Lake Riley Outlet Improvements and Riley Creek Lower Valley Stabilization Feasibility Study

Prepared for
Riley Purgatory Bluff Creek Watershed District

March 20, 2007

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1.0 Introduction

Riley Creek has a ten square mile watershed, with mild topography in the upper and middle portions of the watershed and a steep, north-valley wall of the Minnesota River on the downstream end of the watershed. Riley Creek originates from lakes Lucy and Ann, and flows through Lake Susan, Rice Marsh Lake, and Lake Riley before it begins its descent to the Minnesota River. Riley Creek's discharge outlet is at Grass Lake, within the floodplain of the Minnesota River.

As the Riley Creek Watershed continues to develop, its watershed must adjust to the changes in land use and the increase in watershed runoff that accompanies urbanization. In particular, it has been observed that the Lake Riley Outlet is subject to plugging during intense rainstorms, which has resulted in high water levels within the lake over and extended period of time. In addition, the Lower Valley of Riley Creek requires stabilization in order to limit erosion of the steam channel and the steep valley bluffs. Accordingly, there are three primary goals of this feasibility study:

1) Define the hydrology of the Riley Creek Watershed using XPSWMM modeling software;

2) Evaluate the existing outlet of Lake Riley and make recommendations for modification of the outlet;

3) Evaluate the Lower Valley of Riley Creek, and recommend stabilization measures.

The results of this feasibility study are presented in detail herein, with discussion of the underlying analyses, specific recommendations for the lake outlet and stream stabilization measures, and a presentation of the estimated cost.

2.0 Background

2.1 Lake Riley Outlet

At the request of the residents that live on Lake Riley, the city of Eden Prairie submitted a petition to the District in 2005 to complete a hydrologic analysis of Riley Creek to determine if improvements/modifications of the existing Lake Riley outlet can be made. The existing lake outlet is located in the southeast corner of the lake. The existing outlet is a pipe, equivalent in capacity to a 30-inch pipe, located through a private driveway. Because of the large watershed area draining to Lake Riley and a relatively small outlet capacity, the lake level rises and stays at a higher level for an extended period after large rainfall events. This higher water level has an impact on the recreational use of the lake.

2.2 Riley Creek Lower Valley

The integrity of Riley Creek was also reviewed and recommendations for stream bank stabilization were developed. The Lower Valley of Riley Creek is about 3.8 miles long and up to 1,000 feet wide, descending from Lake Riley to the Minnesota River floodplain. Riley Creek is confined between the often steep valley walls, with little floodplain available for high flows. Therefore, flood flows often produce very high velocities in the confined channel, leading to bed and bank erosion. Furthermore, stabilizing bank vegetation is very sparse in the Lower Valley, owing to the dense canopy of the mature forest. Low-bank erosion is observed frequently along the entire length of the channel in the Lower Valley, while high-bank erosion is present less frequently. The high-bank erosion has larger consequences, however, in that it can contribute enormous quantities of sediment to Riley Creek, and could eventually threaten nearby homes.

The city's petition was modified to include the development and construction of a passive trail system along the creek. The location of the trail has been considered in the evaluation to minimize any potential conflict with the proposed creek stabilization improvements. Several of the high-bank erosion sites currently present a safety hazard for hikers.

3.0 XP-SWMM Hydrologic and Hydraulic Watershed Modeling Study

XP-SWMM is a dynamic rainfall-runoff simulation model that is based on the US Environmental Protection Agency's original Storm Water Management Model (SWMM), with a computerized graphical interface provided by XP Software. The model, which is used for single events or continuous simulation, generates local runoff hydrographs using rainfall data and watershed characteristics and routes the runoff through a system of pipes, ponds, and channels. The model can account for detention in ponding areas, backflow in pipes, surcharging of manholes, as well as tailwater conditions that may exist and affect upstream storage or pipe flows. The 1000-node version of XP-SWMM, Version 10.5, was used to model the Riley Creek watershed.

3.1 Hydrologic Modeling

Generation of storm water runoff was simulated using the SWMM Runoff Non-linear Reservoir Method in the XP-SWMM software. This method simulates hydrologic processes to determine the amount of rainfall that will infiltrate, evaporate, or remain on the ground surface and the amount of rainfall that will leave the watershed as runoff throughout the duration of a precipitation event. To predict the rate and volume of stormwater runoff from a watershed, it is necessary to develop input parameters to describe the physical characteristics of the watershed that impact the hydrologic processes. These input parameters are developed for each subwatershed and are used to generate inflow hydrographs at various points in the storm water system and along the creek. The methodology used to develop the main hydrologic input parameters used in the SWMM Runoff Non-linear Reservoir Method is described in the following sections.

3.1.1 Physical Watershed Characteristics

The amount of storm water runoff from a watershed is highly dependent upon the physical characteristics of the watershed, including the watershed area, the soil characteristics, the percent of impervious area, the runoff path through the watershed, and the slope of the land. ArcView geographic information systems (GIS) software was used extensively in assessing the above mentioned characteristics for each subwatershed within the watershed.

3.1.1.1 Watershed Area

The Riley Creek watershed was subdivided into 385 smaller subwatersheds for modeling purposes (Map 1). The subwatershed delineation for the portion of the Riley Creek watershed within Chanhassen was based on two-foot topographic maps provided by the City of Chanhassen and review of past development plans. The subwatersheds for the areas in Eden Prairie that drain to Rice Marsh Lake and Lake Riley were delineated using past development plans and U.S.G.S. quad-based ten-foot topography, as two-foot topography data was not available for this area. Two-foot topography was provided by the City of Eden Prairie for a large portion of the lower Riley Creek watershed (downstream of Lake Riley). These data, derived from aerial photographs taken in 1989, were used in conjunction with more recent development plans to delineate subwatersheds in the lower portion of the Riley Creek watershed.

3.1.1.2 Watershed Imperviousness

The imperviousness of a watershed is a key parameter in predicting the amount of runoff generated. The quantity of runoff generated from different land uses varies based on the imperviousness of the land. Land use characterized by high imperviousness (eg. commercial areas) will generate higher runoff rates and volumes than land uses with lower imperviousness (eg. residential areas).

The percentage of impervious area was estimated for each individual subwatershed as an input parameter for the hydrologic model. The imperviousness of each subwatershed was estimated using land use data for both existing and future development conditions. A GIS land use coverage representing existing development conditions was developed using land use data derived by the Metropolitan Council from aerial photos taken in 2000. This land use information was updated to reflect 2006 conditions using several additional data sources including the 2003 Farm Service Agency aerial photography, the 2004 U.S.G.S. aerial photography, the National Wetland Inventory (NWI), and the City of Chanhassen's land use data. To represent future development conditions, the 2006 GIS land use coverage was revised based on the Metropolitan Council's 2020 planned land use data and specific development plans that were available for developing areas within the watershed (including the T.H.212 corridor).

Land use within the study area was divided into the following categories: agricultural, airport, commercial, golf course, natural/open/park, golf course, highway, industrial/office, institutional, residential, wetlands, and open water. For modeling purposes, these residential categories were further broken down based on the density of housing units within the area. The GIS land use coverage and aerial imagery was used in ArcView to determine the density of the residential areas. The single-family residential areas were further categorized as very low density residential (<1 unit/acre), suburban low density residential (1-3 units/acre), low density residential (3-4 units/acre), medium density residential (4-8 units/acre), and high density residential (>8 units/acre). Map 2 shows the land use designations for the Riley Creek watershed.

The land use categories were used to estimate the total and "directly-connected" impervious fractions for each subwatershed within the study area. The total impervious fraction of a watershed represents the portion of the watershed that is covered by an impervious surface. The "directly-connected" impervious fraction represents the impervious surfaces that are hydraulically connected to a stormwater conveyance system. For example, if a rooftop drains onto an adjacent pervious area such as a yard, it is not a "directly-connected" impervious area. However, if a rooftop drains onto a driveway, which drains to the street and thence to a stormwater catchbasin, the rooftop would be a "directly-connected" impervious area.

To determine the impervious fractions within each subwatershed, assumptions for the total impervious fraction and "directly-connected" impervious fraction were made for each land use. The land use categories and associated impervious fraction assumptions used for the hydrologic analysis are listed in Table 1. The imperviousness assumptions used for the non-residential land use categories were based on calibrated XP-SWMM models from previous studies. To determine appropriate imperviousness assumptions for the residential land use categories, the impervious areas in several representative residential communities throughout the Riley Creek watershed were digitized in ArcView using aerial imagery. The estimated impervious assumptions for residential and other land uses were further refined based on model calibration.

Table 1. Total Percent Impervious and Percent Directly-Connected Impervious by Land Use for the Riley Creek Watershed

LANDUSE	Percent Impervious	Percent Directly-Connected Impervious
Agricultural	5	1
Airport	85	80
Commercial	86	85
Golf Course	6	4
High Density Residential	68	50
Highway	25	25
Industrial/Office	62	61
Institutional	49	40
Institutional - High Imperviousness	75	70
Low Density Residential	39	24
Medium Density Residential	59	37
Suburban Low Density Residential	32	17
Natural/Park/Open	5	3
Forest	0	0
Open Water	100	100
Other	60	55
Very Low Density Residential	12	10
Wetland	100	100

3.1.1.3 Watershed Width and Slope

The SWMM Runoff Non-linear Reservoir Method was used as the hydrograph generation method. This method computes outflow as the product of velocity, depth and a watershed width factor. The watershed "width" in XP-SWMM is defined as twice the length of the main drainage channel, with adjustments made for watersheds that are skewed (i.e., the areas on both sides of the main drainage channel are not equal). This factor is a key parameter in determining the shape of the hydrograph for each watershed and is often used as a calibration parameter. To determine the width parameter, the main drainage channel for each watershed was digitized in ArcView and a customized ArcView script was used to calculate the width based on the skew of the drainage path within the subwatershed.

The average slope (in percent) for each subwatershed was calculated in ArcView using the U.S.G.S. National Elevation Dataset (NED) 1:24,000 scale digital elevation data. The data were obtained in grid format and the area-weighted percent slope was then calculated by measuring the differences in elevation between each grid cell within each individual subwatershed.

3.1.1.4 Soils

The soil characteristics of a watershed can play a significant role in the amount of stormwater runoff generated. Soils with a high infiltration capacity (well-drained, sandy soils) have a low runoff potential, while soils with a low infiltration capacity (poorly drained, clayey soils) will generate more runoff. Soils data for the Riley Creek watershed were obtained through the Hennepin County and Carver County Natural Resources Conservation Service (NRCS) Soils GIS database. The database included the soil names and the hydrologic soil group (HSG) designation, which classifies soils into groups (A, B, C, and D) based on the infiltration capacity of the soil (well drained, sandy soils are classified as "A" soils; poorly drained, clayey soils are classified as "D" soils). When a hydrologic soil group designation was not included in the soils database, the soil description was used to estimate the HSG. If a soil description was unavailable, the most dominant soil group in the vicinity was assumed. Although all soil types are represented in the watershed, the predominant soil type in the watershed is Type B (sandy loam). Map 3 shows the hydrologic soil group designations for the Riley Creek watershed.

3.1.2 Assumptions for Hydrologic Processes

3.1.2.1 Infiltration

Infiltration was simulated in the XP-SWMM models using the Horton Infiltration equation. This equation is used to represent the exponential decay of infiltration capacity of the soil that occurs during rainfall or snowmelt events. The soil infiltration capacity is a function of the following variables: F_o (maximum or initial value of infiltration capacity), F_c (minimum or ultimate value of infiltration capacity), k (decay coefficient), and time. These infiltration parameters are used for the generation of runoff from the individual subwatersheds.

The actual values of F_o, F_c, and k are dependent upon soil, vegetation, and initial moisture conditions prior to a rainfall or snowmelt event. Because it was not feasible to obtain this detailed information for each subwatershed through field samples, it was necessary to make assumptions based on the various soil types throughout the watershed. Composite infiltration parameters (F_o and F_c) were calculated for each subwatershed based on the fraction of each soil type within the subwatershed. Global databases containing the infiltration parameters for each subwatershed were developed and imported into the XP-SWMM models.

The values of F_o, F_c, and k initially used for modeling the Riley Creek watershed were based on suggested values in the *Storm Water Management Model, Version 4: User's Manual*, U.S. EPA, 1988. The initial values were then adjusted through calibration and those final assumptions are reflected in Table 2, which summarizes the Horton infiltration values used for each Hydrologic Soil Group to calculate composite infiltration parameters for each subwatershed.

Table 2. Horton Infiltration Parameters

Hydrologic Soil Group	F_o (in/hr)	F_c (in/hr)	k (1/sec)
A	7	0.152	0.0008
B	4.2	0.092	0.0008
C	2.8	0.04	0.0008
D	1.4	0.012	0.0008

3.1.2.2 Depression Storage

Depression storage represents the volume (in inches) of storage on the land surface that must be filled with rainfall prior to the occurrence of runoff. This parameter characterizes the loss or "initial abstraction" caused by such phenomena as surface ponding, surface wetting, interception and evaporation. The model handles depression storage differently for pervious and impervious areas. The impervious depression storage is replenished during dry simulation periods by evaporation. The water stored as pervious depression storage is subject to both infiltration and evaporation. Therefore, separate depression storage input values are required in XP-SWMM for pervious and impervious areas. Depression storage inputs were set within the general range of published values. The assumed impervious depression storage was 0.06 inches and the pervious depression storage was 0.17 inches. XP-SWMM also uses a "Zero Detention Storage" parameter to account for areas that generate immediate runoff (i.e., water surface areas). This parameter was estimated for each subwatershed by dividing the water surface area by the directly connected impervious surface area.

3.1.2.3 Overland Flow Roughness

Overland flow is the surface runoff that occurs as sheet flow over land surfaces prior to concentrating into defined channels. A modified version of Manning's equation is used to calculate the rate of overland flow in XP-SWMM. A key parameter in the Manning's equation is the roughness coefficient, which accounts for the surface friction that occurs as water flows across different land surfaces. The shallow flows typically associated with overland flow result in substantial increases in surface friction. As a result, the roughness coefficients typically used in open channel flow calculations are not applicable to overland flow estimates. These differences can be accounted for by using an effective roughness parameter instead of the typical Manning's roughness parameter.

Typical values for the effective roughness parameter are published in the *HEC-1 User's Manual*, September 1990 and in *Engineering Hydrology: Principles and Practices* (Ponce, 1989). After reviewing the above references in combination with the land use data, the general pervious, forested pervious and non-directly connected impervious effective roughness parameters of 0.2, 0.4 and 0.015 were selected, respectively, for this study area. An area weighted pervious roughness was determined for each subwatershed in the study area by weighting the pervious area and unconnected impervious area.

3.2 Hydraulic Modeling

The storm water runoff hydrographs generated by XP-SWMM are routed through the storm sewer, ponding, and stream network in the hydraulic mode of the model. XP-SWMM has advanced hydraulic capabilities and can handle complex hydraulic situations such as large drainage networks, detailed hydraulic structures, natural channel stream flow, detention in ponding areas, backflow in pipes, surcharging of manholes, and impacts of tailwater conditions on upstream storage or flows. The Riley Creek watershed has a large number of ponding basins (both natural and manmade) that are connected by storm sewer networks that ultimately discharge into Riley Creek at various points throughout the watershed. The ponding basins, connecting storm sewer systems, and creek system were all included in the XP-SWMM modeling for Riley Creek. The data required and assumptions made for the hydraulic modeling are summarized below.

3.2.1 Storm Sewer Network

Data detailing the storm sewer network within the Riley Creek watershed were obtained from as-built construction plans obtained from Chanhassen and Eden Prairie and from development plans submitted to the Riley-Purgatory-Bluff Creek Watershed District for permitting purposes. Relevant storm sewer information gathered from the as-built and development plans included the type of pipe (material of construction), invert elevations, pipe sizes, pipe lengths, and manhole rim elevations. All elevations entered into the model are in Mean Sea Level (MSL). Where this data was incomplete, additional information was obtained from other sources such as field surveys or was estimated based on professional judgement.

A variety of pipe types are used throughout the watershed. The assumptions used for the roughness coefficient (Manning's "n") for each type of storm sewer pipe are listed in Table 3.

Table 3. Roughness Coefficient Assumptions

Pipe Type	Abbreviation	Assumed Roughness Coefficient
Corrugated Metal Pipe	CMP	0.024
Clay	-	0.015
Steel	-	0.015
Ductile Iron Pipe	DIP	0.014
Reinforced Concrete Pipe	RCP	0.012
Polyvinyl Chloride	PVC	0.01
High Density Polyethylene	HDPE	0.008

Outlets from ponding areas that may be inlet controlled were modeled in XP-SWMM assuming a groove end projecting concrete pipe inlet condition. This allowed XP-SWMM to determine the controlling flow condition in the outlet pipe (i.e., is the flow in the pipe controlled by the inlet size, barrel capacity, or tailwater conditions).

3.2.2 Natural Channel Cross-Sections and Hydraulic Structures

The Riley Creek system was modeled using representative natural channel cross-sections, with exception to the areas along Riley Creek with a consistent water surface elevation (lakes and wetlands). Cross-section data for the natural channel of Riley Creek were field surveyed to reflect variations in the stream valley topography and to estimate the backwater effects of the bridges and culverts. Cross-section survey data were field collected by Barr Engineering survey staff using a global positioning system (GPS). Additional data at hydraulic structures were also surveyed by Barr Engineering.

Loss coefficients for bridges, other channel obstructions, channel roughness, and channel overbank roughness (Manning's "n") were estimated by field inspection and photographs. For Riley Creek, a Manning's "n" value of 0.035 was used for the relatively smooth stream channel, with the exception of a few steep ravine areas where a channel Manning's "n" of 0.05 was used. Manning's "n" values of 0.05 were used for overbanks that are vegetated.

3.3 Model Calibration

Values for the XP-SWMM model parameters were set based on the hydrologic and hydraulic characteristics of the study area, and the calibration of the XP-SWMM model against flow monitoring data collected the Watershed Outlet Monitoring Program (WOMP) station located just upstream of US Highway 212 (US 212) on Riley Creek (Map 1). Two storm events with differing intensities and initial soil moisture conditions were chosen for calibration purposes – the September 15 and 16, 2004 event, and the June 16, 2006 event. The XP-SWMM model calibration runs assumed 2006 land use conditions. Due to significant development throughout the Riley Creek watershed over the past few years, particularly in the lower valley of the watershed, a small amount of error is expected when comparing XP-SWMM results to monitored storm events before 2006.

The September 15 and 16, 2004 storm event was a 1.63-inch event that took place over approximately 15 hours (Figure 1). Before the September 15-16 event, 0.89 inches of rain fell during the previous eight days, so the soils were somewhat saturated. To account for the moist soils conditions at the onset of the calibration event, the calibrated Horton initial infiltration rates (F_o) were divided by 3, which is consistent with recommendations in XP-SWMM reference material. Figure 2 compares the flows from the calibrated XP-SWMM model for the September 2004 event to the observed flows recorded at the flow monitoring station.

The June 16, 2006 storm event was a 2.5-inch event that took place over approximately 6 hours (Figure 3). It was very dry for a long period before the June 16, 2006 event. To account for the dry period prior to the storm event, the water levels in the stormwater ponds were adjusted to be below the normal outlet elevations, based on regional evaporation estimates. Figure 4 compares the flows from the calibrated XP-SWMM model for the June 2006 event to the flows recorded at the flow monitoring station.

Figure 1. Riley Creek - Storm Event, September 15-16, 2004 (total rainfall 1.63 inches)

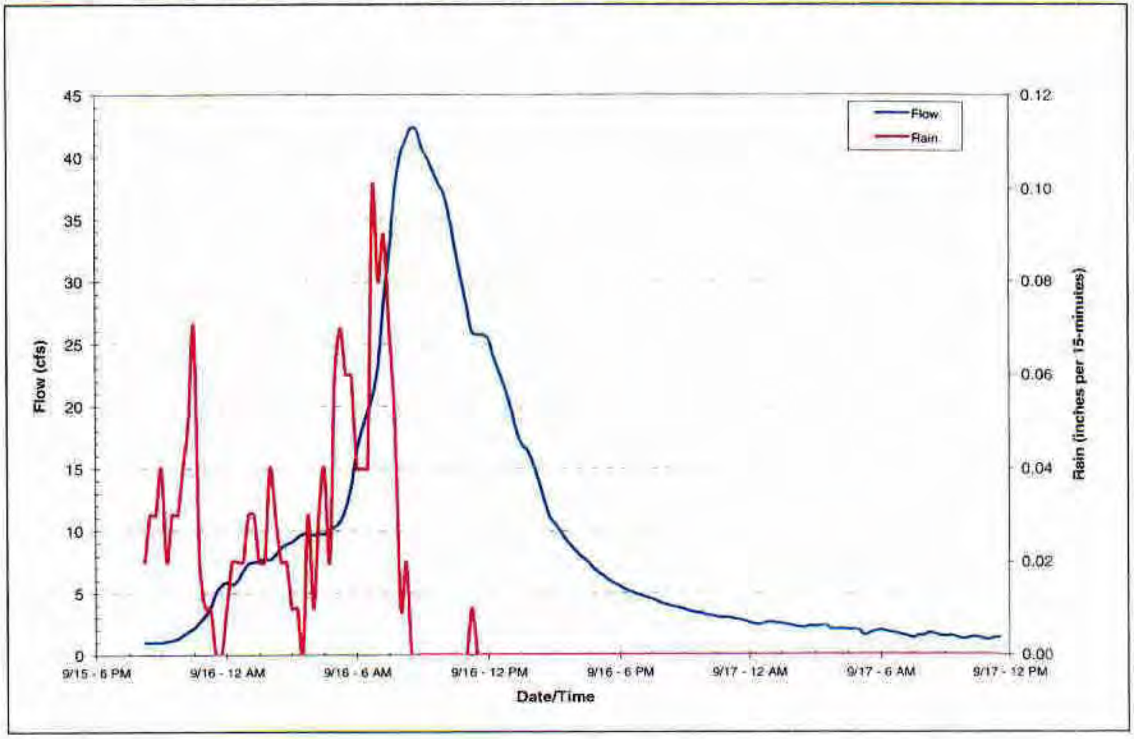


Figure 2. Observed flow from Hwy 212 flow monitoring station on Riley Creek compared to XP-SWMM modeled flow using calibration parameters for the Sept 15 - 16, 2004 storm event (1.63 inches)

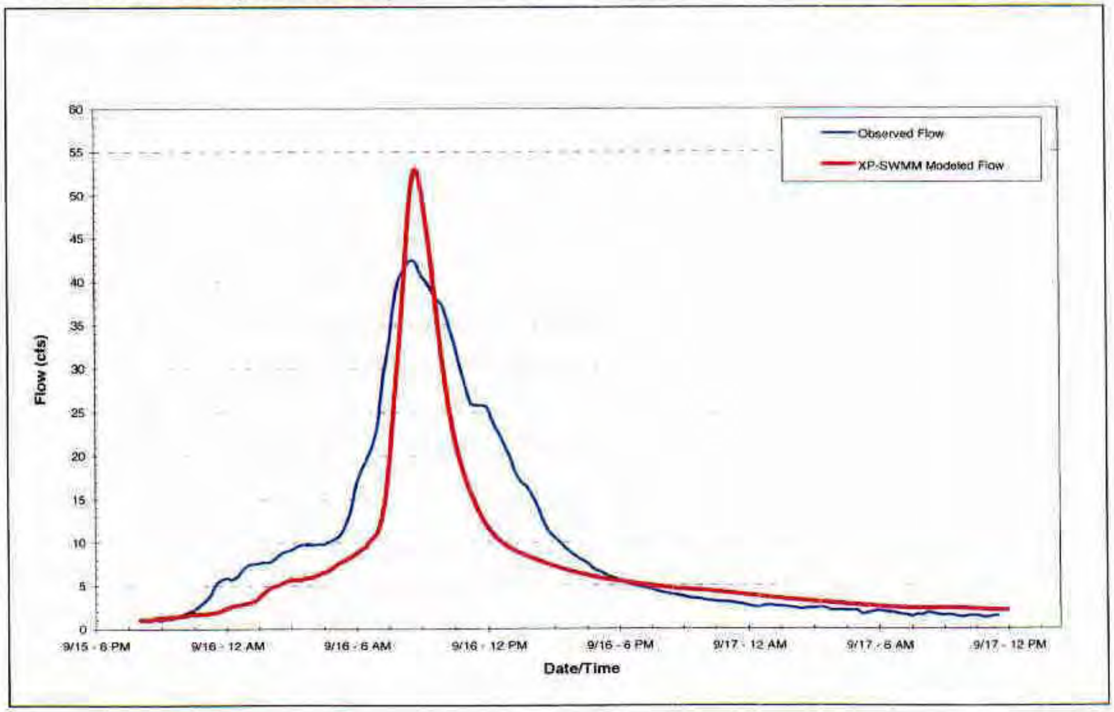


Figure 3. Riley Creek - Storm Event, June 16, 2006 (total rainfall 2.5 inches)

