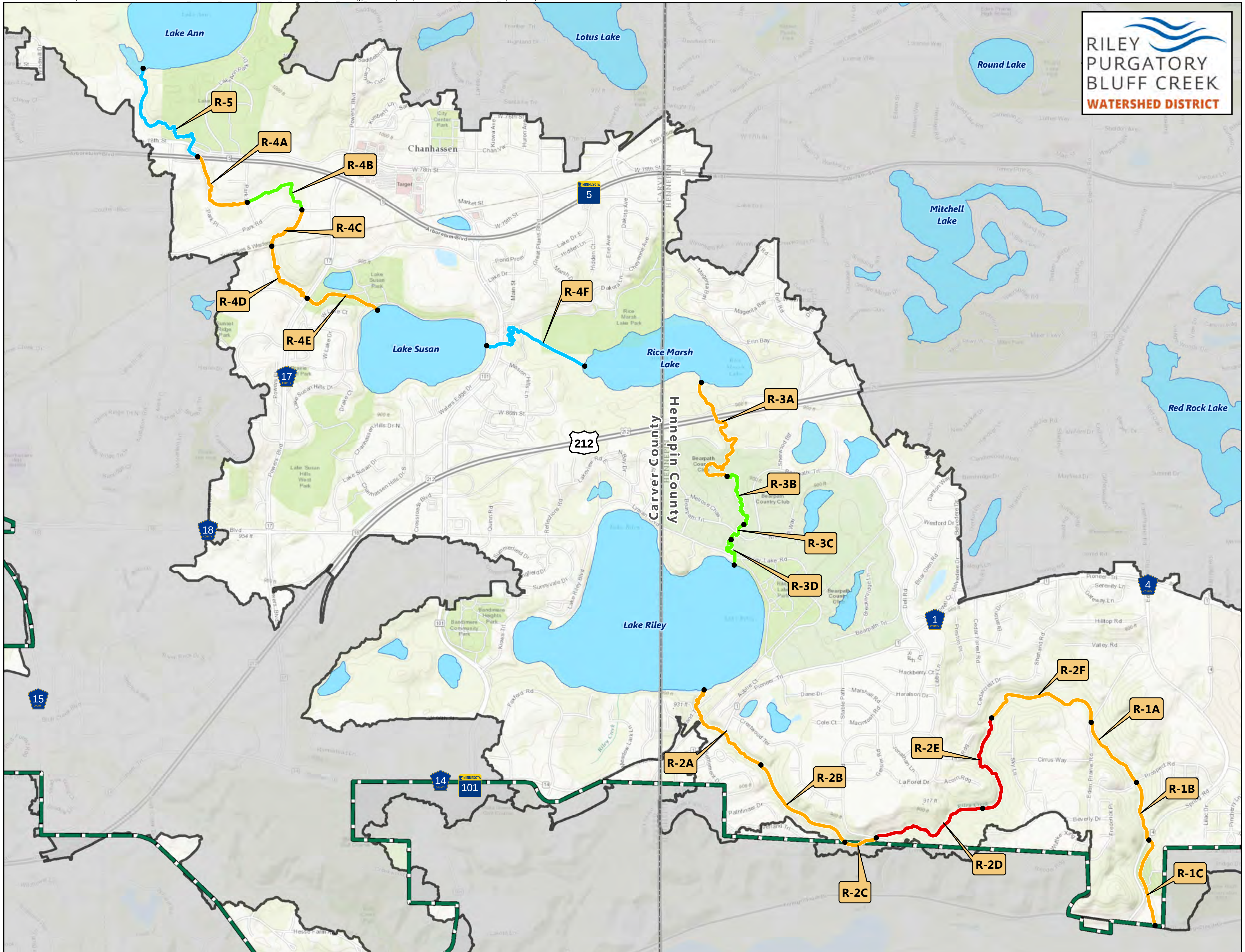

LEGEND

Stream Reaches - Tier 1 Score

- <= 12 (Best)
- 13 - 17
- 18 - 21
- >= 22 (Worst)
- Lakes
- Watershed District Boundary

Feet
2,000 0 2,000

Meters
600 0 600

FIGURE 5-4 TIER 1 SCORE - RILEY CREEK

Creek Restoration Action Strategy
Riley Purgatory Bluff Creek
Watershed District

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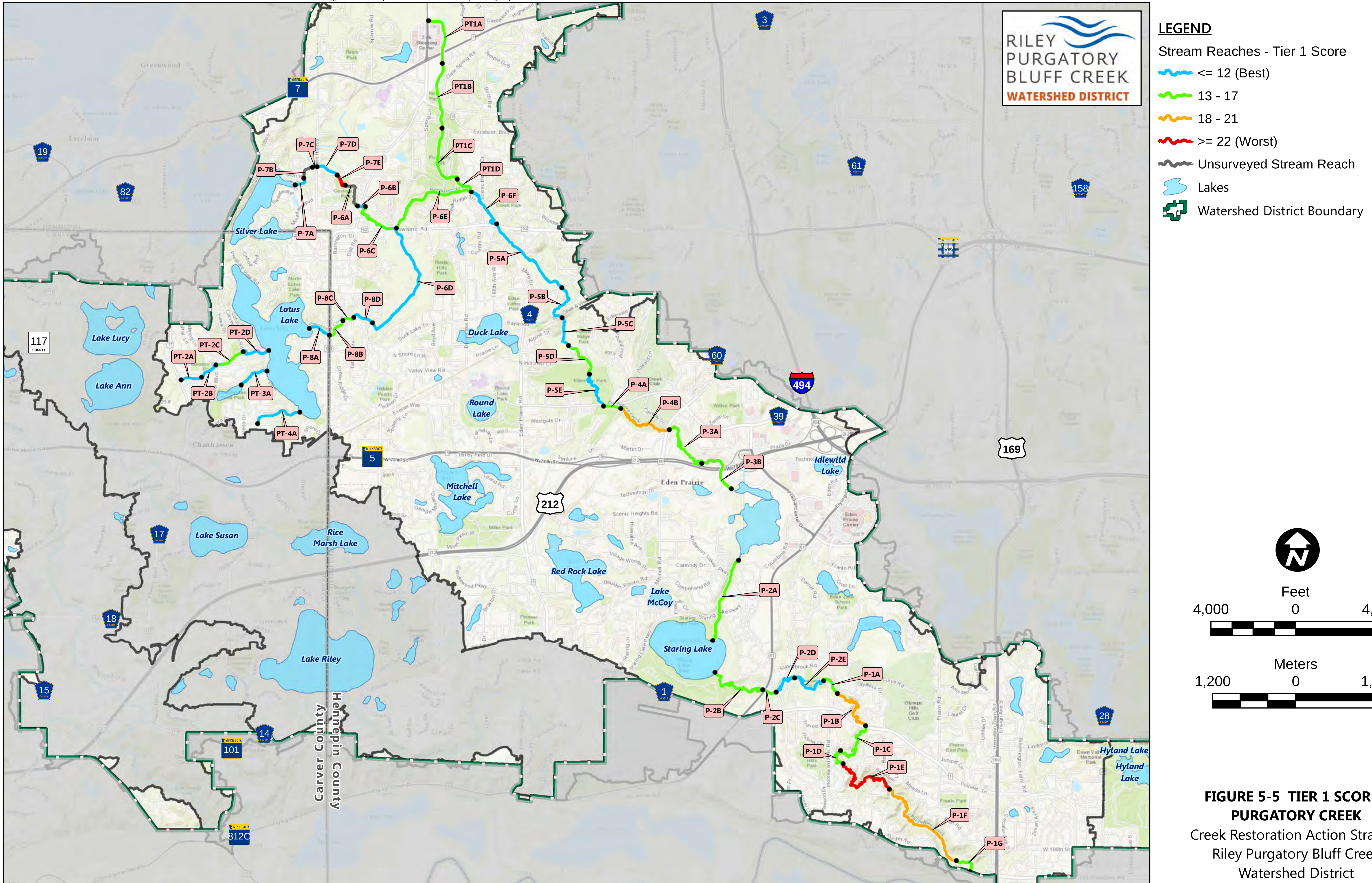

FIGURE 5-5 TIER 1 SCORE - PURGATORY CREEK
Creek Restoration Action Strategy
Riley Purgatory Bluff Creek
Watershed District

5.2.1 Infrastructure Risk

As shown above in Table 5-2 and below in Figure 5-6, eight of the sub-reaches evaluated have infrastructure risks classified as one of the two highest (worst, i.e., score of 7 or 5) ratings. Because infrastructure risk can be an acute problem and may involve the potential for serious injury to the public, Table 5-3 provides a description of infrastructure risks that received high and severe scores.

