BOLTON & MENK, INC.

Consulting Engineers & Surveyors

City of Northfield, MN

Spring Creek Watershed Analysis

Submitted by:

BOLTON & MENK, INC.

2035 County Road D East

Maplewood, MN 55109

October 2015

CITY OF NORTHFIELD, MINNESOTA
SPRING CREEK WATERSHED ANALYSIS

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

By: ______________________________
Timothy J. Olson, P.E., CFM
License No. 49129

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Brent H. Johnson, P.E., CFM
License No. 20378

Date: October 27, 2015

EXECUTIVE SUMMARY

Stormwater modeling of Spring Creek was completed from the southern City boundary to the Cannon River. Modeling included Existing Conditions, Proposed Bridgewater Township Conditions and Future conditions with build out of the City into the Urban Expansion Area and stormwater management per Ordinance 22-302.

Several hydraulic and hydrologic data sources from past studies were assembled with the goal of providing a comprehensive hydraulic model of the Spring Creek watershed through Northfield. A recent Bridgewater Township study identified potential stormwater practices that will reduce peak flow rates and volumes south of the City. While flow is decreased, the reductions in flood elevation along Spring Creek average 0.3 feet.

Future development scenarios were analyzed to determine the pond volumes and foot prints required to meet City ordinances within the Urban Expansion area. Additional scenarios were performed to determine whether additional flow restrictions would translate into elevation reduction benefits along the main channel of Spring Creek. It was concluded that peak flows in the main channel of Spring Creek control the flood profile. Tributary flows contribute little to main stem peak flood flows and the peaks typically do not occur simultaneously. Therefore, peak flow reductions offer the most elevation impact when performed along the main stem.

Flood storage areas were analyzed to determine if a large storage area along the main channel within the City expansion area would result in additional benefits to reduce flooding through town. One concept includes diversion of main channel flows into floodplain storage areas and restricting channel discharge with a culvert structure. The simulation of this floodplain storage concept, also includes the upstream features of the Bridgewater Township proposed improvement conditions, and results in reducing the peak discharge on the main channel from approximately 1100 cfs to 800 cfs and reducing flood elevations downstream along Spring Creek an average of 0.8 feet.

Although potential watershed improvements have been identified, the expected reductions in water surface elevations along Spring Creek are moderate and some residences remain at risk. Additional survey data should be collected in the City of Northfield to detail the low opening elevations of flood prone homes along Spring Creek. This data should be used to compute freeboard and to refine the identification of homes at risk of flood damage in the 1% annual chance event (i.e. 100-year flood). The data should also be used to further evaluate potential flood damage reduction solutions such as storage or volume control BMPs upstream in the Spring Creek watershed, the modification of select bridges, culverts or dams on Spring Creek to reduce flood levels, or the need for specific levees, floodwalls or residential floodproofings. Floodproofing can be very effective for individual homes, but upstream storage and volume control projects can have widespread benefits in reducing flood risks to multiple homes and neighborhoods.

The following recommendations should be considered by the City:

1. While the previously proposed flow diversions, regional ponding, and infiltration areas upstream of Northfield will result in benefits to flood elevations through town (averaging 0.3 feet), it is not recommended that the City pursue any flow diversion within City limits. The concept previously proposed for an outlet pipe from a raingarden along Dennison Boulevard (Highway 246) will provide little to no flow and elevation reduction benefit to the City.
2. Establishing a jurisdictional flow rate at the southern City limits will encourage Bridgewater and Northfield Townships to reduce rate and volume of runoff under future development scenarios. It is recommended that the flood insurance study discharge rate of 800 cfs be chosen as the jurisdictional flow rate since this provides a conservative approach toward maintaining the established FEMA NFIP flood hazard zones within the City.
3. Additional survey data should be collected in the City of Northfield to detail the low opening elevations of flood prone homes along Spring Creek. This data should be used to refine the identification of homes at risk of flood damage in the 1% annual chance event and to further evaluate potential flood damage reduction solutions such as storage or volume control BMPs upstream in the Spring Creek watershed, the modification of select bridges, culverts or dams on Spring Creek, or the need for specific levees, floodwalls or residential floodproofings.

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PROJECT BACKGROUND

Spring Creek is a tributary of the Cannon River. The Creek flows northerly from its headwaters near Dundas through the eastern section of Northfield and outlets to the Cannon River just downstream from Lyman Lakes. Spring Creek is a small meandering stream with a bankfull width ranging from about 5 feet in the upper reaches to about 20 feet near the mouth. The contributing watershed area of Spring Creek is 10.4 square miles. The landscape topography in the Spring Creek watershed is typically rolling hills of a glacial moraine origin. Land uses in the upper stream reaches are generally farmland interspersed with wooded areas, whereas the lower stream reaches are single-family residential, open space recreational, and parkland developments within the City of Northfield. Vegetation within the Spring Creek stream corridor varies from agricultural fields, forests and lawns. Within Northfield the creek is also bordered in some reaches by wetlands and stormwater ponds. Open space recreational lands also border the creek within Northfield including parks, soccer fields, and a golf course. **Exhibits 1, 2 and 3** are photos of Spring Creek depicting open and naturally meandering sections with other highly channelized sections in areas with higher rates of development. **Figure 1** is a watershed map showing the contributing watershed and the main creek channel and tributary alignments. **Figure 2** is a location map showing the Urban Expansion Area and a tabulation of anticipated flood storage volumes for rate control and volume control. **Figure 3** is a shaded relief map showing the basin topography.

The channel profile is steep in the headwaters with over 60 feet of fall per mile and has a milder slope of about 10 feet per mile within Northfield between Ford Street East and Jefferson Parkway. Streamflow in Spring Creek is flashy--varying from little or no base flow to very high flood flows due to the watershed characteristics and land uses.

Exhibit 1: Spring Creek within Golf Course near Spring Creek Road.

Exhibit 2: Spring Creek looking downstream from Jefferson Parkway.

Exhibit 3: Spring Creek within Soccer Complex downstream from Southbridge Drive.

