BARR

Waste Load Allocation Implementation Plan

Prepared for
City of Northfield

Prepared by
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November 2024

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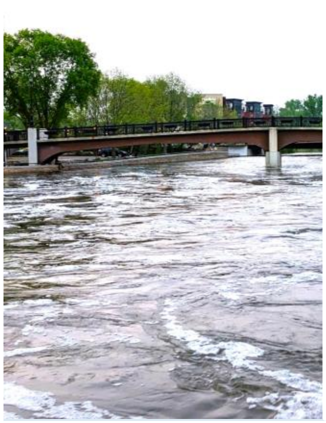

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Abbreviations

BMP	Best Management Practice
DCI	Directly Connected Imperviousness
GIS	Geographic Information System
GIS WQM	GIS Water Quality Model
LiDAR	Light Detection and Ranging
MIDS	Minimal Impact Design Standard
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer System
NAIP	National Agriculture Imagery Program
SSA	Storm and Sanitary Model
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
USGS	U.S. Geological Survey
WLAs	Waste Load Allocations
WRAPS	Watershed and Restoration Protection Strategies

1 Executive Summary

In the Fall of 2021, the City of Northfield was authorized for coverage by Minnesota Pollution Control Agency (MPCA) under the updated Municipal Separate Storm Sewer System (MS4) General Permit. Along with authorization under this new permit, the city received new Total Maximum Daily Load (WLA) Waste Load Allocations (WLAs) from the Cannon River Watershed and Restoration Protection Strategies (WRAPS) Report. With the addition and evaluation of the new and existing WLAs, this study was commissioned to identify ways the city can continue to enhance its efforts to reduce storm water pollution and identify strategies that will assist in meeting WLAs over the next several decades. A detailed pollutant loading assessment was also warranted to further assist with gauging compliance and prescribing and implementing future water quality improvements. Barr Engineering Co. (Barr) was hired to develop a WLA Implementation Plan and adaptive tool that supports future modeling scenarios and plan development.

The GIS Water Quality Model (WQM) is a GIS-module that uses watershed, best management practice (BMP), and stormwater infrastructure information to generate pollutant loading, route loading through the stormwater system, predict pollutant load removal by BMPs, and summarize pollutant loading and removal at any point within the stormwater infrastructure network. The results of the water quality modeling were used to develop pollutant loadings for areas tributary to each TMDL WLA.

The total phosphorus (TP) WLA from the Lake Byllesby TMDL requires an approximately 45 percent reduction from the existing overall discharge loading rate and controls implementation planning for the City of Northfield. The areas of the city with the highest TP discharge rates to the Cannon River are in portions of Northfield that are already developed where there is less space for BMP retrofits, so it will be significantly more difficult to comply with the TP WLA. Implementation planning discussions with MPCA regarding indicated that Northfield must simply “show progress” towards meeting the WLAs and that compliance dates are not specifically mandated. Given the setting along the Cannon River, with rural areas draining through Northfield’s jurisdiction, the city is encouraged to look at making water quality improvements to all stormwater flow and/or address additional sources of phosphorus.

Based on current understanding, the long-term goal will be for the City of Northfield to attain a 45 percent reduction from the existing discharge TP loading rate from the overall drainage area, which is equivalent to a TP load reduction rate of 4.5 percent every ten years. This TP load reduction rate would correspond with approximately 20 pounds of additional TP loading that the city would need to successively reduce on an annualized basis.

As a part of implementation planning, the associated calculations and parameter sensitivity within the water quality modeling were reviewed to inform street sweeping frequency recommendations that could be optimized for pollutant reduction credits. In addition, other strategies for pollutant load reductions were considered for evaluation/optimization based on current city operations, land ownership/ management, and/or unique source areas (such as excess phosphorus in Lyman Lake), including experience with implementation and maintenance of specific BMPs associated with future redevelopment and/or street reclamation and overlay projects. The potential annual total phosphorus load reduction was quantified and/or recommendations for implementation are summarized as follows:

1) Street sweeping—potential for 300-pound TP reduction by increasing street sweeping frequency in priority pipesheds, with emphasis in the spring and fall
2) Street reclamation and overlay projects—potential for 100-pound TP reduction by implementing structural BMPs in priority pipesheds

3) Agricultural sources—potential for at least 700-pound TP reduction from structural BMPs implemented with future development
4) Streambank and bed erosion—sources of erosion are unknown currently; it is recommended that the city inventory (and/or use new LiDAR data), and subsequently stabilize erosion
5) Chemical treatment of Spring Creek flow—potential for at least 500-pound TP reduction from this tributary; it is recommended that the city survey/verify existing TP load reductions that could be realized from alum treatment (plant or aerial lake application).

2 Background

In the Fall of 2021, the City of Northfield was authorized for coverage by Minnesota Pollution Control Agency (MPCA) under the updated Municipal Separate Storm Sewer System (MS4) General Permit. Along with authorization under this new permit, the city received new Waste Load Allocations (WLAs) from the Cannon River Watershed and Restoration Protection Strategies (WRAPS) Report. With the addition and evaluation of the new and existing WLAs, this study was commissioned to identify ways the city can continue to enhance its efforts to reduce storm water pollution and identify strategies that will assist in meeting WLAs over the next several decades. A detailed pollutant loading assessment was also warranted to further assist with gauging compliance and prescribing and implementing future water quality improvements.

The city hired Barr Engineering Co. (Barr) to develop a Waste Load Allocation Implementation Plan (Plan) and adaptive tool that supports the plan and can be used for future modeling scenarios. This Plan is intended to play an active role in supporting the city's Strategic Initiatives, Climate Action Goals, and relate with the city's geographic information system (GIS) and 2020 Surface Water Model.

The results of the water quality modeling (including the accounting for street sweeping, sump cleanouts and stormwater treatment BMPs) were used to develop pollutant loadings for each tributary area that is subject to each TMDL WLA for each of the applicable baseline years of the respective TMDLs. Table 2-1 shows the TMDL MS4 WLAs that apply to the City of Northfield.

Table 2-1 TMDL MS4 WLAs for City of Northfield

TMDL Receiving Water	TP WLA (lbs/ac/yr)	TSS WLA (lbs/ac/yr)
Lake Byllesby	0.20(1)	
Cannon River Reach 509		63.1(2)
Chubb Creek Reach 528		61.7(2)
Lower Cannon River Reach 502		45.8(3)
Lower Cannon River Reach 646		47.5(3)
South Metro Mississippi River		154

[1] 2003 baseline year
[2] 2012 baseline year
[3] 1998 baseline year

The WLA from the Lake Byllesby TMDL controls the phosphorus load reduction goal, which would require approximately 45 percent reduction from the existing overall discharge loading rate. It was determined that the City of Northfield has a segment of gravel road but does not own or operate any type of stormwater conveyance tributary to Chubb Creek watershed. Both lower Cannon River reaches are downstream of Lake Byllesby, which would greatly mask any further benefit derived from future BMP implementation in Northfield. As a result, the WLA from the Cannon River Reach 509 TMDL controls the TSS load reduction goal, which would require approximately 21 percent reduction from the existing overall discharge loading rate. Because the required TP load reduction rate is higher than TSS, and stormwater BMPs are more efficient at removing TSS than TP, compliance with the TP WLA reduction goal for Lake Byllesby controls implementation planning for the City of Northfield.

3 GIS Water Quality Model (GIS WQM)

The GIS Water Quality Model (WQM) is a GIS-module that uses watershed, best management practice (BMP), and stormwater infrastructure information to generate pollutant loading, route loading through the stormwater system, predict pollutant load removal by BMPs, and summarize pollutant loading and removal at any point within the stormwater infrastructure network. Pollutant loading and BMP removal estimates are calculated on an annualized basis (e.g., pounds of total phosphorus [TP] or total suspended solids [TSS] removal per year) based on empirical relationships.

The GIS WQM allows for rapid evaluation of watershed pollutant loading and estimates pollutant reduction from a variety of structural and non-structural BMPs (e.g., wet ponds, raingardens, dry ponds, pervious pavement, green roofs, street sweeping, etc.). Additionally, because the model is based in GIS, updating and maintaining the model based on changing land use and BMP implementation and construction is simplified. The GIS WQM utilizes data from the city's storm sewer GIS data to route runoff and associated pollutants through the city's drainage system, in to and out of water quality BMPs, and ultimately to outfalls from the city. The GIS WQM performs a mass balance of runoff and pollutant at every point within the drainage system network allowing for quantification of pollutant loading and pollutant removal at any point within the network (e.g., any manhole, outfall, BMP, etc.).

Pollutant reduction methodology within the GIS WQM is based on methodology developed for the MPCA Minimal Impact Design Standard (MIDS) Calculator (MPCA, 2017). The model uses simplified watershed and BMP inputs to estimate annualized pollutant loading and pollutant reduction from modeled BMPs. Model methodology is outlined in documentation provided in Barr (2020). The GIS WQM is an annualized, empirically based model intended to be used as a planning-level tool for quickly evaluating and summarizing water quality performance of BMPs and pollutant loading results, as well as "what if" scenarios related to BMP implementation, cost-benefit evaluation of proposed BMPs, modifications to existing BMPs, and regional planning of BMP implementation to meet pollutant reduction goals (e.g., MS4 WLAs, etc.). The version of the GIS WQM model developed for the City of Northfield is compatible with the Esri product ArcGIS Pro.