Table 5-3 Summary of High and Severe Infrastructure Risks

Creek	Reach	Location Description	Description of Risk
Bluff	B1D	475 feet Upstream of Great Plains Boulevard to Great Plains Boulevard	Culvert is severely perched. Erosion under and adjacent to the culvert may cause problems for tall embankment supporting railroad right-of-way
Bluff	B5C	Galpin Boulevard to West 78th Street	Housing development directed gutters to upper bank edge, which is causing severe gully formation with severe erosion in multiple areas.
Riley	R2E	Stormwater pond in lower valley, approximately half way between Dell Road and Eden Prairie Road	Channel incision and bank erosion may cause banks between creek and pond to breech.
Riley	R4A	Highway 5 to Park Drive	Bank erosion may cause banks between creek and stormwater pond to breech
Riley	R4C	Park Road to Railroad Bridge	Channel incision and bank erosion may cause damage to storm sewer outfalls. Culvert under railroad bridge is damaged,
Riley	R4D	Railroad Bridge to Powers Boulevard	Channel incision and bank erosion may cause damage to storm sewer outfalls. Culvert under railroad bridge is damaged,
Purgatory	P1E	1,350 feet Downstream of Pioneer Trail to Burr Ridge Lane	Major slope instability poses threat to private home near top of the slope. Six major mass wasting locations with some posing potential long-term future threat to homes.
Purgatory	P7C	220 feet Upstream of Vine Hill Road to Vine Hill Road	Culvert is nearly filled with sediment, only allowing a small volume of water to pass through.
Purgatory	P7E	Covington Road to Pond in Covington Park	Culvert end section has separated with significant washout and erosion occurring. Stormwater culvert suspended above ground surface on right bank.

5.2.2 Erosion and Channel Stability

As shown in Table 5-1, the majority of the sub-reaches scored in the poor/high or severe category for erosion and channel stability (49 sub-reaches, equaling 58% of all sub-reaches). As shown in Figure 5-7, the majority of poor/high or severe erosion scores occur in lower valleys of the creeks and is largely related to mass wasting on tall valley walls.

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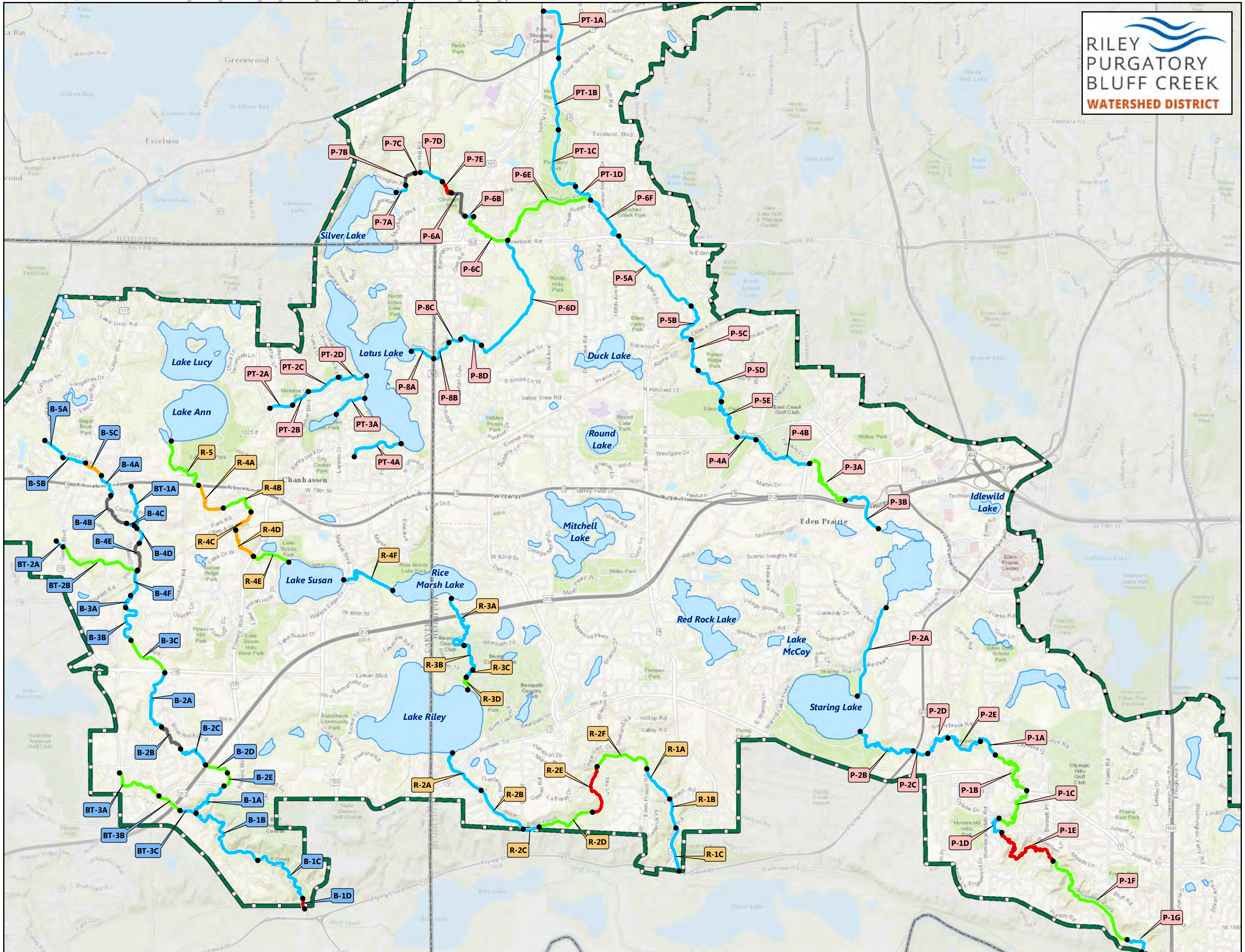

LEGEND

Stream Reaches - Infrastructure Risk*

- 1 (Best)
- 3
- 5
- 7 (Worst)
- No Score
- Lakes
- Watershed District Boundary

*Note:
Scores do not represent the results of an in-depth engineering analysis regarding the risks of failure at individual sites.

N

Feet
4,000 0 4,000

Meters
1,200 0 1,200

FIGURE 5-6
INFRASTRUCTURE RISK
Creek Restoration Action Strategy
Riley Purgatory Bluff Creek
Watershed District