Stormwater modeling of Spring Creek was completed from the southern City boundary to the Cannon River. Models were updated, calibrated and run to simulate existing conditions, proposed Bridgewater Township conditions and future conditions with City buildout to the Urban Expansion Area limits including future stormwater management per Ordinance 22-302. Simulated events include the 100-year 24-hour rainfall events using both TP-40 and Atlas 14 rainfall depths as well as the 100-year 10-day snowmelt event.

Furthermore, options for establishing a "Jurisdictional Flow Rate" were identified at the southern City boundary along Spring Creek to establish a regulatory flow under future development conditions. This will allow the City to develop regional stormwater management planning with a consistent inflow at the upstream boundary. This report discusses flow data sources, recommendation for selection of a flow rate, and the potential implications for doing so.

Based on the results of the comprehensive hydraulic model, several recommendations are summarized which include the following.

- Analysis of and recommendations for flood control options proposed in a previous study upstream of and in City limits.
- Proposed required rate control, pond volumes, and water quality considerations for future development in the anticipated growth boundary.
- Quantifying improvements in terms of flood elevations along the Spring Creek corridor.
- Options for establishing a Jurisdictional Flow Rate.
- Additional improvements for lowering the flood profile along Spring Creek.

STORMWATER ANALYSIS AND MODELING

The Spring Creek watershed has been modeled within several previous studies. In 2004, the City of Northfield, in cooperation with developers, completed hydrologic and hydraulic modeling within the Spring Creek watershed as part of an application to FEMA for a Letter of Map Revision (LOMR). An approved LOMR is FEMA's modification to the maps of the National Flood Insurance Program. The 2004 hydrologic analyses included an XP-SWMM model of the Spring Creek watershed. The hydraulic analysis included a HEC-RAS model of the detailed study reach within Northfield.[1]

The Rice County Flood Insurance Study (FIS) was updated and effective April 2, 2012. The floodplain of Spring Creek was studied and mapped as part of the FEMA National Flood Insurance Program (NFIP). Part of the Creek includes a detailed study with water surface profiles computed for the 10%, 2%, 1% and .2% annual chance floods as well as mapping of the 1% and .2% annual chance floodplains. This detailed study reach extends from Spring Creek Road upstream to near Ford Street. Limited detail study reaches extend both upstream and downstream from the detailed reach. **Figure 5** is a map showing the FEMA 1% Annual Chance Floodplain of the Effective Flood Insurance Study.[2]

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[1] Hydrologic Modeling Report, Polaris Group, January 2004 and Map Revision Application, Spring Creek Watershed, Northfield, MN December 2004.

[2] Flood Insurance Study, Rice County, Minnesota and Incorporated Areas, Effective April 3, 2012

Bridgewater Township completed a hydrologic study in 2015.[3] In this study, an EPA SWMM model of the Spring Creek watershed was completed upstream from Northfield. This model was used to develop proposed stormwater storage and infiltration BMPs within the watershed targeted at reducing the runoff volume, the rate of runoff, as well as pollutant loads from Bridgewater and Northfield Townships to the City of Northfield.

MODEL ASSEMBLY

As part of this study, components of the previous models were compiled in order to develop a comprehensive hydraulic model of the Spring Creek watershed to the Cannon River. An Autodesk Storm and Sanitary Analysis (SSA) model was constructed for the watershed using data from the previous XP-SWMM, EPA SWMM and HEC-RAS models. Storage areas in the model within Northfield were updated based upon a GIS analysis of storage area versus elevation. The GIS elevation data used is based upon LiDAR data. LiDAR data was also used to "cut" Spring Creek channel cross sections for use as links within the SSA model. The SSA model bridge and culvert geometry was also updated with data from the City of Northfield storm sewer GIS geo-database. The Lyman Lakes dams were added to the SSA model. **Exhibit 4** is a photo of the Lower Lyman Lake dam near Highway 19.

Exhibit 4: Lower Lyman Lake Dam.

[3] Flood Management Plan for Projects Within the Spring Creek Watershed, WSB & Associates, Inc. February, 2015

HYDROLOGIC PARAMETERS

Soils within the Spring Creek watershed are generally well drained with typical "B" hydrologic soils groups. **Figure 6** is a map showing the hydrologic soils groups within the Spring Creek Watershed. **Figure 4** is a watershed summary map showing the sub basins in the SSA model as well as the corresponding drainage areas, curve numbers and times of concentration.

The SSA hydrologic model was used to simulate several storm runoff events including the:

- 100-year 24-hour rainfall events with rainfall depths of 6.0 inches and 7.32 inches per the National Weather Service TP-40[4] and NOAA Atlas 14,[5] respectively; and the
- 100-year 10-day snowmelt of 7.05 inches per the Minnesota Hydrology Guide.

HYDRAULIC CHARACTERISTICS AND MODELING

The SSA Hydrologic and Hydraulic model was used to simulate and provide a relative comparison of the various scenarios including the Existing conditions, the Proposed Bridgewater Township conditions and the Future development conditions into the City's Urban Expansion Area. Future conditions include the expected land uses of the planned build out as well as City stormwater management requirements complying with Ordinance 22-302. Each of the Future Conditions analyses include the Proposed Bridgewater Township improvement conditions.

EXISTING CONDITIONS AND CALIBRATION

The Spring Creek Existing Conditions model was calibrated to peak flows using the USGS regional regression equations within the StreamStats website. Calibrating the peak flow to the FEMA Flood Insurance Study flow values within the Spring Creek detailed study reach was considered, but the current regression peak flow values were used since these values are up to date and provide peak flow data along the entire length of Spring Creek including those reaches where the flood insurance study was limited detail without published peak flows. Measurements of stage and discharge in Spring Creek were not available, so we were unable to calibrate to stage in the model. Model time of concentration parameters were adjusted to calibrate model peak flow. The final calibration increased the model times of concentration by 10%. Our general calibration target was for modeled peak flow to be within +/- 10% of USGS regression peak flow. Model and regression peak flows were compared at seventeen points. After calibration, eight of the 17 comparisons had modeled peak flows that fell within this 10% range, with 1 point where modeled flow exceeded regression flow + 10% and 8 points where modeled flow was less than regression flow – 10%. **Exhibit 5** is a chart showing the comparison of regression peak flows to calibrated model peak flows. The model compares very well with the regression peak flows for drainage areas of 5 square miles and less (and peak flows less than 1300 cfs). At comparison sites of 5 and 10 square miles, the model generally predicts about 20% less flow than the regression—due to the storage in the landscape that attenuates peak flows. It appears that further global changes to times of concentration