3.1 GIS WQM Overview

This section provides a general overview of how the GIS WQM is structured within ArcGIS Pro and how the calculation of pollutant loading, routing, and pollutant reduction is completed within the model. The general calculation operational procedure within the GIS WQM is highlighted in Figure 3-1. The following steps outline the process by which pollutants are generated from subwatersheds, routed, and accumulated throughout the model utility network and removed by BMPs within the utility network:

1) Raw runoff and pollutant loading from subwatersheds are calculated from background pollutant areal loading raster files.
2) Runoff and pollutant reduction from street sweeping and cisterns is removed prior to network routing.
3) Runoff and pollutants not removed by street sweeping and cisterns are routed into the utility network. Runoff and pollutants accumulate throughout the utility network, and a complete mass balance of runoff and pollutant loading is calculated at each model utility network node.
4) When runoff and pollutants are routed to a BMP node, runoff and pollutant reduction is calculated. Runoff and pollutant reduction calculated at a BMP is dependent on (a) BMP type, (b) dimensions

of the BMP, (c) area and impervious area routed to the BMP, and (d) the amount of water quality treatment in portions of the watershed tributary to the BMP.

5) Finally, total runoff and pollutant loading are calculated at outfall nodes from the model. At every node within the model (including outfalls), all parameters required to account for runoff and pollutant mass balance are recorded and are available for user review, including total pollutant loading, total pollutant removal, total tributary area, etc.

The results of the model can be summarized at every junction, BMP, subwatershed, waterbody, and outfall within the model. GIS WQM model data is stored in two Esri ArcGIS file geodatabases, and all inputs and results are stored in these geodatabases.

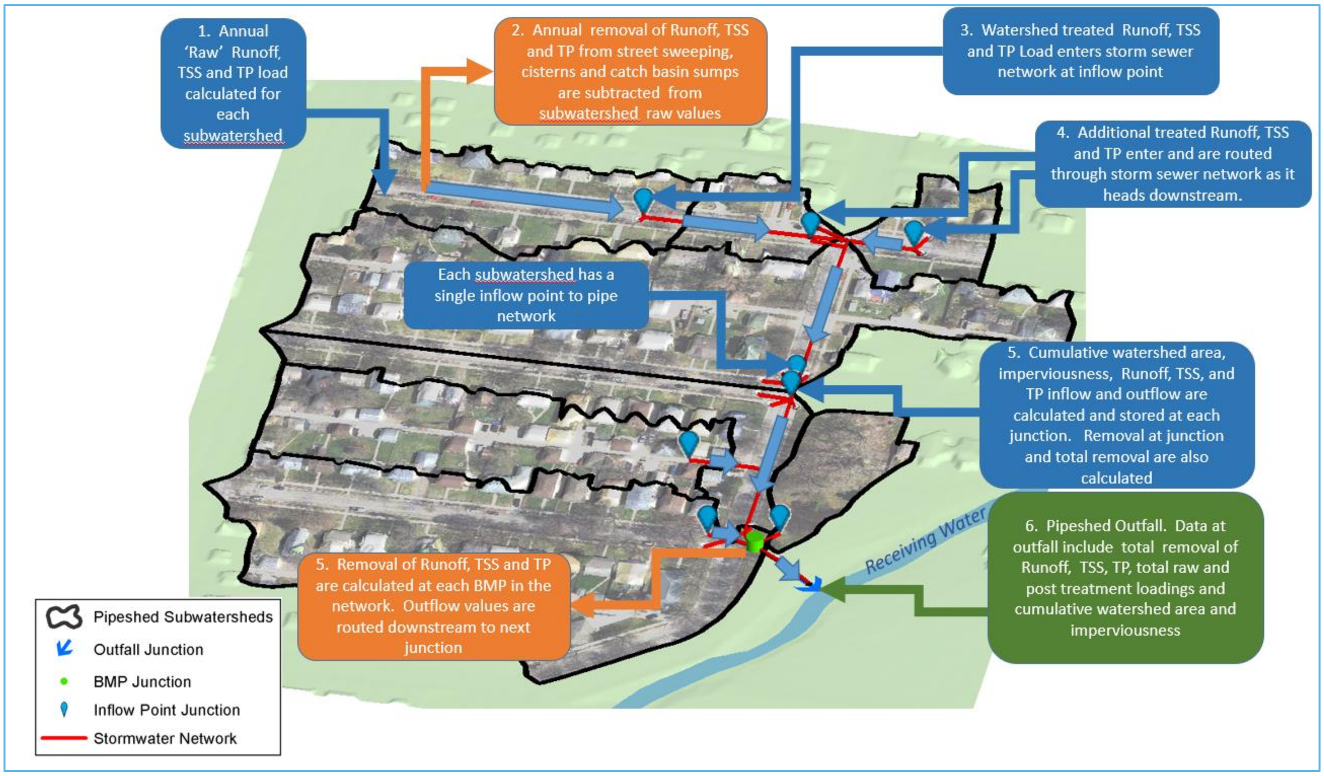


Figure 3-1 GIS WQM Calculation Operational Procedure

The following subsections describe each step of the development process followed and data sources used for the City of Northfield GIS WQM model.

3.2 GIS WQM Development

The assumptions and data used in the development of the Northfield GIS WQM are discussed in this section.

3.2.1 GIS WQM Subwatershed Delineation

Subwatersheds generated from the Northfield Storm and Sanitary Model (SSA) were utilized in the development of subwatersheds for the Northfield GIS WQM. Several adjustments were made to the SSA subwatersheds due to the identification of several dozen additional BMPs identified by Barr and Northfield that were not included in the original SSA model.

Adjustments included splitting subwatersheds to reflect areas flowing directly to each BMP. The subwatersheds were delineated using 2021 Minnesota 3DEP Light Detection and Ranging (LiDAR) collected by the USGS and the State of Minnesota for Rice County. When available, development plans provided by the city were also used in the delineation of subwatersheds. No field verifications of subwatersheds were performed.

The approximately 710 subwatersheds delineated were grouped into 49 'Pipesheds' which represent areas tributary to outfall points to the Cannon River, Heath Creek, Rice Creek and Spring Creek. Several pipesheds also include reaches of land directly tributary to these features. Figure 3-2 provides a map of the pipesheds and receiving waters.

3.2.2 Hydrology and Pollutant Loading

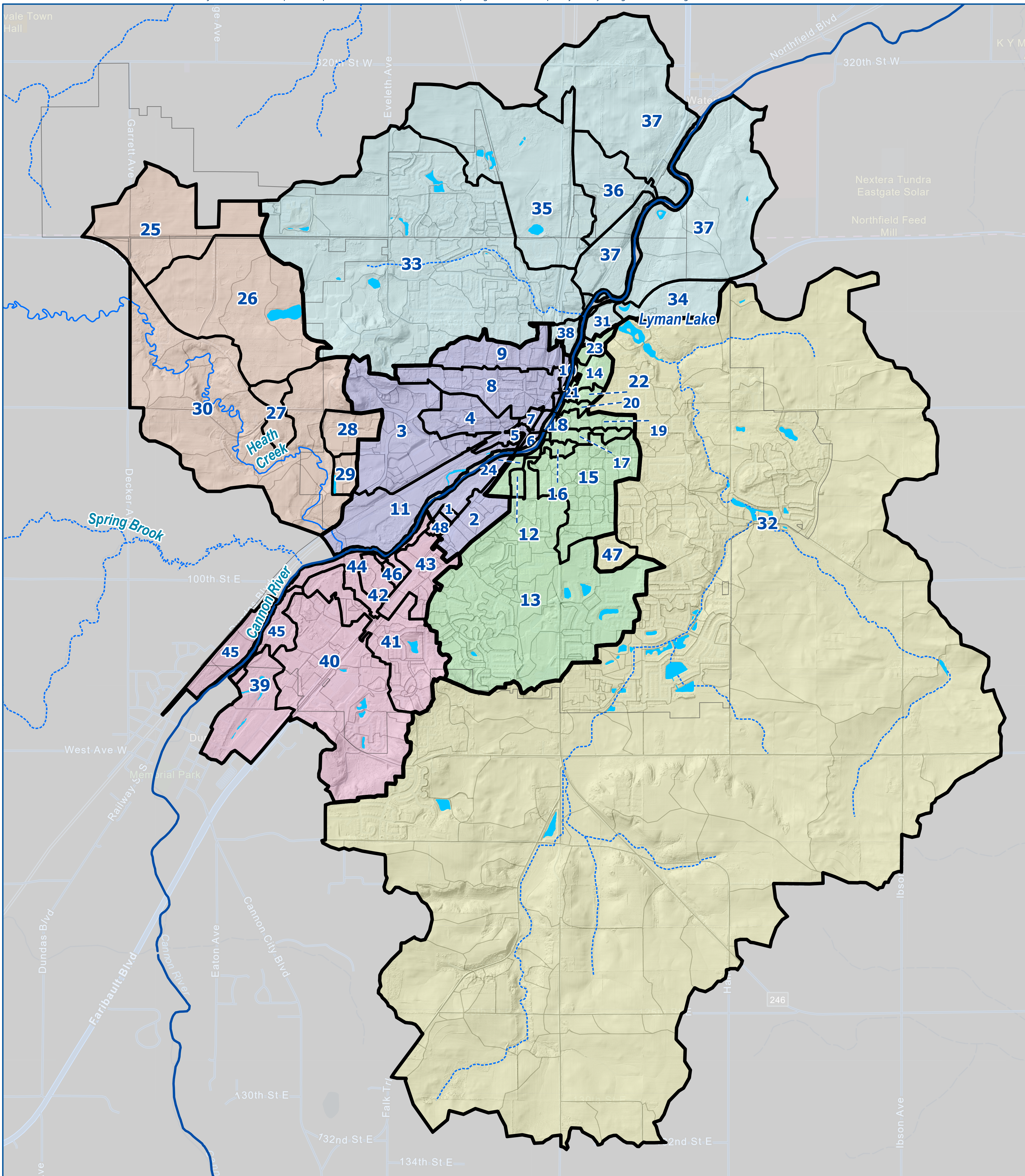
Runoff and pollutant areal loading GIS raster files were developed based on the directly connected impervious area within each subwatershed and empirical relationships relating directly connected impervious area to annual areal loading (e.g., pounds TSS/acre/ year, inch runoff/year, etc.). Empirical relationships were previously developed from P8 Model analysis of the 50-year period from January 1, 1955, through January 1, 2005 (with the July 23–24, 1987 "super storm" removed) (Barr, 2018)).