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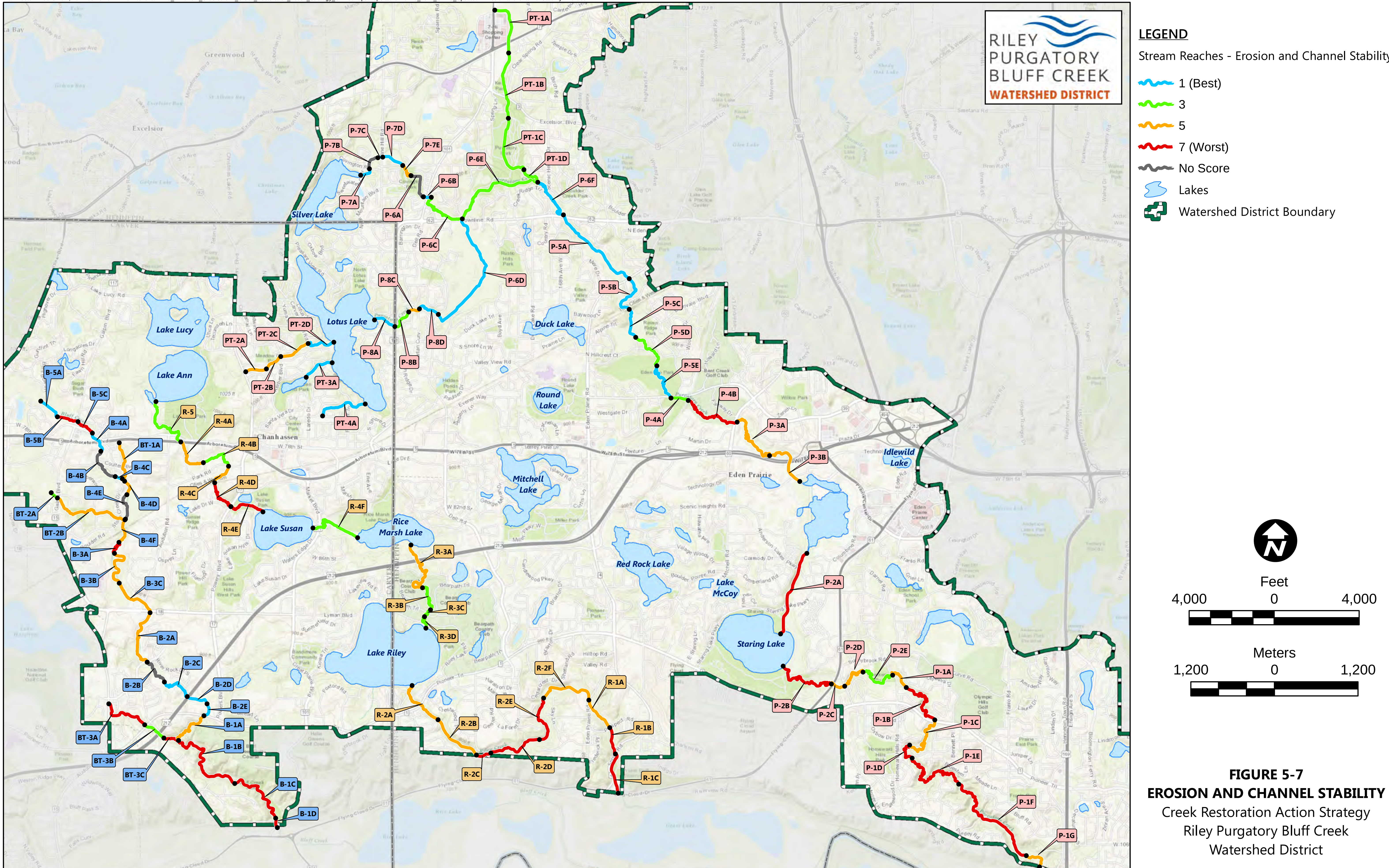


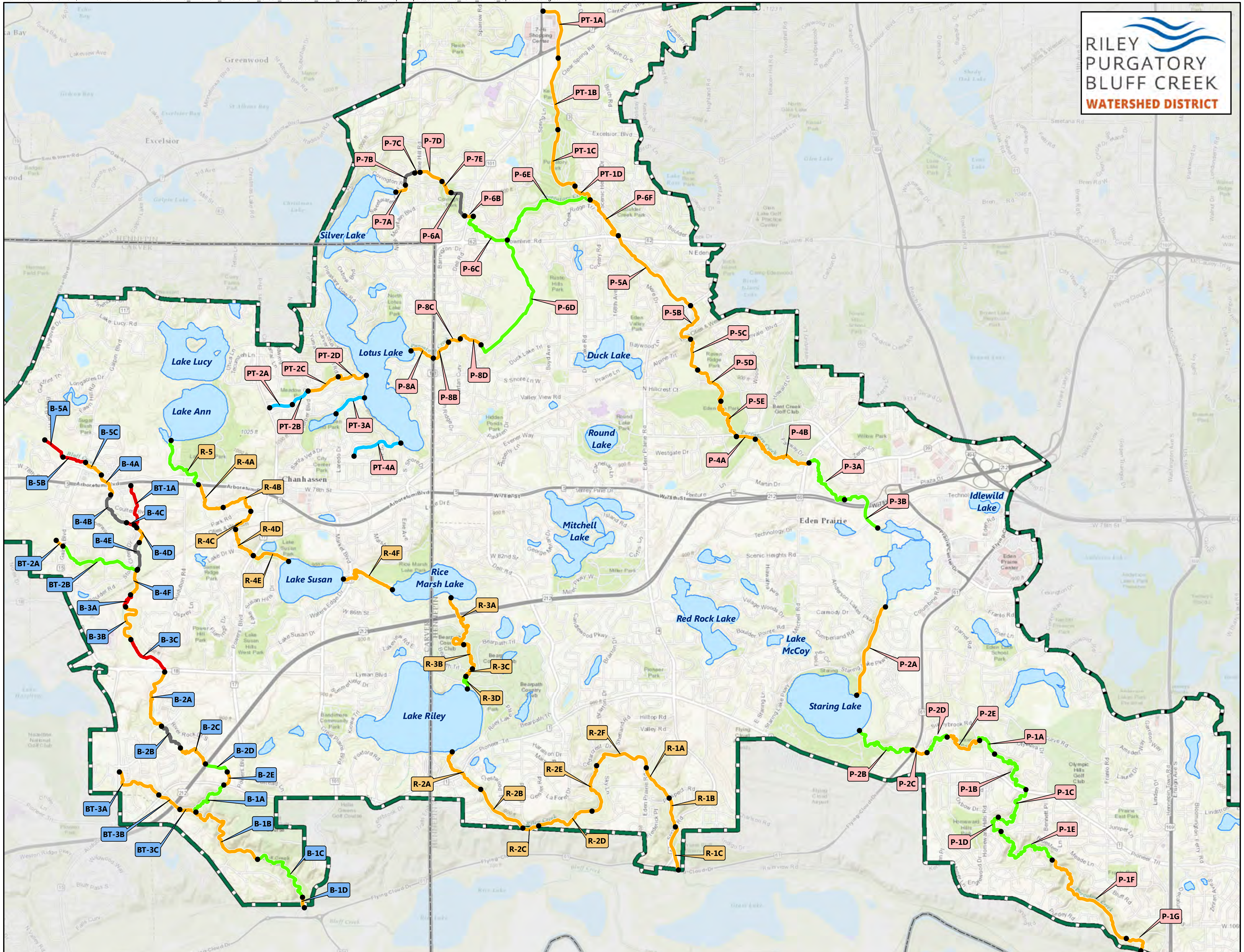
FIGURE 5-7
EROSION AND CHANNEL STABILITY
Creek Restoration Action Strategy
Riley Purgatory Bluff Creek
Watershed District

5.2.3 Ecological Benefit

As shown in Table 5-1 and Figure 5-8, the majority of the sub-reaches scored in the moderate/low or poor/high categories for ecological benefit (74, equaling 88% of all sub-reaches). Overall, the ecological benefit scores are similar to what can be expected for urban streams. Several factors influenced the moderate/low and poor/high scored throughout the watershed. Land uses surrounding the creeks were primarily residential and urban/industrial. Riparian areas were generally narrow with moderate to severe bank erosion. Many of the sub-reaches lacked diverse in-channel substrate (i.e. muck, sand, gravel, cobble, etc.) and both type (i.e. deep pools, overhanging banks, logs, boulders, etc.) and level of cover needed to provide diverse habitat for aquatic species. Floating or submerged aquatic vegetation within the creeks themselves was absent from many of the sub-reaches.

5.2.4 Water Quality

As shown in Table 5-1 and Figure 5-9, most of the sub-reaches scored in the poor/high or severe category for water quality (73 sub-reaches, equaling 87% of all sub-reaches). Sub-reaches receiving water quality scores in these categories frequently exceed the MPCA's established thresholds. As shown in Figure 5-9, sub-reaches of Bluff and Riley Creeks generally had the most water quality threshold exceedances.