[4] TECHNICAL PAPER NO. 40, RAINFALL FREQUENCY ATLAS OF THE UNITED STATES
for Durations from 30 Minutes to 24 Hours and Return Periods from I to 100 Years, Weather Bureau, US Dept. of Commerce, Washington D.C. 1961

[5] NOAA Atlas 14, Vol. 8 Version 2.0, Midwestern States (Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, Wisconsin) Precipitation-Frequency Atlas of the United States, Silver Spring, MD 20910, 2014

will not improve the overall calibration. **Table 1** lists the model and regression peak flows after the calibration.

Table 1: Comparison of 100-year Peak Flows by USGS Regression and SSA Stormwater Model.

Site Number	Site Letter	Description	Drainage Area (sq. mi.)	Regression Flow (cfs)	Model Flow (cfs)
1		110th Street	4.07	1271	1209
2		City Boundary Upstream from Ford Street East	4.38	1270	1241
3		Southbridge Street	4.54	1250	1163
4		Maple Street S.	5.02	1320	1106
5		Jefferson Parkway East	6.07	1481	1126
5	B	Hall Avenue	0.52	353	421
5	C	110th Street	0.28	259	254
6		Spring Creek Road Bridge	6.32	1456	1135
7		Woodley Street E., West Culvert	6.35	1444	1141
8		Woodley Pond	8.55	1834	1340
8	A	Woodley Street East, East Culvert	2.01	637	646
8	C	East Branch Spring Creek at Ibson Ave.	0.5	297	302
8	D	East Branch Spring Creek at 110th Street E.	0.4	271	273
9		Wall Street Road	9.14	1838	1481
10		Spring Creek near Cannon River	10.4	1940	1525
10		Spring Creek below tributary	10.2	1959	1707
10	B	Tributary	0.81	333	307

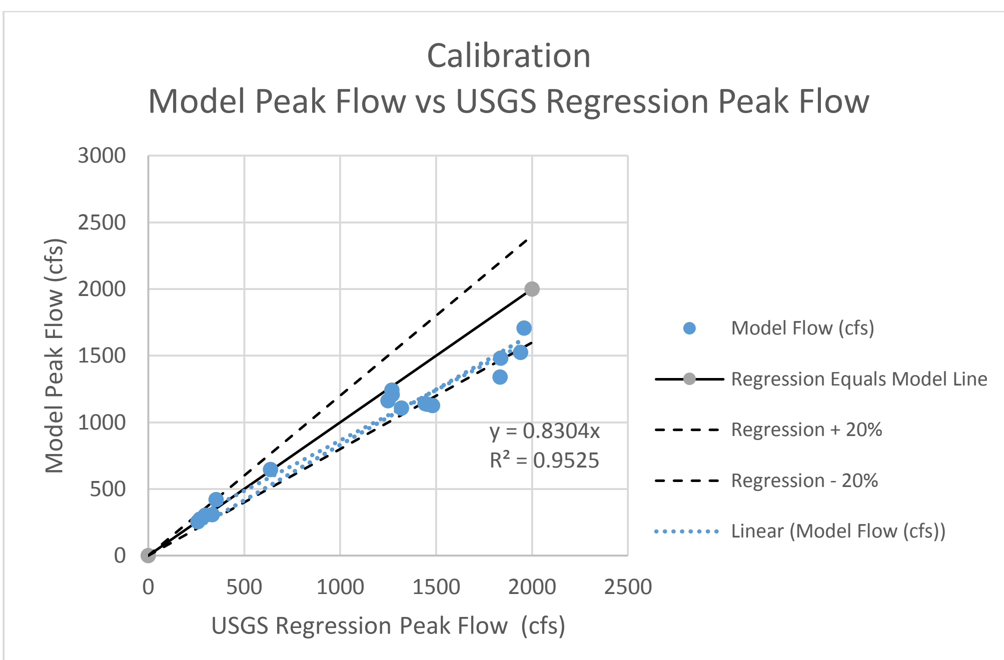

Exhibit 5: Model Calibration Plot of Regression Flow vs Adjusted Model Flow

PROPOSED CONDITIONS – BRIDGEWATER TOWNSHIP

A hydrologic study for Bridgewater Township was completed in 2015.[6] In this study, an EPA SWMM model of the Spring Creek watershed upstream from Northfield was assembled. This model was used to develop stormwater storage and infiltration BMPs within the watershed targeted at reducing the volume and rate of runoff as well as reducing pollutant loads. Programmatic improvement policies were identified including measures for rate and volume restrictions. Proposed BMP features include:

- Central Pond near intersection of Falk and Gates to provide stormwater runoff rate control and water quality treatment;
- Diversion and 24-inch Pipeline from Bridgewater Heights Pond Improvement to Central Pond
- Rock Farm Waterway Ditch Improvement including Check Dams for enhanced volume control.
- Additional localized water quality BMPs and rain garden and outlet pipe in the City of Northfield.

The storm water storage features of Bridgewater Township's proposed BMPs were imported into the SSA model. The Bridgewater Township model also includes a significant exfiltration volume control component. Exfiltration has also been included within the SSA model.

FUTURE CONDITIONS – CITY OF NORTHFIELD BUILD-OUT

The City of Northfield's Stormwater Management Ordinance 22-302 requires that runoff from all new developments be controlled so that post development rates not exceed the runoff rate for pre-settlement conditions. The SSA model was used to estimate the live storage volume required within the City of Northfield expansion area as full development within the expansion area is achieved. Future storage ponds were inserted into the storm water model to determine the flood storage volumes required to provide the necessary rate control. Each of the Future Conditions analyses include the Proposed Bridgewater Township conditions. **Table 2** provides the computed flood storage volumes within the expansion area. Refer to **Figure 2** for proposed pond locations in the expansion area. The computed volume may be considered an "ideal" storage volume for planning purposes and actual volumes may be higher due to some reduced storage efficiency of individual ponds.