Pollutant loading for agricultural areas were estimated using values from the MPCA's Simple Estimator Tool (MPCA, 2022). The value of 0.38 lbs/acre/year was used for TP and 77 lbs/acre/year for TSS. These were applied to areas that were classified as cultivated crops and pasture/hay in the USGS NLCD land cover data from 2021. Some editing of the extent of the agricultural land covers was made based on 2023 aerial photos.

The directly connected imperviousness (DCI) was estimated using pavement cover extracted from remote sensing using April 2023 leaf-off photography obtained from Nearmap along with building footprint data obtained from Rice County. Visual verification and correction of larger building footprints were performed using the 2023 aerial photography. Planned buildings and buildings under construction were not included in the DCI and loading calculations. One meter (3.28 feet) pixel rasters were developed representing both total imperviousness and directly connected imperviousness in the study area.

The empirical relationships developed previously using DCI were applied to create annual runoff, TSS, and TP raw loading raster files that were used to estimate loadings in subwatersheds. The subwatersheds were summarized by the three rasters in GIS providing an estimate of annual runoff (acre feet), TSS (lbs) and TP (lbs) raw (pre-treatment) loadings for each subwatershed.

Figures 3-3, 3-4, and 3-5 provide the raw (pretreatment) annual loadings for runoff, total phosphorous (TP), and total suspended solids (TSS) assigned to subwatersheds, respectively.



Pipeshed ID	Pipeshed ID	Receiving Water	Pipeshed Lable	Pipeshed ID	Receiving Water	Pipeshed Lable	Pipeshed ID	Receiving Water	Pipeshed Lable	Pipeshed ID	Receiving Water
1	CCR-1	Cannon River	14	ECR-10	Cannon River	33	NCR-1	Cannon River	45	SCR Upstream Direct	Cannon River
2	CCR-2	Cannon River	15	ECR-2	Cannon River	34	NCR-2	Cannon River	46	SCR_6_5	Cannon River
3	CCR-3	Cannon River	16	ECR-3	Cannon River	35	NCR-3	Cannon River	48	CCR-10	Cannon River
4	CCR-4	Cannon River	17	ECR-4	Cannon River	36	NCR-4	Cannon River	49	SCR-8	Cannon River
5	CCR-5	Cannon River	18	ECR-5	Cannon River	37	NCR Downstream Direct	Cannon River	25	HC-1	Heath Creek
6	CCR-6	Cannon River	19	ECR-6	Cannon River	38	NCR Upstream Direct	Cannon River	26	HC-2	Heath Creek
7	CCR-7	Cannon River	20	ECR-7	Cannon River	39	SCR-2	Cannon River	27	HC-3	Heath Creek
8	CCR-8	Cannon River	21	ECR-8	Cannon River	40	SCR-4	Cannon River	28	HC-4	Heath Creek
9	CCR-9	Cannon River	22	ECR-9	Cannon River	41	SCR-5	Cannon River	29	HC-5	Heath Creek
10	CCR Downstream Direct	Cannon River	23	ECR Downstream Direct	Cannon River	42	SCR-6	Cannon River	30	HC-Direct	Heath Creek
11	CCR Upstream Direct	Cannon River	24	ECR Upstream Direct	Cannon River	43	SCR-7	Cannon River	32	Lyman Lake	Lyman Lake
12	ECR-0	Cannon River	31	Lower Spring Creek	Cannon River	44	SCR Downstream Direct	Cannon River	47	Wetland_LL	Sibley Marsh
13	ECR-1	Cannon River									

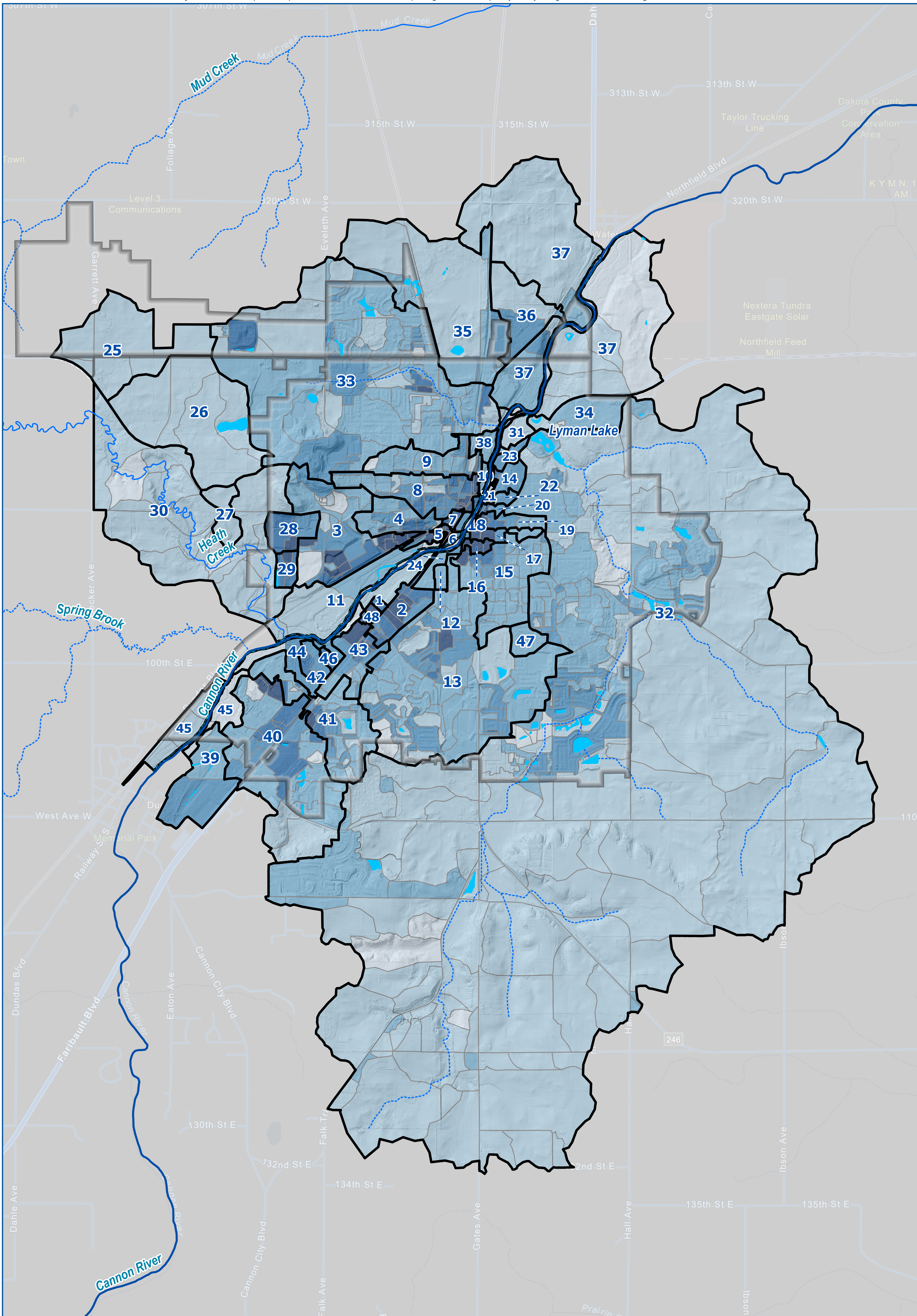
Northfield
WQM Pipesheds
City Watersheds
Central Cannon River
East Cannon River
Heath Creek
Rice Creek
South Cannon River
Spring Creek