LEGEND

Stream Reaches - Ecological Benefits

- 1 (Best)
- 3
- 5
- 7 (Worst)
- No Score
- Lakes
- Watershed District Boundary

N

Feet

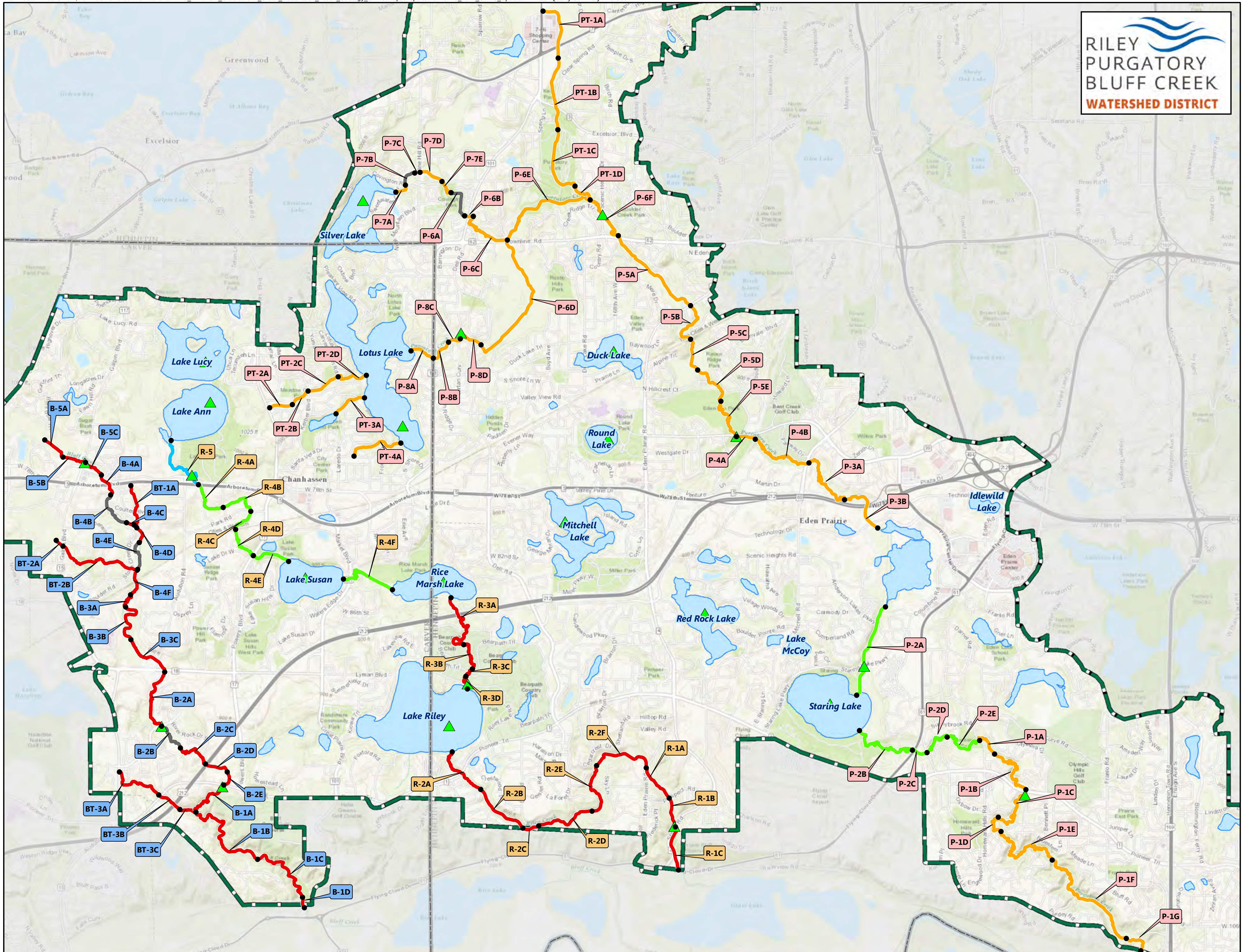
4,000 0 4,000

Meters

1,200 0 1,200

FIGURE 5-8
ECOLOGICAL BENEFITS
Creek Restoration Action Strategy
Riley Purgatory Bluff Creek
Watershed District

Barr Footer: ArcGIS 10.4, 2017-05-25 10:36 File: I:\Client\RPBC_WD\Work_Orders\2014_Creek_Restoration_Action_Strategy_CRAS\Maps\Reports\20170425_2017_CRAS_Update\All Water Quality Summary.mxd User: MEM2



LEGEND

Stream Reaches - Water Quality Summary

- 1 (Best)
- 3
- 5
- 7 (Worst)
- No Score
- Lakes
- Watershed District Boundary

Feet

4,000 0 4,000

Meters

1,200 0 1,200

FIGURE 5-9
WATER QUALITY SUMMARY
Creek Restoration Action Strategy
Riley Purgatory Bluff Creek
Watershed District

5.3 Tier II Results

As described in Section 3.2, the Tier II categories are intended to provide additional considerations to assist in prioritizing projects on sub-reaches. As described previously, Tier I results determined the categorical ranking of "severe," "high," "moderate," and "low" rankings for each sub-reach. Once a sub-reach was classified as being in one of those levels, it would not change levels without changes to the scores that determined the Tier I score. The scores for Tier II categories were developed by considering public education potential, watershed benefits, partnerships, and cost/lb. (see section 3.2.2 for further details). These scores were then added to the Tier I scores. Once Tier II scores are added to the Tier I scores, then the sub-reaches within each priority category are rearranged to reflect the Tier II scores. Table 5-4 below provides a summary the Tier II results for all sub-reaches, and includes both Tier I and Tier II rankings.