The City may wish to further restrict future peak flow rates below the current ordinance requirement. One option would be to require that future 100-year discharge rates be reduced to the pre-settlement 50-year runoff rate. While this would require additional storage in the watershed, the City may contribute to overall flood mitigation by supplementing the additional storage not required by the developer. **Table 3** summarizes the anticipated pond volume requirements if the 50-year pre-settlement rates are met.

Infiltration of runoff, for volume control, is the City's preferred approach for water quality treatment requirements. Infiltration can also be used in part to meet rate control requirements. **Table 2** also provides an estimate of the water quality volume control requirement within the City of Northfield Expansion Area. We have estimated the infiltration volume control quantity needed for water quality requirements. Exfiltration was simulated in the storage ponds of the City expansion area in order to analyze the flow and stage effects within Spring Creek.

[6] Flood Management Plan for Projects Within the Spring Creek Watershed, WSB & Associates, Inc. February, 2015

Table 2: Approximate Regional Pond Volume Requirements for Reduction of Future Flows to the 100-Year Pre-Settlement Rate.

Node ID	Watershed Area	Future Expansion Area	Anticipated Storage Volume	Pond Footprint Area	% of Future Expansion	Estimated Impervious Area (38% impervious, Single Family Residential)	Volume Control of 1-inch
	[ac]	[ac]	[ac-ft]	[ac]		[ac]	[ac-ft]
A	159.6	111.5	8.7	2.2	2.0%	42.4	3.5
B	632.9	363.1	36.7	9.2	2.5%	138.0	11.5
C	685.0	476.8	63.8	16.0	3.3%	181.2	15.1
D	320.7	289.3	30.1	7.5	2.6%	109.9	9.2
E	129.9	228.4	24.7	6.2	2.7%	86.8	7.2
TOTALS:	**1928.1**	**1469.0**	**164.0**	**41.0**	**2.8%**	**558.2**	**46.5**

Table 3 Approximate Regional Pond Volume Requirements for Reduction of Future Flows to the 50-Year Pre-Settlement Rate.

Node ID	Watershed Area	Future Expansion Area	Anticipated Storage Volume	Pond Footprint Area	% of Future Expansion	Estimated Impervious Area (38% impervious, Single Family Residential)
	[ac]	[ac]	[ac-ft]	[ac]		[ac]
A	159.6	111.5	15.4	3.8	3.5%	42.4
B	632.9	363.1	58.2	14.6	4.0%	138.0
C	685.0	476.8	89.1	22.3	4.7%	181.2
D	320.7	289.3	42.1	10.5	3.6%	109.9
E	129.9	228.4	28.7	7.2	3.1%	86.8
TOTALS:	**1928.1**	**1469.0**	**233.5**	**58.4**	**4.0%**	**558.2**

FLOOD PRONE PROPERTIES AND FLOOD DAMAGE REDUCTION

A widespread flash flood occurred across a large area in Southern Minnesota in September 2010. Seven to eight inches of rain fell near Northfield during this flood on September 22-24, 2010. Precipitation of 7 to 8 inches in a 3-day period has a 50-year to 100-year recurrence interval.[7] The heavy rainfall and wet antecedent conditions caused record streamflow and stages in some areas, including the Cannon River in Northfield where the peak flow recurrence interval was estimated to be greater than 500 years.[8]

During the afternoon and evening of June 14, 2012 heavy rains fell on Goodhue, Rice and Dakota Counties in Minnesota. Six to eight inches of rain were recorded in Goodhue County. 5.51 inches was recorded 1 mile southeast of Northfield. 7.13 inches was recorded in Northfield in Rice County. A 24-hour rainfall of 7.1 inches has approximately a 100-year recurrence interval. Highway 19 was closed between Stanton and Northfield due to high water.[9]

Flow and stage were not measured within Spring Creek during these floods, but residential flood damages have occurred in some reaches of the Creek.

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[7] NOAA Atlas 14, Vol. 8 Version 2.0, Midwestern States (Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, Wisconsin) Precipitation-Frequency Atlas of the United States, Silver Spring, MD 20910, 2014

[8] USGS Scientific Investigations report 2011-5045, Floods of September 2010 in Southern Minnesota;

[9] Minnesota DNR Climate Journal, Flooding Rains: June 14, 2012 http://www.dnr.state.mn.us/climate/summaries_and_publications/flash_floods_2012.html

Figures 7, 8 and **9** are maps showing FEMA Flood Zones and 1% Chance Water Surface Elevations for the analyzed conditions of this study including: Current Conditions with 100-year Atlas 14 Precipitation, Bridgewater Improvements, Bridgewater Improvements plus Expansion Area Future Conditions Pre-settlement Flows and Optional Flood Control Ponds. **Figures 7** and **8** also show parcels having less than 1 foot of freeboard above the water surface elevation of the Current Conditions with 100-year Atlas 14 Precipitation 24-hour storm. Freeboard was evaluated on a group of parcels identified as flood prone by the City following floods. While the proposed Bridgewater Township improvements and resulting rate and volume control requirements in the Urban Expansion area assist in reducing flood elevations along the main channel of Spring Creek, several properties still appear to remain flood prone—with approximate lowest adjacent grade elevations from LiDAR less than 1 foot above the modeled 1% chance flood elevation. The resulting reductions in stage average 0.27 feet for the Bridgewater improvements and 0.35 feet for the combined Urban Expansion requirements with Bridgewater improvements. Further reducing the future flows from the Urban Expansion area in a 100-year event to the 50-year pre-settlement flows yielded elevation differences of less than 0.05', on average. This indicates that flow in the main channel of Spring Creek dominates the flood response while the tributary contributions are relatively insignificant. The flow reduction requirements in the Urban Expansion area are primarily along the tributary flow channels. **Exhibits 6 and 7** show comparisons of the existing 100-year main channel flow to the tributary flows at Jefferson Parkway and Spring Creek Road, respectively. It is observed that not only are the peak flow contributions much smaller in the tributaries, but the peaks do not occur simultaneously. Also, **Table 4 in Appendix A** shows the expected stage reductions at locations along the channel. **Figure 11** is a profile drawing showing the Spring Creek 100-year water surface profile along with Bridgewater and Urban Expansion scenarios.