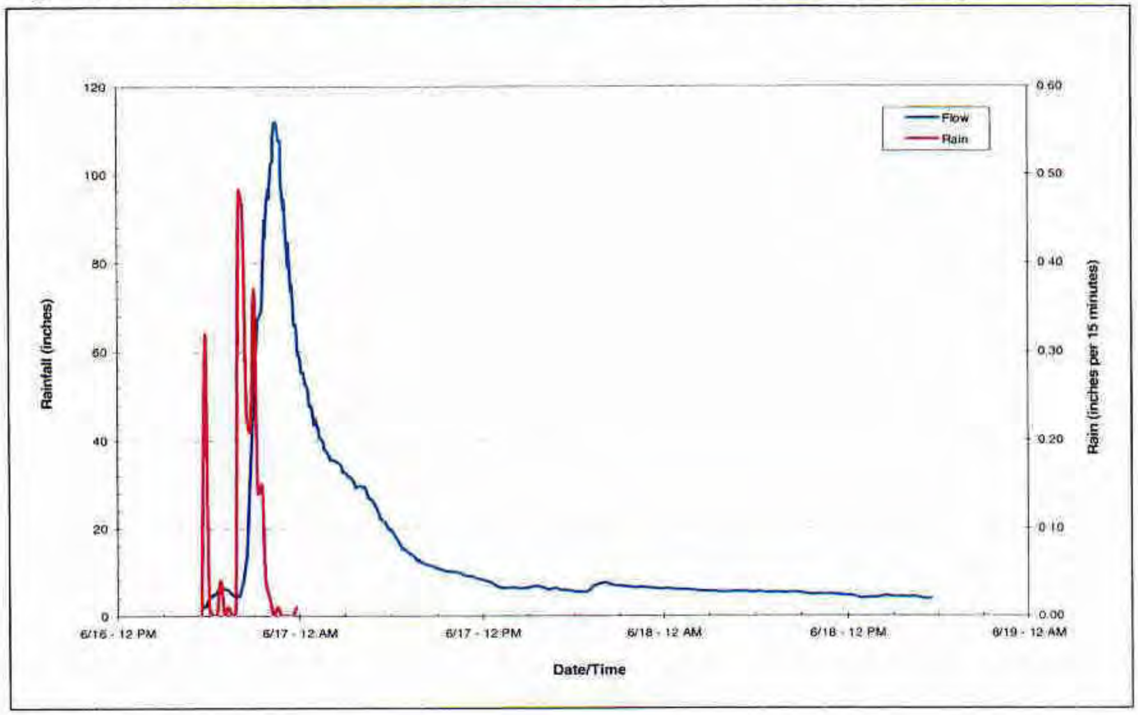
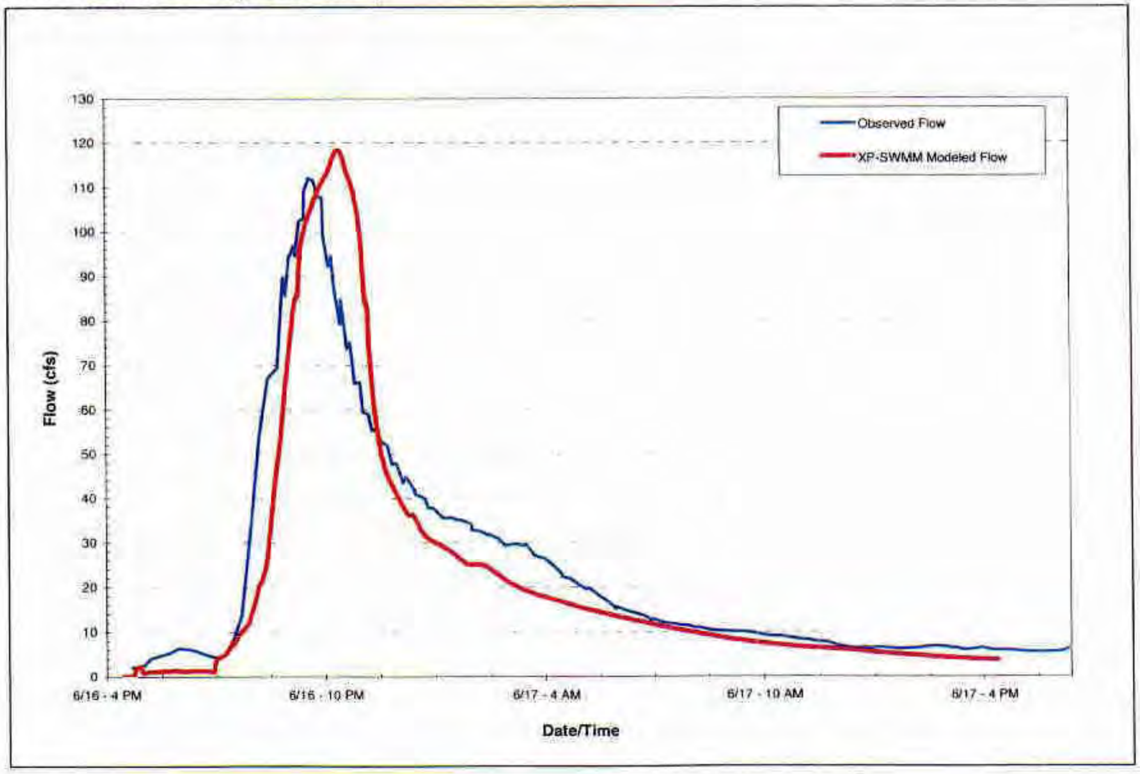


Figure 4. Observed flow from Hwy 212 flow monitoring station on Riley Creek compared to XP-SWMM modeled flow using calibration parameters for the June 16, 2006 storm event (2.5 inches)



4.0 Lake Riley Outlet Analysis

4.1 Background and Objectives

Lake Riley is located in the cities of Chanhassen and Eden Prairie and is approximately 294 acres in surface area. The lake has a direct drainage area of approximately 1,061 acres, excluding the lake surface. Riley Creek enters Lake Riley in the northeast side of the lake and continues at the outlet in the southeast side of the lake. Riley Creek begins at Lake Lucy, it inlets to and outlets from Lake Ann, Lake Susan, and Rice Marsh Lake before it enters Lake Riley. The total drainage area to Lake Riley, including both direct and indirect drainage, is over 5,100 acres.

The normal water level of Lake Riley is controlled at elevation 864.5 M.S.L. by a 20-foot long weir structure, which is located in the creek channel approximately 170 feet downstream of the lake. Under existing outlet conditions, the discharge from Lake Riley is controlled by several factors, including restrictive channel geometry and a pipe that is equivalent in capacity to a 30-inch pipe, located underneath Lakeland Terrace (approximately 700 feet downstream of Lake Riley).

Because of the large watershed area draining to Lake Riley and a relatively small outlet capacity, the lake level rises and stays at a higher level for an extended period of time after large rainfall events. The high water levels and the length of time it takes for the water level to return to normal conditions are of concern to the local residents due to the impact on the recreational use of the lake. In addition, the outlet pipe at Lakeland Terrace has been subject to plugging during intense rain storm events, prolonging the high water elevations.

The objectives of the Lake Riley outlet analysis were to 1) evaluate the impact of significant runoff events on Lake Riley under existing outlet conditions, and 2) to analyze outlet modification alternatives that would decrease the duration of high water levels on Lake Riley during significant runoff events, without impacting the stability of the stream channel downstream of Lake Riley.

4.2 Evaluation of Existing Outlet Conditions

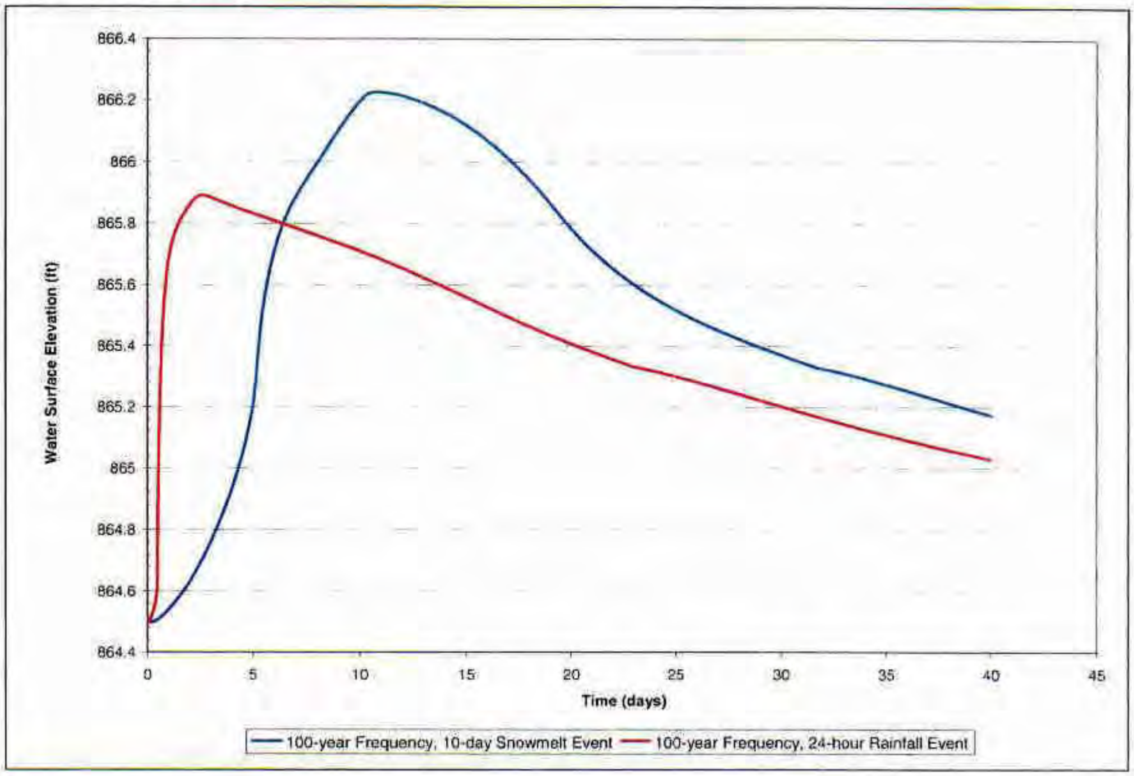
The XP-SWMM hydrologic and hydraulic model described in Chapter 3 was used to gain a better understanding of how the watershed tributary to Lake Riley, including the upstream lakes and Riley Creek, responds to significant rainfall and snowmelt events. The model was used to evaluate flood levels and flow rates throughout the creek system, with special attention focused on the flood levels at Lake Riley and the predicted duration of high water levels based on the existing outlet configuration. Flood levels and discharge rates were evaluated for the 100-year, 10-year, and 2-year frequency recurrence intervals.

As discussed in Chapter 3, the XP-SWMM model was first developed and calibrated to observed storm events based on existing land use characteristics. Upon calibration of the model input parameters, the model was revised to reflect ultimate land use conditions. Using this model, several 100-year frequency rainfall and snowmelt events of differing durations were simulated to establish the "critical" conditions for flood levels on Lake Riley. It was determined that the 10-day snowmelt event (6 inches of runoff over the watershed) resulted in the highest predicted flood level at Lake Riley. The 24-hour rainfall event (6 inches of rainfall), using an SCS Type II rainfall distribution, resulted in a slightly lower flood elevation than the 10-day snowmelt event.

The predicted water surface elevations of Lake Riley as a result of a 100-year, 10-day snowmelt event (shown in blue) and a 100-year, 24-hour rainfall event (shown in red) are depicted for a 40 day time period in Figure 5. Based on the model results for the 10-day snowmelt event, the critical 100-year flood elevation in Lake Riley is approximately 866.2 M.S.L. The peak water surface elevation from the 100-year frequency, 24-hour event is approximately 865.9 M.S.L. Figure 5 shows that the duration of high water elevations in Lake Riley is significant, with the surface water levels remaining at least a half foot above the normal water elevation after 40 days (assuming no additional precipitation occurs during this time period).

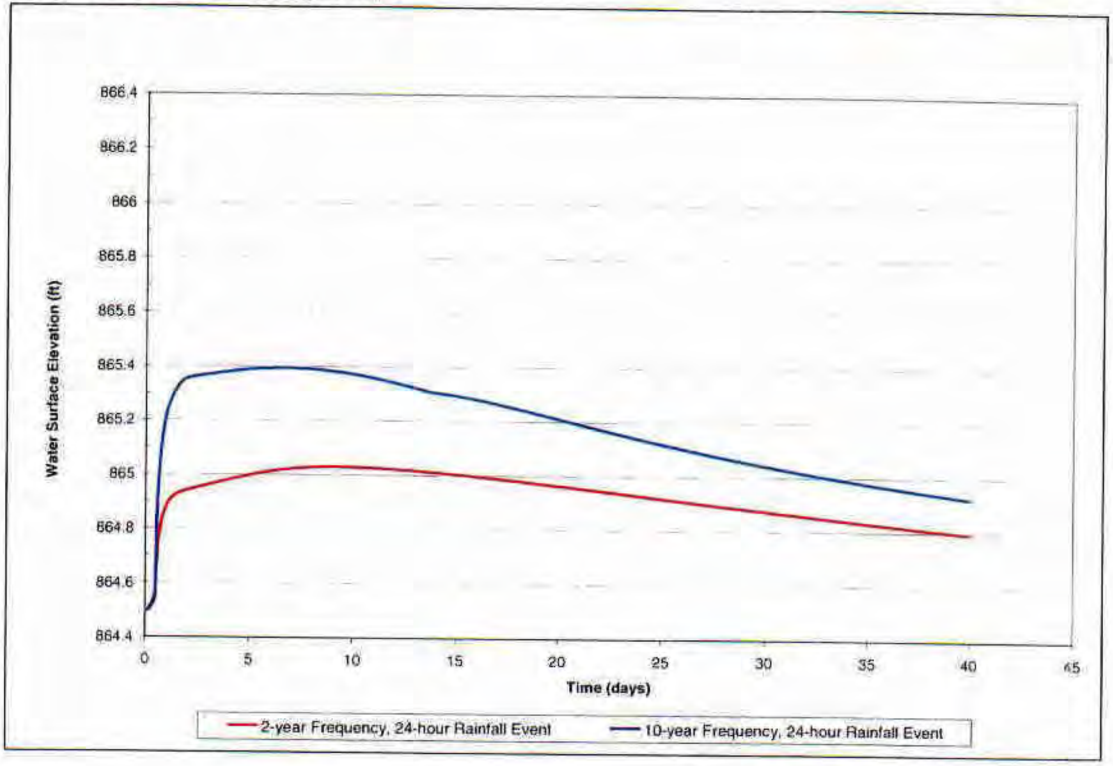
The predicted water elevations in Lake Riley shown in Figure 5 are based on the recommendation that an outlet be constructed at Rice Marsh Lake to control the discharge capacity from Rice Marsh Lake into Lake Riley. Currently the discharge from Rice Marsh Lake is restricted only by the natural channel of Riley Creek, which results in high discharge rates to Lake Riley. A controlled outlet at Rice Marsh Lake would better utilize the flood storage available in Rice Marsh Lake and decrease the peak flood elevation in Lake Riley. For modeling purposes, the Rice Marsh Lake outlet was assumed to be a 42-inch reinforced concrete pipe (RCP), establishing a normal elevation of 876 M.S.L., one foot below the ordinary high water elevation of Rice Marsh Lake as determined by the Minnesota Department of Natural Resources.

Figure 5. Predicted 100-Year Frequency Water Surface Elevation at Lake Riley based on Existing Outlet



The 10-year frequency, 24-hour event (4.1 inches) and the 2-year frequency, 24-hour event (2.8 inches) were also modeled to determine approximate flood elevations and assess the duration of high water levels for more frequently occurring storms. The predicted water surface elevations for the 10-year, 24-hour event and the 2-year, 24-hour event are shown in Figure 6.

Figure 6. Predicted 10-Year and 2-Year Frequency Water Surface Elevations at Lake Riley based on Existing Outlet



4.3 Evaluation of Outlet Modification Alternatives

The objectives of the Lake Riley outlet analysis were to evaluate the impact of significant runoff events on Lake Riley under existing outlet conditions and to analyze outlet modification alternatives to decrease the duration of high water levels on Lake Riley during significant runoff events, without impacting the stability of the stream channel downstream of Lake Riley.

The normal water level of Lake Riley is controlled by a 20-foot long weir structure, which is located in the channel of Riley Creek approximately 170 feet downstream of the lake. A private channel crossing (Lakeland Terrace) is located approximately 500 feet downstream of the Lake Riley weir structure. The pipe under Lakeland Terrace was originally a 3-foot by 3-foot rock culvert that was slip-lined with polyethylene pipe for stability purposes in 1996. The resulting culvert has a diameter of approximately 2.5 feet. Downstream of the Lakeland Terrace crossing is a railroad crossing of the creek with a 6-foot by 6-foot box culvert and the County Road 1 (Pioneer Trail) crossing of the creek with a 6-foot diameter metal culvert.

4.3.1 Existing Outlet Capacity Constraints

When evaluating outlet modification alternatives for increasing the outlet capacity from Lake Riley, it is important to understand the discharge capacity constraints of the existing system. The XP-SWMM model was used to analyze the existing outlet configuration to determine which hydraulic structures or channel reaches are currently "limiting" the discharge capacity from Lake Riley. Prior to this study, the assumption was that the discharge capacity from Lake Riley was controlled solely by the pipe at the Lakeland Terrace crossing. However, modeling results, which are summarized below, indicate that it is a combination of constraints that control the discharge from the lake.

To quantify the impact that the Lakeland Terrace culvert crossing has on the discharge from Lake Riley, the 100-year frequency, 24-hour rainfall event was modeled using the assumption that the Lakeland Terrace culvert was replaced with a significantly larger culvert (a 10-foot by 12-foot box culvert was assumed to ensure that the culvert would not be restricting the flow). The discharge from Lake Riley under this scenario was compared with the predicted discharge under existing outlet conditions (Figure 7). As shown in Figure 7, the discharge hydrographs from these two scenarios are nearly identical, with slight variations occurring as the surface water elevation approaches 865.8 M.S.L (Figure 8). This indicates that the Lakeland Terrace crossing does not restrict the discharge from Lake Riley when the lake is at elevations below 865.8 M.S.L. Modeling results indicate that the channel between Lake Riley and the weir outlet structure limits the discharge from the lake when the surface water elevation of Lake Riley is below this elevation.

The 100-year frequency, 10-day snowmelt event was also modeled using the assumption that the Lakeland Terrace culvert was replaced with a significantly larger culvert. The discharge from Lake Riley under this scenario was compared with the predicted discharge under existing outlet conditions (Figure 9). The discharge hydrographs from these two scenarios are identical until Day 6.5, when the discharge from the Lakeland Terrace culvert replacement scenario exceeds that of the existing conditions scenario. This variation in discharge from Lake Riley coincides with a surface water elevation in Lake Riley of approximately 865.8 M.S.L. (Figure 10), which indicates that the existing Lakeland Terrace culvert controls the discharge from Lake Riley when the lake level is at or above 865.8 M.S.L.

Figure 7. Comparison of Discharge for Existing Conditions versus Larger Culvert for 100-Year, 24-Hour Rainfall Event

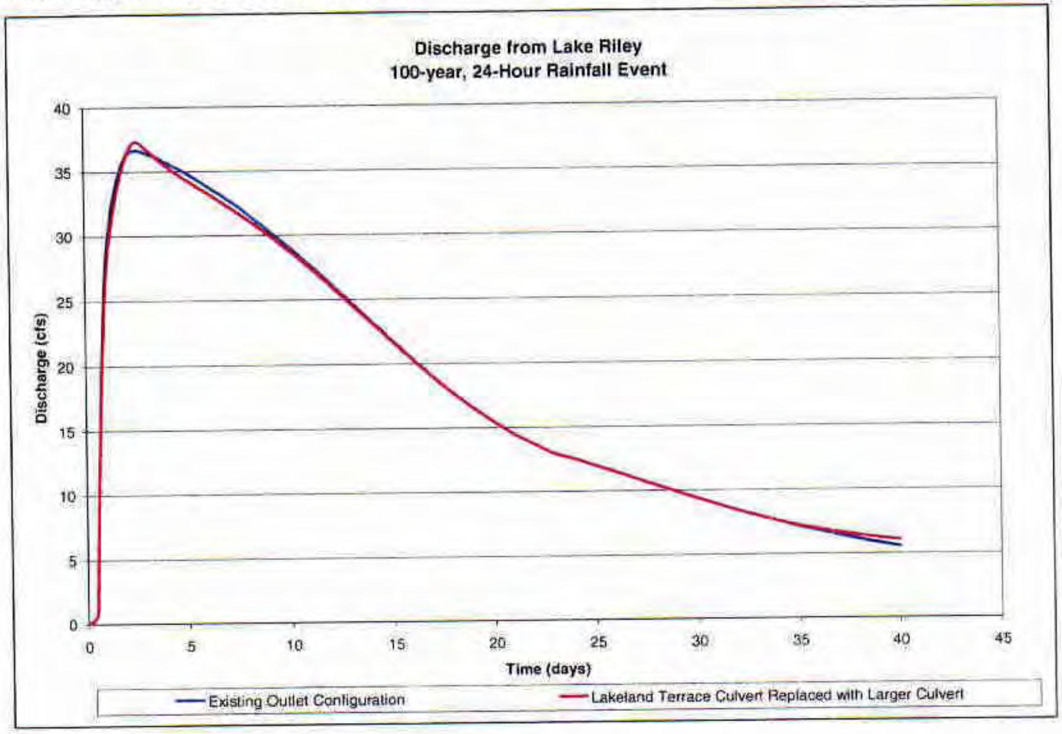


Figure 8. Comparison of Stage for Existing Conditions versus Larger Culvert for 100-Year, 24-Hour Rainfall Event

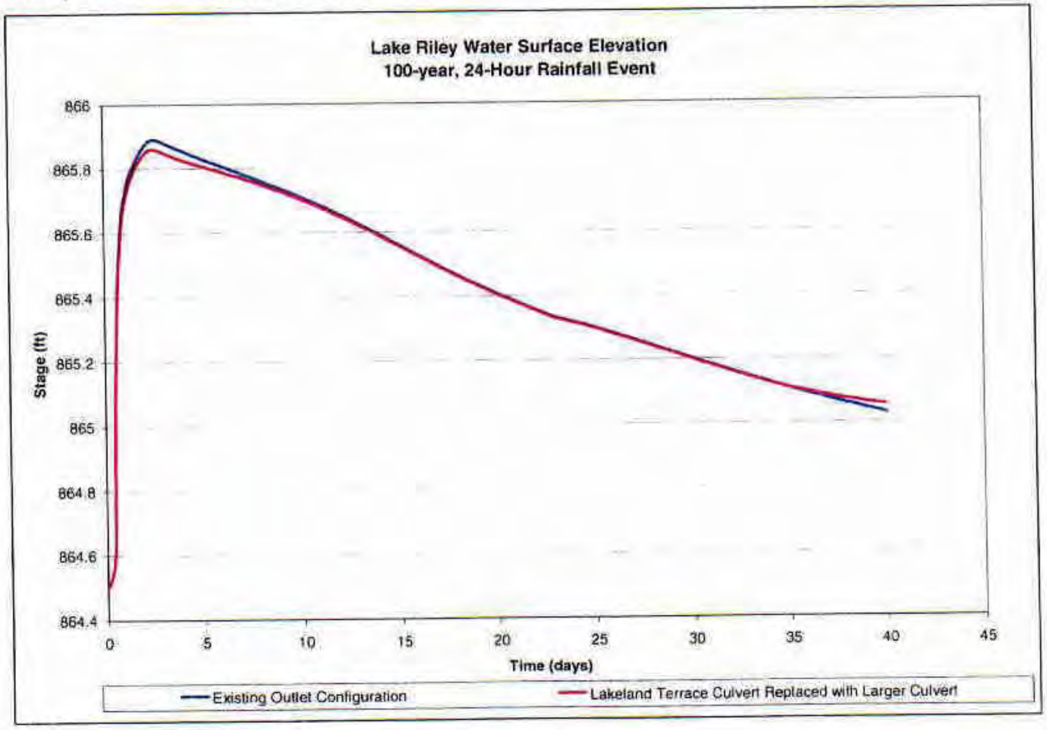


Figure 9. Comparison of Discharge for Existing Conditions versus Larger Culvert for 100-Year, 10-Day Snowmelt Event