0 1,500 3,000 4,500 6,000
Feet

BARR

Pipesheds and Receiving Waters Current Conditions City of Northfield

FIGURE 3-2



WQM Pipesheds

Northfield

WQM Subwatershed Annual Runoff (inches)

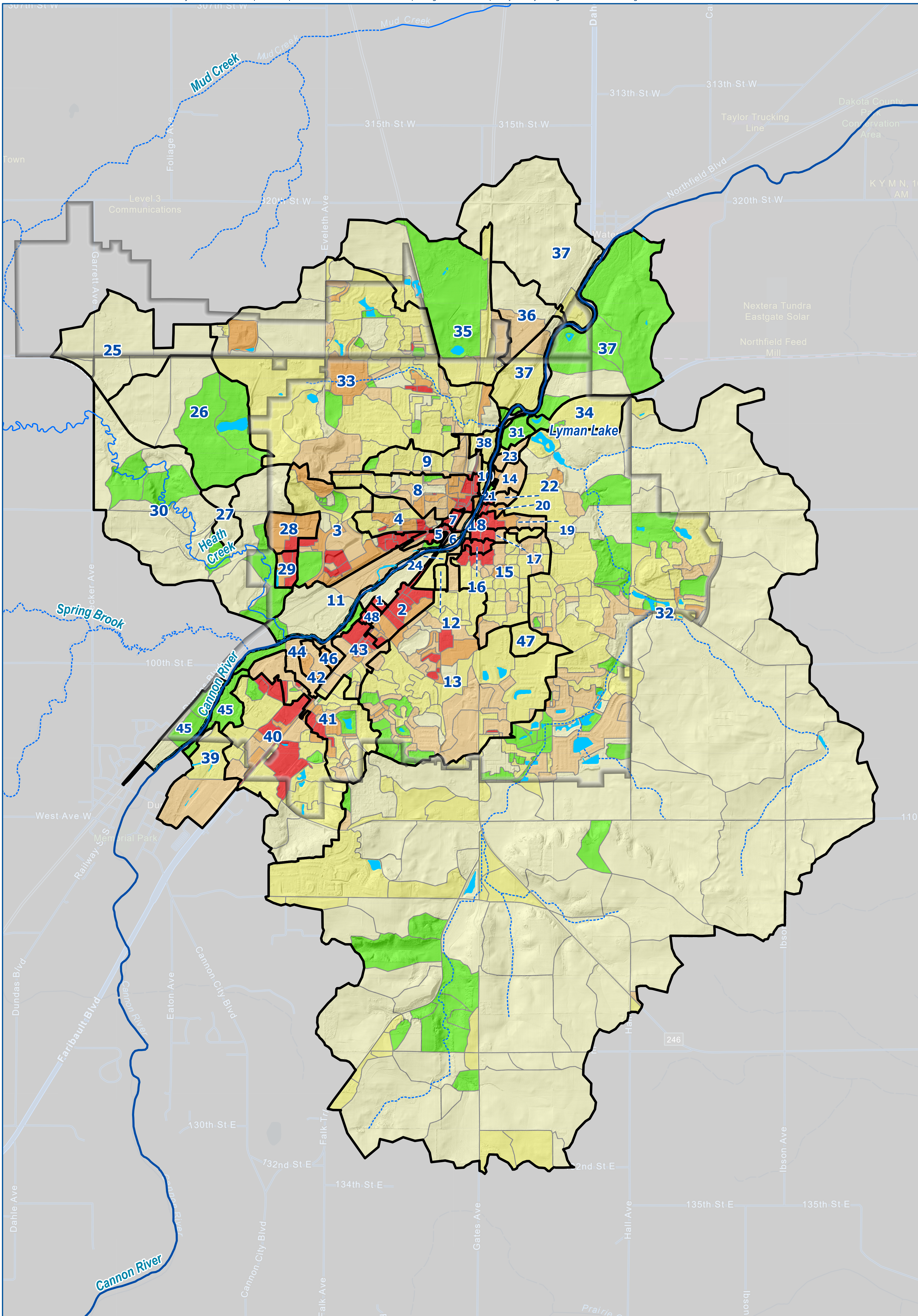
- 1.6 - 2.5
- 2.6 - 5.0
- 5.1 - 10.0
- 10.1 - 15.0
- 15.1 - 20.0
- 20.1 - 26.4

0 1,500 3,000 4,500 6,000

Feet

ANNUAL RUNOFF MAP
Northfield

FIGURE 3-3



WQM Subwatershed Raw TSS Load (lbs/acre)

- 14.6 - 63.1
- 63.2 - 100.0
- 100.1 - 200.0
- 200.1 - 300.0
- 300.1 - 400.0
- 400.1 - 641.2

WQM Pipesheds

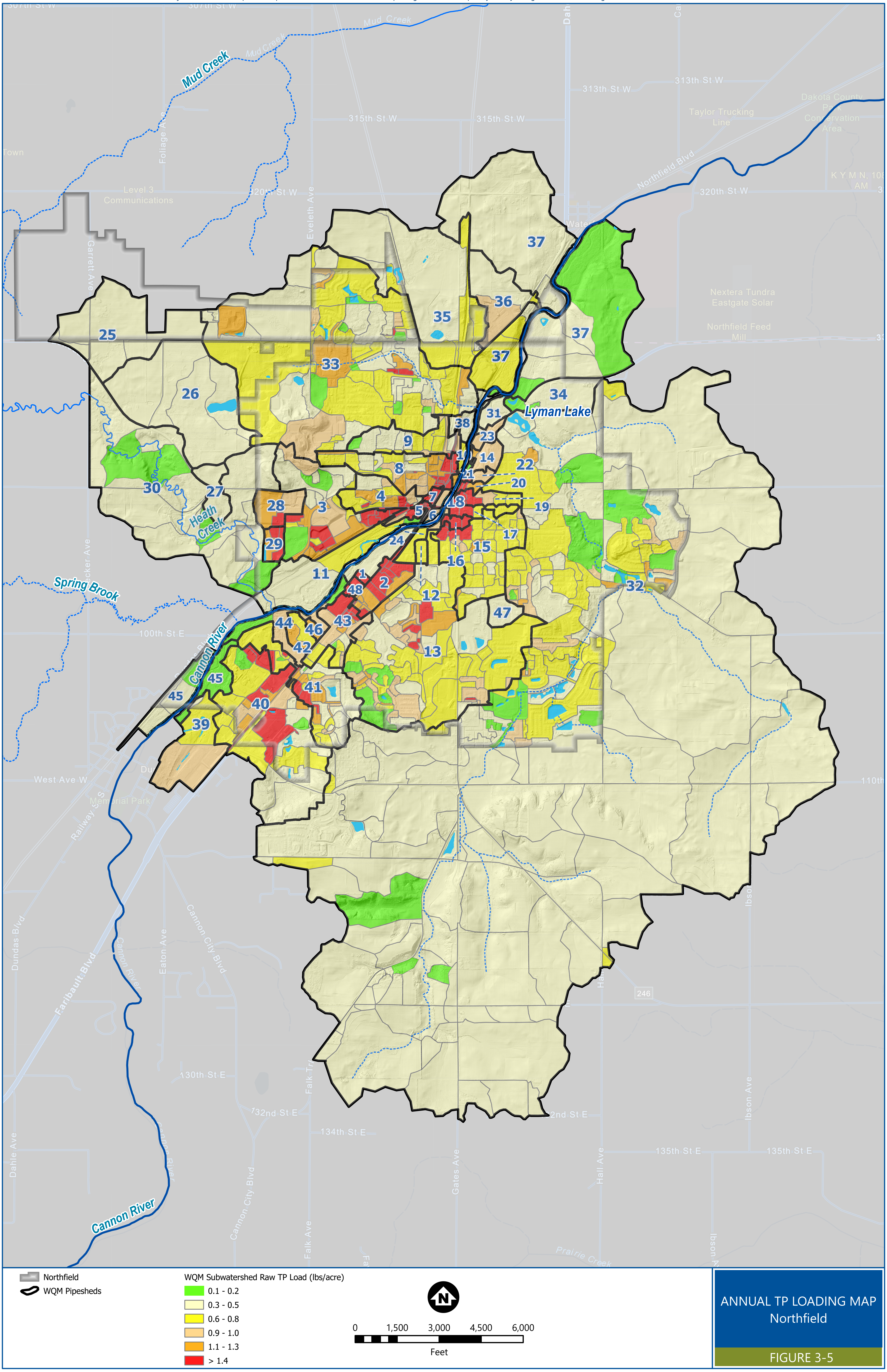
Northfield

0 1,500 3,000 4,500 6,000

Feet

ANNUAL TSS LOADING MAP
Northfield

FIGURE 3-4



ANNUAL TP LOADING MAP
Northfield

FIGURE 3-5

3.2.3 Street Sweeping TSS and TP Removal

Pollutant removal associated with street sweeping was modeled within the GIS WQM by removing pollutants directly from subwatershed raw loading (i.e., runoff and pollutant reduction are removed prior to routing runoff and pollutants through the downstream link/node network). Because street sweeping is not included in the MPCA MIDS Calculator model, Barr developed a unique methodology to estimate the performance of street sweeping during the development of the original GIS WQM for the City of Minneapolis (Barr, 2018).