Table 5-4. Tier II Scores

Tier II Rank	Tier I Rank	Reach	Subreach	Location	Tier I Scores	Public Education Summary	Watershed Benefits	Partnerships	Cost/LB P	Tier II Scores
1	9	P7	P7E	Covington Road to Pond in Covington Park	22	5	7	7	7	48
2	2	R2	R2E	Middle Third between Dell Road and Eden Prairie Road	26	5	1	7	7	46
3	5	BT3	BT3A	Audubon Road to Pioneer Trail	22	1	7	7	7	44
4	4	P1	P1E	1,350 feet Downstream of Pioneer Trail to Burr Ridge Lane	22	7	1	7	7	44
5	1	B1	B1D	475 feet Upstream of Great Plains Boulevard to Great Plains Boulevard	26	1	1	7	7	42
6	7	B3	B3A	750 feet Downstream of Railroad to 860 feet Downstream of Railroad	22	7	5	1	7	42
7	10	B3	B3C	1,675 feet Upstream of Audubon Road to Lyman Boulevard	22	7	5	1	7	42
8	6	R2	R2D	Upper Third between Dell Road and Eden Prairie Road	22	3	1	7	7	40
9	3	B5	B5C	Galpin Boulevard to West 78th Street	24	3	7	1	3	38
10	8	B5	B5B	985 feet Upstream of Galpin Boulevard to Galpin Boulevard	22	1	7	1	3	34
11	14	BT3	BT3C	Bluff Creek Drive to Bluff Creek	20	1	7	7	5	40
12	29	B4	B4D	350 feet Downstream of Stone Creek Drive to 950 feet Downstream of Stone Creek Drive	18	7	7	1	7	40
13	30	B4	B4F	530 feet Upstream of Railroad to 750 feet Downstream of Railroad	18	7	7	1	7	40
14	18	R2	R2F	Lower Third between Dell Road and Eden Prairie Road	20	5	1	7	5	38
15	13	B1	B1B	2,150 feet Downstream of Pioneer Trail to 300 feet Upstream of Bluff Creek Park	20	1	1	7	7	36
16	27	B2	B2A	Lyman Boulevard to Bluff Creek Boulevard	18	7	3	1	7	36
17	24	R4	R4A	Highway 5 to Park Drive	18	7	5	1	5	36
18	19	BT1	BT1A	Arboretum Boulevard to Bluff Creek	20	3	7	1	3	34
19	15	R1	R1B	1,700 feet Downstream of Eden Prairie Road to Spring Road	20	3	1	3	7	34
20	16	R1	R1C	Spring Road to Flying Cloud Drive	20	3	1	3	7	34
21	12	P1	P1F	Burr Ridge Lane to 1,250 feet Upstream of Riverview Road	20	5	1	1	7	34
22	11	R4	R4D	Railroad Bridge to Powers Boulevard	20	1	5	1	7	34
23	20	B1	B1C	300 feet Upstream of Bluff Creek Park to 475 feet Upstream of Great Plains Boulevard	18	1	1	7	7	34
24	21	P1	P1B	380 meters Downstream of Homeward Hills Road to Pioneer Trail	18	1	1	7	7	34
25	23	P4	P4B	Bent Creek Golf Club to Mitchell Road	18	3	5	1	7	34
26	35	BT3	BT3B	Pioneer Trail to Bluff Creek Drive	18	1	7	7	1	34
27	17	R2	R2C	720 feet Upstream of Dell Trail to Dell Road	20	3	1	1	7	32
28	26	BT2	BT2B	Gaplin Boulevard to Bluff Creek	18	3	7	1	3	32
29	28	B3	B3B	860 feet Downstream of Railroad to 1,675 feet Upstream of Audubon Road	18	7	5	1	1	32
30	25	R4	R4C	Park Road to Railroad Bridge	18	1	5	1	7	32
31	22	R4	R4E	Powers Boulevard to Lake Susan	18	1	5	1	7	32
32	31	R1	R1A	Eden Prairie Road to 1,700 feet Downstream of Eden Prairie Road	18	3	1	1	7	30
33	32	R2	R2A	Lake Riley to 3,000 feet downstream of Lake Riley	18	3	1	3	3	28
34	34	R3	R3A	Rice Marsh to Northern Portion of Bearpath Country Club	18	1	3	1	3	26
35	33	R2	R2B	3,000 feet downstream of Lake Riley to 720 feet upstream of Dell Road	18	3	1	3	1	26
36	42	PT2	PT2C	Kerber Boulevard to Carver Beach Road	16	5	7	1	7	36
37	63	PT1	PT1B	430 feet Downstream of Highway 7 to North Portion of Purgatory Park	14	7	5	7	3	36
38	64	PT1	PT1C	North Portion of Purgatory Park to Stadola Road	14	7	5	7	1	34
39	56	P6	P6C	175 feet Downstream of Highway 101 to Highway 62	14	5	5	5	5	34
40	50	B4	B4C	Stone Creek Drive to 350 feet Downstream of Stone Creek Drive	16	7	7	1	1	32
41	51	B5	B5A	Ridgeview Road Recreational Trail to 985 feet Upstream of Galpin Boulevard	16	7	7	1	1	32
42	44	B1	B1A	Pioneer Trail to 2,150 feet Downstream of Pioneer Trail	16	1	1	7	7	32
43	52	P2	P2B	Staring Lake to Flying Cloud Drive	14	7	3	1	7	32
44	68	B4	B4A	West 78th Street to 485 feet Downstream of Highway 5	14	7	7	1	1	30
45	41	P8	P8C	Tartan Curve to Duck Lake Trail	16	3	7	1	3	30
46	36	P1	P1D	2,950 feet Downstream of Pioneer Trail to 1,350 feet Downstream of Pioneer Trail	16	5	1	1	7	30
47	48	P7	P7C	220 feet Upstream of Vine Hill Road to Vine Hill Road	16	3	7	3	1	30
48	67	B2	B2C	1,750 feet Upstream of Highway 212 to Highway 212	14	5	3	1	7	30
49	37	P2	P2A	Purgatory Creek Conservation Area to Staring Lake	16	7	3	1	1	28
50	39	P3	P3A	Mitchell Road to 1,375 feet upstream of Highway 212	16	3	5	1	3	28
51	55	P2	P2C	Flying Cloud Drive to Creek Knoll Road	14	7	3	1	3	28
52	58	R4	R4B	Park Drive to Park Road	14	1	5	1	7	28
53	54	P3	P3B	1,375 feet Upstream of Highway 212 to Purgatory Creek Conservation Area	14	5	5	1	1	26
54	45	BT2	BT2A	380 feet Upstream of Galpin Road to Galpin Boulevard	16	1	7	1	1	26
55	38	P1	P1C	Pioneer Trail to 2,950 feet Downstream of Pioneer Trail	16	1	1	1	7	26
56	62	PT1	PT1A	Highway 101 to 430 feet Downstream of Highway 7	14	3	5	3	1	26
57	66	B2	B2D	Highway 212 to 830 feet Downstream of Highway 212	14	3	3	1	3	24
58	43	R3	R3D	Lake Riley to 250 feet Downstream of Bearpath Trail Bridge	16	1	3	1	3	24
59	65	PT1	PT1D	Stadola Road to Purgatory Creek	14	1	5	3	1	24
60	59	P4	P4A	Valley View Road to Bent Creek Golf Club	14	3	5	1	1	24
61	61	P8	P8B	Chanhassen Road to Tartan Curve	14	1	7	1	1	24
62	57	P6	P6E	Highway 62 to 985 feet Upstream of Scenic Heights Drive	14	3	5	1	1	24
63	46	R3	R3B	Northern Portion of Bearpath Country Club to 260 feet Upstream of Bearpath Trail Bridge	16	1	3	1	1	22
64	49	B2	B2E	830 feet Downstream of Highway 212 to Pioneer Trail	16	1	3	1	1	22
65	47	R3	R3C	260 feet Upstream of Bearpath Trail Bridge to 250 feet Downstream of Bearpath Trail Bridge	16	1	3	1	1	22
66	53	P1	P1A	Homeward Hills Road to 380 meters Downstream of Homeward Hills Road	14	1	1	1	5	22
67	60	P5	P5D	1500 feet Downstream of Railroad to 3550 feet Downstream	14	1	5	1	1	22
68	40	P1	P1G	1,250 feet Upstream of Riverview Road to Riverview Road	16	1	1	1	1	20
69	69	PT2	PT2A	Powers Boulevard to 1,000 feet Downstream of Powers Boulevard	12	3	7	1	5	28
70	70	PT2	PT2B	1,000 feet Downstream of Powers Boulevard to Kerber Boulevard	12	1	7	1	7	28
71	81	P7	P7D	Vine Hill Road to Covington Road	12	3	7	3	1	26
72	85	R5	R5	Lake Ann to Highway 5	10	5	7	3	1	26
73	83	P8	P8D	Duck Lake Trail to Dell Road	12	3	7	1	1	24
74	71	P2	P2D	Creek Knoll Road to 1,725 feet Downstream of Creek Knoll Road	12	1	3	1	7	24
75	80	P7	P7A	Silver Lake to Covington Road	12	3	7	1	1	24
76	84	PT2	PT2D	Carver Beach Road to Lotus Lake	12	3	7	1	1	24
77	78	P6	P6B	190 feet Upstream of Highway 101 to 175 feet Downstream of Highway 101	12	3	5	1	1	22
78	82	P8	P8A	Lotus Lake to Chanhassen Road	12	1	7	1	1	22
79	79	P6	P6F	985 feet Upstream of Scenic Heights Drive to Highway 62	12	3	5	1	1	22
80	72	P2	P2E	1,725 feet Downstream of Creek Knoll Road to Homeward Hills Road	12	3	3	1	1	20
81	74	P5	P5A	Highway 62 to Eden Prairie Road	12	1	5	1	1	20
82	75	P5	P5B	Eden Prarie Road to Railroad	12	1	5	1	1	20
83	76	P5	P5C	Railroad to 1500 feet Downstream	12	1	5	1	1	20
84	77	P5	P5E	3550 feet Downstream of Railroad to Valley View Road	12	1	5	1	1	20
85	73	R4	R4F	Lake Susan to Rice Marsh Lake	12	1	5	1	1	20
86	86	P6	P6D	Dell Road to CR 62	10	1	5	1	1	18
87	87	PT3	PT3A	Kerber Pond to Lotus Lake	8	1	7	1	1	18
88	88	PT4	PT4A	Santa Fe Trail to Lotus Lake	8	1	7	1	1	18

6.0 Future Work

The CRAS was designed to be a living document that can be updated continuously as more information is gathered, projects are implemented, and partnership opportunities arise. From 2013 to 2016, District staff were able to walk many stream reaches that until that point had very little information available. This information was critical to the initial startup of the CRAS study. In the process of completing initial assessments and analysis, District and Barr engineering staff identified future assessment that could be implemented to complement the CRAS and further help in decision making.

6.1 Future Creek Assessments

Through 2016, District staff was able to complete site visits and assessments on almost all reaches within the District, although the scoring for three sub-reaches remained dependent on photographs and assessments from older studies. These sub-reaches will be given first priority moving forward.