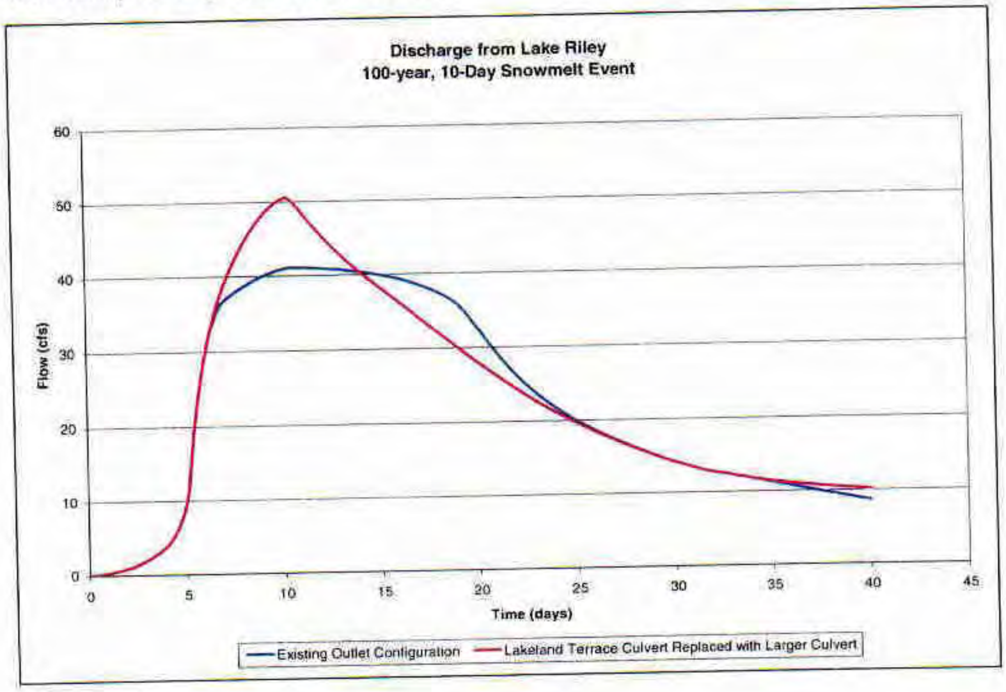
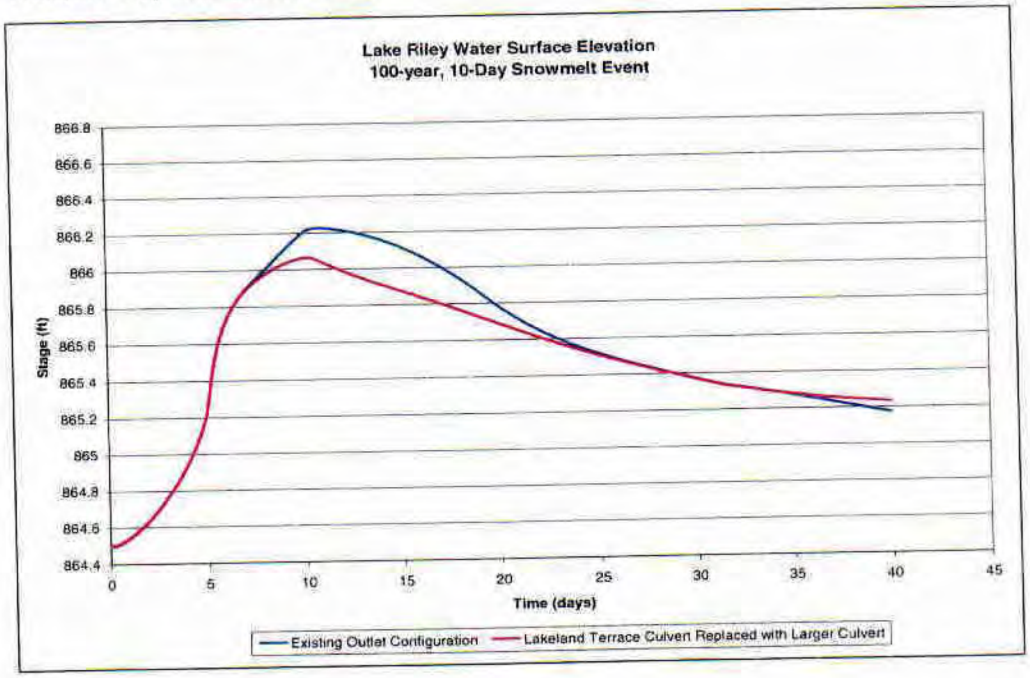


Figure 10. Comparison of Stage for Existing Conditions versus Larger Culvert for 100-Year, 10-Day Snowmelt Event



4.3.2 Lake Riley Outlet Modification Recommendations

Based on modeling results, it was determined that the stream channel between Lake Riley and the outlet weir is restrictive, controlling the discharge from Lake Riley when the water surface of the lake is below an elevation of 865.8 M.S.L. When the water levels in Lake Riley are above this approximate elevation, the existing culvert underneath Lakeland Terrace limits the discharge capacity.

4.3.2.1 Widen Stream Channel at Lake Riley Outlet

To increase the outflow capacity of the lake, it is recommended that the stream channel between Lake Riley and the outlet weir be widened so as not to limit the flow out of the lake. This scenario was modeled for the 100-year, 24-hour rainfall and 100-year, 10-day snowmelt events to determine the impact on the elevation and duration of high water levels in Lake Riley. The predicted water surface elevations of Lake Riley assuming a widened stream channel scenario (shown in green) are compared with existing outlet conditions (shown in blue) for the 100-year, 24-hour and 100-year, 10-day events in Figures 11 and 12, respectively.

Modeling results for the 100-year, 24-hour rainfall event indicate that widening the stream channel between Lake Riley and the outlet weir would result in a peak flood level in Lake Riley of 865.8 M.S.L, which is 0.1 foot below the flood level under existing outlet conditions. Although the change in flood elevation can be considered insignificant, the duration of high water levels is decreased considerably under this scenario (Figure 11). The period of time that water levels are high (water level of 865.0 M.S.L. or greater) decreases from just over 40 days to approximately 16 days.

Modeling results for the 100-year, 10-day snowmelt event indicate that widening the stream channel between Lake Riley and the outlet weir would result in a peak flood level in Lake Riley of approximately 866.0 M.S.L, which is 0.2 foot below the flood level under existing outlet conditions. Although the change in flood elevation is somewhat minor, the duration of high water levels is decreased considerably under this scenario, as well (Figure 12). The period of time that water levels are high (water level of 865.0 M.S.L. or greater) decreases from over 50 days to approximately 26 days.

Figure 11. Comparison of Discharge for Existing Conditions versus Outlet Modification Scenarios for 100-Year, 24-Hour Rainfall Event

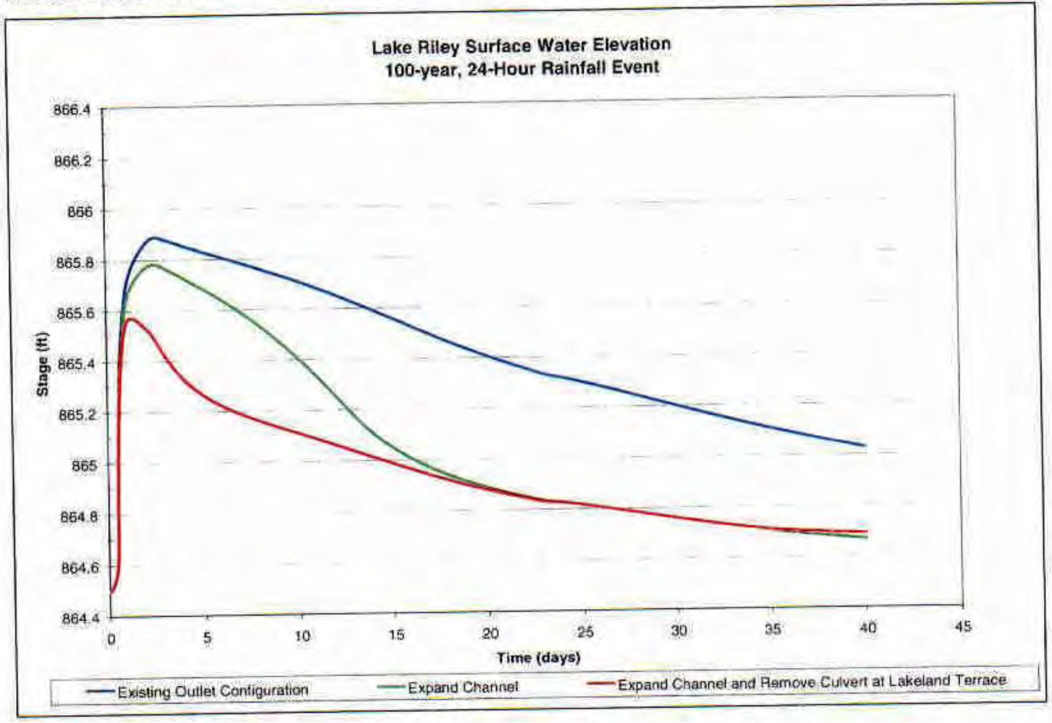
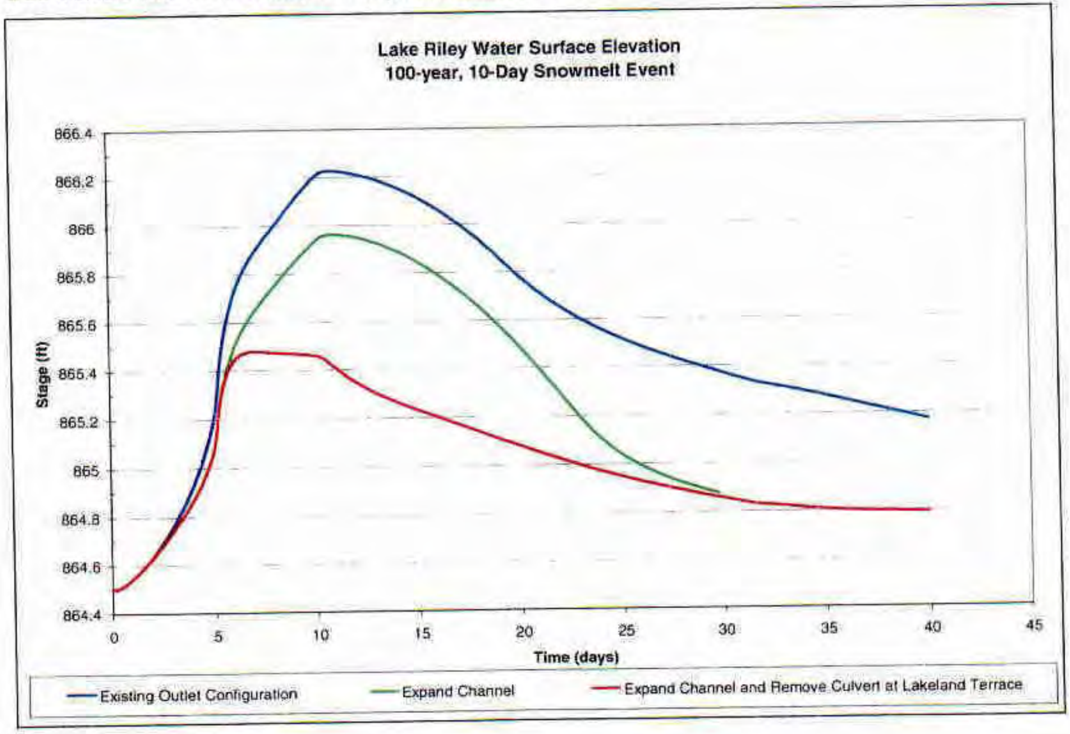


Figure 12. Comparison of Stage for Existing Conditions versus Outlet Modification Scenarios for 100-Year, 10-day Snowmelt Event



4.3.2.2 Replace Lakeland Terrace Culvert with Larger Structure

As previously stated, the existing culvert underneath Lakeland Terrace limits the discharge capacity from Lake Riley at times when lake levels are extraordinarily high (greater than 865.8 M.S.L.). Due to the relatively small size of this culvert, there have been problems in the past with debris blocking the culvert during times of high flow, causing further restrictions on the outflow from Lake Riley. To increase the discharge capacity through the crossing and help prevent potential plugging of the pipe, it is recommended that the existing culvert be removed and replaced with a larger structure.

To determine the impact of replacing the existing Lakeland Terrace culvert with a larger structure, the 100-year, 24-hour and 100-year, 10-day runoff events were modeled, assuming that the channel between Lake Riley and the weir structure is also widened. Figure 11 compares the Lake Riley surface water elevations under this scenario (shown in red) with the predicted lake levels under existing outlet conditions (shown in blue) for the 100-year, 24-hour rainfall event. The predicted peak flood elevation in Lake Riley under this scenario is approximately 865.6 M.S.L, which is 0.3 feet lower than under existing conditions. The predicted duration of high water levels (water level of 865.0 M.S.L. or greater) decreases from just over 40 days to approximately 15 days.

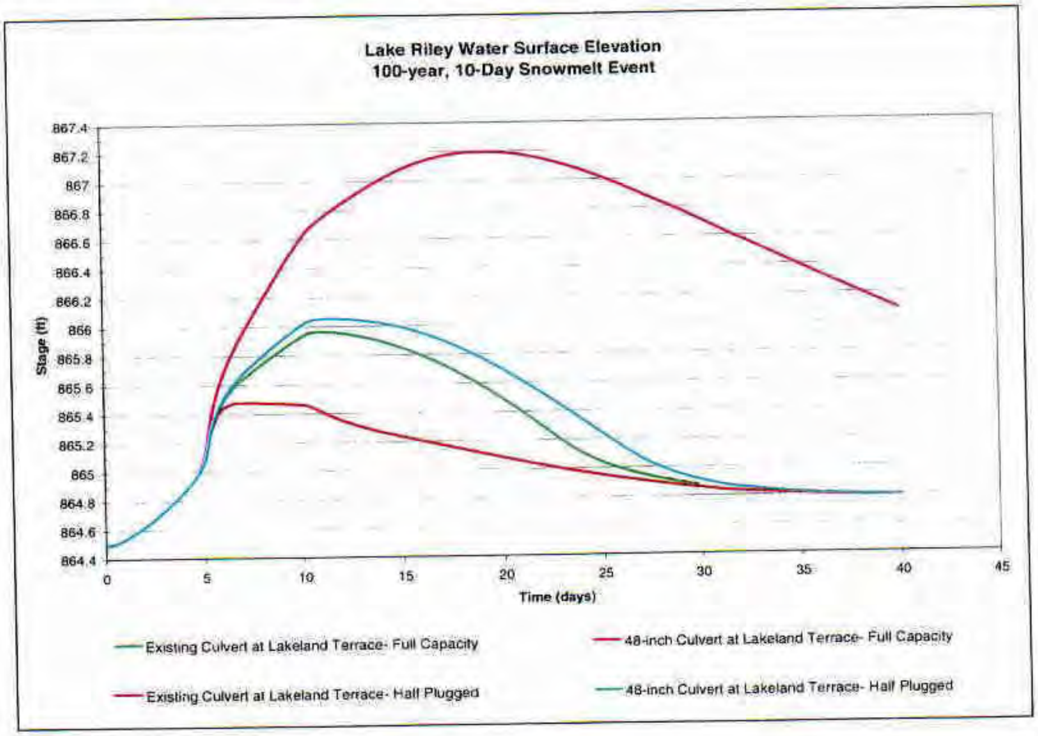
Figure 12 compares the Lake Riley surface water elevations predicted under the Lakeland Terrace culvert expansion scenario (shown in red) with the predicted lake levels under existing outlet conditions (shown in blue) for the 100-year, 10-day snowmelt event. The predicted peak flood elevation at Lake Riley under this scenario is approximately 865.5 M.S.L, which is 0.7 feet lower than under existing conditions. The period of time that water levels are high (water level of 865.0 M.S.L. or greater) decreases from over 50 days to approximately 23 days.

Replacing the existing Lakeland Terrace culvert with a larger structure reduces the elevation and duration of high water levels in Lake Riley, assuming the stream channel is widened between Lake Riley and the weir outlet structure. Modeling results indicate that replacing the existing culvert with a 48-inch RCP pipe would provide sufficient capacity to prevent flow restrictions at this crossing. However, a 48-inch diameter pipe will still pose a risk of plugging with debris during high flow events, similar to existing conditions.

Two scenarios were modeled to evaluate the potential impacts from the culvert at Lakeland Terrace being partially blocked by debris: 1) the existing culvert being half plugged, and 2) a 48-inch culvert being half plugged. Figure 13 compares the predicted surface water elevations in Lake Riley for these two scenarios and with results assuming the existing and 48-inch culverts are flowing at full capacity for the 100-year, 10-day snowmelt event (the critical event for Lake Riley). The scenarios shown in Figure 13 assume that the stream channel between Lake Riley and the weir structure is widened.

The scenario assuming the existing Lakeland Terrace culvert is half-plugged (shown in pink in Figure 13) results in a peak surface water level of 867.2 M.S.L., which is 1.2 feet higher than the predicted high water level under full flow capacity (assuming the stream channel between Lake Riley and the weir structure is widened). This scenario results in a 100-year flood level that is approximately 1.0 feet higher than the 100-year flood level of 866.2 M.S.L, based on existing outlet conditions. In addition to the increase in flood level predicted under partially-blocked conditions, the duration of high water levels also increases significantly.

Figure 13. Predicted surface water elevations at Lake Riley assuming half-plugged conditions at the Lakeland Terrace crossing



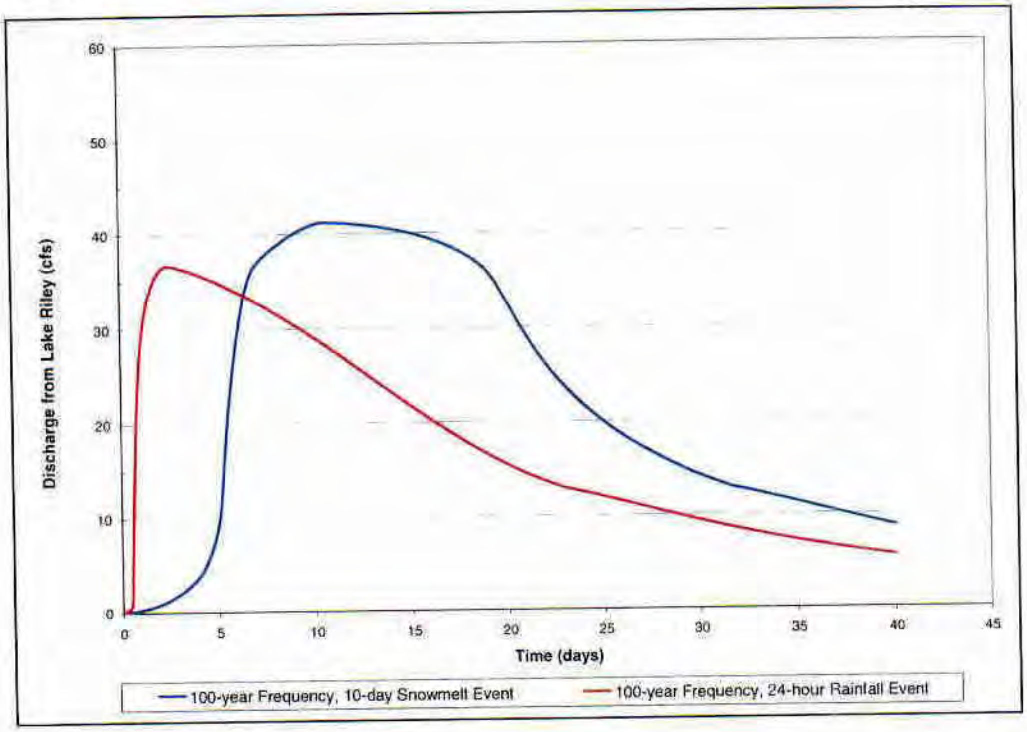
The scenario assuming that a 48-inch culvert at Lakeland Terrace is half-plugged (shown in cyan blue in Figure 13) results in a peak surface water level of just over 866.0 M.S.L., which is 0.5 feet higher than the predicted high water level under full flow capacity through the 48-inch culvert (assuming the stream channel between Lake Riley and the weir structure is widened). This scenario results in a 100-year flood level that is approximately 0.2 feet lower than the existing conditions 100-year flood level of 866.2 M.S.L. The duration of high water levels predicted with a partially blocked 48-inch culvert is approximately 5 days longer than under full-flow conditions.

Replacing the existing Lakeland Terrace culvert with a 48-inch RCP would provide sufficient capacity to prevent flow restrictions at this crossing. The estimated cost of this alternative is $90,000. However, replacement of the existing culvert with a 48-inch RCP will still pose a risk of plugging with debris during high flow events. Plugged conditions at this crossing will result in higher water levels in Lake Riley for longer durations. Debris blockages at the upstream end of the culvert can also be a public safety concern. To prevent debris obstruction at this location, installation of a 24-foot long span precast concrete arch structure or equivalent is recommended. A long span arch structure would provide an aesthetically pleasing, bridge-like crossing that would provide more than sufficient discharge capacity. The open bottom of the structure would also minimize impacts to the stream channel. The estimated cost of this alternative is $260,000.

4.3.2.3 Flow Considerations of Recommended Outlet Modifications

The objective of the Lake Riley outlet modifications is to decrease the duration of high water levels on Lake Riley during significant runoff events without impacting the stability of the stream channel downstream of Lake Riley. The predicted flows from Lake Riley under the existing outlet conditions for the 100-year frequency, 10-day and 100-year frequency, 24-hour runoff events are shown in Figure 14. Modeling results indicate that the discharge from Lake Riley is controlled by the channel between Lake Riley and the weir structure when the lake is below the elevation of 865.8 M.S.L and controlled by the culvert at Lakeland Terrace when lake levels exceed 865.8 ft M.S.L. The predicted peak flows from Lake Riley following a 100-year frequency, 10-day snowmelt event and 100-year frequency, 24-hour rainfall events are approximately 41 cfs and 37 cfs, respectively. As shown in Figure 14, the shape of the discharge hydrograph from Lake Riley varies significantly based on the nature of the runoff event.

Figure 14. Predicted 100-year Frequency Discharge from Lake Riley based on Existing Outlet



The predicted flows from Lake Riley for the recommended outlet modifications for the 100-year frequency, 10-day and 24-hour runoff events are shown in Figures 15 and 16, respectively. Modeling results indicate that widening the channel between Lake Riley and the weir structure would result in peak discharges (shown in green) of 41 cfs for the 10-day snowmelt event and 40 cfs for the 24-hour rainfall event, which are similar to the discharges predicted under existing conditions (shown in blue). However, when the channel is widened, the discharge capacity from Lake Riley is controlled by the culvert at Lakeland Terrace, resulting in a longer period of high flow, and a faster drawdown of the lake level. If the capacity of the culvert at Lakeland Terrace is increased, in addition to widening the restrictive channel, the peak of the predicted discharge hydrograph (shown in red in Figures 15 and 16) increases to approximately 58 cfs for the 10-day snowmelt event and 66 cfs for the 24-hour event. Under this scenario, the shape of the discharge hydrograph from Lake Riley is controlled by the weir structure downstream of Lake Riley. Although this scenario results in higher peak flows, the duration of high flows is decreased from existing conditions.

Results of the stream stability analysis, discussed in subsequent sections, indicate that the reach of Riley Creek directly downstream of Lakeland Terrace is relatively stable. Therefore, increased magnitude and/or duration of flows resulting from the recommended outlet modifications are not expected to be detrimental to the downstream stability of Riley Creek.