GIS WQM street sweeping evaluation methodology is outlined in Barr (2020). Multiple street sweeping studies were reviewed to develop a methodology to predict TSS and TP annual reduction associated with street sweeping. Annualized street sweeping removal calculated within the GIS WQM is dependent on:

- Road type (e.g., residential vs. major arterial).
- Road surface area and curb length.
- Canopy cover (i.e., tree canopy cover overlapping road surfaces).
- Street sweeping operations per year (i.e., number of street sweeping operations per year).

Road surfaces and curb length were estimated using data provided by the City and MnDOT. Tree canopy over the road surface was estimated using remote sensing of recent leaf-on aerial photography (NAIP, 2021). For this study, one spring and one fall sweep each were assumed for all paved roads.

TP and TSS loads (in lbs) recovered from street sweeping are subtracted from the raw loadings to estimate the loadings entering the city's drainage system. The annual runoff and the adjusted pollutant loading from each subwatershed were routed to inflow "nodes" (e.g., inlets, catch basins, BMPs, etc.) within the GIS storm sewer utility network. The results are included in Section 3.3.

3.2.4 Node and Link Routing Network

The GIS WQM uses the City of Northfield's SSA hydrologic and hydraulic model node/link network as the stormwater utility network within the model. Nodes and links representing storm sewer and overland conveyance channels from the SSA models, along with stormsewer GIS data provided by the city, were used to create a connected network for the GIS WQM (see Figure 3-1). Some manual additions were added to the network when required to connect newly identified BMPs. Removal of some model linkages were also performed to remove multiple links exiting specific nodes.

Runoff and pollutants generated from subwatersheds are routed to the GIS WQM model network inflow nodes. The dimensions of the nodes/links (e.g., pipe diameter, material, etc.) do not impact the model result, as the GIS WQM node/link network functions only to (a) route runoff and pollutant downstream through the utility network and (b) accumulate runoff and pollutant loading throughout the utility network.

3.2.5 BMP Modeling

As opposed to "subwatershed" BMPs (i.e., street sweeping), which apply runoff and pollutant reduction directly to subwatershed loading before routing through the storm sewer network, "network" BMPs are modeled as nodes within the storm sewer network. Modeling BMPs within the storm sewer network allows the user to model the actual effective drainage area to each BMP (e.g., multiple subwatersheds routed to a single BMP, flow diversions limiting flow to a BMP, etc.) and capture network dynamics that can impact the water quality performance of an individual BMP (e.g., modeling multiple BMPs in series).

Pollutant reduction methodology for network BMPs is based on methodology developed for the MPCA MIDS Calculator (MPCA, 2017). During the development of the original Minneapolis GIS WQM model (Barr, 2018), several studies were completed to incorporate BMPs not included in the MIDS Calculator (e.g., street sweeping, grit chambers, etc.). The GIS WQM uses the following simplified parameters to describe the dimensions of modeled BMPs:

- **Permanent pool volume (PP_{vol}):** The permanent pool of volume stored below the normal outlet (i.e., "dead storage" or "bathymetric volume" of a wet pond).
- **Water quality volume (WQ_{vol}):** The abstracted volume provided by the BMP (e.g., the volume below the normal outlet or overflow elevation of a bioretention basin, the "live storage" of a wet pond, the void space volume of media in a green roof, etc.).
- **Dry pond surface area (A_{pond}):** The maximum surface area or footprint of a dry pond (i.e., the footprint area of the dry pond at the overflow elevation). This parameter is only required for dry ponds.

BMP water quality treatment volumes are compared to the respective volumes used for MIDS performance goals (i.e., 1.1 inches from impervious surfaces) to determine the portion of runoff and pollutant loading that is treated or bypassed, the portion of runoff that is infiltrated for "infiltration" BMPs, and the pollutant reduction effectiveness of "non-infiltration" BMPs (e.g., pollutant removed through filtration, sedimentation, etc.). Although the GIS WQM BMP modeling methodology is based on the methodology developed for the MPCA MIDS Calculator, several updates were made to allow the GIS WQM to model a wide variety of BMPs and networking configurations, including the modeling of undersized BMPs and BMPs in series (i.e., BMP "treatment trains"). The following list highlights key differences in BMP modeling methodology between the GIS WQM and the MIDS Calculator:

- **Bypass from undersized BMPs:** The MIDS calculator was designed to assist designers and engineers with the sizing of BMPs for development/redevelopment sites. Because the model is used primarily for design, it is limited in its ability to model undersized BMPs. For this reason, a methodology was incorporated into the GIS WQM to calculate bypass (i.e., influent runoff and pollutant loading which bypasses the BMP) from undersized BMPs. The water quality BMP only treats the portion of influent runoff and pollutants that do not bypass, and the bypass runoff and pollutant loading are passed to the downstream network.
- **BMPs in series (i.e., "treatment trains"):** The MIDS calculator does not adjust the treatment efficiency calculated for non-infiltration BMPs in series. For this reason, the methodology was incorporated into GIS WQM to track the "treated" and "untreated" portions of runoff and pollutant loading from upstream sources and calculate unique pollutant reduction efficiency values for each source of pollutant loading.
- **MIDS performance goal definition:** The MIDS performance goal states that BMPs should be designed to treat "1.1 inches of runoff from impervious surfaces" and does not distinguish between "total" impervious area and "directly connected" impervious area. As outlined above, the MIDS calculator was designed to assist designers and engineers with the sizing of BMPs for development/redevelopment sites. When designing a BMP for an individual site with new impervious area, the new impervious area is often "directly connected" to the designed BMP. In this situation, the total impervious area is equivalent to the directly connected impervious area. Because the GIS WQM requires the flexibility to model all BMPs within a municipality, including large, regional BMPs with portions of directly and indirectly connected impervious area in the contributing watershed, BMP sizing within the GIS WQM is evaluated based on the *directly*

connected impervious area tributary to the BMP, rather than the *total* impervious. Note that for individual development/redevelopment sites where all impervious area is directly connected to the designed BMP, the GIS WQM assumption is equivalent to the MIDS performance goal.

The GIS WQM allows for the modeling of 17 network BMP types. All known BMPs constructed in or before 2023 are included in the Northfield model representing current conditions. This includes 114 within Northfield and five in areas tributary to Northfield.

The inputs for each BMP in the GIS WQM (e.g., wet ponds, dry ponds, infiltration basins, etc.) were developed using the following data sources provided by the City of Northfield:

- SSA hydrologic & hydraulic models
- Bathymetric contours
- Topography data and aerial imagery
- Plan sheets
- GIS data layers
- Notes on approximate BMP dimensions

For BMPs modeled explicitly within the SSA models, the SSA models were used to determine the BMP outlet elevations, which in turn, were used to calculate the permanent pool volume (or “dead storage”) for wet ponds. The BMP overflow elevations defined in the SSA models were compared against topography data and revised, if necessary.

The bottom area for dry ponds, infiltration basins, and swales was determined by approximating a representative bottom area over which infiltration would likely occur. The bottom area was determined using the stage-storage curve within the SSA models or publicly available 2007 LiDAR data.

The BMP overflow elevations were used to calculate the water quality volume (or “live storage”) for wet ponds, dry ponds, infiltration basins, permeable pavement, and swales. The water quality volume for BMPs was calculated from stage-area curves within the SSA models, from stage-area curves developed using publicly available 2007 LiDAR data, or from BMP drawings or descriptions provided by the city.

Bathymetric data provided by the city were reviewed and used to calculate bathymetric volume for several wet ponds and wetlands within the city. If bathymetry data were not available, the stage-storage curves within the SSA models were used to calculate the permanent pool volume. For wet ponds and wetlands without bathymetry data that were not explicitly included in the SSA models, permanent pool volumes were approximated by assuming a permanent pool depth based on the National Wetland Inventory classification and a 4:1 side slope from the water elevation of the 2007 LiDAR data.

Additionally, BMP drawings and descriptions received by the city during model development were reviewed and incorporated. The estimated implementation date of BMPs were also determined. In most cases, the date was provided by the City of Northfield, however some dates were estimated be examining historical aerial photography. Two additional models were created with subsets of BMPs:

1) Identified BMPs existing during 2003 to reflect conditions when the Lake Byllesby was designated impaired due to Total Phosphorus.
2) Identified BMPs existing during 2012 to reflect conditions when the Cannon River was designated impaired due to Total Suspended Solids.

Table 3-1 shows the number and types of BMPs included in each model condition.