Once all sub-reaches are fully assessed and identified within the District, continual monitoring is recommended to evaluate the success of projects that were implemented, assess damage after severe storms, and to monitor temporal changes within each sub-reach. Ideally, each stream would be walked annually; however, due to the vast area this would encompass, it would be difficult to accomplish. As such, it is recommended that streams be assessed on a rotating schedule with each stream field checked every three years. Upon review of the past assessments across all three creeks, the tentative assessment schedule is as follows:

- Riley Creek 2017
- Bluff Creek 2018
- Purgatory Creek 2019

6.2 Bank Pins for Erosion Measurement

The CRAS criteria will also be updated and revised as other methodologies are added to the analysis. One such method that has already been implemented is the addition of bank pins (four-foot long metal bars) near all current water quality monitoring sites across the three creeks (18 sites). Three pins were installed horizontally into both the right and left stream banks at each location to verify erosion rates for each reach. The bank pins will be measured over time to observe changes in the both stream banks. Bank pin measurements can then be used to estimate rates of erosion and sediment loading a given stream reach.

Data from monitored erosion at each of the bank pin sites will help refine erosion estimates along different segments of the creeks. The results will be used to refine the cost per pound of phosphorus estimates.

6.3 Further Assessment Methods

While the CRAS identified stream bank erosion areas along the creeks, identifying the causes of the problems were beyond the current CRAS scope. Future work should include efforts to improve the understanding of why erosion is occurring at individual locations (e.g. changes in watershed hydrology, loss of vegetation, groundwater seepage, development, etc.). This could be accomplished through application of more detailed tools such as, such as the stream function pyramid, USA, WARSS, enhancements to the District's SWMM modeling, sub-watershed assessments, groundwater monitoring program, and feasibility studies.

7.0 References

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Appendices

Appendix A

Pfankuch and MSHA Sample Data Sheets

MPCA STREAM HABITAT ASSESSMENT (MSHA)

(revised April 2014)

1. Stream Documentation

MSHA SCORE **Max=100**

Field Number: ______________ Stream Name: ______________________________ Date: ______________

Person Scoring: ________________ Water Level (circle one): Flood / High / Normal / Low / Interstitial

2. Surrounding Land Use (Streams) or Floodplain Quality (Rivers)

(check the most predominant or check two and average scores) **[L=left bank/R =right bank, facing downstream]**

L	R			L	R		
☐	☐	Forest, Wetland, Prairie, Shrub	[5]	☐	☐	Diked Wetland	[2]
☐	☐	Old Field/Hay Field	[3]	☐	☐	Urban/Industrial	[0]
☐	☐	Fenced Pasture	[2]	☐	☐	Open Pasture	[0]
☐	☐	Residential/Park	[2]	☐	☐	Mining/Construction	[0]
☐	☐	Conservation Tillage, No Till	[2]	☐	☐	Row Crop	[0]

Land Use **Max=5**

3. Riparian Zone (check the most predominant)

A. Riparian Width

L	R			
☐	☐	Extensive	> 100 m	[5]
☐	☐	Wide	50-100 m	[4]
☐	☐	Moderate	10-50 m	[3]
☐	☐	Narrow	5-10 m	[2]
☐	☐	Very Narrow	1-5 m	[1]
☐	☐	None		[0]

B. Bank Erosion

L	R			
☐	☐	None		[5]
☐	☐	Little	5-25%	[4]
☐	☐	Moderate	25-50%	[3]
☐	☐	Heavy	50-75%	[1]
☐	☐	Severe	75-100%	[0]

C. Shade

L	R			
☐	☐	Heavy	>75%	[4]
☐	☐	Substantial	50-75%	[3]
☐	☐	Moderate	25-50%	[2]
☐	☐	Light	5-25%	[1]
☐	☐	None		[0]

Riparian **Max=14**

4. Instream Zone

A. Substrate (check two for each channel type)

	Boulder [10]	Cobble [9]	Gravel [8]	Sand [6]	Clay [5]	Bedrock [5]	Silt [2]	Muck [1]	Detritus [1]	Sludge [0]	Channel Type %
Pool	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	______
Riffle	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	______
Run	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	______
Glide	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	______
Note	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Presence

B. Embeddedness

- ☐ None [5]
- ☐ Light 25-50% [3]
- ☐ Moderate 50-75% [1]
- ☐ Severe 75-100% [-1]
- ☐ No coarse substrate [0]

C. Siltation

- ☐ Silt Free [1]
- ☐ Silt Normal [0]
- ☐ Silt Moderate [-1]
- ☐ Silt Heavy [-2]

D. Substrate Types

- ☐ ≥4 [2]
- ☐ <4 [0]

Substrate **Max=28**

E. Cover Type (check all that apply)

- ☐ Undercut Banks [1]
- ☐ Overhanging Vegetation [1]
- ☐ Deep Pools [1]
- ☐ Logs or Woody Debris [1]
- ☐ Boulders [1]
- ☐ Rootwads [1]
- ☐ Oxbows, Backwaters [1]
- ☐ Shallows (in slow water) [1]
- ☐ Macrophytes [1]
  - ☐ Submergent
  - ☐ Emergent
  - ☐ Floating Leaf

F. Cover Amount (check one)

- ☐ Extensive >50% [9]
- ☐ Moderate 25-50% [7]
- ☐ Sparse 5-25% [3]
- ☐ Nearly Absent [0]
- ☐ Choking Vegetation only [-1]

Cover **Max=18**

5. Channel Morphology

A. Depth Variability

- ☐ Greatest Depth >4X Shallow Depth [4]
- ☐ Greatest Depth 2-4X Shallow Depth [2]
- ☐ Greatest Depth <2X Shallow Depth [0]

B. Channel Stability

- ☐ High [9]
- ☐ Moderate/High [6]
- ☐ Moderate [3]
- ☐ Low [0]

C. Velocity Types (check all that apply)

- ☐ Fast [1]
- ☐ Moderate [1]
- ☐ Slow [1]
- ☐ Eddies [1]
- ☐ Torrential [-1]
- ☐ None [-1]
- ☐ Interstitial [-1]
- ☐ Intermittent [-2]

D. Sinuosity

- ☐ Excellent [4]
- ☐ Good [3]
- ☐ Fair [2]
- ☐ Poor [0]

E. Pool Width/Riffle Width

- ☐ Pool Width > Riffle Width [2]
- ☐ Pool Width = Riffle Width [1]
- ☐ Pool Width < Riffle Width [0]
- ☐ No Riffle [0]
- ☐ No Pool [0]
- ☐ Impounded [-2]

F. Channel Development

- ☐ Excellent [9]
- ☐ Good [6]
- ☐ Fair [3]
- ☐ Poor [0]

G. Modifications (check all that apply)

- ☐ Leveed [-1]
- ☐ Dredged [-1]
- ☐ Bank Shaping [-1]
- ☐ Railroad Ties [-1]
- ☐ Cemented [-2]
- ☐ Bulkheads [-2]
- ☐ Rip Rap [1]
- ☐ Const. Island [1]
- ☐ Wood Pilings [1]

Channel **Max=35**

Aquatic Vegetation (indicate as follows for observed abundance: Abundant=[3]; Moderate=[2]; Sparse=[1])

A. Beneficial Aquatic Vegetation

____ Pond Lilies (*Nymphaea*/*Nuphar*) ____ Sedge (*Cyperaceae*) ____ Wild Celery (*Vallisneria*)
____ Wild Rice (*Zizania*) ____ Pond Weed (*Potamogeton*) ____ Bulrush (*Scirpus*)
____ Waterweed (*Elodea*) ____ Coontail (*Ceratophyllum*) ____ Water Cress (*Nasturtium*)

B. Invasive and Negative Aquatic Vegetation

____ Eurasian Milfoil (*Myriophyllum*) ____ Purple Loosestrife (*Lythrum*) ____ Reed Canary Grass (*Phalaris*)
____ Cattails (*Typha*) ____ Duckweed (*Lemna*) ____ Algae (Floating Mats)
____ Algae (Planktonic) ____ Algae (Benthic)

No Vegetation Noted ☐

Comments: ____

Worksheet 19. Modified Pfankuch Channel Stability Rating Procedure Summary

Stream: ______________ Reach: ______________ Date: ______ Observers: ______________ Comments: ______________