In order to plan for additional flood damage reduction, along with the Bridgewater improvements, flow reductions along the main channel were modeled to target flood elevation reductions within the flood prone areas. Flood control storage ponds located along the Spring Creek main channel in the Urban Expansion Area between Ford Street and 110th Street were identified. Initial planning indicates that removing about 100 ac-feet of volume from the 100-year rainfall event will provide benefits along the main channel. This will result in reductions in the 100-year stage in Spring Creek from **0.1 to 2.9** feet, with an average reduction of 0.8 feet.

Figure 10 shows the general location of the optional flood control ponds in the southern portion of the Urban Expansion area. The ponds would be designed and constructed within the FEMA Zone A flood hazard area—to the extent practicable--to reduce the amount of developable space consumed. Construction of new homes will be avoided in this area anyway and preservation of the flood area from any development will result in maintained flood capacity in the future. **Exhibit 8** shows the comparison of the peak flow and volume hydrographs at the upstream and downstream ends of the proposed main channel flood storage ponds.

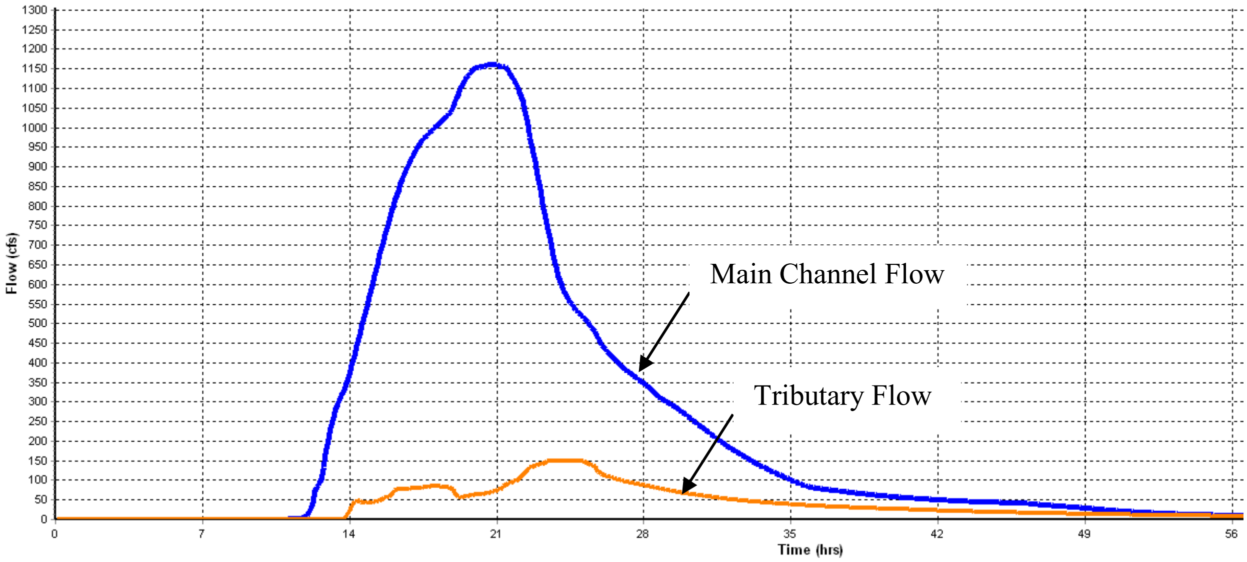


Exhibit 6: Comparison of existing 100-year peak flows at Jefferson Pkwy along the main channel of Spring Creek and the tributary flow contribution.

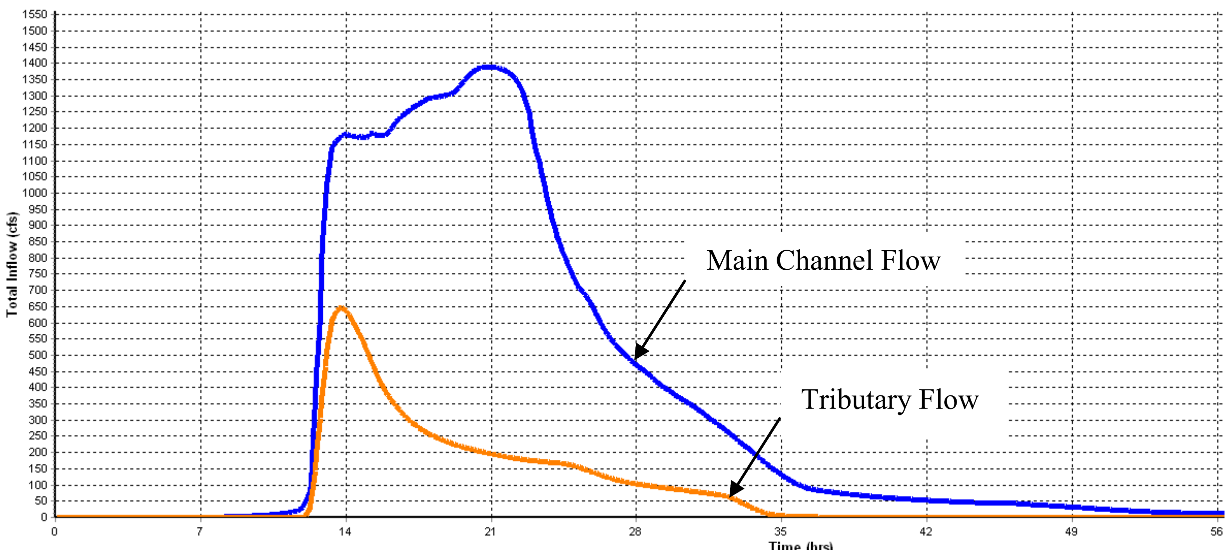


Exhibit 7: Comparison of existing 100-year peak flows at Spring Creek Rd along the main channel of Spring Creek and the tributary flow contribution.