Table 3-1 BMP Summary for Modeled Conditions

	Current Conditions		2003 Conditions		2012 Conditions	
BMP Type	Number in Northfield	Number in Areas tributary to Northfield	Number in Northfield	Number in Areas tributary to Northfield	Number in Northfield	Number in Areas tributary to Northfield
Bioretention basin (w/o underdrain)	22		1		3	
Bioretention basin (with underdrain)	9					
Constructed wetland		1				1
Dry Pond	17		6		7	
Permeable pavement	2				2	
Swale main channel	3					
Underground Filtration	1					
Wet Pond	60	4	46		57	1
TOTAL	**114**	**5**	**53**	**0**	**69**	**2**

3.3 GIS WQM Results

An individual node and link network exists for 49 discrete pipesheds in the model. Each pipeshed ends at an outflow point to the Cannon River or Heath Creek. The model was developed for the three conditions described in the previous section. Note that current runoff, TP, and TSS loadings were used for all three conditions. The only difference in the modeled conditions is the number of BMPs included in the network.

A summary of basin characteristics, number of BMPs, and pollutant loading and removal for each pipeshed and scenario was developed. Overall pollutant removal results of the model showing TP and TSS percent removal for all the pipesheds in the current conditions model are shown in Figures 3-6 and 3-7 for TSS and TP, respectively.

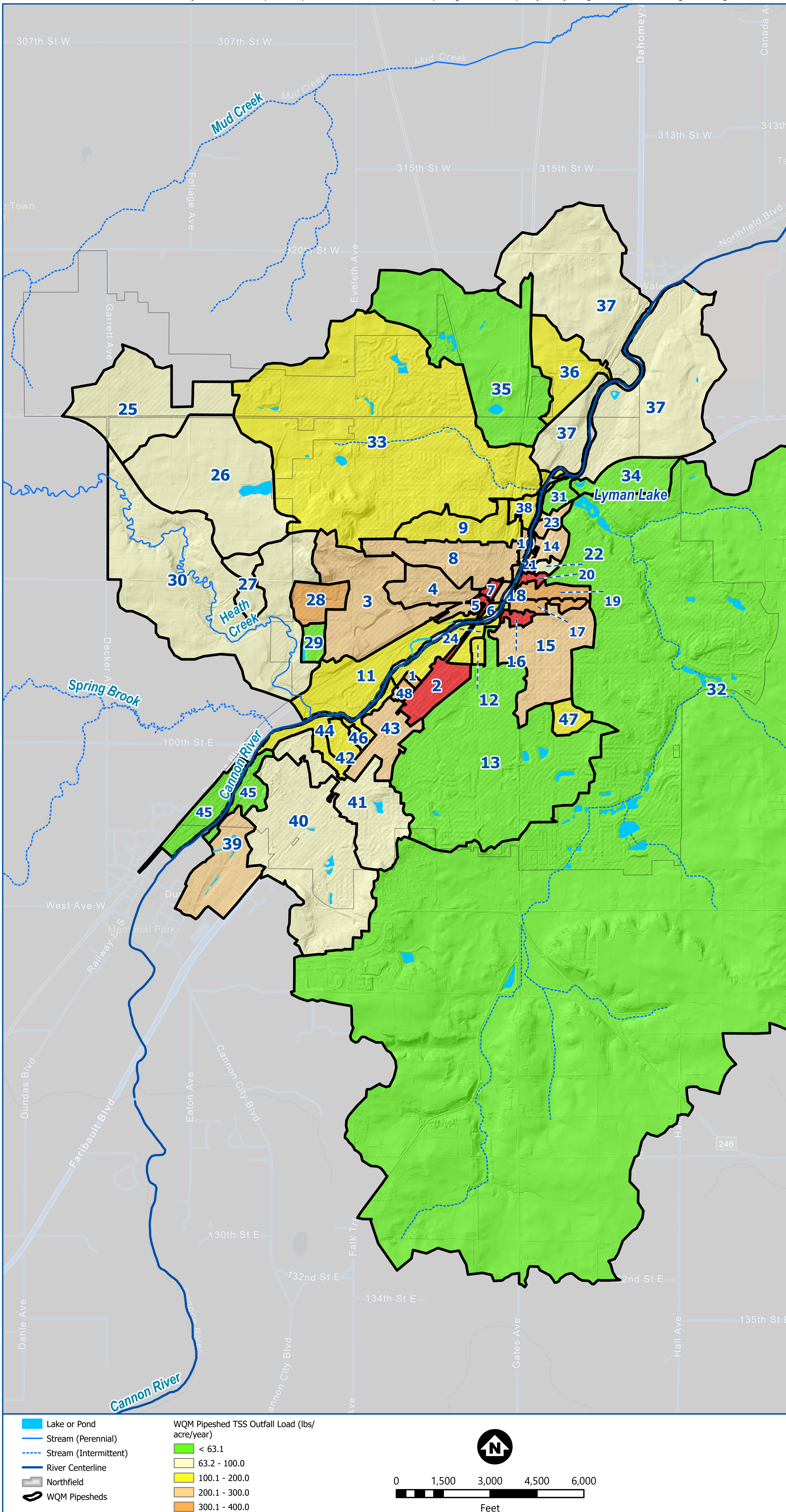
The current conditions Northfield GIS WQM model was evaluated to estimate water quality treatment provided by Northfield BMPs of stormwater flowing into the city from areas tributary to Northfield. These areas have primarily agricultural land covers.

The estimate was performed by adjusting the runoff, TSS, and TP loading raster files so no inflow entered the city drainage system from outside of the city. This provided an estimate of the effectiveness of the current BMPs and street sweeping to treat stormwater that originates in the Northfield. After accounting for removal from street sweeping and the five BMPs located outside of the city, tributary TP and TSS loading and removals were then re-evaluated. The results of the Northfield and tributary areas estimates were compared to the current conditions model to provide an estimate of the amount of treatment

Northfield BMPs provide for stormwater entering the city from tributary areas. The results are shown in Table 3-2.

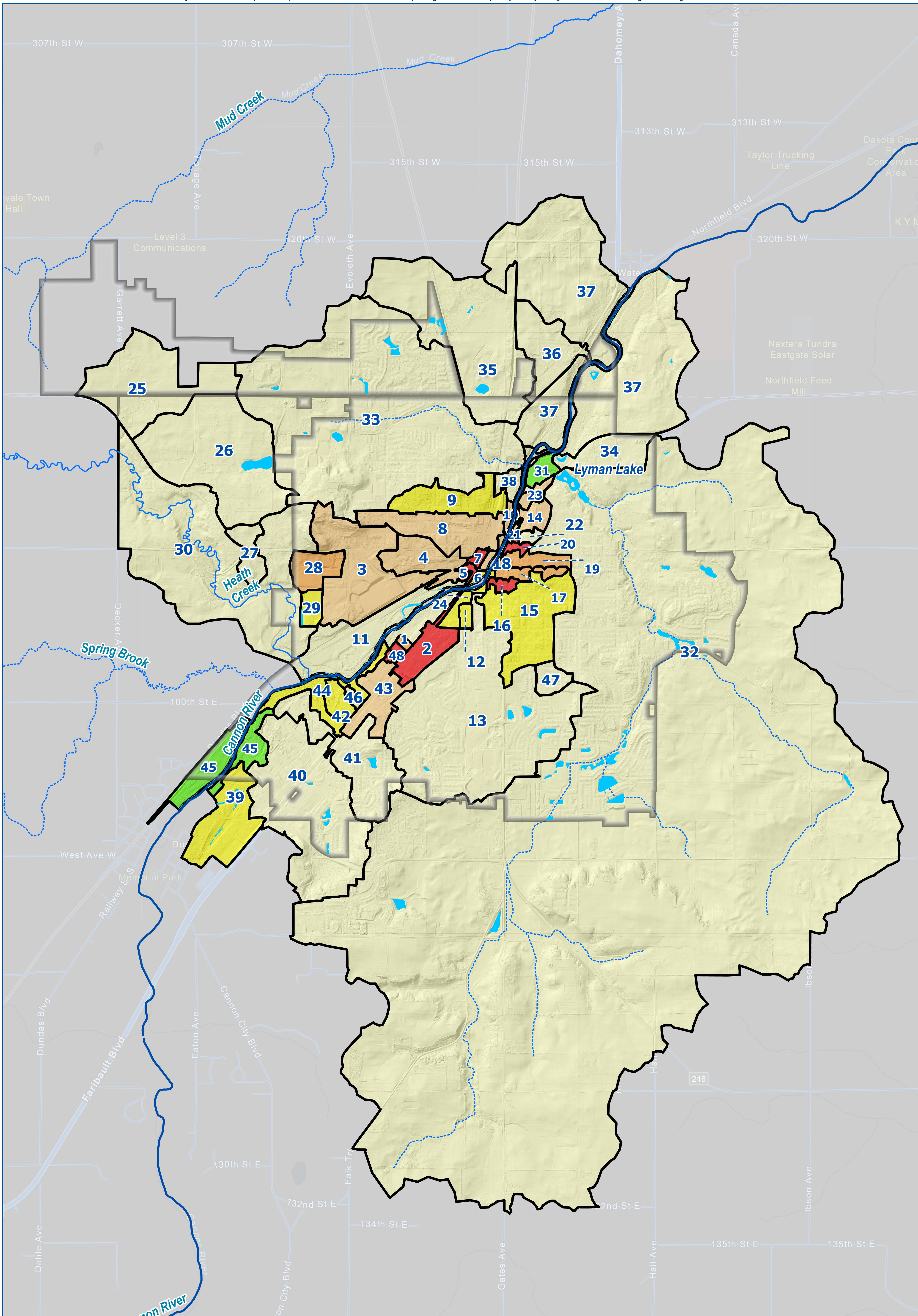
Table 3-2 Estimated Tributary Outfall Pollutant Loadings