Figure 15. Predicted 100-year Frequency Discharge from Lake Riley for the 10-day Snowmelt Event based on Recommended Outlet Modifications

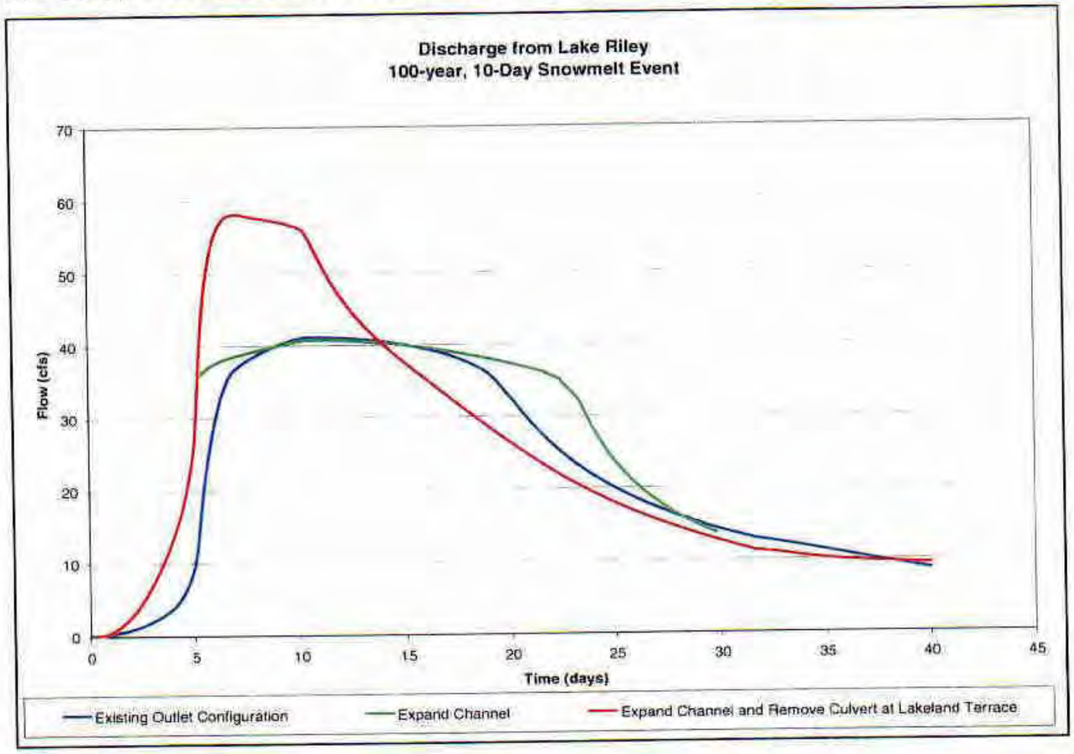
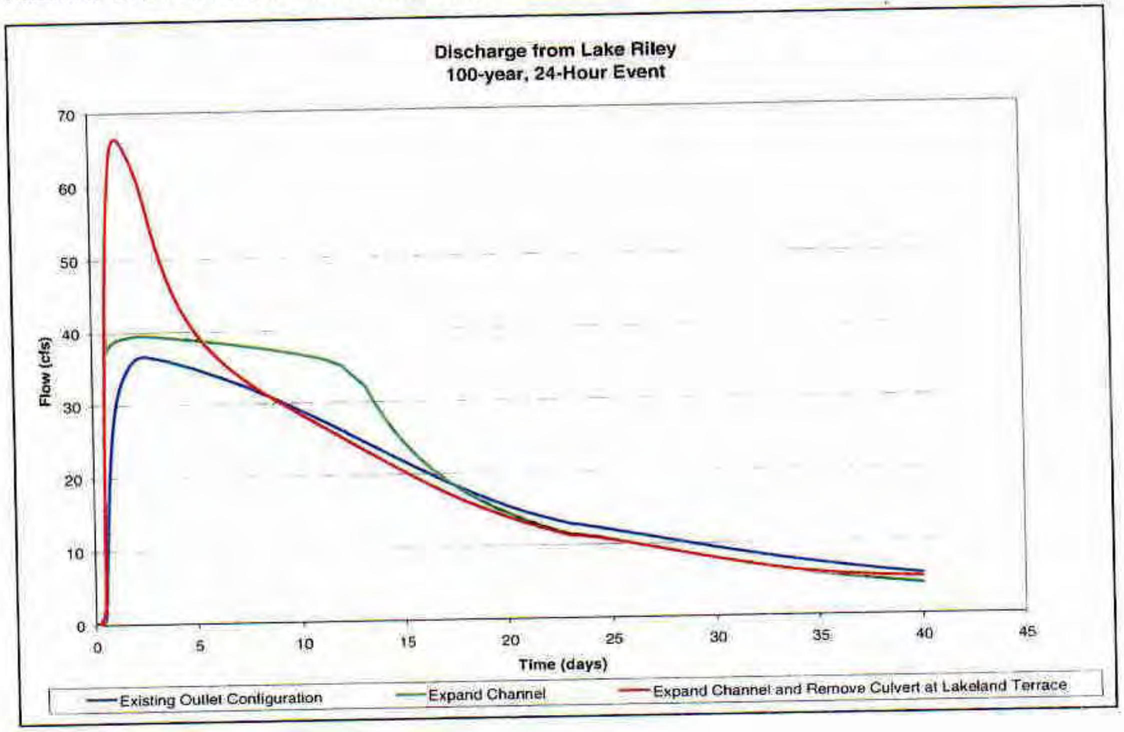


Figure 16. Predicted 100-year Frequency Discharge from Lake Riley for the 24-hour Rainfall Event based on Recommended Outlet Modifications.



5.0 Lower Valley Riley Creek Study

A detailed investigation of the Lower Valley of Riley Creek (Lower Valley) was performed in order to quantify the morphologic sensitivity of Riley Creek for different scenarios of hydrology and sediment supply, and to predict the evolution of the longitudinal profile of Riley Creek within the Lower Valley as land use continues to evolve toward a more urbanized setting.

5.1 Watershed Characteristics

The Lower Valley watershed includes the reach between the outlet of Lake Riley and the culvert crossing of US 212 (Map 4). The drainage area of the Lower Valley is 6,600 acres.

Riley Creek flows through loamy till immediately downstream of Lake Riley, and then meanders through relatively steep, glacial outwash deposits of sand and gravel in its course to the Minnesota River floodplain.

5.1.1 Watershed Slopes

Map 5 presents the results of computing area-weighted slopes for each of the sub-watersheds defined in the XP-SWMM model of the Lower Valley watershed. This map indicates that the overall slope of the study watershed is relatively steep, with more than 50 percent of the catchment area having a slope of more than 10 percent. This is an indication that, independent of other factors (such as runoff intensity, soil erodibility, land use, etc.), the potential for soil erosion in the watershed uplands is relatively high. Map 5 also shows that the slope of the watershed uplands increases from the watershed divide to the stream channel, which implies that in addition to the relatively high potential for soil erosion, the conditions are favorable for most of this sediment to reach the main channel rather than depositing before reaching the stream.

Another important finding from Map 5 is the existence of three sub-reaches in which the slope within the stream corridor is steeper than 20 percent: between Stations 35+00 and 70+00, between Stations 95+00 and 130+00, and between Stations 195+00 and 220+00. These sub-reaches are ones in which, independent of other factors, there is not only greater potential for sediment delivery from the watershed uplands to the main channel, but also a greater chance for gully development.

5.1.2 Soil Types

Map 6 shows the surficial geology of the Lower Valley watershed, based on data from the Minnesota Geological Survey (1989) for Hennepin County. The map indicates that the watershed soils consist of loamy tills on the western half, and outwash deposits on the eastern half, with the latter covering the stream corridor downstream of Station 50+00 (i.e., approximately 80 percent of the study reach length). This is consistent with Map 7, which depicts that, according to the Unified Soil Classification System (USCS), there are two soil types covering most of the Lower Valley watershed: low plasticity fine silts dominating the western half, and coarser silty sands dominating the eastern half.

Detailed information about the distribution of soils throughout the watershed is shown in Map 8, which shows that loams cover the western half of the study watershed, whereas coarser sandy loams cover the eastern half of the study watershed (United States Department of Agriculture (USDA) classification). Map 8 shows that beginning approximately at Station 60+00 downstream to the WOMP station, the area within or adjacent to the stream corridor is dominated by loamy sands. Other important soil groups near the stream corridor are sandy loams between Stations 110+00 and 200+00, and coarse sandy loams downstream of Station 200+00.

It is likely that the gradation of sediment delivered from the watershed uplands to the main channel becomes coarser as one progresses down the valley, but a grain size corresponding to medium to coarse sand was assumed to provide a general characterization of the sediment for the entire stream length.

Although a quantification of the volumes of sediment eroded from the watershed uplands and delivered to the main channel was not conducted as part of this study, the relative erosivity of the watershed is presented in Map 9. Using the soil erodibility factor K (as defined by the Universal Soil Loss Equation method), it is evident that, per unit watershed area, the western half of the Lower Valley watershed will contribute more sediment than the eastern half of the watershed for two reasons. First, the soil erodibility factor K is one to two times larger on the western half because the soils are finer (as indicated above). Second, the catchment area is narrower on the western half, therefore sediment delivery rates are anticipated to be higher in this sector.

5.1.3 Imperviousness

The imperviousness of a watershed is a good indicator of the relative volume of runoff that will be generated. Maps 10 and 11 show the percentage of imperviousness for four years from which land use information has been derived: 1945, 1980, 1991, and 2004 (Existing Conditions).

It is evident in Map 11 that, although slight, the percent imperviousness increased between 1945 and 1991, in particular on the northwestern end and the north central sector of the Lower Valley watershed. Map 10 shows that the increase on the northern half of the basin has been significantly greater between 1991 and 2004, and even more dramatic in the eastern corner of the study watershed. Not only runoff volumes but also the magnitude and duration of relatively high flows have likely increased as a result of urbanization. If this is combined with a reduction of the watershed area that is agricultural and subject to soil erosion (as discussed in Section 5.1.4), it can be expected that reaches of the main channel are undergoing channel incision resulting from larger inflows and less sediment supply.

5.1.4 Land Use / Land Cover

Historic aerial photographs from 1945, 1980, 1991, and 2004 (Existing Conditions) in combination with the USDA database for cultivated areas by county were analyzed to estimate changes in land use that have occurred in the past sixty years. The first three periods were selected for the following reasons: Year 1945 represents conditions when field crop agriculture was dominant in the Lower Valley watershed, right before the introduction of row crop agriculture. Year 1980 represents conditions when row crop agriculture was dominant in the watershed, right before the beginning of urbanization. Year 1991 represents conditions of transition from a rural to an urban watershed, yet well before the intense years of urbanization that began in 1998. 2004 represents existing conditions.

Maps 12 and 13 show that areas of the northern and eastern parts of the study watershed have experienced the greatest change in land use. According to the USDA database, the three dominant crops by 1945 were corn, oats and hay, whereas by 1980 soybeans began to displace oats and hay but corn continued being important. The change from field crop to row crop agriculture likely caused an increase in the amount of sediment supply from the watershed uplands to the main channel. This trend likely reversed, however, when land use in the Riley Creek watershed shifted from agricultural to urban beginning in the 1980s. Although, with urbanization, storm events tend to produce larger runoff volumes and flows, the higher percentage of area that is paved or covered with turf grass usually results in less sediment delivered from the watershed uplands to the main channel.

Maps 12 and 13 show that the greatest change in land use occurred between Stations 120+00 and 145+00, which corresponds closely to the reach in which the channel is severely incised (see Section 6.5).

5.1.5 Drainage Patterns and Stormwater Ponds

Map 14 shows that, in general, historic drainage patterns have not been affected in a significant way. However, stormwater ponds continue to be constructed since at least 1997, in order to reduce peak flows and the flashiness of the flood hydrographs contributing to the main channel of Riley Creek.

5.2 Channel Geometry

The channel geometry of most streams is influenced by several factors. Channel slope, streambed material, stream bank material, and riparian vegetation are factors that are directly connected to the stream and have significant influence over channel geometry. Similarly, several hydrologic factors have significant influence as well since they will control how much water enters the stream. These factors include the amount of rainfall, the intensity of rainfall, watershed slopes, storage within the watershed, infiltration capacity within the watershed, impervious area, and land use. All of these factors can change over time or change along the length of the stream, so the stream is constantly trying to achieve equilibrium with these changing influences.

Natural processes of change, such as changing weather patterns or changing vegetation communities, typically happen at a gradual rate, so the stream and the channel geometry has ample time to slowly adjust to these influential factors. Even with these slow processes, it is possible for a stream to undergo significant changes and have large erosion problems. This can be caused either by large catastrophic events or by the stream channel and/or valley reaching a point where a major adjustment is necessary.

Man-made processes of change, such as increased development, altering of storage areas, and altering drainage patterns, tend to happen too quickly for the stream to gradually adjust.

Even though greater measures are being taken to protect streams through the use of detention ponds and other best management practices within the watershed, the streams still require a certain amount of adjustment to once again achieve equilibrium with their watersheds.

Riley Creek, as it flows through the Lower Valley, has varying channel geometries that reflect the influence of some of the factors listed above. Between Lake Riley and Dell Road, the channel has characteristics that are typical of a stream that flows through a wooded area and whose flow is largely controlled by a large body of water. The basic channel geometry changes in typical ways as the stream moves between riffle and pools and over fallen trees. Approximately 3,500 feet downstream of Dell Road, the channel geometry changes dramatically as the stream enters a reach that is experiencing some severe erosion problems. After this reach, the stream returns to a somewhat stable channel geometry. These transitions are explained in more detail in Chapter 6.

5.3 Stream Profile

As with any stream, the slope of Riley Creek varies along its length. Analyzing the changes in channel slope can help identify either current or potential problem areas. The greater the channel slope is, the greater potential there is for erosion because the slope plays a critical role in the flow velocities and the stresses imposed on the stream bed. Given that the streambed in Riley Creek ranges from cohesive clay to gravel and some cobble, a slope less than or equal to 0.5 percent would likely result in a stable creek system. For slopes greater than approximately 0.5 percent, the stream would need larger bed material in order to remain stable for the long term. These reaches, with slopes between approximately 0.5 and 0.75 percent, can be stable and many of them on Riley Creek are stable. However, periodic monitoring of these reaches is recommended to detect early signs of erosion problems. Slopes between 0.75 percent and 1 percent are an additional indicator of potential erosion. If erosion is not already present along these reaches, they should be monitored on an annual basis. Slopes greater than approximately 1 percent are a strong indicator of potential erosion problems. These slopes can generate stream velocities that easily erode streambed or streambank materials.

Appendix A contains plan/profile drawings showing the stream slope over the entire length of Riley Creek as it flows through the Lower Valley.

5.4 Erosion Types

There are four main types of erosion along Riley Creek. They can be categorized as Groundwater Erosion, Stream Bank Erosion, Incision, and Bluff Erosion. These are described in more detail in the following discussion.

5.4.1 Groundwater Induced Erosion

Groundwater erosion is caused by springs and groundwater seepage. Along Riley Creek, this type of erosion occurs most commonly where a bluff meets the floodplain (usually at the toe of the bluff slope). It is characterized by very moist soils or visible springs at the toe of the bluff and results in two subcategories of erosion. The first and most common type of erosion attributed to groundwater flow is a result of the groundwater seepage being a catalyst for additional erosion. The high moisture content in the toe of the bluff significantly reduces cohesion between the soil particles and makes the toe of the bluff highly susceptible to erosion by the creek. During high flows, creek flow easily erodes the soils at the toe of the bluff that are already saturated from the groundwater flow. As the toe of the bluff erodes, the bluff above the toe also recedes. This process also happens in bluffs that do not have groundwater seepage along the toe, but the rate of erosion is often greatly increased by the presence of seepage.

The second form of erosion attributed to groundwater flow results from the groundwater flow itself. The saturated soil has a positive pore water pressure that can cause soil in the area of the spring to be displaced. This causes a slow failure of the bank as small quantities of soil are carried away by the seeping groundwater. This type of erosion generally occurs slowly, but can occur more quickly if groundwater flows are high and soil cohesion is low. It is observed in several areas of the Lower Valley well above the channel level.

Along the Lower Valley of Riley Creek, the majority of erosion caused by groundwater flow is of the first type described above. The presence of the groundwater seepage at the toe of a slope makes the toe more susceptible to stream erosion. This is primarily happening along Reaches G, H and I between Eden Prairie Road and US Highway 212 (US 212). There is a high concentration of this type of erosion in Reach H between the fish barrier on the former Cedar Hills Golf Course and Spring Road.

5.4.2 Stream Bank Erosion

Stream bank erosion is caused by water flowing in the stream channel. The shear stress caused by the flow entrains soil particles into the flow, causing the stream bank to erode away. This is, by far, the most common type of erosion that occurs in streams. Virtually all streams have some amount of this type of erosion occurring as streams naturally change their flow path over time. However, the rate of stream bank erosion can increase when the stream is out of equilibrium with its watershed. Increased flow from a watershed will increase the rate of erosion.

Stream bank erosion is occurring along all reaches on Lower Riley Creek. In most cases, it appears to be a part of the natural process of stream evolution. However, it can lead to high-bank failure where the stream abuts the steep valley walls, and it can exacerbate other forms of erosion.

5.4.3 Channel Incision

Channel incision, or down-cutting, occurs when there is an imbalance between the sediment supply and the sediment carrying capacity of the stream. Erosion occurs when the sediment carrying capacity of a stream exceeds the sediment supply. In streams with cohesive banks, such as Riley Creek, the erosion will occur primarily as streambed incision because that is where the erosive forces are the strongest. Channel incision is more insidious than bank erosion. While sediment that is eroded from bank erosion often redeposits locally (such as on the opposite bank), sediment is often transported a large distance in an incised system. This indicates that the stream is out of balance with the watershed hydrology. As the channel deepens, the banks gradually fail and stream becomes wider. Although the stream will eventually return to equilibrium, the process can take many years and significant amounts of erosion can occur during the process.

Channel incision is occurring along Reach E (Map 15). From station 10,500 to station 14,000, there is evidence that the channel is incising. And, from station 11,800 to station 13,300, there is evidence that the channel is beginning to widen as well.

5.4.4 Bluff Erosion

Bluff erosion occurs on the valley walls of the stream corridor. For the purposes of this analysis, bluff erosion is distinguished as erosion that is above the creek itself and is, therefore, not entirely due to the flow in the creek. It is a naturally occurring phenomenon that can have several different causes, including groundwater seepage, concentrated runoff on the bluff, effects from falling trees, or massive slope failure due to an imbalance of geotechnical forces.

There are some areas of isolated bluff erosion within the Lower Valley, most notably at Site E2 in Reach E. Other areas of bluff erosion within the Lower Valley are more typically a side effect of either groundwater or fluvial bank erosion.

5.5 Suspended Sediments

Total suspended solids (TSS) data has been collected at Riley Creek since 1963. TSS data has been presented and analyzed in the Engineer's Annual Report since 1970. However, the suitability of the TSS data to represent the characteristic climatic and hydrologic variability of the Riley Creek watershed has not been determined. Therefore, the historical data has been revisited in order to identify trends in the amount of sediment produced by the upland areas of the watershed and to relate the amount of sediment conveyed through the main channel with precipitation and flow data. This analysis is discussed in detail in Appendix B.

The study began with analyzing the earliest TSS measurements collected in 1963 by the Minnesota Department of Health, and in 1969 by the MPCA. Grab sample measurements of TSS and turbidity were measured upstream of Lake Riley and downstream of US 212 from 1972 through 1995. Estimating total sediment load from these earlier measurements is difficult because they were conducted randomly, and did not necessarily cover all of the high flow periods, when most of the sediment is transported. TSS values at US 212 were generally greater than measured upstream of Lake Riley, even though much of the suspended sediment from upstream of Lake Riley settles in the lake. This supports the notion that the channel bed and banks of the Lower Valley are contributing a greater amount of total sediment load than the channel upstream of Lake Riley.

The Watershed Outlet Monitoring Program (WOMP) station was installed at US 212 in 1998. Grab and composite sediment samples were obtained on a bi-weekly to monthly basis, with more frequent composite samples during periods of high flows in the creek. The samples were analyzed for TSS concentration and volatile suspended solids (VSS), which is a measure of the organic content of the TSS. In addition, precipitation and flow rates were recorded every 15 minutes. This more detailed data collection, with an emphasis on high flow conditions, provides much more valuable data from which to estimate the total suspended sediment load.

Two different relationships were derived for estimating the total sediment load in the Riley Creek Lower Valley watershed. The first relationship is based on the best fit between the measured concentration of TSS and the corresponding flow rates, accounting for the results of both grab and composite samples. The second relationship is based on the best fit between the measured sediment load and the corresponding runoff volume, accounting for the results of composite samples (collected during high flows) only. The second approach is preferred, and yields an average sediment transport rate of suspended solids of 1675 tons per year, or 704 tons per square mile, as shown in Table 4.

The concentration of VSS from the 1999-2004 WOMP data represents, on average, only 12 percent that of TSS. The measurements in 1963 indicated that the concentration of organic matter represented as much as 40 percent of total solids. A likely explanation is that urbanization of the watershed reduced the amount of agricultural runoff to the stream, which is typically higher in organic matter than runoff from urbanized areas.

Table 4. Estimated Sediment Load (tons/year) in the Riley Creek Lower Valley Watershed

Year	Cumulative from composite samples	Based on relation between TSS and flows	Preferred, Based on relation between Load and volume runoff
1999	61	650	1750
2000	17	65	550
2001	357	4350	2550
2002	38	2150	2050
2003	144	400	1050
2004	82	5000	2100
Average	117	2103	**1675**

5.6 Results of XP-SWMM runs

Four simulations for the Riley Creek Lower Valley watershed were conducted using the event-based calibrated XP-SWMM model previously discussed in Section 3.0:

- Runoff event corresponding to a return period of 2 years, duration of 6 hours, and existing (2006) land use conditions.

- Runoff event corresponding to a return period of 10 years, storm duration of 6 hours, and existing (2006) land use conditions.

- Runoff event corresponding to a return period of 2 years, storm duration of 6 hours, and ultimate (2020) land use conditions.

- Runoff event corresponding to a return period of 10 years, storm duration of 6 hours, and ultimate (2020) land use conditions.

These events were selected for the following reasons. Preliminary XP-SWMM runs showed that the 6-hour storm event produces the largest peak flows in the Lower Valley watershed. In general, the magnitude and duration of relatively high flows in the Lower Valley watershed downstream of Pioneer Trail do not appear to be affected by discharges from Lake Riley, hence the typical duration of the rising limb of the flood hydrograph is relatively short. A flood event with a recurrence interval between 1.5 to 2.5 years is usually considered responsible for determining the geometry of a stream channel in temperate environments. The larger flood event with a recurrence of 10 years was included in this evaluation to investigate the potential for significant changes in the stream profile resulting from larger volumes of sediment being transported. Flood hydrographs at thirteen different locations along the main stem of Riley Creek in the Lower Valley are presented in Figures 17 through 20.

For the reach upstream of Pioneer Trail, as indicated above, flows are primarily controlled by the outlet channel and structure of Lake Riley, with flows increasing at a much slower rate than in the reaches downstream. Between Stations 40+00 and 90+00, the flows substantially increase and the shape of the hydrographs change, and subsequently increase even more progressing further downstream, between Stations 90+00 and 140+00. This increase in large flows is important because it represents flows that are capable of mobilizing significant quantities of bed sediment. The reach between Stations 110+00 and 140+00 has been identified in the field as undergoing severe channel incision (down-cutting), and likely the reach that most critically requires stabilization. Greater increases in peak flows and particularly the duration of relatively high flows is observed in the reaches downstream of Station 140+00, but in this sector the channel has a more developed floodplain area which allows the stream to pass floods without substantial increases in flow velocities that would cause significant erosion of the channel bed or channel banks.

A comparison of Figures 17 and 19 show that peak flow of the 2-year flood event can increase by as much as 50 percent near the lowest reaches of Riley Creek (near US 212). This increase is in part explained by discharges from stormwater ponds located on the eastern end of the catchment area to control runoff volumes, and localized flows and suspended sediments being delivered to the main channel. An increase of this magnitude would definitely have a negative effect on the morphologic stability of the stream. It is worth pointing out, however, that the simulations for ultimate (2020) land use conditions did not consider implementation of additional Best Management Practices (BMPs), so the actual conditions may be less critical than assumed in this evaluationn. Comparison of Figures 18 and 20 does not show a big change for the 10-year flood events under existing (2006) and ultimate (2020) land use conditions.

It is standard practice to determine the morphodynamic stability of a stream based on an indicator of the erosive energy (e.g., stream power or boundary shear stress) that is normally associated with the peak flow magnitude. However, such assessment is incomplete, as the amount of sediment that is transported during the passage of a flood is a function not only of the peak flow but also of the duration of the so-called competent flows (that is, those flows that are able to mobilize bed sediment in significant quantities). For instance, it can be anticipated that a flood event with a peak flow of 100 cfs and a duration of 3 hours above a threshold value of 20 cfs would mobilize significantly less bed sediment than a flood event with the same peak flow of 100 cfs but a duration of 50 hours above the same threshold value of 20 cfs.

XP-SWMM produces an output hydrograph in time increments as fine as 1-minute. This information was tabulated to compute first an indicator of the erosive energy of the flowing water, which was aggregated over the entire flood hydrograph. This indicator was then used in combination with the bulk sediment transport relation by Engelund and Hansen (1976) to compute the total load of sediment transported during the given hydrograph. The results were considered reasonable when compared against the TSS data collected at the WOMP station (see Section 5.5), with total sediment concentrations in the order of 2,000 to 3,000 mg/L for the 2-year flood events, and in the order of 5,000 to 12,000 mg/L for the 10-year flood events.

For the 2-year storm event, the reach-averaged sediment transport rate under ultimate (2020) land use conditions increases by only 8 percent with respect to the case under existing land use conditions, however the lower reaches of Riley Creek could see increases as high as 35 percent. A similar small increase is observed for the 10-year events comparing existing and ultimate land use conditions. However, the sediment transport rates are as much as three times higher for the 10-year event compared to the 2-year event. Therefore, appropriate measures to maintain or even reduce the magnitude of the 10-year and larger flood events could help alleviate significant erosion of the channel bed and banks during these extreme events.

For any of the scenarios, the sediment transport rates increase significantly (one to three times) from Station 94+00 to Station 117+00, and decreases downstream of Station 146+00. This is strong evidence that the reach between Stations 110+00 and 140+00 is currently undergoing severe channel incision, which could be aggravated if the channel bed is not stabilized in this reach.