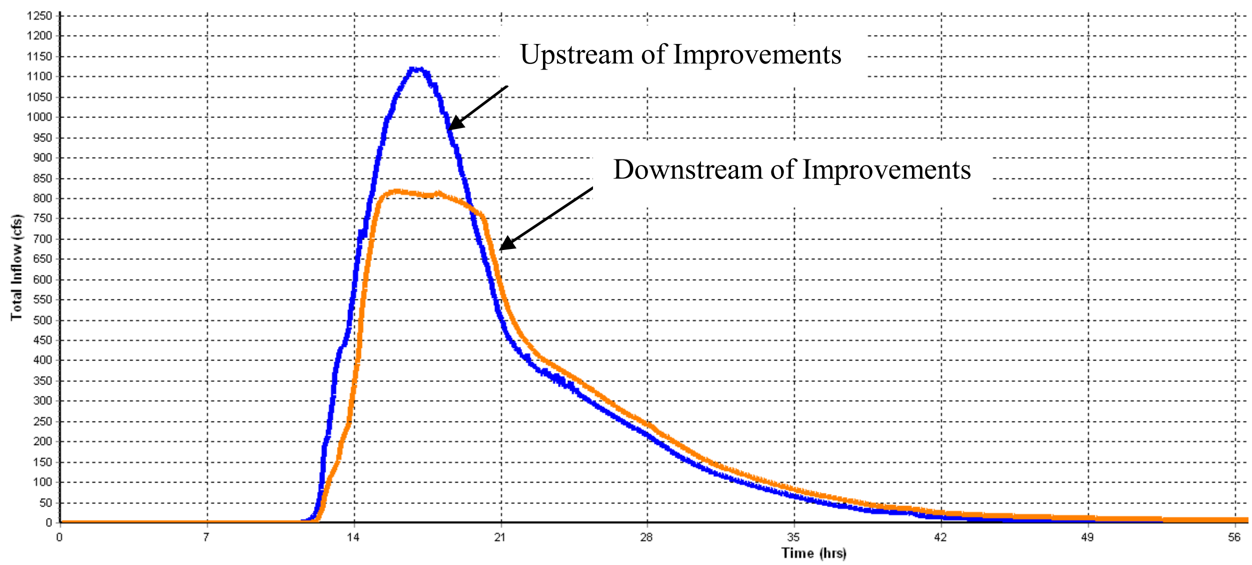


Exhibit 8: Comparison of main channel 100-year flow rates up and downstream of the proposed main channel improvements.

JURISDICTIONAL FLOW RATE AT CITY BOUNDARY

Identification of a jurisdictional flow at the upstream City boundary was evaluated. The intent of this jurisdictional flow is to provide an agreement, with adjoining Bridgewater and Northfield Townships, setting a regulated flow limit at the municipal boundary so that future development upstream from the City of Northfield does not cause harm by exceeding the established flow rate. Options for setting such a flow rate include the following.

a) **Past – 800 cfs:** regulate to established FEMA FIS peak flows. The Rice County Flood Insurance Study, effective dated April 2, 2012, includes analysis and mapping of the floodplain of Spring Creek. Part of Spring Creek includes a detailed study with water surface profiles computed for the 10%, 2%, 1% and .2% annual chance floods as well as mapping of the 1% and .2% annual chance floodplains. This detailed study reach extends from Spring Creek Road upstream to the Northfield city limits approximately 700 feet upstream from Ford Street. The established peak flow for the 1% annual chance flood at the city limits is 800 cfs. The adoption of Atlas 14 rainfall depths has bumped up the expected runoff in the watershed from the original TP40 rainfall runoff simulations done in 2004. Therefore, the FEMA FIS flow rates at the City Boundary, based upon TP40 rainfall, are likely to be lower than modeled runoff based upon Atlas 14 rainfall and more restrictive to runoff upstream from the City. This also adds conservation in future planning and maintenance of the established flood hazard zones within the City.
b) **Present – 1270 cfs:** regulate to existing conditions including additional data collected for Atlas 14 rainfall depths. The comprehensive model described herein was calibrated to the results of the current stream flow regressions provided by the USGS. These flow rates at the City Boundary are higher than the FEMA FIS, but may be more realistic of the peak flood flows resulting from higher rainfall depths, higher intensity, and shorter duration events that are becoming more prevalent. These conditions would be less restrictive to runoff upstream from the City, and less conservative for maintaining the established flood hazard zones within the City. However, the

USGS regression flows provide the current design peak flow for the 100-year flood at the City boundary and would not currently require additional flood mitigation in the upstream townships.

c) **Future – 1020 cfs**: regulate to future goals to reduce 100-year peak flow rates to the 50-year pre-settlement flow rate. Developers would be required to either provide the full flood reduction storage needed to meet the rate control goals, or provide pond volume for the 100-year flow with contribution from the City to furnish the remaining volume. These flow rates at the City Boundary are higher than the FEMA FIS, but incorporate future flood damage reduction goals through development rate control requirements. These conditions would be restrictive to runoff upstream from the City, and moderately conservative for maintaining the established flood hazard zones within the City. While reducing the 100-year flows to the 50-year pre-settlement flows were less impactful along the tributaries to Spring Creek, mitigation along the main channel will reduce flood elevations.

Setting a jurisdictional flow limit at the municipal boundary is intended to guide future development upstream from the City of Northfield so that the established flow rate is not exceeded. The difference in the 1% chance rainfall between the Atlas 14 and TP 40 models result in stage differences along the channel of about 1 foot. From a City perspective, regulating to the established flows of the effective flood insurance study (800 cfs at the City Boundary) provides a conservative approach toward maintaining the established FEMA NFIP flood hazard zones within the City. Meeting this jurisdictional flow goal will not be easy since the current design peak flow for the 1% annual chance flood is 1270 cfs—nearly 60% higher than the FIS flowrate.

ESTIMATED CONSTRUCTION COSTS

Exhibit 9 is a plot of construction and maintenance cost per water quality volume of wet basins. Values from this exhibit have been updated to 2015 dollars, for cost estimating in this report, assuming 3% annual inflation**. Table 5** summarizes the estimated regional pond construction and maintenance costs as well as estimated costs for the additional flood storage between 110^{th} and Ford described above.