Pollutant	Estimated Loading and Pollutant Removal in Northfield Assuming No Tributary Inflow			Estimated Loading and Pollutant Removal in Tributary Areas Only			Estimated Removal of Tributary Pollutants Provided by Northfield BMPs (lbs.)
	Total Raw Load (lbs.)	Pollutant Removed (lbs.) in BMPs/Street Sweeping	Load to River (lbs.)	Total Raw Load (lbs.)	Pollutant Removed (lbs.) in BMPs/Street Sweeping	Load to River (lbs.)	
Total Phosphorus	3,043	742	2,301	2,762	54	2,709	431
Total Suspended Solids	903,520	322,086	581,433	629,307	15,834	613,473	180,148



TSS Outfall Loading to Receiving Waters
City of Northfield

FIGURE 3-6



Northfield
WQM Pipesheds
TP Load Post Treatment (lbs/acre/yr)
<= 0.2
0.3 - 0.5
0.6 - 0.8
0.8 - 1.0
1.1 - 1.3
> 1.4

0 1,500 3,000 4,500 6,000
Feet

TP Outfall Loading to Receiving Waters
City of Northfield

FIGURE 3-7

4 Implementation Plan

4.1 Pollutant Loading Assessment

The results of the water quality modeling (including the accounting for street sweeping, sump cleanouts and stormwater treatment BMPs) were used to develop pollutant loadings for each tributary area that is subject to each TMDL WLA for each of the applicable baseline years of the respective TMDLs.

As discussed in Section 3.3, the GIS WQM results were used to inform the TSS and TP credits that can be applied to each of the respective TMDL WLAs, based on the BMP enhancements that were applicable to each of the respective baseline years. The conclusion that the TP WLA reduction requirement controls implementation planning can also be inferred by comparing Figures 3-6 and 3-7, which shows that a substantially larger area of the city is already discharging TSS at levels that comply with the Cannon River TSS WLA while most of the city is discharging TP at levels that are more than a third higher than the Lake Byllesby TP WLA. Figure 3-7 shows that several of the pipesheds that are closer to downtown Northfield, along both sides of the Cannon River, have higher TP loading rates than the areas that either had less imperviousness or were part of development that incorporated existing BMPs.

4.2 Phosphorus Reduction Goal Setting

The results of the pollutant loading assessment were used to quantify the gaps between the existing TP and TSS loadings and respective WLAs for each applicable TMDL for its associated baseline year. The results were tabulated and shared with the city to discuss the BMP priorities and areas that should be targeted to satisfy the regulatory requirements of each of the respective TMDL WLAs. The preliminary results were also used for communications with MPCA regarding compliance schedule (or implementation timeline) and reasonableness.

Because the pipesheds with the highest TP discharge rates to the Cannon River are in portions of Northfield that are already developed there is less space for BMP retrofits, so it will be significantly more difficult to comply with the TP WLA. Meetings and communications with MPCA resulted in the following insights for implementation planning, given the current development conditions and attainability of the TP WLA:

- The current MS4 Permit benchmark for TMDL compliance only requires that Northfield “show progress” towards meeting the WLAs
- Compliance dates for the TMDL WLAs are not specifically mandated
- Given the setting along the Cannon River, with rural areas draining through Northfield’s jurisdiction, the city is encouraged to look at making water quality improvements to all stormwater flow and/or address additional sources of phosphorus (e.g., streambank erosion, cropland runoff, internal phosphorus load) that are not typically addressed by implementation of urban BMPs.

It is expected that MPCA (based on the MS4 Permit) will require all permittees subject to TMDL WLAs to complete an annual reporting of compliance, beginning in 2025. As a result, reporting that “shows progress” will need to be based on a long-term goal that is both actionable and realistic (or attainable). Based on current understanding, the long-term goal will be for the City of Northfield to attain a 45 percent reduction from the existing discharge TP loading rate from the overall drainage area shown in Figure 3-7.

A TP load reduction rate of 4.5 percent every ten years for the next several decades would correspond to the long-term goal while allowing time to adapt to MPCA's future monitoring of Lake Byllesby, its watershed and associated guidance for MS4 permit compliance. This TP load reduction rate would correspond with approximately 20 pounds of additional TP loading that the city would need to successively reduce on an annualized basis. Because costs for treating each additional pound of TP with urban BMPs could approach $1,000 to $2,000 (Barr, 2017), the city may need to secure between $20,000 to $40,000 in additional funding for stormwater treatment, successively each year to attain/maintain increasing levels of stormwater treatment. The unit costs for implementation of nonpoint source BMPs (e.g., practices that reduce TP in cropland runoff) may be an order of magnitude lower than urban BMPs, which could drop costs to between $2,000 to $4,000 in additional funding for stormwater treatment, successively each year. Due to the expected differences in implementation costs, implementation planning should initially focus on addressing nonpoint source loadings and associated BMPs. This in turn, should extend the life of downstream BMPs in the developed areas of the city.

4.3 Implementation Plan

As a part of the detailed street sweeping analysis, the associated calculations and parameter sensitivity within the water quality modeling were reviewed for combinations of input parameters along various roadways within the city to inform street sweeping frequency recommendations that could be optimized for pollutant reduction credits. In addition, other strategies for pollutant load reductions were considered for evaluation/optimization based on current city operations, land ownership/management, and/or unique source areas (such as excess phosphorus in Lyman Lake), including experience with implementation and maintenance of specific BMPs associated with future redevelopment and/or street reclamation and overlay projects. Finally, implementation planning also needs to consider that the city does not want to use up park space to create new BMPs, completed most major street reconstruction and storm sewer replacement projects in its current Capital Improvement Program, and prefers that private landowners maintain rain gardens and other similar installations. The following subsections provide more detail on addressing specific pollutant sources and/or improved treatment options that warrant further consideration for the implementation plan, including a summary of planning level estimates for potential phosphorus load reductions that could be realized from each concept.

4.3.1 Street Sweeping

4.3.1.1 Increased Sweeping Frequency in Downtown Area

Based on the preliminary GIS WQM results, there was interest in assessing whether increased street sweeping in the downtown area would be beneficial for further TP load reductions. The GIS WQM was used to assess the benefit of adding ten extra sweepings per year, but the results indicated that it would only reduce the TP loading by 3.5 pounds per year in the 67-acre downtown zone. As shown in green in Figure 4-1, tree canopy coverage is limited in the downtown area, so there were diminishing returns on street sweeping frequency increases.

Figure 4-1 Tree Canopy Coverage in Downtown Zone

4.3.1.2 Recommended Pipesheds for Increased Street Sweeping

Street sweeping is only occurring twice per year outside of the downtown zone where, in many areas, there is more significant tree canopy coverage and/or areas that drain directly to surface waters without structural BMPs. As a result, it is recommended that the following pipesheds with more significant tree canopy coverage (shown in Figure 4-2) be prioritized for increased street sweeping frequency, with special emphasis in the fall and (to a lesser extent) the spring:

- Eastern portion of 17, 19, 20 and 43
- Western portion of 39
- Northern portion of 28
- All of 3, 4, 8, 9, 12, 14, 15, 23, 24 and 42.