Figure 17. Modeled Flood Hydrograph, Existing Conditions, 2-Year Event

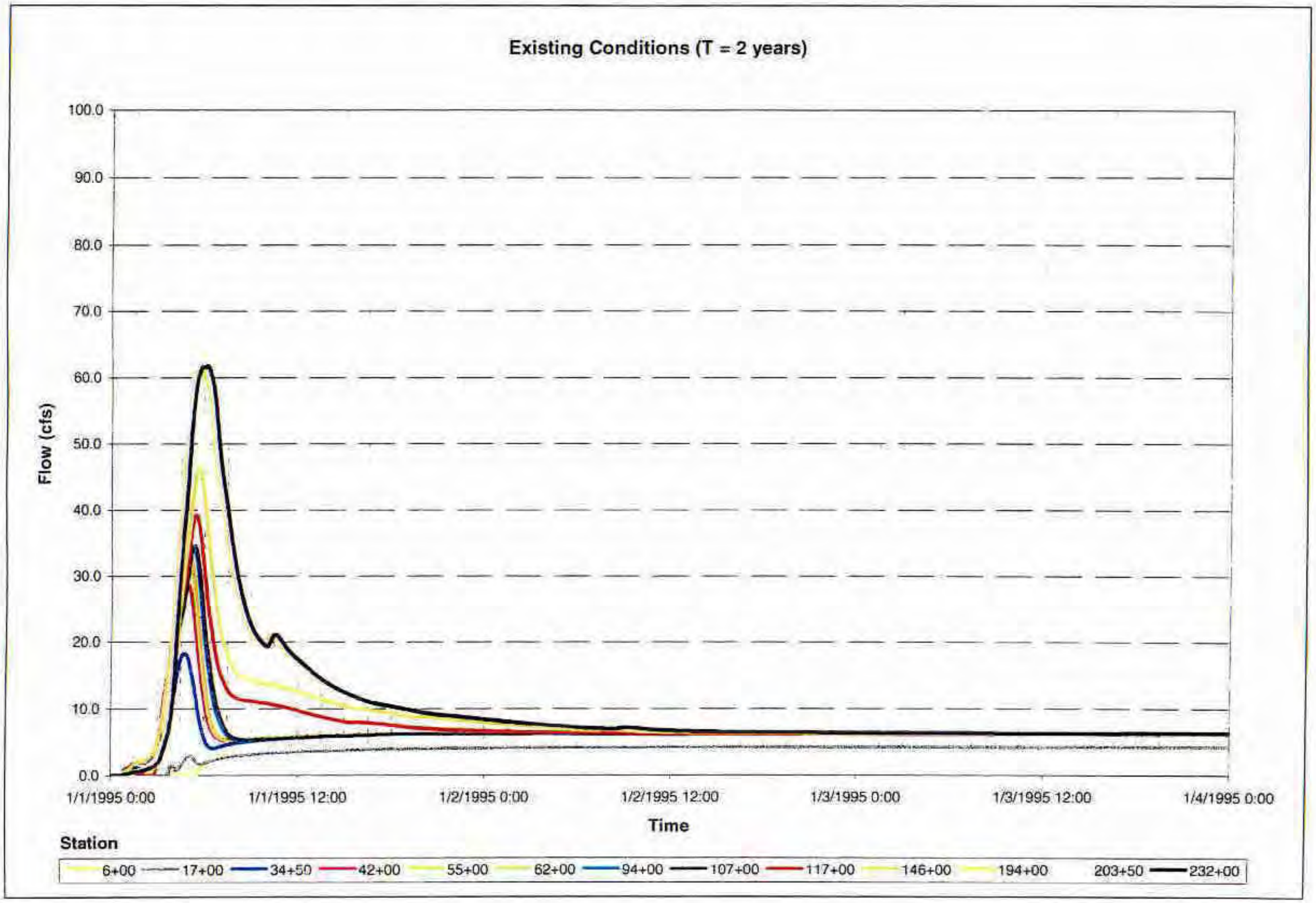
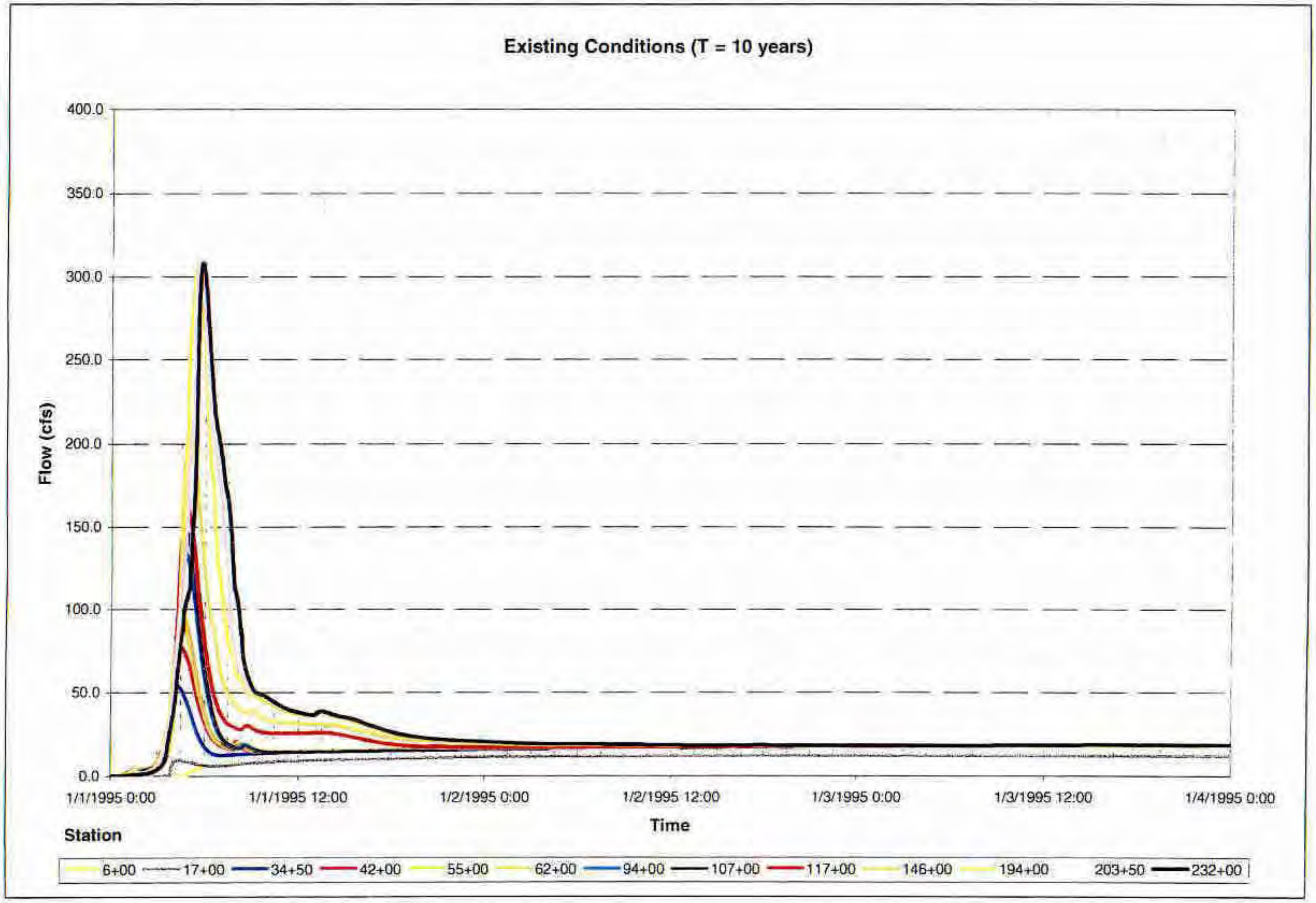


Figure 18. Modeled Flood Hydrograph, Existing Conditions, 10-Year Event



Existing Conditions (T = 10 years)

Figure 19. Modeled Flood Hydrograph, Future Conditions, 2-Year Event

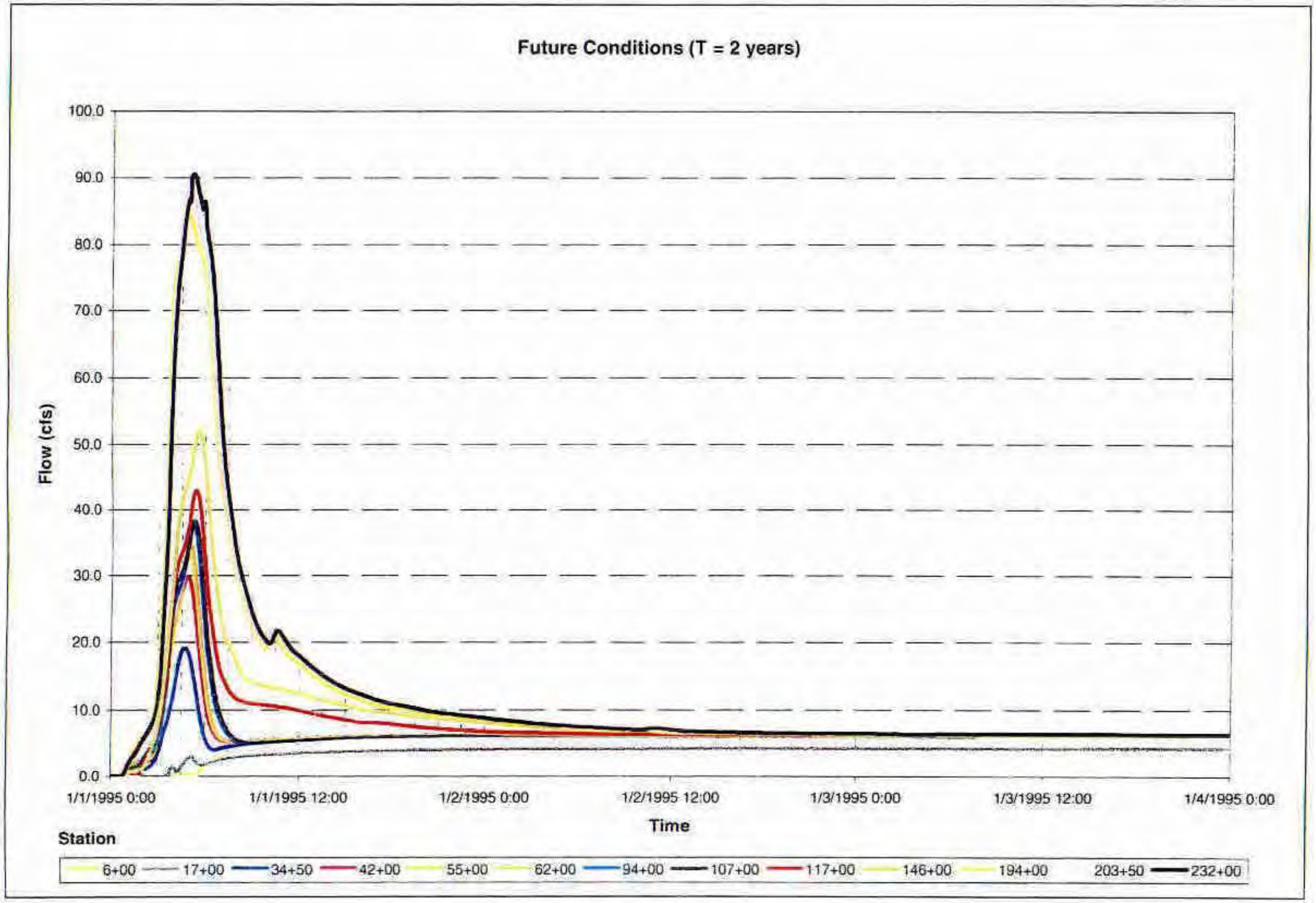
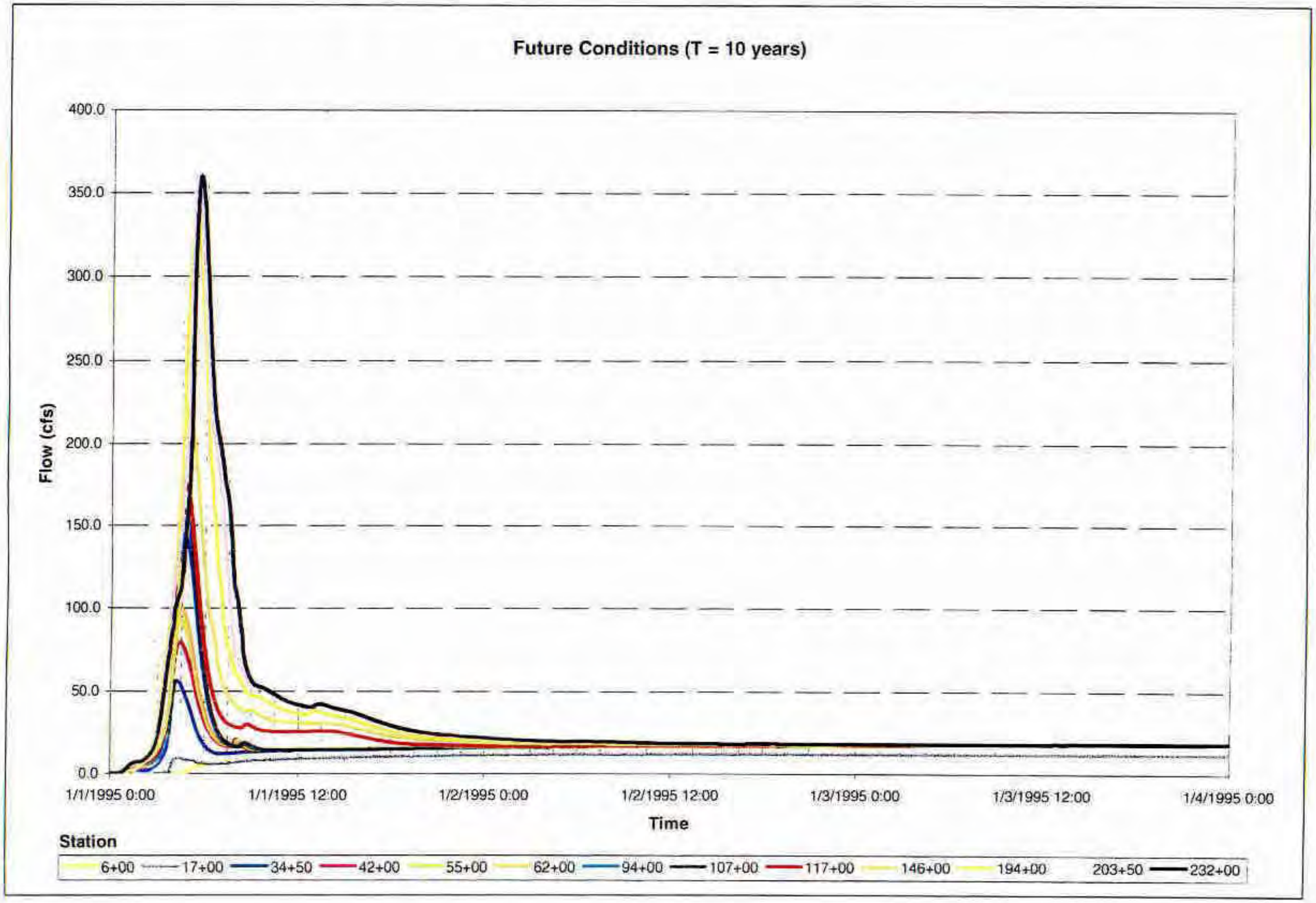


Figure 20. Modeled Flood Hydrograph, Future Conditions, 10-Year Event



6.0 Stream Reach Descriptions

A detailed field survey was completed in the Lower Valley of Riley Creek during 2005-2006. Channel dimensions were measured at representative locations; the channel thalweg (low point) was surveyed; and significant erosion areas were mapped. Worksheets describing the geomorphological characteristics of the stream are contained in Appendix C. Streams can be broken down into reaches that have distinct characteristics from other portions of the stream. Both man-made and natural features can generate boundaries between reaches, as is the case with Riley Creek. The creek is divided into several reaches and characteristics of each reach will be described.

Figures A-1 to A-17 (Appendix A) illustrate portions of the following discussion.

6.1 Reach A – Lake Outlet to Station 30+00

Reach A is a stable reach as it passes from Lake Riley to Pioneer Trail. The valley along this reach is open and the stream has well-established and adequate floodplains available. The channel geometry is typical for a stream such as Riley Creek. The cross sectional area, mean depth, maximum depth, flood flows and flood velocities are all within normal ranges and indicate that the channel is relatively stable.

Riley Creek has a very mild slope of less than 0.25 percent between the Lake Riley outlet and Lakeland Terrace (Figure A-1), resulting in this reach being stable. The slope of the reach between Lakeland Terrace and Pioneer Trail (Figure A-1) ranges between 0.5 percent and 0.75 percent and also appears to be very stable. The same slope range exists between Pioneer Trail and Station 30+00 (Figure A-2). As previously mentioned, these slopes warrant periodic monitoring, but the frequency of culverts along this reach would cause any erosion problems to remain localized. By the time the stream passes under Pioneer Trail, the channel has increased in size by a small but reasonable amount since the contributing watershed area has also grown. The stream still has rather healthy and typical characteristics of a stream with woody riparian vegetation. It goes through typical pool-riffle sequences, which indicate a stable bed and a diversity of habitat for aquatic organisms. The stream has a slightly small width-to-depth ratio, which is the ratio of the bankfull width to the bankfull depth. However, the valley is relatively steep and narrow, which can contribute a lower width-to-depth ratio.

There is relatively little noteworthy erosion in this reach, but the erosion that is present is predominantly fluvial bank erosion, of which most is relatively normal and a low priority for repair.

The primary feature in this reach that requires attention is the culvert under Lakeland Terrace. There is one high priority problem within this reach (Site A1). This is described in detail, along with a proposed remedy, in Appendix D.

6.2 Reach B - Station 30+00 to Private Drive (Station 61+00)

Reach B is similar to Reach A with the primary difference being that the valley and the floodplains are not as wide as in Reach A. The stream channel is slightly larger within this reach, but it is within proportion to the increase in watershed area that contributes flow to this portion of the stream. The cross sectional area, mean depth, maximum depth, flood flows and flood velocities are all within normal ranges. All of these parameters show slight increases when compared to Reach A, but this would be expected due to a slight increase in contributing watershed area.

The channel slope is between 0.25 percent and 0.75 percent for this entire reach (Figures A-3 to A-5). Much like Reach A, it appears to be stable. The width-to-depth ratio for this reach is acceptable, but borderline too low for a stream in a wooded area. The pool-riffle sequences are still present along this reach, so the stream bed appears to be fairly stable. The combination of the stream slope, narrowing valley and borderline-low width-to-depth ratio warrants periodic monitoring of this reach to detect early signs of additional erosion problems.

There is more bank erosion within this reach compared to Reach A, but most of it appears to be part of natural stream processes and are currently low priorities for repair. There are no high priority sites within this reach. There are two other sites of lower priority that will eventually require some attention, and they are described in Appendix D.

6.3 Reach C - Private Drive to Dell Road (Station 61+00 to 70+00)

Reach C is a short, but unique reach on Riley Creek. The changes in channel characteristics are similar to the changes from Reach A to Reach B, with a few exceptions. The valley in this reach is very narrow, so the floodwaters do not have much room to spread out and dissipate energy. This is likely a cause for the channel to continue to grow larger and the width-to-depth ratio to become abnormally low for a stream in a wooded area. Because of the large channel and small floodplain, the flood flows and flood velocities are rather high. The high flood velocities have caused this reach to experience some channel incision, and it currently has some fluvial bank erosion issues. The channel incision that has taken place will possibly lead to some additional bank failures. For nearly 200 feet immediately downstream of the culvert under Private Drive, the stream has a slope of greater than 1 percent. This relatively steep slope is likely a remnant of the channel incision. The remainder of the reach has slopes between 0.5 and 0.75 percent (Figure A-5). The presence of culverts under Dell Road and Private Drive provide a degree of grade control and flow constriction that helps prevent some additional erosion from taking place. There are pool-riffle sequences within this reach, so this reach appears to be fairly stable.

There are no high priority sites within this reach, but it should be monitored to detect any additional problems as they develop. The channel incision will eventually need to be addressed, but it is possible that it can wait until the work can be done in conjunction with any major work that would be done on Dell Road, either replacing the culvert or complete road reconstruction. Details of the work necessary at that time are discussed further in Appendix D.

6.4 Reach D - Dell Road (Station 70+00) to Station 100+00

Reach D is similar to Reach A and B in that the stream appears to be relatively stable. The valley continues to deepen through this reach, but the stream still has sufficient, well developed floodplains in most areas. Erosion is typically limited to bank erosion. The frequency of tall, eroding banks is increasing in this reach, but they would typically remain low priorities for repair.

The cross sectional area continues to slowly grow larger, as do the widths, depths, flows and velocities. The width-to-depth ratio is larger than in Reach C, but it is still small enough to be a concern for long term stability. The channel slopes range from 0.25 percent to more than 1 percent (Figures A-6 and A-7). Another possible future concern for this reach is that the next reach downstream is experiencing some significant changes that could begin to impact this reach. Given the low width-to-depth ratios, the occasionally high channel slope, the increase in bank erosion, and the downstream changes, this reach should be monitored annually.

One site along this reach that is a high priority for repair, but not directly on the stream, is Site D3. A gully that carries runoff from residential neighborhoods is experiencing significant bank erosion that is likely contributing very high sediment loads to the stream. This is discussed in detail in Appendix D.

6.5 Reach E - Station 100+00 to Station 140+00

The stream makes a dramatic change in Reach E. Compared to Reach D, the cross sectional area triples to 150 square feet; the mean depth nearly doubles to 4.5 feet; the maximum depth increases by 50 percent to 7 feet; the flood flows triple to 980 cfs for bankfull flow; and the flood velocities increase by 25 percent to 6.6 feet per second. The channel slope varies much more than in the upper reaches, ranging from less than 0.25 percent to greater than 1 percent (Figures A-8 to A-10). This is the result of this reach experiencing severe channel incision. Channel incision can be caused by both natural and man-made processes, and it is often difficult to pinpoint the exact cause. However, in this case, it is likely that the urbanization of the watershed generated increased runoff volume, which in turn increased the frequency of high velocity flows that can cause channel incision. Also, it is possible there was a natural weakness within the channel system that was exploited by the increased volume in the creek. The stream is currently trying to reach an equilibrium with its watershed. After the initial incision, the stream channel typically erodes its banks and forms a wide, deep channel. From there, it will continue to erode the banks and the channel more slowly as it works to reestablish a floodplain at an appropriate level. This process can take many years to complete and significant amounts of erosion can occur during the process. It is possible to help the stream along during the process by constructing a stable channel that is properly connected to a floodplain.

Stabilizing this reach is a high priority issue. In total, there are ten erosion sites within this reach, including four high priority erosion sites (Sites E1, E2, E3 and E7) within this reach that require immediate attention. This is detailed in Appendix D. This reach needs annual monitoring until the high priority sites are corrected.

6.6 Reach F - Station 140+00 to Eden Prairie Road (Station 168+00)

This portion of the creek is a transition reach. The upper portions of this reach are downstream of Reach E and experience some influence from that reach. The upper half of this reach has woody vegetation along its banks. This reach has some floodplain, but less than required. The lower half of this reach also has woody vegetation on its banks, but the vegetation quickly transitions into grasses further away from the stream. The channel characteristics of cross sectional area, mean depth, maximum depth, flood flows and flood velocities show a gradual increase when compared to Reach D, which provides a better comparison than Reach E since it has not experienced the same amount of erosion. This is a normal progression as more watershed area contributes to the flows.

In this reach, the stream returns to a healthy width-to-depth ratio. Pool-riffle sequences increase in frequency, but at not as prominent as they are in the upper reaches of the stream. Most of this reach has slopes that range between 0.5 percent and 0.75 percent, however there are a few isolated reaches with more severe slopes, including a few of over 1 percent (Figures A-11 to A-12). The primary difference between this reach and any of the reaches further upstream is the amount of floodplain available to the stream. In some places, the stream has an extremely large floodplain, which helps the stream dissipate energy and detain water during high flow conditions.

The dominant erosion on this reach is isolated fluvial bank erosion, primarily on the upper portions of this reach. All in all, this reach is fairly stable, with one significant exception. At station 157+00, a log jam has developed that blocks the stream in high flows and has resulted in a new channel being formed. This is a high priority site, Site F1, that requires immediate attention. Site F2 is not as high priority but would best be done in conjunction with construction on the 2008 Eden Prairie Road improvements. This is explained in detail in Appendix D.

6.7 Reach G - Eden Prairie Road to Fish Dam (Station 168+00 to Station 186+00)

This reach is very stable, with only a few isolated bank erosion sites that appear to be part of normal stream processes. There is an unexpected decrease in many of the characteristic channel parameters within this reach. Between Eden Prairie Road and the fish barrier on the former Cedar Hill Golf Course, the channel cross sectional area actually becomes smaller and is approximately the same size as downstream of Pioneer Trail. The slope through this reach is generally milder than through some of the upper reaches with most of the slopes ranging between 0.25 percent and 0.5 percent with a few steeper reaches (Figure A-13).