Exhibit 9 Plot of total cost of construction and maintenance per water quality volume for wet basins. The dashed line represents average cost and the two solid lines represent the range of costs. Source: Mn/DOT, 2005[10]

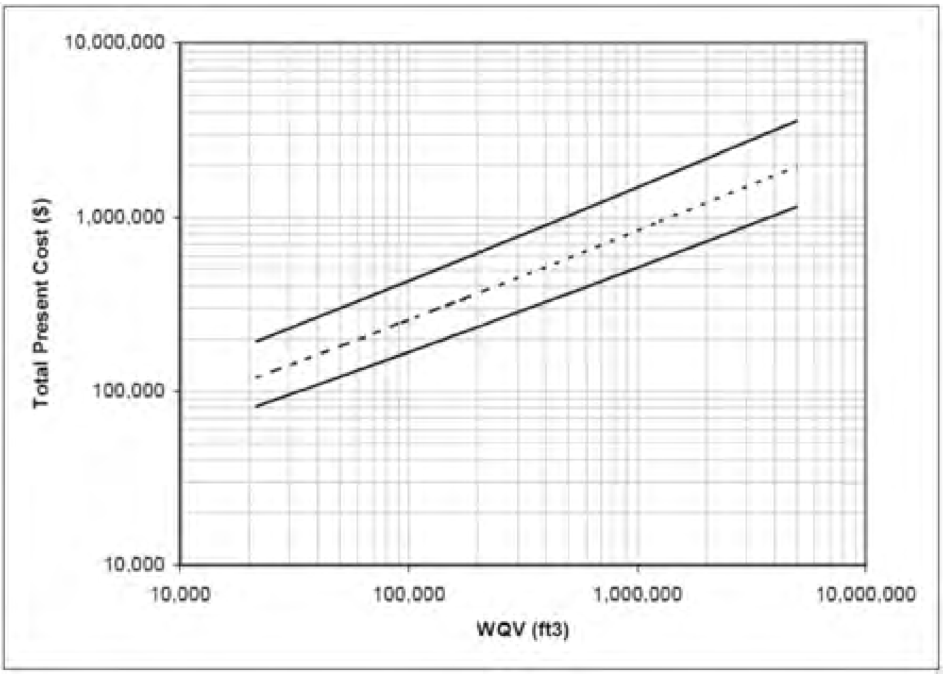


Table 5: Estimated regional pond construction and maintenance costs.

Node ID	100-Year Ponds			50-Year Ponds		
	Anticipated Storage Volume	Pond Footprint Area	Estimated Cost	Anticipated Storage Volume	Pond Footprint Area	Estimated Cost
	[ac-ft]	[ac]		[ac-ft]	[ac]	
A	8.7	2.2	$690,000	15.4	3.8	$920,000
B	36.7	9.2	$1,450,000	58.2	14.6	$1,850,000
C	63.8	16	$1,940,000	89.1	22.3	$2,310,000
D	30.1	7.5	$1,310,000	42.1	10.5	$1,560,000
E	24.7	6.2	$1,180,000	28.7	7.2	$1,280,000
Additional Storage Area	100	22.8	$2,460,000	100	22.8	$2,460,000
TOTALS:	**264**	**63.8**	**$9,030,000**	**333.5**	**81.2**	**$10,380,000**

[10] http://stormwater.pca.state.mn.us/index.php/Process_for_selecting_Best_Management_Practices

SUMMARY AND RECOMMENDATIONS

Several hydraulic and hydrologic data sources from multiple past studies were assembled with the goal of providing a comprehensive hydraulic model of the Spring Creek watershed through Northfield. A recent study identified potential stormwater practices that will reduce peak flow rates and volumes south of the City by storing flow from tributary reaches within regional ponding areas. Additional channel modifications to encourage infiltration and piped flow diversions were also proposed. Data from these models was reproduced in the comprehensive model to determine the benefits along the Spring Creek channel in terms of elevation reduction. While flow is decreased, the reductions in flood elevation along Spring Creek average 0.3 feet.

Future development scenarios were analyzed to determine the pond volumes and, in turn, pond foot prints required to meet City ordinances within the Urban Expansion area. Additional scenarios were performed to determine whether additional flow restrictions would translate into elevation reduction benefits along the main channel of Spring Creek. Specifically, the 100-year discharge under future conditions was restricted to the 50-year pre-settlement flow. It was concluded that peak flows in the main channel of Spring Creek control the flood profile. Tributary flows contribute little to mainstem peak flood flows and the peaks typically do not occur simultaneously. Therefore, peak flow reductions in the 100-year to the 50-year pre-settlement flows offer the most elevation impact when performed along the main stem, or in the upstream contributing subwatersheds.

Finally, flood storage areas were analyzed to determine if a large storage area along the main channel within the City expansion area would result in additional reductions in flooding through town. **Figure 10** displays one concept that includes diversion of main channel flows into floodplain storage areas and restricting channel discharge with a culvert structure. The simulation of this floodplain storage concept, also includes the upstream features of the Bridgewater Township proposed conditions. In combination with Bridgewater Township proposed conditions, reducing the peak discharge on the main channel and providing 100 ac.-ft. of storage, will result in reducing flood elevations downstream along Spring Creek an average of 0.8 feet.

Although potential watershed improvements have been identified, the expected reductions in water surface elevations along Spring Creek are moderate and some residences remain at risk. Additional survey data should be collected in the City of Northfield to detail the low opening elevations of flood prone homes along Spring Creek. This data should be used to compute freeboard and to refine the identification of homes at risk of flood damage in the 1% annual chance event (i.e. 100-year flood). The data should also be used to further evaluate potential flood damage reduction solutions such as storage or volume control BMPs upstream in the Spring Creek watershed, the modification of select bridges, culverts or dams on Spring Creek to reduce flood levels, or the need for specific levees, floodwalls or residential floodproofings. Floodproofing can be very effective for individual homes, but upstream storage and volume control projects can have widespread benefits in reducing flood risks to multiple homes and neighborhoods.