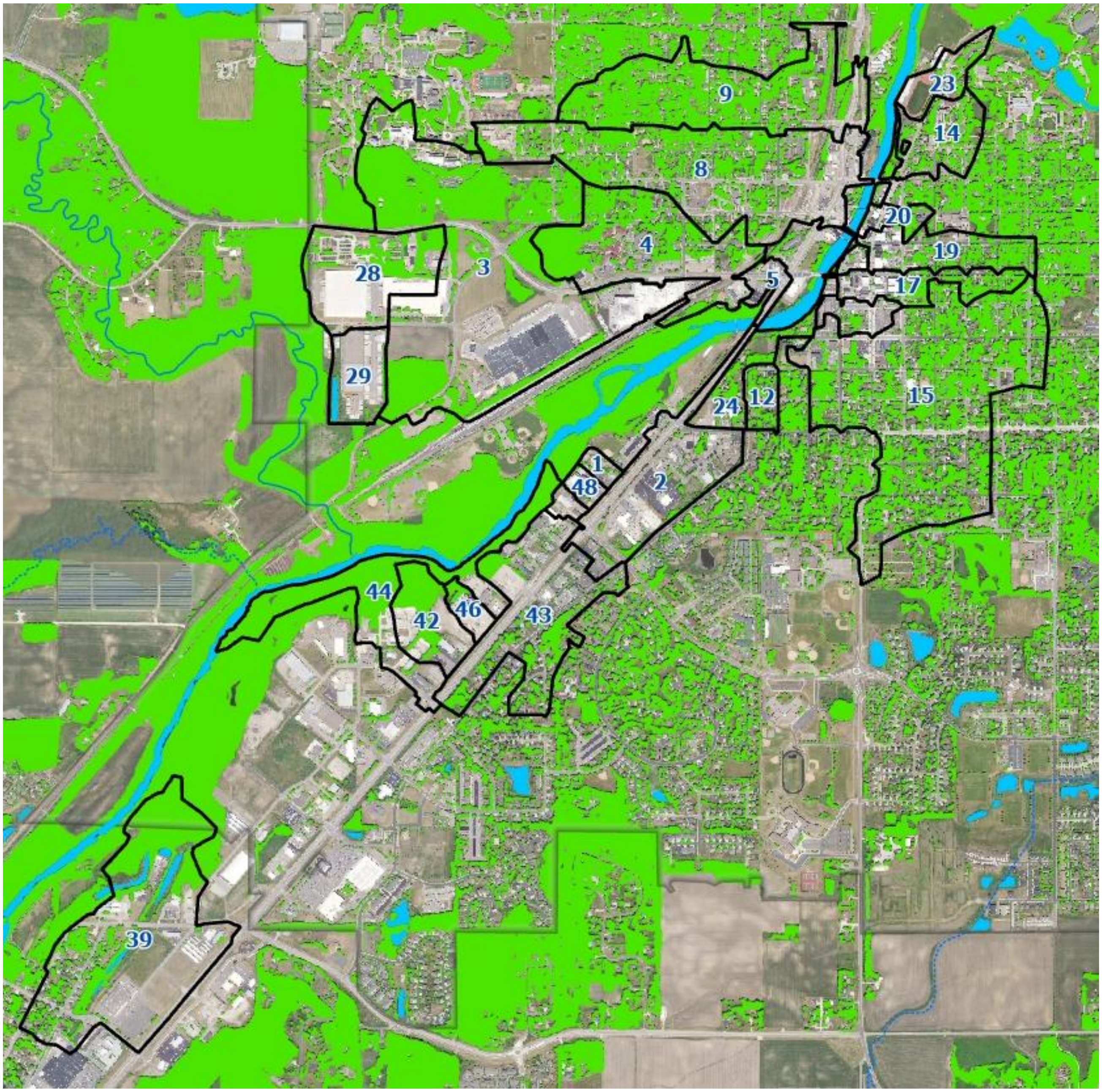


Figure 4-2 Priority Pipesheds for BMPs and Street Sweeping (with Tree Canopy Coverage)

4.3.2 Street Reclamation and Overlay Projects

As previously indicated, many of the pipesheds that drain directly to surface waters lack stormwater treatment from structural BMPs. As a result, it is recommended that pipesheds 1-5, 8, 9, 12, 14, 15, 17, 19, 20, 23, 24, 28, 29, 39, 42-44, 46 and 48 (which includes some of the same pipesheds that are prioritized for increased street sweeping, as described in Section 4.3.1.2 and shown in Figure 4-2) should also be prioritized for BMP implementation as a part of street reclamation and overlay projects. Infiltration BMPs should be prioritized for implementation within these pipesheds for areas with permeable soils, outside of drainage to karst features. Ash tree removal may also create opportunities to implement tree trenches in the same locations. At a minimum, the city should prioritize the implementation of filtration practices as a part of street reclamation/overlay and redevelopment projects in pipeshed areas that won't support tree trenches or infiltration practices.

4.3.3 Agricultural Sources

Currently, there is nearly 5,400 acres of land within the city boundary that is undeveloped and/or used for agriculture/farming. There could be a significant benefit, approximately 100 to 300 pounds of TP load reduction, in a situation where the city requires cover crops, nutrient management, or some other combination of recommended structural/nonstructural practices be utilized annually on leased land. Returning the same land to native prairie would achieve similar or greater benefits. At a minimum, the city should prioritize the review and assessment of its agricultural land holdings for potential TP and TSS load reductions. Likewise, the city should also complete the same assessment of agricultural land that drains to the stormwater outfalls contained in the GIS WQM to determine whether implementation of structural/nonstructural practices should be prioritized for TP (and TSS) load reductions. The city can take implementation credit for pollutant load reductions that would not have been realized without their intervention.

4.3.4 Streambank and Bed Erosion

The GIS WQM does not account for sources of streambank erosion. Recent high-water events provide an opportunity to inventory significant sources of streambank and streambed erosion in and around the City of Northfield. Significant TP and TSS load reductions can be realized from stabilizing active sources of erosion, including sheet/rill and gully erosion sources that may already be addressed as a part of the agricultural land assessment recommended in Section 3.3.3.

Another option for identifying and prioritizing sources of erosion in and around the city involves the comparison of the 2007 and 2021 LiDAR data to quantify the soil loss rate associated with individual sources of channel erosion. This methodology would also allow for the identification and prioritization of headcuts (i.e., bed erosion) that are developing in stream channels, as well as pourpoints from field runoff that are good candidates for grade stabilization practices.

As with the agricultural sources, the city can take implementation credit for pollutant load reductions that would not have been realized without their intervention.

4.3.5 Spring Creek

Spring Creek is a public water located just upstream of the Cannon River that flows through Lyman Lake and receives stormwater flow from a very large drainage area (see Figure 3-7), a portion of which is controlled by the city. The designated lake is made up of two separate basins with the southeast basin draining to the northwest basin before it discharges to the Cannon River. Limited water quality monitoring data is publicly available for either basin. The GIS WQM currently assumes that Lyman Lake is removing TP load at a rate that is consistent with a wet detention pond. It is possible that Lyman Lake is not removing TP at the modeled rate due to excess sedimentation and/or because internal phosphorus load (due to sediment phosphorus release under low oxygen conditions) is compromising the water quality assimilation capacity of the lake.

Depending on recent survey information, it is recommended that an updated bathymetric survey be completed for each basin of Lyman Lake to assess for excess sedimentation and/or short-circuiting of treatment areas. If an updated bathymetric survey indicates that excess sedimentation has occurred, then dredging may be warranted for a portion of the lake area. In addition, multiple sediment cores could also be collected and analyzed for potential impacts on sediment phosphorus release.

Alum is a water treatment chemical that is typically used to treat or immobilize phosphorus in water but can also be used at the sediment-water interface to control sediment phosphorus release. Two potential implementation options involve alum at either or both basins of Lyman Lake:

1) Alum can be used to treat stormwater flow as it is discharged from the lake to the Cannon River
2) Alum can be applied on an aerial basis to treat sediment phosphorus release or internal TP load from the lake.

Option 1 would involve the construction of an alum treatment plant to inject an alum dose designed to produce alum floc that removes 80 to 90 percent of the TP from a design flow following sedimentation in a separate floc pond. While this option involves significant capital and operation/maintenance costs, it would also provide significant improvements in the TP load reductions from what was assumed in the GIS WQM. If Option 1 is implemented it could reduce the reliance on BMP implementation or retrofits for upstream areas of the watershed.

Depending on the lake sediment accumulation rate, Option 2 could be viewed as a treatment that would occur occasionally or as a part of a multi-phase treatment effort to restore the TP assimilation capacity of the lake. As a result, Option 2 can be viewed as an alternative to restore TP load reductions to what was assumed in the GIS WQM over the long term, but Option 2 would likely involve significantly less capital and operation/maintenance costs than Option 1.

MPCA would need to permit either one of the alum treatment options before implementation. It is recommended that both alum treatment options be considered for feasibility and implementation for future TP load reductions.

4.3.6 Summary of Implementation Plan Benefits and Recommendations

As discussed in Section 4.2, the overall water quality treatment goal is defined by 2,000 pounds of additional TP load reduction. Using the background and methods described in Sections 4.3.1 through 4.3.5, the potential annual total phosphorus load reduction was quantified and/or recommendations for implementation are summarized as follows:

1) Street sweeping—potential for 300-pound TP reduction by increasing street sweeping frequency in priority pipesheds, with emphasis in the spring and fall
2) Street reclamation and overlay projects—potential for 100-pound TP reduction by implementing structural BMPs in priority pipesheds
3) Agricultural sources—potential for at least 700-pound TP reduction from structural BMPs implemented with future development
4) Streambank and bed erosion—sources of erosion are unknown currently; it is recommended that the city inventory (and/or use new LiDAR data), and subsequently stabilize erosion
5) Chemical treatment of Spring Creek flow—potential for at least 500-pound TP reduction from this tributary; it is recommended that the city survey/verify existing TP load reductions that could be realized from alum treatment (plant or aerial lake application).

5 References

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