Location	Key	Category	Excellent Description	Rating	Good Description	Rating	Fair Description	Rating	Poor Description	Rating
Upper Banks	1	Landform Slope	Bank slope gradient <30%.	2	Bank slope gradient 30-40%.	4	Bank slope gradient 40-60%.	6	Bank slope gradient 60%+.	8
	2	Mass Wasting	No evidence of past or future mass wasting.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly year long.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris Jam Potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative Bank Protection	90%+ plant density. Vigor and variety suggest a deep, dense soil binding root mass.	3	70-90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50-70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species & less vigor indicating poor, discontinuous, and shallow root mass.	12
Lower Banks	5	Channel Capacity	Ample for present plus some increases. Peak flows contained. W/D ratio <7.	1	Adequate. Bank overflows are rare. W/D ratio = 8-15.	2	Barely contains present peaks. Occasional overbank floods. W/D ratio = 15-25.	3	Inadequate. Overbank flows common. W/D ratio > 25.	4
	6	Bank Rock Content	65%+ w/ large angular boulders. 12"+ common.	2	40-65%. Mostly boulders and small cobbles 6-12".	4	20-40%. With most in the 3-6" diameter class.	6	<20% rock fragments of gravel sizes, 1-3" or less.	8
	7	Obstructions to Flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12-24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock Angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges, surfaces smooth, flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, ie 35-65% mixture range.	3	Predominantly bright, 65%+, exposed or scoured surfaces.	4
	12	Consolidation of Particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom Size Distribution	No size change evident. Stable material 80-100%.	4	Distribution shift light. Stable material 50-80%.	8	Moderate change in sizes. Stable materials 20-50%.	12	Marked distribution change. Stable materials 0-20%.	16
	14	Scouring and Deposition	<5% of bottom affected by scour or deposition.	6	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30-50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic Vegetation	Abundant growth moss-like, dark green perennial. In swift water, too.	1	Common. Algae forms in low velocity and pool areas. Moss here, too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	4
			Excellent Total =		Good Total =		Fair Total =		Poor Total =	

Stream Type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream Type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand Total =	
Stream Type =	
Modified Channel Stability Rating =	

Appendix B

Summary of Severe Reaches

B.1 Sub-reach B1D

Photo 1-1 Eroding bank downstream of Culvert

Sub-reach B1D (Figure 5-3) is the most downstream sub-reach within the RPBCWD boundary and consists of approximately 500 feet of Bluff Creek upstream of Highway 101. There are multiple issues in this sub-reach, including a long, tall eroding bank at the toe of a large slope, a significantly perched culvert that has been linked to habitat degradation, and threats to public infrastructure if either the culvert or the large slope were to fail due to continuing erosion.

The perched culvert is more appropriately labeled a tunnel measuring approximately 20 feet wide and 15 feet tall and goes through the embankment created to support a railroad right-of-way. The right-of-way is currently used as a regional trail. The embankment is approximately 80 feet tall with a steep slope from the top of the embankment the creek level. Downstream of the tunnel, Bluff Creek has incised and the tunnel is now perched approximately 8 feet above the bed of the creek. The large vertical distance impedes aquatic organism passage and was identified as the primary cause of the habitat fragmentation impairment in the Bluff Creek TMDL.

The eroding bank downstream of the tunnel is eroding toe of both the man-made embankment that is part of the right-of-way and what appears to be a natural slope. The erosion contributes to poor water quality, and the contributions can become extreme if the bank erosion proceeds enough to cause a significant slope failure.

Photo 1-2 Perched Culvert

B.2 Sub-reach B3A

Sub-reach B3A (Figure 5-3) is located at the top of Reach 3 between the Lake Drive West recreational trail and Lyman Blvd. This stream section is divided into 3 sub-reaches with sub-reach B3A being located at the top.

Photo 2-1 Incised channel in sub-reach B3A

The creek is significantly incised in this sub-reach, as shown in Photo 2-1, which has resulted in tall eroding banks with nearly continuous bank sloughing (Photo 2-2). Raw bank heights in this stretch measured consistently between 1 and 1.5 m in height. The stream runs through a prairie restoration site and is extremely sinuous in nature. There was some easily movable instream gravel present, however the predominant substrate type was silt caused by the erosion occurring along both stream banks. The stream section has almost no channel development (riffle, run, pool sequencing) and almost no instream habitat, which led to a poor MSHA score. The surrounding slopes in this area are very low, however due to the soil types present and the erosive cutting nature of the stream, an unstable channel has been cut creating immediate steep slopes. Over time the stream will continue to create a channel with more stable dimensions which will continue to significantly erode banks contributing to the degradation of the already poor water quality in this sub-reach.

Photo 2-2 Bank sloughing in sub-reach B3A

B.3 Sub-reach B3C

Sub-reach B3C (Figure 5-3) is located in Reach 3 between the Lake Drive West recreational trail and Lyman Blvd. The section between the recreational trail and Lyman Blvd is divided into 3 sub-reaches with sub-reach B3C being the bottom sub-reach ending at Lyman Blvd. The sub-reach begins at the recreational trail and stream intersection which can be accessed off of Valley Ridge Trail North.

Photo 3-1 Incised channel in sub-reach B3C

Conditions in this sub-reach are very similar to conditions in sub-reach B3A. The creek is again incised, although slightly less than in sub-reach B3A as shown in Photo 3-1. The continuous raw eroding banks in this sub-reach measure 1 m in height (Photo 3-2), with bank sloughing and undercutting occurring frequently. The floodplain at this site is constricted by the recreational trail paralleling the creek along the right bank and a residential area along the left bank when facing downstream. The stream is very straight with poor channel development and little instream habitat present. The predominant substrate type is sand and silt which is most likely caused by the continuous erosion occurring on both stream banks. Near the middle of the sub reach there is a stormwater culvert on the right bank that is undercut and slightly suspended in the air. The surrounding slopes in this area are very low, however due to the soil types present, the straightened stream channel, and the erosive cutting nature of the stream, the immediate stream banks are unstable similar to banks within sub-reach B3A. Over time the stream will continue to attempt to stabilize, leading to significant erosion and the continual degradation of the already poor water quality.

Photo 3-2 Exposed raw bank in sub-reach B3C

B.4 Sub-reach B5B

Sub-reach B5B (Figure 5-3) is located in Reach 5 between the origin of Bluff Creek, slightly upstream of the recreational trail off of Ridgeview Way, and Galpin Blvd. The section between the recreational trail and Galpin Blvd is divided into 2 sub-reaches with sub-reach B5B being the bottom sub-reach. The sub-reach begins approximately 290m upstream of Galpin Blvd and ends at Galpin Blvd.

Photo 4-1 Straight incised channel of sub-reach B5B

The stream channel in this sub-reach has been channelized and straightened at some point in the past, and has a very narrow riparian zone along both banks (Photo 4-1). The faster moving water from the straightened channel exerts more force on the surrounding banks than a normal sinuous stream channel thus causing nearly continuous bank erosion. Raw banks heights in this sub-reach measure approximately 1m in height, as seen in Photo 4-2. Some bank sloughing and exposed root systems of fallen trees along the bank are contributing to the siltation and degradation of water quality within the sub-reach. Near the end of the sub-reach, erosion is occurring around a stormwater culvert on the left bank, as well as around the left side of the culvert under Galpin Blvd. An old dumpsite is also located between the stormwater culvert and Galpin Blvd on the left bank.

Photo 4-2 Incised channel in sub-reach B5B

B.5 Sub-reach B5C

Sub-reach B5C (Figure 5-3) is located in Reach 5 between Galpin Blvd and Highway 5. This sub-reach is approximately 310m long and is the final sub-reach within Reach 5, closest to Highway 5.

Photo 5-1 Erosion on outside bend in sub-reach B5C

The culvert under Galpin Blvd is undercut approximately 0.2m, causing a drop of 0.7m from the culvert to the stream channel below. Bank erosion around the culvert measured 1m in height, and is eating away at the small riprap placed around it. A large pile of rock that has been placed in the center of the channel immediately downstream of the culvert, is directing flow into the left bank causing undercutting measuring approximately 0.6m. Further undercutting of the bank will cause it to eventually collapse, constricting the stream channel further and causing significant siltation downstream.