There are several possible reasons for the channel to decrease in size within this reach. First, the size of the culvert under Eden Prairie Road reduces the peak flows downstream of the culvert. Second, the large floodplain upstream of Eden Prairie Road detains floodwater thereby reducing peak flows downstream of Eden Prairie Road. Third, the large amount of erosion that is taking place within the critically incised reach has resulted in a considerable amount of sediment to enter the stream system. As the sediment slowly moves downstream, it will settle out and then be resuspended in flood flows. This is possibly resulting in the reach downstream of Eden Prairie Road simply filling with sediment that has been washing downstream, thus making the channel smaller. This would also explain the fact that typical pool-riffle sequences are largely non-existent downstream of Eden Prairie Road and that the width-to-depth ratios are very large for this reach of the creek. Last, the reach just upstream of Eden Prairie Road is the reach farthest upstream that consistently carries baseflow. All reaches upstream of this area periodically run dry. The reaches that consistently carry baseflow are more consistently in equilibrium with the moving water, and therefore the streambed is less susceptible to increased shear stresses during floods.

The fish barrier at the downstream portion of this reach has acted as very effective grade control and helped keep this reach stable. Several springs exist along this reach, maintaining baseflow from this reach on downstream. There are no erosion sites within this reach that are discussed in Appendix D. Periodic monitoring should be sufficient for this reach.

6.8 Reach H - Fish Barrier to Spring Road (Station 186+00 to Station 205+00)

The channel in Reach H shows a gradual increase in characteristic channel parameters that are consistent with an increased watershed area, much like the transitions between reaches on the upper portions of this stream. The channel cross sectional area is still surprisingly small, and the same reasons described in Section 6.7 likely apply here as well. In addition to those potential reasons, the fish barrier likely dampens some peak flows as well. Otherwise, channel width, depth, flood flows and flood velocities look reasonable. The slopes along this reach Range from 0.25 percent to 1 percent (Figures A-14 and A-15).

There appear to be relatively few problems with the stream itself, but this reach is experiencing some significant erosion from tall, eroding banks, most of which are either being caused by or exacerbated by groundwater seepage. Springs are present in abundance along both sides of the valley. The presence of springs along the toes of the bluffs makes the toes more susceptible to erosion during high flows in the stream. When the toe erodes away, the bluff above the toe is undermined and portions of the bluff fall into the stream. Along with Reach E, this is a high priority reach. There are four high priority sites, Sites H1, H2, H3 and H6, that will require immediate attention. These and other lower priority sites are discussed in detail in Appendix D. This reach needs annual monitoring until the high priority sites are fixed.

6.9 Reach I - Spring Road to Hwy 212 (Station 205+00 to Station 234+00)

The last reach within the Lower Valley is fairly stable. Once again, there is a typical increase in characteristic channel parameters. The channel is slightly larger and can carry than in Reach H. The slopes on this reach range from 0.25 percent to some short reaches with greater than 1 percent (Figures A-15 to A-17).

There are a few springs through this reach that contribute to some erosion, but the problems are not nearly as severe as in Reach H. They will likely require some attention in the future, but they are not high priorities. There are two medium to high priority sites, Sites I3 and I4, along this reach that involve erosion of the embankment for Spring Road. These are detailed in Appendix D. This reach needs annual monitoring until the high priority sites are fixed.

7.0 Stabilization Measures

The following is a brief discussion of potential stabilization measures for the Lower Valley of Riley Creek. For additional information on the proposed measures, please refer to the schematics presented in Appendix E.

7.1 Vegetation Management

Vegetation management involves the selection of an optimal species mix to contribute to a healthy and stable stream. Typically an optimal species mix will provide good root structure to help stabilize streambanks and provide good habitat for riparian birds and animals. Obtaining this mix often requires planting new species, removing unwanted or exotic species, and/or thinning existing vegetation to provide enough sunlight to allow new ground vegetation to become established. Vegetation management is recommended for the entire Lower Valley, where mature trees block most of the sunlight from reaching the forest floor during the summer months. It is recommended that invasive species of vegetation and less desirable tree species be removed, leaving the more valuable trees and vegetation in place. Supplemental planting of ground vegetation is also desirable.

7.2 Channel Grade Control

Grade control measures are used where channel downcutting has occurred. This is common on Riley Creek where the channel is confined by the steep valley walls, and where the channel slope is relatively steep. Both of these factors contribute to high flow velocities during flood conditions, thereby increasing the sediment-carrying capacity of the stream. This tends to result in channel downcutting and subsequent widening as the banks become oversteepened and slump into the channel.

The grade control measures should be constructed with boulders and coarse gravel. A V-shaped weir is constructed so that the flow is concentrated toward the center of the channel and away from the banks. Multiple weirs can be constructed to stabilize a longer reach.

7.3 Low Bank Stabilization Measures

Lower bank "toe" protection measures are used at the lower portion of the bank when it is being undercut by channel flow, resulting in bank sloughing and mass wasting. Such erosion is common on Riley Creek, and these measures are recommended at many of the restoration sites.

The recommended bank toe protection measures explained below should be used in conjunction with upper bank stabilization techniques.

7.3.1 Rock Vanes

Rock vanes are constructed from boulders on the creek bottom. They function by diverting channel flow toward the center and away from the bank. They are typically oriented in the upstream direction and occupy no more than one third of the channel width. Vanes are largely submerged and inconspicuous. The rocks are chosen such that they will be large enough to not move during flood flows or by vandalism, with additional smaller rock material to add stability. Rock vanes function in much the same way as rootwads in that they push the stream centerline away from the outside bend. They also promote sedimentation behind the vane, which adds to the toe protection.

7.3.2 Root Wads

Root wads consist of logs with the root ball attached anchored into the bank, so that only the root ball is exposed. Typically placed about half below and half above the normal water line, they are well suited to deeper locations such as outside bends. The trunk portion is placed in the bank by either placing it in a trench or by pushing the trunk into the bank. The root wad absorbs energy and diverts flows away from the bank. Rootwads are generally cost effective and provide excellent fish habitat.

7.3.3 Stone Toe Protection

Stone toe protection employs stones to armor the toe of the bank. It is often used on sites that are too shaded to support good ground vegetation cover, and where vanes or root wads are not necessary. Stones are selected to be large enough so that they would not be moved by flood flows, but small enough to be consistent with the size of other stones found in and near the stream and thus appear natural.

7.4 High Bank Stabilization Measures

High bank stabilization methods are employed on the taller eroded banks to prevent future slumping and bank failure. Bank stabilization will reduce sediment loading to the stream and will reduce the loss of adjacent property.

Stabilizing the high, eroded banks of the Lower Valley will require a combination of methods, depending on the specific site conditions. In particular, many of the erosion sites are exacerbated by groundwater seepage, which when combined with steep banks, sparse vegetation, and fluvial erosion leads to bank failure. Two basic methods of upper bank stabilization are recommended for Riley Creek – bank grading and revegetation, and vegetated reinforced soil slope technique. With either method, stabilization of the lower bank is usually required and is a priority if resources are limited.

Grading and revegetation of the eroded bank is the most common method for stabilization. With this method, the upper bank is graded at a 2:1 (2 foot horizontal to 1 foot vertical) or flatter slope to allow for replanting. The slope is typically seeded with a cover crop and covered with erosion control fabric. Plant plugs and shrubs such as willows or dogwood can then be installed through the erosion control fabric. The stabilized slope and vegetation work together to prevent erosion from stream flows, wind, and raindrop impact.

Vegetated reinforced soil slope (VRSS) is the second method recommended for upper bank stabilization on Riley Creek. It is typically used on steep slopes where grading the bank to a more stable slope is not an option due to site restrictions. VRSS typically involves protecting layers of soils with a blanket or geotextile material (e.g. erosion control blanket) and vegetating the slope by either planting selected species (often willow or dogwood species) between the soil layers or by seeding the soil with desired species before it is covered by the protective material. In either case, if given enough light and moisture, the vegetation grows quickly and provides significant root structure to strengthen the bank. This method tends to be labor intensive and, therefore, somewhat expensive.

8.0 Cost Estimate

Conceptual level cost estimates were prepared for the Lake Riley outlet improvements and for the Lower Valley stabilization measures. The Lower Valley stabilization measure costs are presented in two different manners – by priority level, and by reach. Because site access is difficult for some reaches of Riley Creek, contractor mobilization costs will likely be relatively high. Therefore, it may make more sense to complete the stream stabilization measures for a given reach for all priority levels, rather than completing the high priority sites first.

Table 5. Lake Riley Outlet Improvements Cost Estimate[1,2]

Item	**Estimated Cost ($)**
Rice Marsh Outlet Installation	85,000
Channel Widening/Deepening at Lake Riley Outlet	60,000
Replacement of Culvert at Lakeland Terrace- *48-inch Culvert Option*	90,000
Replacement of Culvert at Lakeland Terrace- *Long Span Arch Option*	260,000
Total	**235,000 - 405,000**

[1] Cost estimates for each item include a 20% Contingency and 30% Engineering, Legal and Administrative cost.

[2] All costs in 2007 dollars

Table 6. Riley Creek Lower Valley Stabilization Cost Estimate – By Priority[1,2,3]

Priority Level	**Estimated Cost ($)**
High	631,000
Medium	181,000
Low	183,000
Subtotal	995,000

[1] All costs in 2007 dollars

[2] Cost Estimate does not include Lake Riley Outlet Improvements

[3] Cost Estimate does not include annual inspection, potential future stabilization, or comprehensive vegetation management

Table 7. Riley Creek Lower Valley Stabilization Cost Estimate – By Reach[1,2,3]

Reach	Item	Estimated Cost ($)
A	Recommended Stabilization	2,000
B	Recommended Stabilization	30,600
C	Recommended Stabilization	32,400
D	Recommended Stabilization	41,300
E	Recommended Stabilization	367,200
F	Recommended Stabilization	29,500
G	Recommended Stabilization	0
	Potential Future Stabilization	40,000
H	Recommended Stabilization	374,700
I	Recommended Stabilization	117,300
Annual Inspection		20,000
Comprehensive Vegetation Management		368,000
Subtotal[4]		1,403,000
20% Contingency		281,000
30% Engineering, Legal and Admin.		421,000
Total		**2,105,000**

[1] All costs in 2007 dollars

[2] Cost Estimate does not include Lake Riley Outlet Improvements

[3] Future maintenance of area stabilized by the project will be undertaken based on a maintenance agreement between the District and the City.

[4] Subtotal cost does not include annual inspection cost.

9.0 Conclusions

The XP-SWMM hydrologic and hydraulic model of the Riley Creek watershed will prove to be invaluable for managing the surface water of the watershed. The model has already proven to be valuable in the analysis of the Rice Marsh Lake outlet, the Lake Riley outlet and the Lower Valley of Riley Creek.

The outlet of Lake Riley was found to be limiting the drawdown rate of the lake in two different ways: first, the channel between the lake and weir structure is restrictive to flow; that is, the weir can pass more flow than the channel is capable of delivering. Second, the culvert under Lakeview Terrace is restrictive to flow and subject to clogging. Correcting either deficiency alone has only limited value, but correcting both would significantly reduce the length of time that the lake will remain elevated following heavy rainfall. Therefore, it is recommended that a larger culvert be installed under Lakeland Terrace, and that the channel be widened between the lake and weir. This analysis was based on the assumption that a permanent outlet will be constructed at Rice Marsh Lake to control the discharge to Lake Riley through Riley Creek.

A detailed field survey and evaluation was conducted for Riley Creek in the Lower Valley, from Lake Riley to US Highway 212. The stream was divided into reaches based on landmarks and similar channel characteristics, and erosion areas were measured and prioritized. Severe erosion is evident in a 3,000-foot stretch of creek located midway between Dell Road and Eden Prairie Road. Stabilization measures were recommended on a prioritized basis for Riley Creek, including stabilization of several large bluff erosion sites. Existing and future erosion could be reduced by improving and maintaining the vegetation throughout the Lower Valley. Removal of invasive plants and selective tree species would increase the amount of sunlight reaching the ground, which would encourage a much greater density and diversity of ground vegetation.

Site F1, located upstream of Eden Prairie Road, has a log jam that is completely blocking the channel. This site should be addressed as soon as possible to prevent a new channel from developing on the adjacent land.

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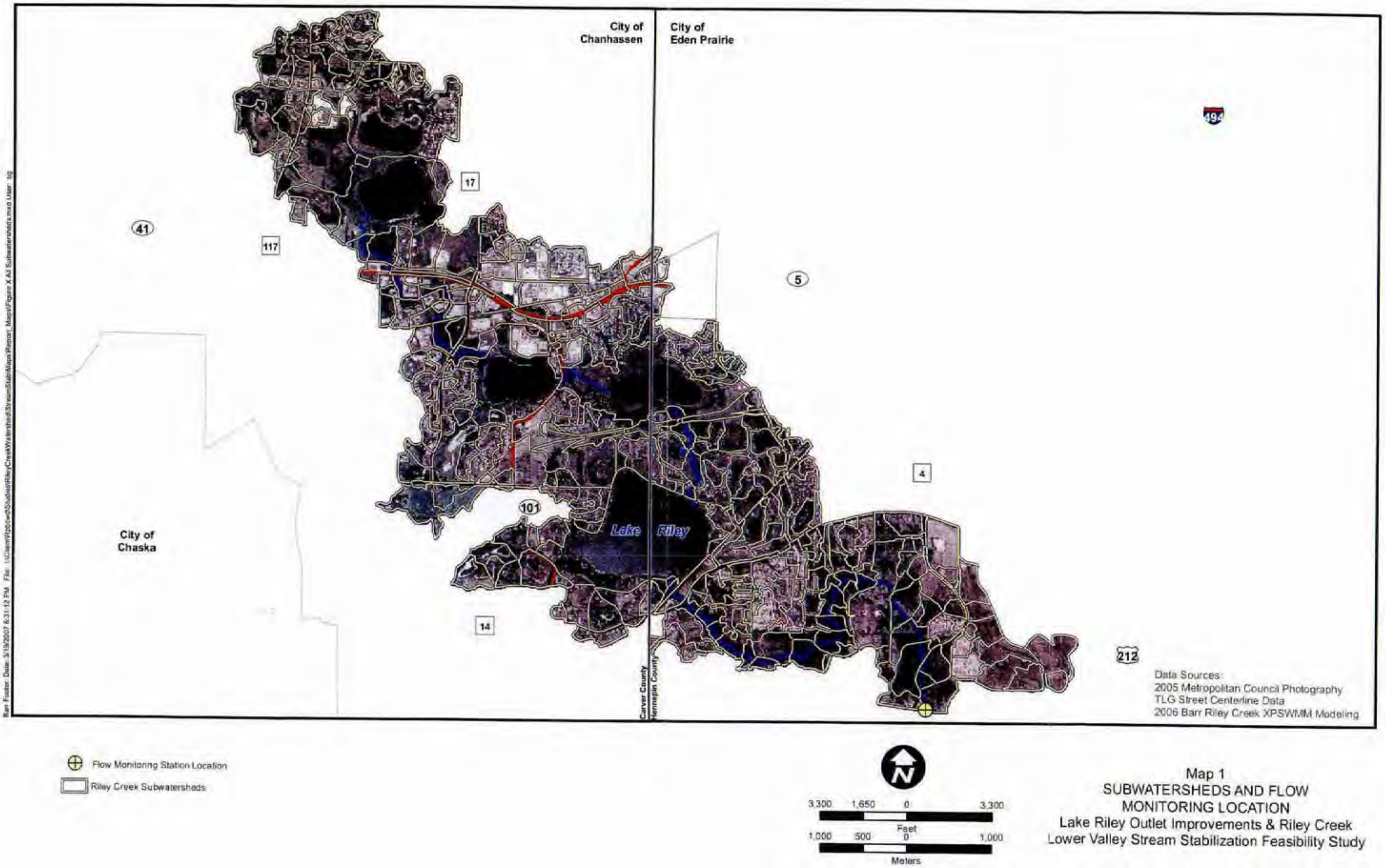
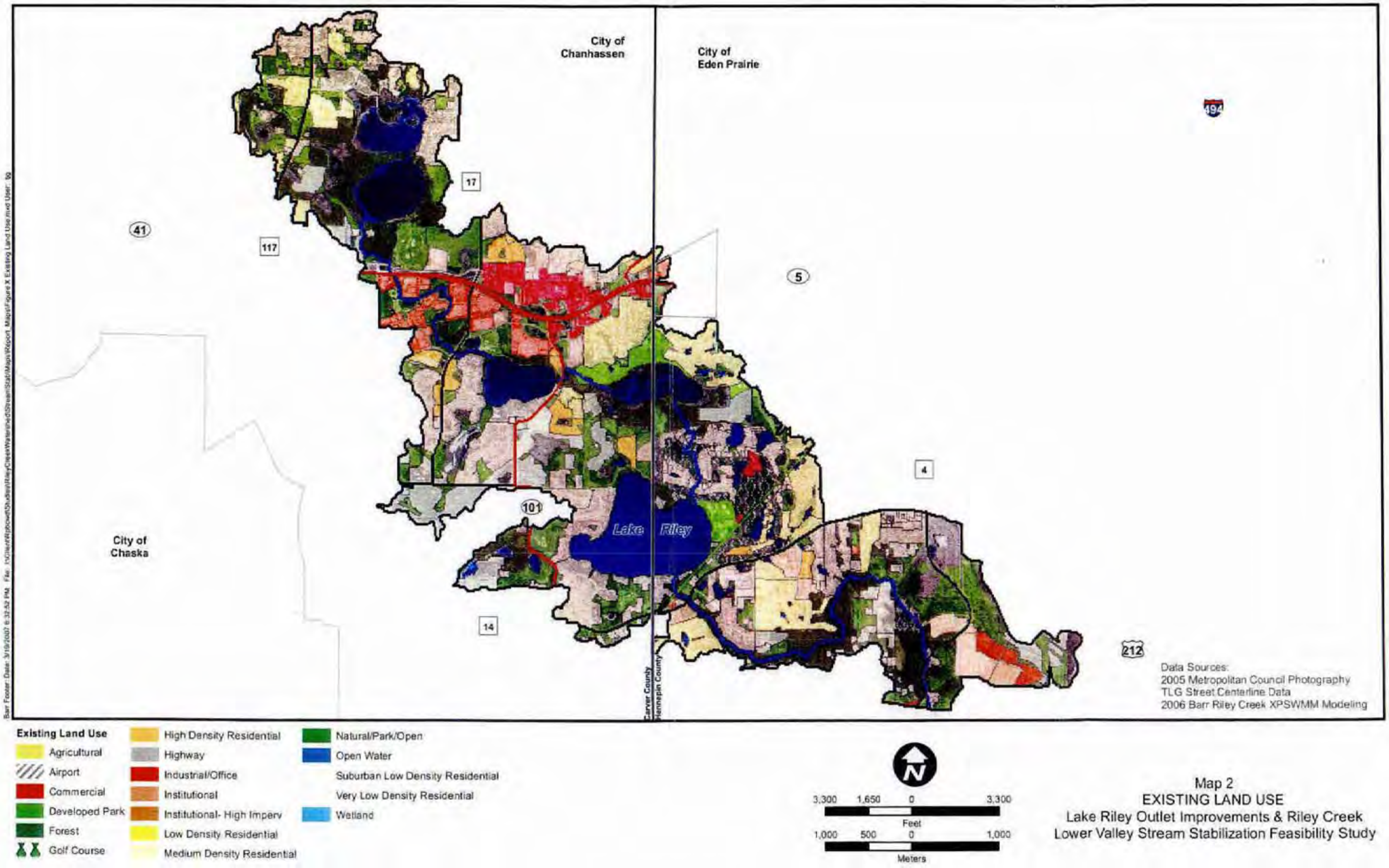
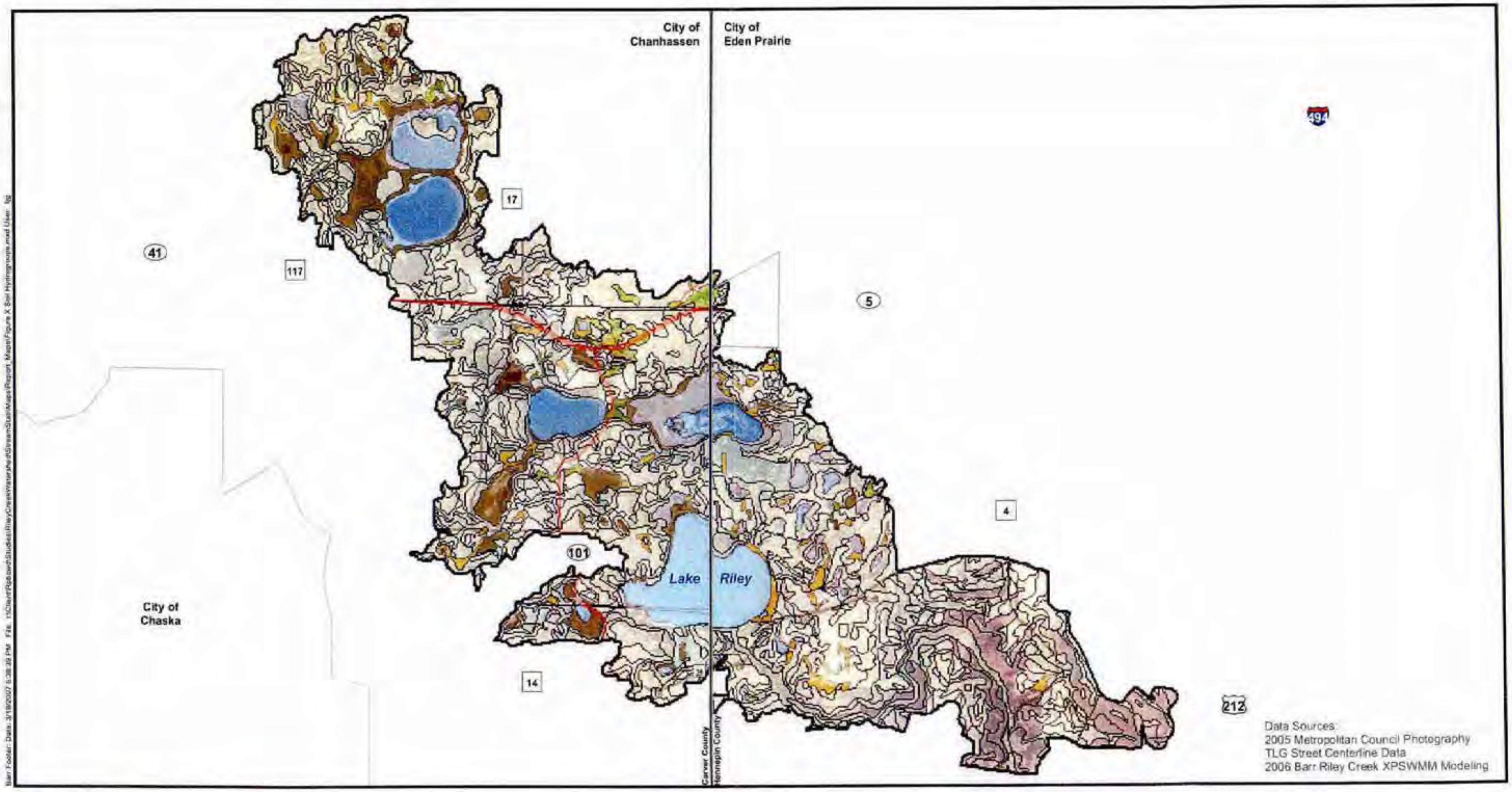


Map 1
SUBWATERSHEDS AND FLOW
MONITORING LOCATION
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study



Data Sources:
2005 Metropolitan Council Photography
TLG Street Centerline Data
2006 Barr Riley Creek XPSWMM Modeling

Map 2
EXISTING LAND USE
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study