Photo 5-2 Gully formation from rain gutters in sub-reach B5C

Continuous erosion measuring between 0.5-1m in height is occurring on both banks in this sub-reach. The stream is fairly sinuous with erosion increasing to 2-3m along most outside bends. Larger erosion areas are present along both banks with some bank sloughing occurring. Several large debris dams are scattered throughout the sub-reach which are actively directing the stream flow into nearby banks, causing erosion. Pools along this stretch are filled with silt, and other substrate types present in the channel were significantly imbedded in silt. Near the middle of the sub-reach a housing development bordering the left bank has directed its gutters to the top of the slope near the stream edge. The gutters have caused large gully formations and severe erosion at 3 separate locations, significantly contributing to the poor water quality in the sub-reach and downstream.

B.6 Sub-reach BT3A

Sub-reach BT3A (Figure 5-3) is in Reach 1 and is the west tributary located furthest downstream on Bluff Creek. The section between Audubon Road and Pioneer Trail is divided into 2 sub-reaches with sub-reach B5B being the top sub-reach. The sub-reach begins at Audubon Road and stretches 370m downstream.

This section begins with the stream being highly incised with raw banks measuring 1.5-2m in height. The substrate composition at this point in the creek includes mostly silt with severely embedded gravel. Residential areas are setback approximately 50m on the right bank and 25m on the left bank moving downstream. The immediate stream banks eventually become steeper as the creek slope gradients increase to >40%. The substrate eventually becomes entirely comprised of very soft and moveable silt, causing difficult walking conditions. Garbage is scattered across the sub-reach along both banks.

Photo 6-1 Incised channel in sub-reach BT3A

Photo 6-2 Bank sloughing in sub-reach BT3A

Further downstream, smaller mass wasting sites become more frequent and the stream becomes increasingly incised. There is a stormwater culvert located on the left bank which is suspended 2m in the air causing sites of severe erosion and bank sloughing nearby. Beyond this culvert an extreme mass wasting site is present measuring 3 x 15m. The stream becomes even more incised, averaging about 4 to 5m on both banks, contributing to the degradation of the water quality downstream. Many trees have fallen into the stream channel due to the severe erosion of the banks, making it difficult to walk the stream. Due to the accumulation of woody debris in the channel, many debris dams are present, deflecting flow into nearby banks causing erosion along both banks.

B.7 Sub-reach R2D

Sub-reach R2D (Figure 5-4) is located within Reach 2 of Riley Creek, beginning downstream of Dell Road south of Lake Riley. The sub-reach stretches approximately 3,000ft east before ending at R2E. The section between Dell Road and Eden Prairie Road is divided into 3 sub-reaches; sub-reach R2D is the top sub-reach.

The stream sub-reach was surrounded by low density deciduous forest (Eden Prairie park land) with residential development set back about 100m from both banks. The substrate within this sub-reach was dominated by fine silt and small gravel, containing frequent large depositional areas of fine sediments. Much of the instream habitat in this sub-reach consisted of woody debris, much of which was from the eroding upper banks. Immediately downstream of the Dell Road culvert, the stream turned 90 degrees to the right causing a large washout on the left bank measuring 4.5m x 4.5 m. The creek in this section was continuously incised by approximately 1m, with severe incising up to 2m present. This sub-reach became more severely entrenched as staff moved downstream. The creek was then directed close to the right bank (Dell Road), causing erosion measuring 5m in height. The erosion wrapped around a narrow peninsula, measuring 2-3m. Before the channel wrapped around the peninsula, the channel was directed into the left bank causing another large erosion site measuring approximately 4m by 6m. This caused undercutting under a stormwater culvert, causing it to be suspended 2.5m in the air (Photo 7-1). Near the halfway point of the sub-reach, a large mass wasting site was located on the right bank measuring 6m x 9m. This was identified as major erosion site E1R1 (Photo 7-2). Moving downstream, the right bank was again severely cut on the outside bend measuring 4.5m x 8m. Eventually, staff came across two wooden/steel bridges, both of which had undercutting near the footings. Following the last bridge, the right bank was cut measuring approximately 3m x 10m. Here, many trees from the upper banks had fallen into the channel.

Photo 7-1 Suspended stormwater culvert with large eroding bank

Photo 7-2 Severe mass wasting site on right bank

B.8 Sub-reach R2E

Sub-reach R2E (Figure 5-4) is located between Dell Road and Eden Prairie Road in the Riley Creek Lower Valley. The section between Dell Road and Eden Prairie Road is divided into three sub-reaches, and sub-reach R2E is the middle sub-reach.

There is extensive erosion along this reach and a significant threat to infrastructure. The creek is severely incised, as shown in Photo 8-1, and has resulted in tall eroding banks. There are also large scarps that have had mass wasting events in the past (Photo 8-2). Over time, the stream will attempt to create a channel with more stable dimensions; however the process of doing so will significantly erode banks as the stream creates a wider floodplain and then builds a new channel within the lower floodplain. Towards the downstream end of the sub-reach, there is a detention pond that was constructed in the floodplain. There is typical local bank erosion adjacent to the pond on the outside bank of a meander. Through the typical outside bank erosion and the channel widening processes, the relatively narrow embankment between the pond and the creek could be breeched as channel erosion continues. If the embankment were breeched, then pond would no longer be an effective treatment device and water quality in Riley Creek would be further degraded.

Photo 8-1 Channel incision in sub-reach R2E

Photo 8-2 Mass wasting in sub-reach R2E

B.9 Sub-reach P7E

Sub-reach P7E (Figure 5-5) is located in Reach 7 between Covington Road and Highway 101. The section is divided into 2 sub-reaches with sub-reach P7E being the top sub-reach starting at Covington Road and stretching approximately 220m downstream to a wetland.

The culvert under Covington Road has failed due to severe erosion occurring around it. The magnitude of the erosion has the potential to threaten the road in the future. Due to the failing culvert, significant erosion exists on both the upstream and downstream ends of the culvert, contributing to the poor water quality in this sub-reach. Frequent and almost continuous bank erosion is occurring, with exposed banks measuring up to 1.5m in height. The bottom sediment consists of gravel with areas of high silt concentrations and depositional peninsulas in slack water due to the eroding banks. Near the center of the sub-reach a severely eroded, undercut, and suspended stormwater culvert is present on the right bank (Photo 9-2). On the right bank down from the culvert the stream has cut into the right bank causing severe erosion measuring 2m in height (Photo 9-1). The creek then makes a hairpin turn to the right, causing severe bank erosion on the inside bend and moderate erosion on the outside bend of the turn.

Photo 9-1 Severe channel cutting in sub-reach P7E

Photo 9-2 Suspended stormwater culvert in sub-reach P7E

B.10 Sub-reach P1E

Sub-reach P1E (Figure 5-5) is located in Reach 1 of Purgatory Creek between the recreational trail off of Wild Heron Point and Riverview Road. This section is divided into 4 sub-reaches with sub-reach P1E being located in the middle of the section. The sub-reach begins 280m downstream of the recreational trail off of Wild Heron Point and ends at the restored Burr Ridge Lane mass erosion site. There are multiple issues in this sub-reach including continuous incising measuring up to 1m, severely eroded stormwater culverts, and 6 large mass wasting locations with 1 site having the potential to threaten private infrastructure if the erosion continues.

In the lower valley of Purgatory Creek, the slopes are very steep and the stream is actively meandering within the area. As the stream floodplain becomes constricted by the ravine slopes, large bank failures occur caused by the stream cutting into the valley slopes. There are 6 very large mass wasting sites within this section, which are contributing sediment yearlong to downstream sections and eventually the Minnesota River. The most significant mass wasting site measured approximately 9m high and 11m wide. The slope failure has exposed a massive, nearly vertical, raw bank. Watershed District staff and City of Eden Prairie staff gauged that the threat posed to the house present there is significant (approximately 25m to the deck footings of the home), however corrective actions to remediate the situation would be difficult and expensive due to equipment access issues.

Multiple stormwater culverts enter the stream along this sub-reach. Each is experiencing some magnitude of erosion with some being severely eroded. Due to the increased volume and speed of the water in this sub-reach as compared to upstream reaches, the stream is continually incised approximately 0.5-1m. Multiple large depositional areas consisting of fine sand/silt are located throughout this section due to the continuous bank erosion and large mass wasting sites. These areas are occurring along the inside bends of the stream channel or in other areas where slack water is present.

Photo 10-1 Mass wasting near home in sub-reach P1E

Photo 10-2 Large mass wasting site in sub-reach P1E

Appendix C

Photos on CD

Not included with this Draft