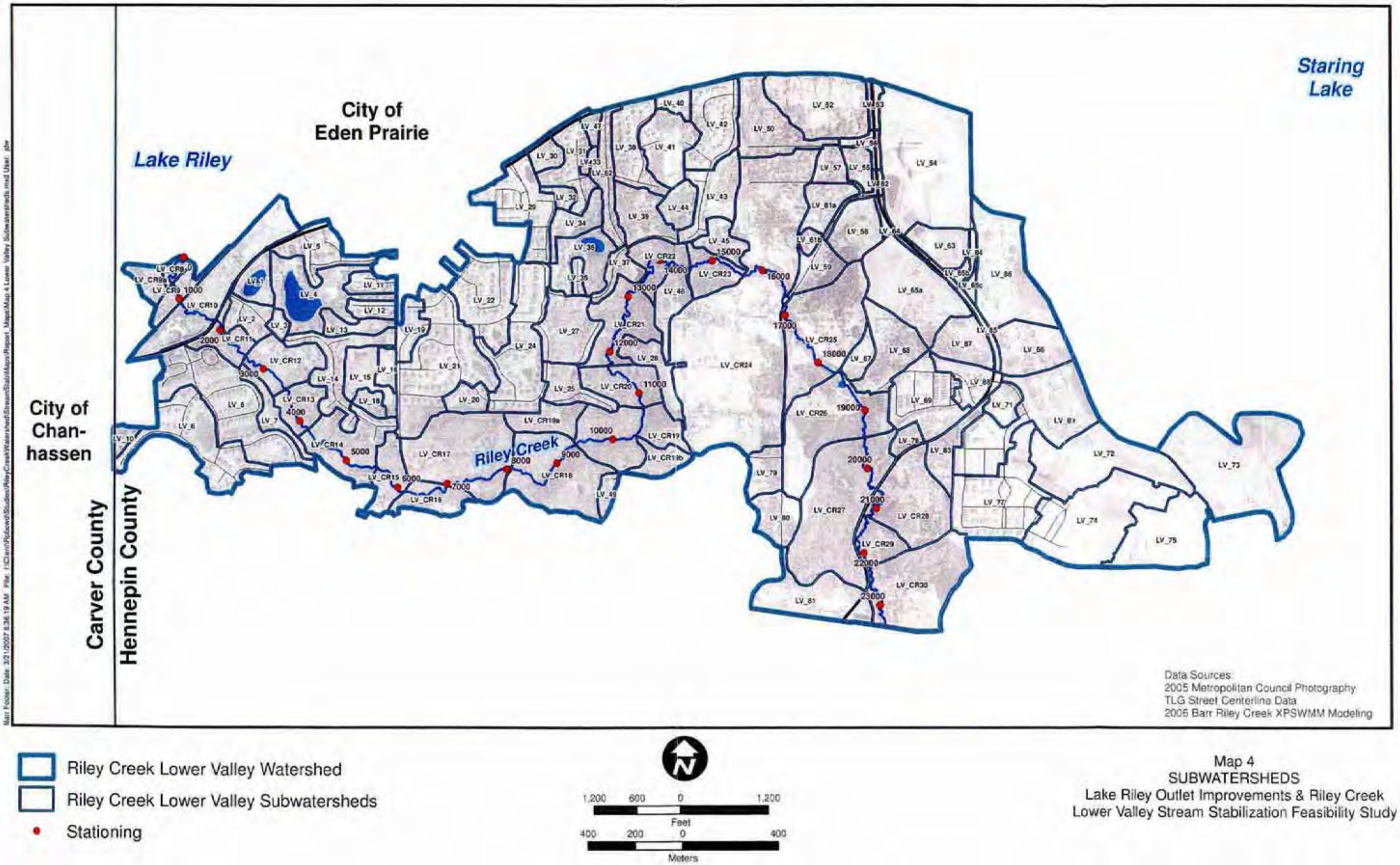
Data Sources:
2005 Metropolitan Council Photography
TLG Street Centerline Data
2006 Barr Riley Creek XPSWMM Modeling

Hydrologic Soil Group

☐	A	☐	C
▨	A/D	🟩	C/D
☐	B	☐	D
▨	B/D	☐	W

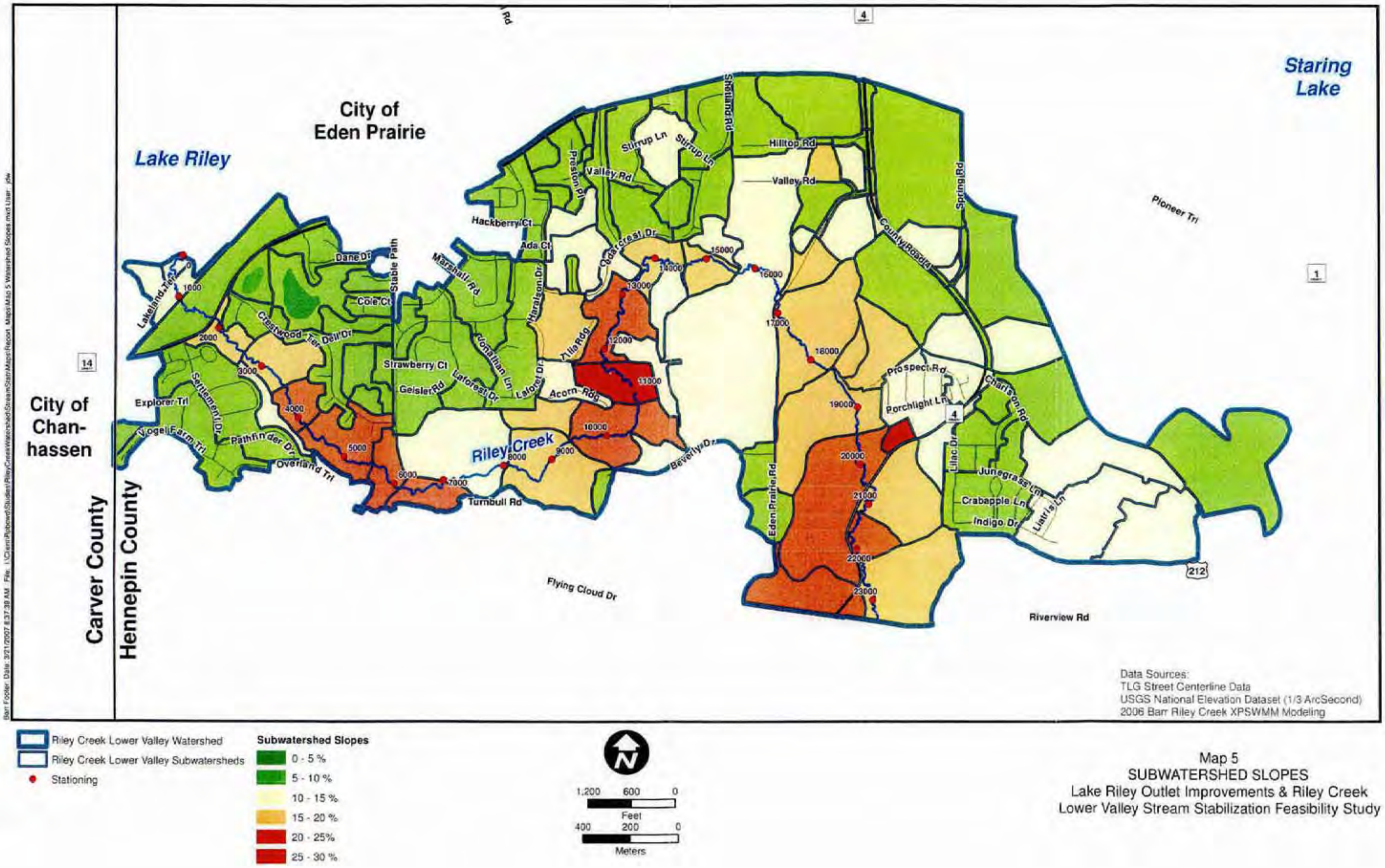
Map 3
HYDROLOGIC SOIL GROUPS
Lake Riley Outlet Improvements & Riley Creek Lower Valley Stream Stabilization Feasibility Study

Barr Footer: Date: 3/21/2007 8:36:19 AM File: I:\Client\Rpbcwd\Studies\RileyCreekWatershed\StreamStabil\Maps\Report_Maps\Map 4 Lower Valley Subwatersheds.mxd User: jdw



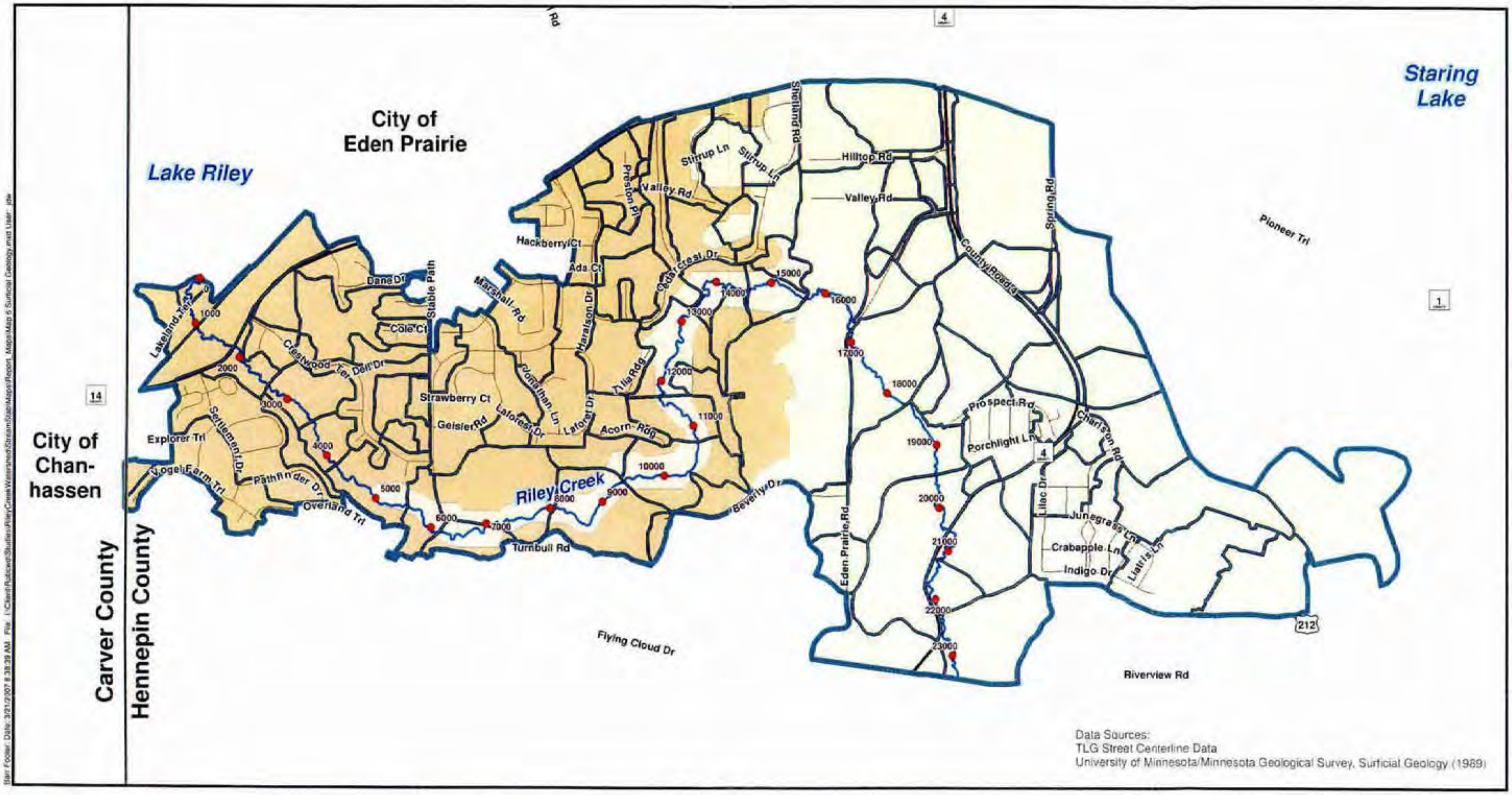
Data Sources:
2005 Metropolitan Council Photography
TLG Street Centerline Data
2006 Barr Riley Creek XPSWMM Modeling

Map 4
SUBWATERSHEDS
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study



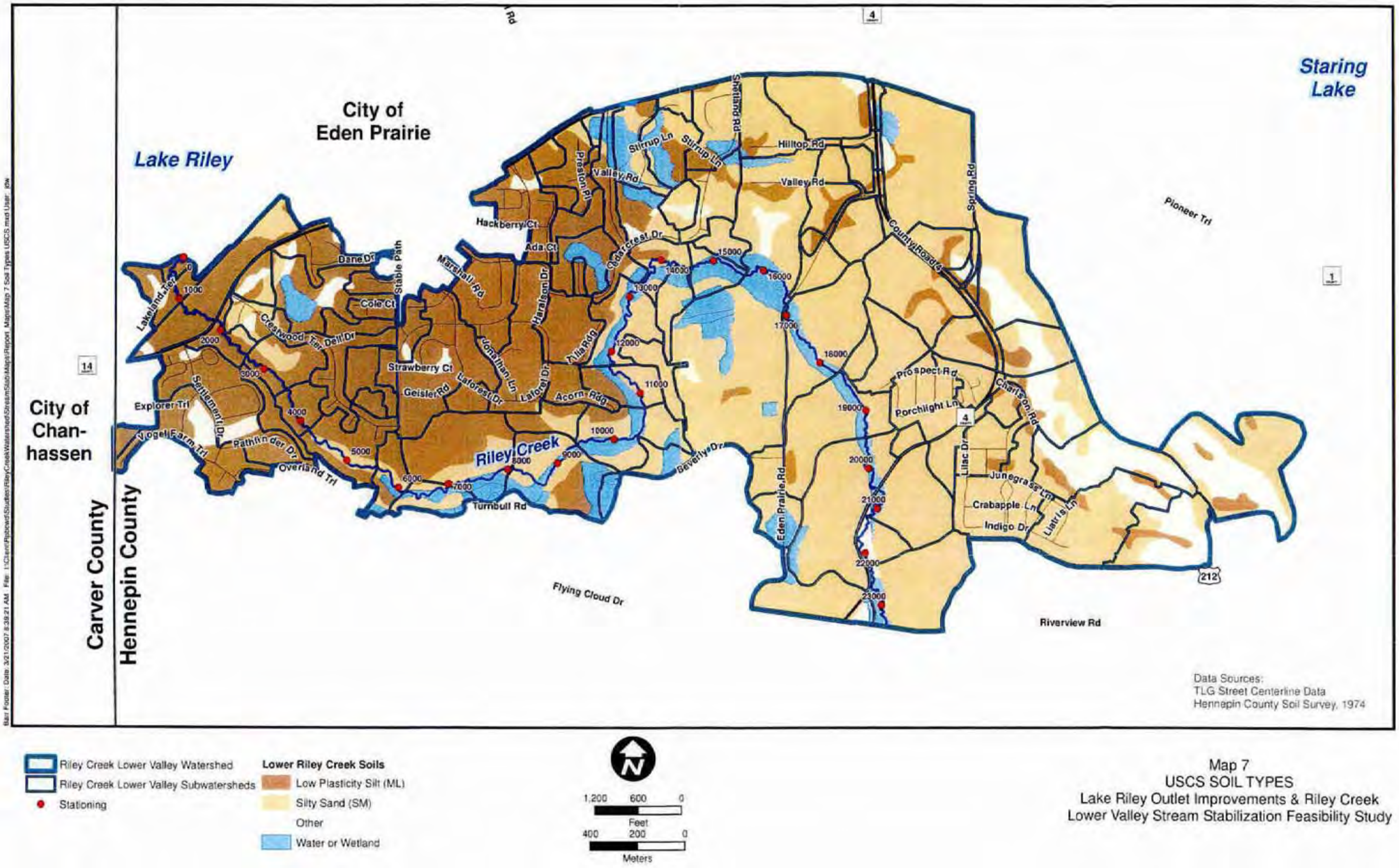
Data Sources:
TLG Street Centerline Data
USGS National Elevation Dataset (1/3 ArcSecond)
2006 Barr Riley Creek XPSWMM Modeling

Map 5
SUBWATERSHED SLOPES
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study



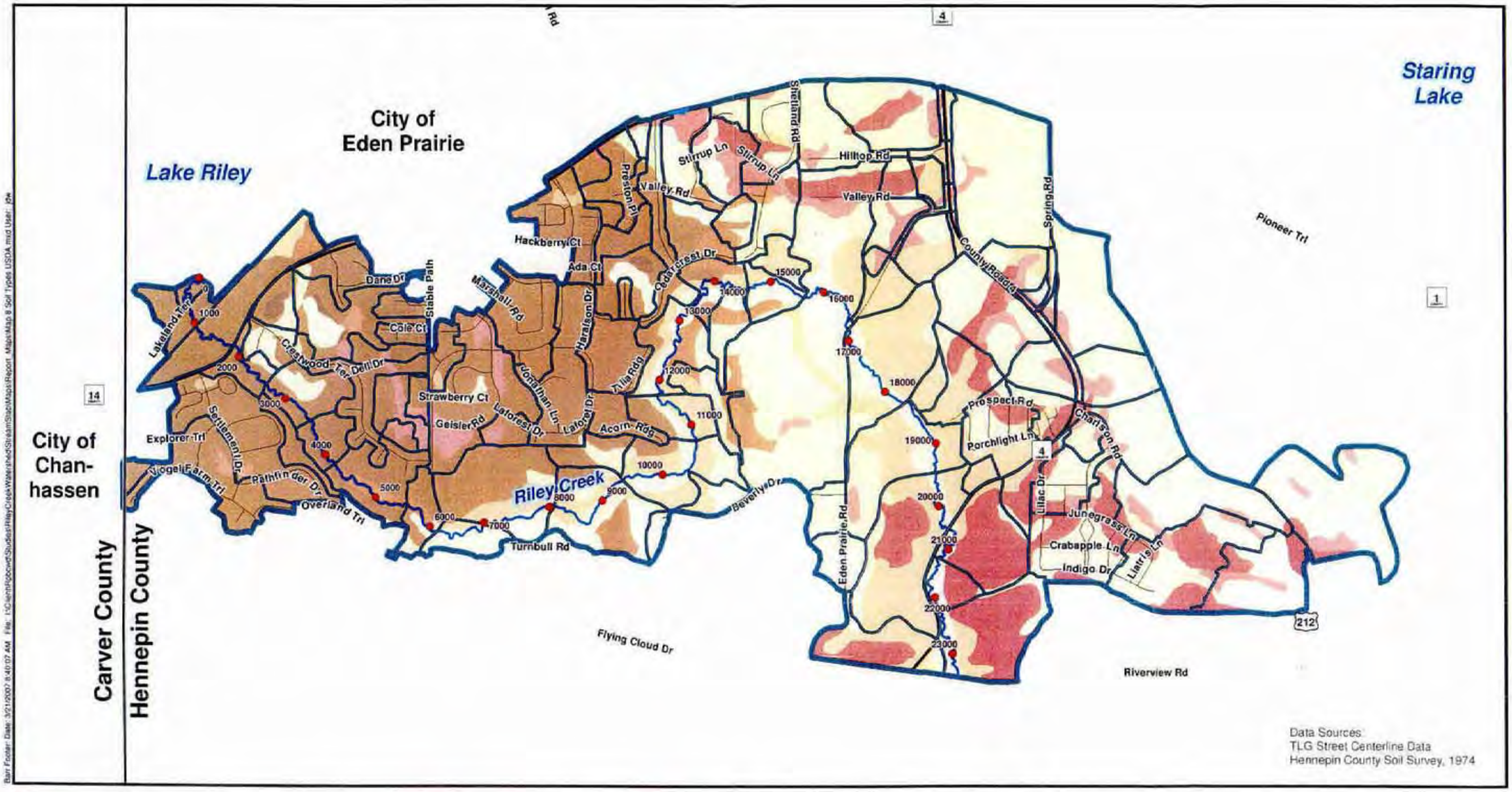
Data Sources:
TLG Street Centerline Data
University of Minnesota/Minnesota Geological Survey, Surficial Geology (1989)

Map 6
SURFICIAL GEOLOGY
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study



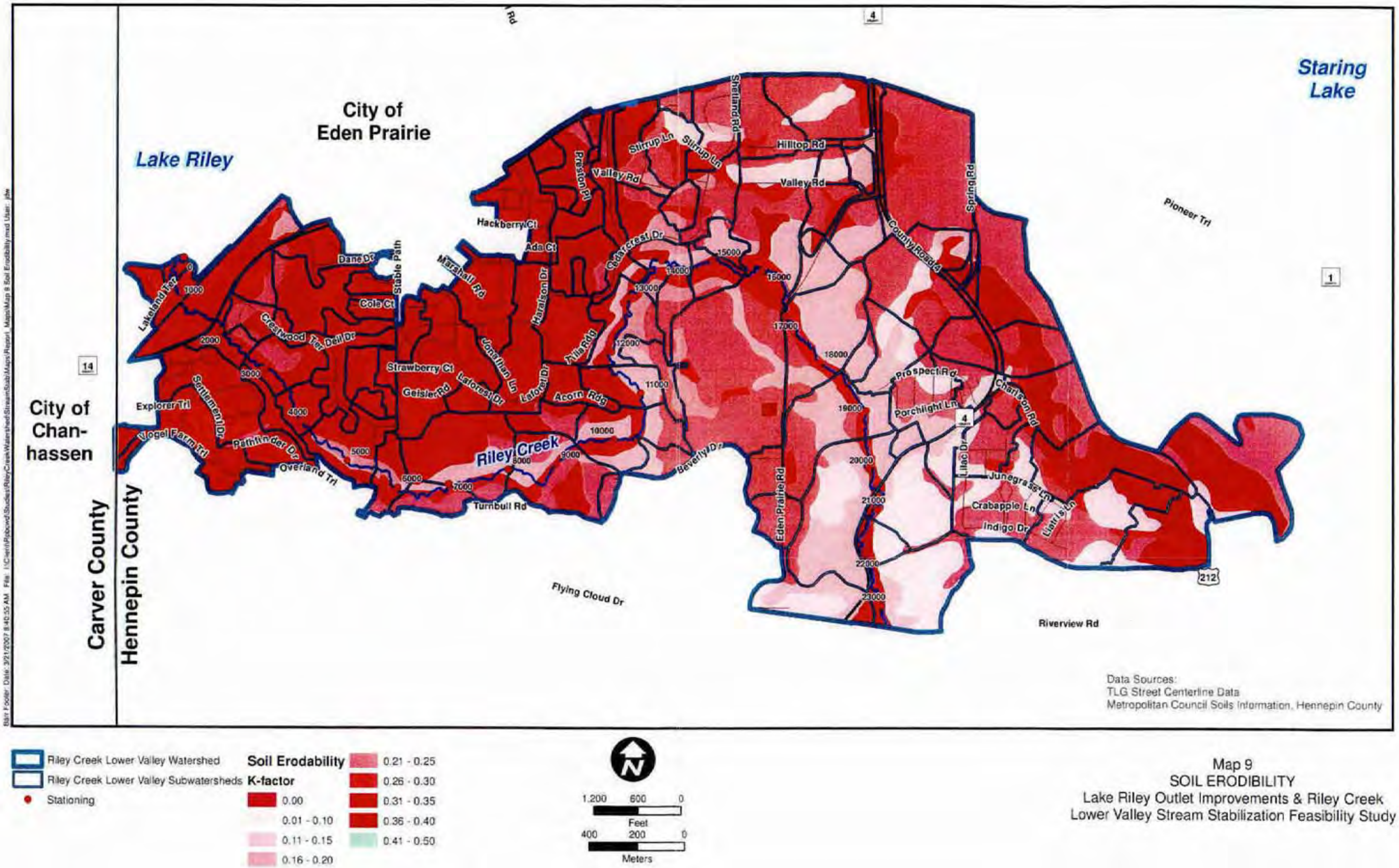
Data Sources:
TLG Street Centerline Data
Hennepin County Soil Survey, 1974

Map 7
USCS SOIL TYPES
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study

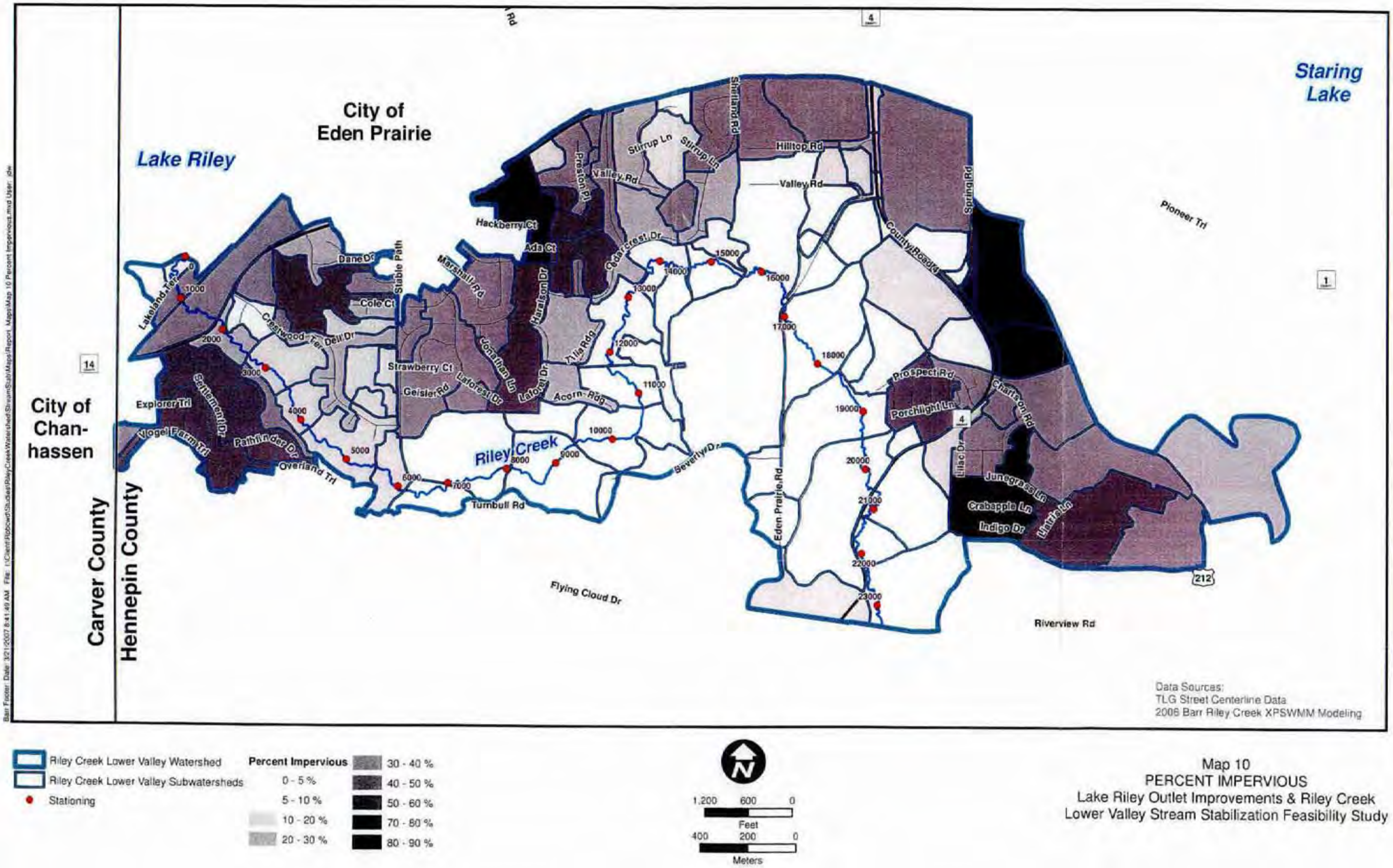


Data Sources:
TLG Street Centerline Data
Hennepin County Soil Survey, 1974

Map 8
USDA SOIL TYPES
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study

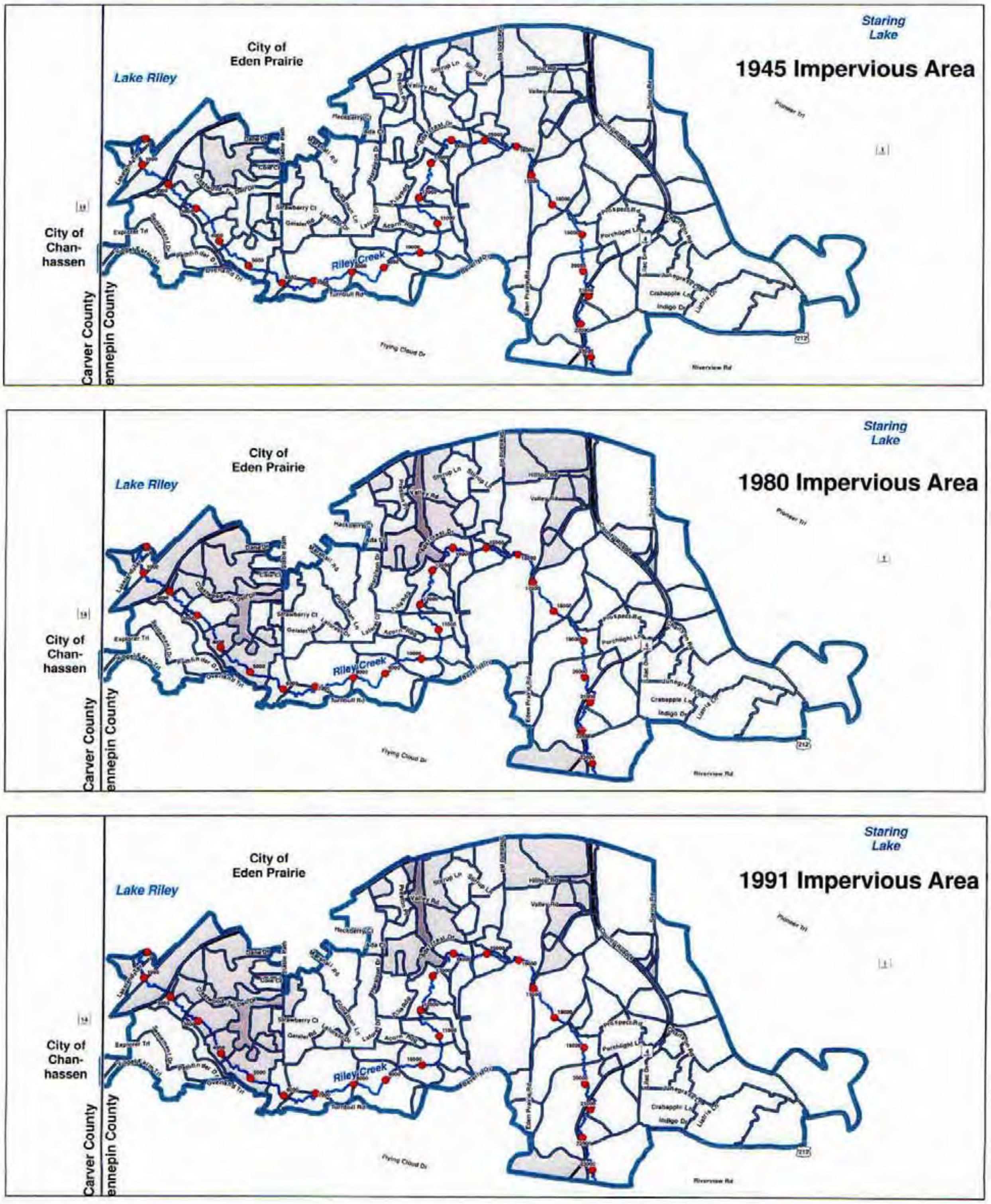


Map 9
SOIL ERODIBILITY
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study



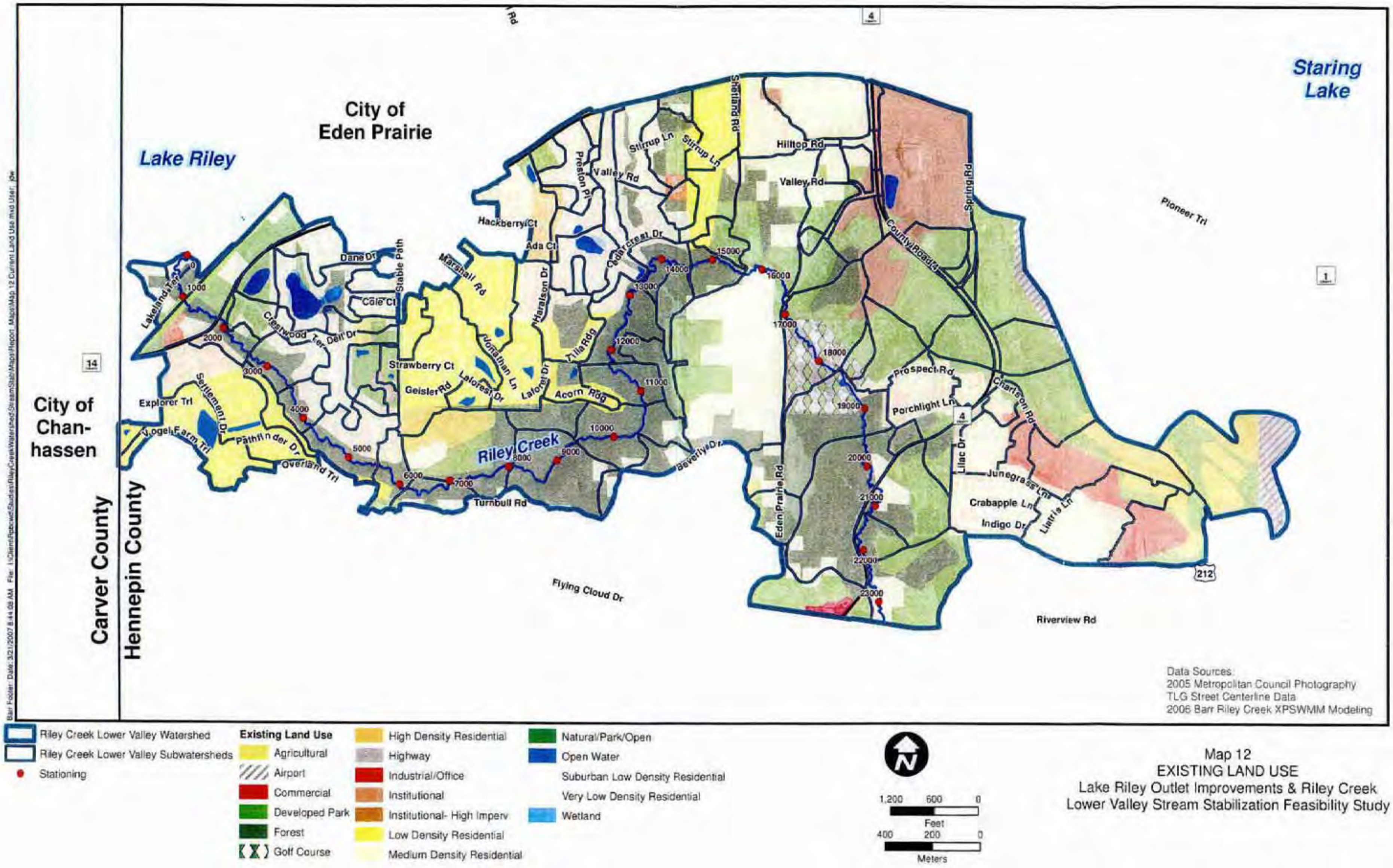
Data Sources:
TLG Street Centerline Data
2006 Barr Riley Creek XPSWMM Modeling

Map 10
PERCENT IMPERVIOUS
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study



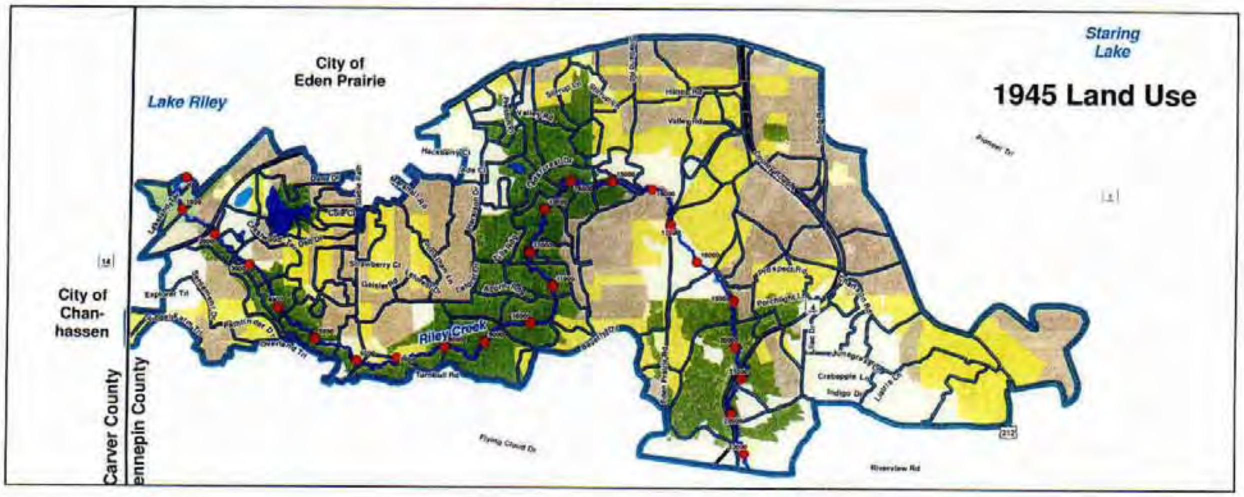
Data Sources:
1945 Aerial Photographs
1980 Aerial Photographs
1991 USGS DOQs
TLG Street Centerline Data
2006 Barr Riley Creek XPSWMM Modeling

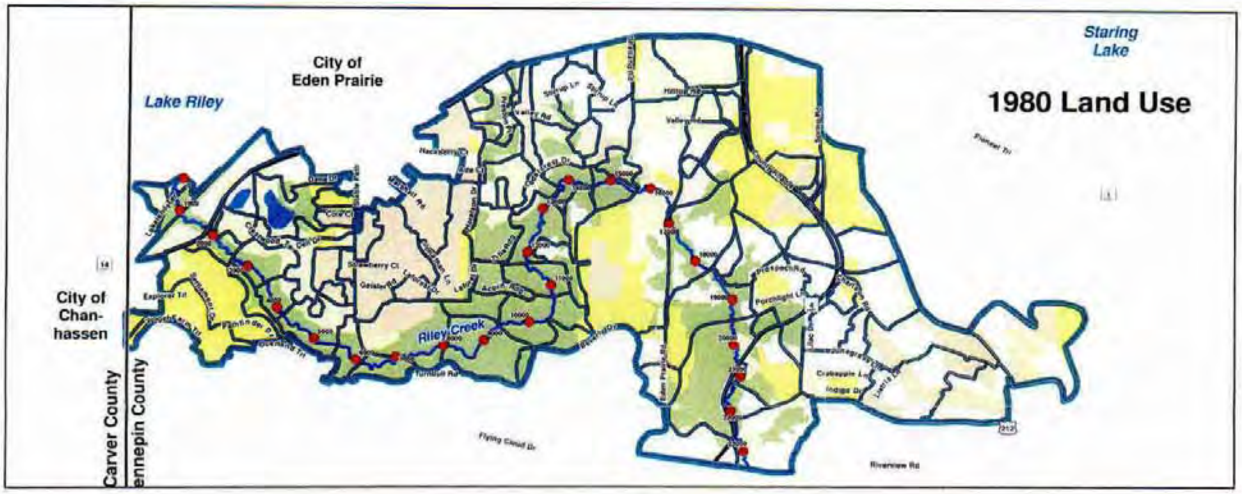
Map 11
HISTORIC IMPERVIOUS AREA (1945, 1980, 1991)
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study

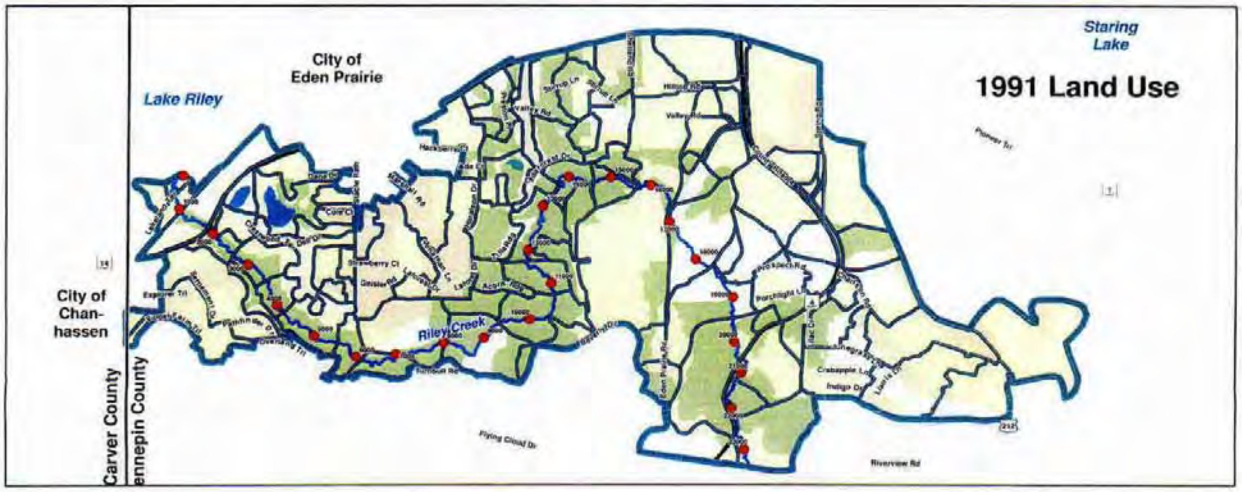


Data Sources:
2005 Metropolitan Council Photography
TLG Street Centerline Data
2006 Barr Riley Creek XPSWMM Modeling

Map 12
EXISTING LAND USE
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study







Data Sources:
1945 Aerial Photographs
1980 Aerial Photographs
1991 USGS DOQs
TLG Street Centerline Data
2006 Barr Riley Creek XPSWMM Modeling

▭ Riley Creek Lower Valley Watershed
▭ Riley Creek Lower Valley Subwatersheds

Landuse_1980

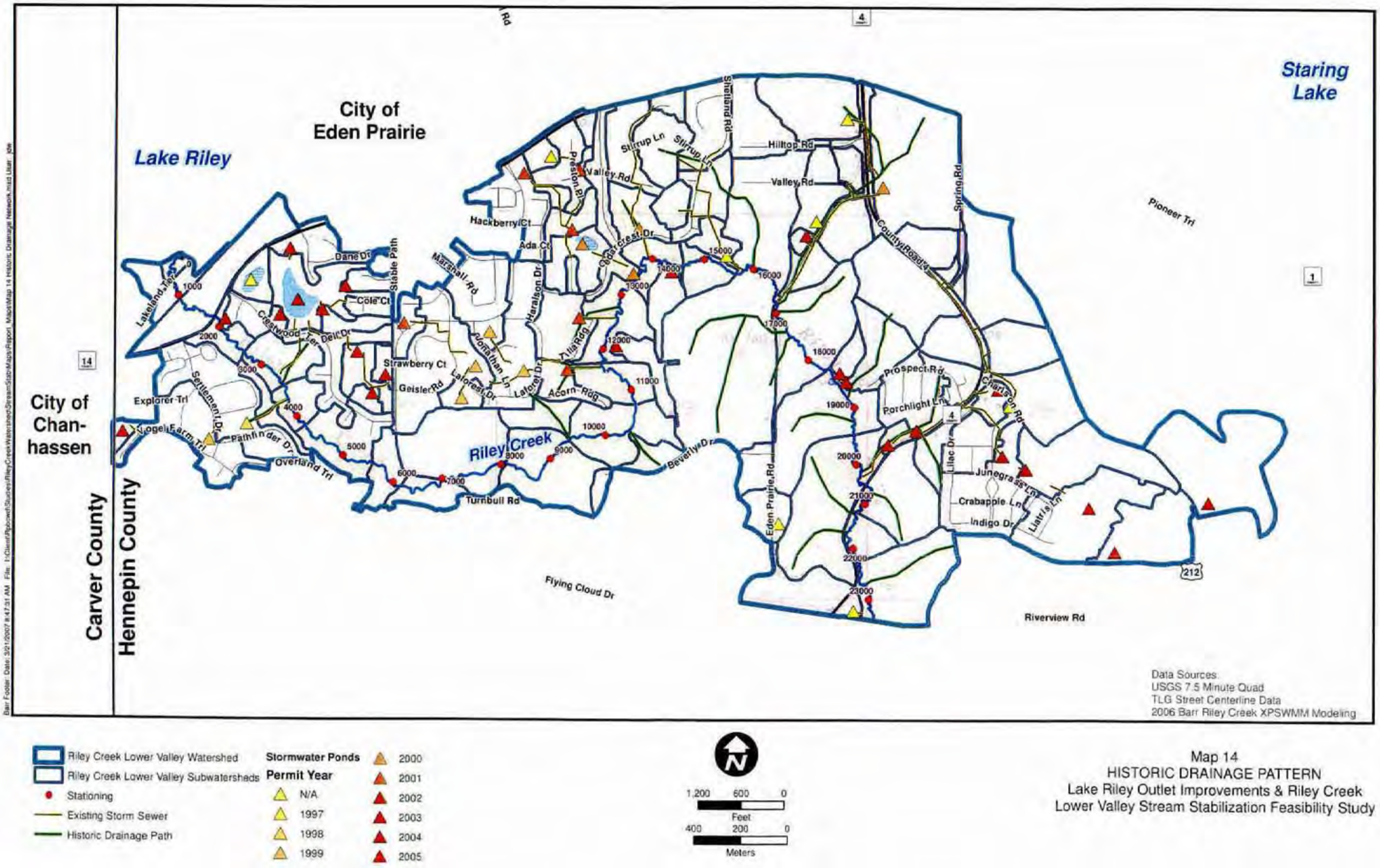
- 🟨 Non-Row Crop
- 🟫 Row Crop
- Grassland
- ▨ Roads
- Suburban Low Density Res
- Very Low Density Res
- 🟪 Urban
- 🟦 Water
- 🟩 Woodland

N

Feet
2,000 0

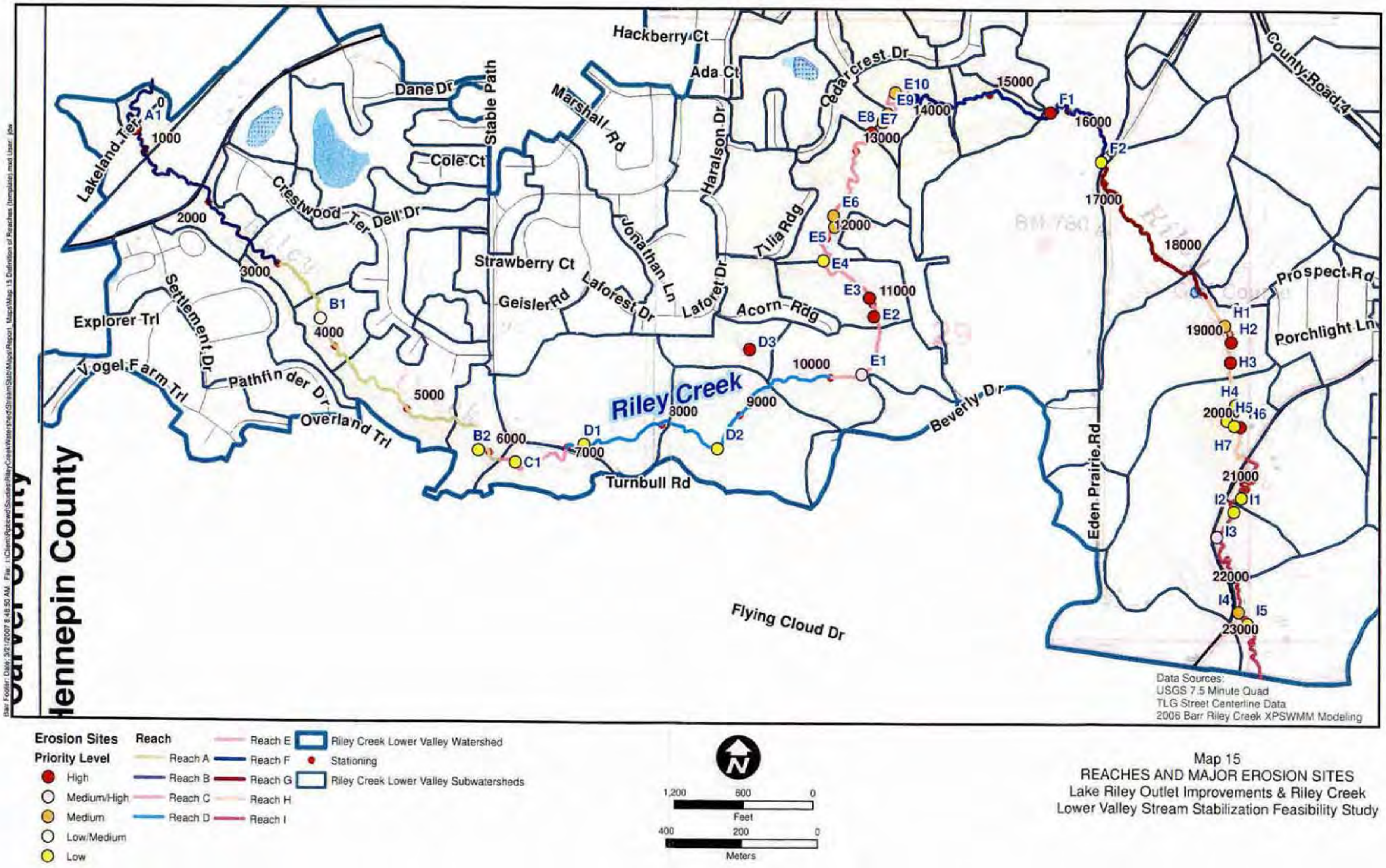
Meters
660 0

Map 13
HISTORIC LAND USE (1945, 1980, 1991)
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study



Data Sources:
USGS 7.5 Minute Quad
TLG Street Centerline Data
2006 Barr Riley Creek XPSWMM Modeling

Map 14
HISTORIC DRAINAGE PATTERN
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study



Map 15
REACHES AND MAJOR EROSION SITES
Lake Riley Outlet Improvements & Riley Creek
Lower Valley Stream Stabilization Feasibility Study