RECOMMENDED ACTIONS

The following recommendations should be considered by the City to develop a flood reduction plan that controls discharge from future development at the tributary heads to Spring Creek as well as define additional areas along the main stem to reserve for flood protection. The following recommendations should be considered by the City.

1. While the previously proposed flow diversions, regional ponding, and infiltration areas upstream of Northfield will result in benefits to flood elevations through town (averaging 0.3 feet), it is not recommended that the City pursue any flow diversion within City limits. The concept previously proposed for an outlet pipe from a raingarden along Dennison Boulevard (Highway 246) will provide little to no flow and elevation reduction benefit to the City.
2. Establishing a jurisdictional flow rate at the southern City limits will encourage Bridgewater and Northfield Townships to reduce rate and volume of runoff under future development scenarios. It is recommended that the flood insurance study discharge rate of 800 cfs be chosen as the jurisdictional flow rate since this provides a conservative approach toward maintaining the established FEMA NFIP flood hazard zones within the City.
3. Additional survey data should be collected in the City of Northfield to detail the low opening elevations of flood prone homes along Spring Creek. This data should be used to refine the identification of homes at risk of flood damage in the 1% annual chance event and to further evaluate potential flood damage reduction solutions such as storage or volume control BMPs upstream in the Spring Creek watershed, the modification of select bridges, culverts or dams on Spring Creek, or the need for specific levees, floodwalls or residential floodproofings.

APPENDIX

Table 4: Summary of Analyzed Water Surface Elevations for the 100-year Events.

										Atlas 14 Precipitation							
Location Number	Description	Distance from Con. of Cannon River (ft)	Spring Creek Channel Elevation (ft)	Flood Insurance Study Base Flood Elevations (ft.)	Current Water Surface Elevations 100-year Atlas 14 Precipitation (ft.)	100-year TP 40 Precipitation (ft.)	Difference Atlas 14 100-year Precip and TP-40 Precip	Current Water Surface Elevations 100-year 10-day Snowmelt (ft.)	Difference Atlas 14 100 year Precip and 10-Day Snowmelt (ft.)	Bridgewater Improvements (ft.)	Potential Flood Reduction (ft.)	Bridgewater Improvements + Expansion Area Future Conditions 100-Year Presettlement Flow Match (ft.) *	Potential Flood Reduction (ft.) *	Bridgewater Improvements + Expansion Area Future Conditions 50-Year Presettlement Flow Match (ft.) *	Potential Flood Reduction (ft.) *	Bridgewater Improvements + Expansion Area Future Conditions 100-year & Optional Flood Control Ponds (ft.) *	Potential Flood Reduction (ft.) *
1	Spring Creek Con. with Cannon River	0	889.0	897	893.9	893.2	0.7	893.4	0.5	893.9	0.0	893.7	0.2	893.7	0.2	893.5	0.4
2	Divisions Street, MN Hwy. 19	1029	890.2	897	897.1	896.2	0.9	896.4	0.7	897.0	0.1	896.9	0.2	896.8	0.3	896.6	0.5
3	Lower Lyman Lakes Dam	1092	897.6	897	903.2	902.4	0.8	902.6	0.6	903.2	0.0	903.0	0.2	903.0	0.2	902.8	0.4
4	Goodsell Circle	1955	897.6	897	903.2	902.4	0.8	902.6	0.6	903.2	0.0	903.0	0.2	903.0	0.2	902.8	0.4
5	Upper Lyman Lakes Dam	2031	899.6	897	906.1	904.9	1.2	905.1	1	906.0	0.1	905.7	0.4	905.7	0.4	905.4	0.7
6	Wall Street Road	5338	909.0	n/a	918.9	917.3	1.6	917.6	1.3	918.9	0.0	918.7	0.2	918.5	0.4	918.1	0.8
7	Spring Creek Road	9134	930.0	938.0	937.4	937.1	0.3	937.1	0.3	937.3	0.1	937.4	0.0	937.3	0.1	937.2	0.2
8	West Woodley Pond Dam	9627	935.0	940.8	939.8	939.5	0.3	939.5	0.3	939.7	0.1	939.8	0.0	939.8	0.0	939.6	0.2
9	Woodley Street East	10228	936.0	945	944.3	943.7	0.6	943.8	0.5	944.0	0.3	944.0	0.3	944.0	0.3	943.7	0.6
10	Spring Creek Road	11180	939.4	949.0	949.0	947.6	1.4	947.9	1.1	948.4	0.6	948.4	0.6	948.4	0.6	947.7	1.3
11	Footbridge	13587	948.7	956.3	953.5	953.0	0.5	953.1	0.4	953.3	0.2	953.2	0.3	953.2	0.3	953.0	0.5
12	Jefferson Parkway East	14474	951.0	958	956.9	956.5	0.4	956.5	0.4	956.7	0.2	956.7	0.2	956.7	0.2	956.5	0.4
13	Footbridge and Con. Fargaze Pond	14981	955.0	962.2	961.7	960.4	1.3	960.5	1.2	960.9	0.8	960.9	0.8	960.9	0.8	960.4	1.3
14	Maple Street South	15950	958.2	965.2	964.7	963.5	1.2	963.5	1.2	964.2	0.5	964.1	0.6	964.1	0.6	963.4	1.3
15	Southbridge Drive	17506	960.3	966.1	966.7	965.6	1.1	965.7	1	966.3	0.4	966.3	0.4	966.3	0.4	965.4	1.3
16	Ford Street East	17970	960.9	968	969.7	967.4	2.3	967.4	2.3	968.8	0.9	968.7	1.0	968.7	1.0	966.8	2.9
17	Junction 2300	19442	968.3	n/a	971.4	971.0	0.4	971.0	0.4	971.3	0.1	971.2	0.2	971.2	0.2	971.4	0.0
18	110th Street East	20409	970.1	n/a	976.9	975.8	1.1	975.7	1.2	976.5	0.4	976.4	0.5	976.4	0.5	976.4	0.5
						average	0.9	average	0.8	average	0.3	average	0.3 *	average	0.4 *	average	0.8 *

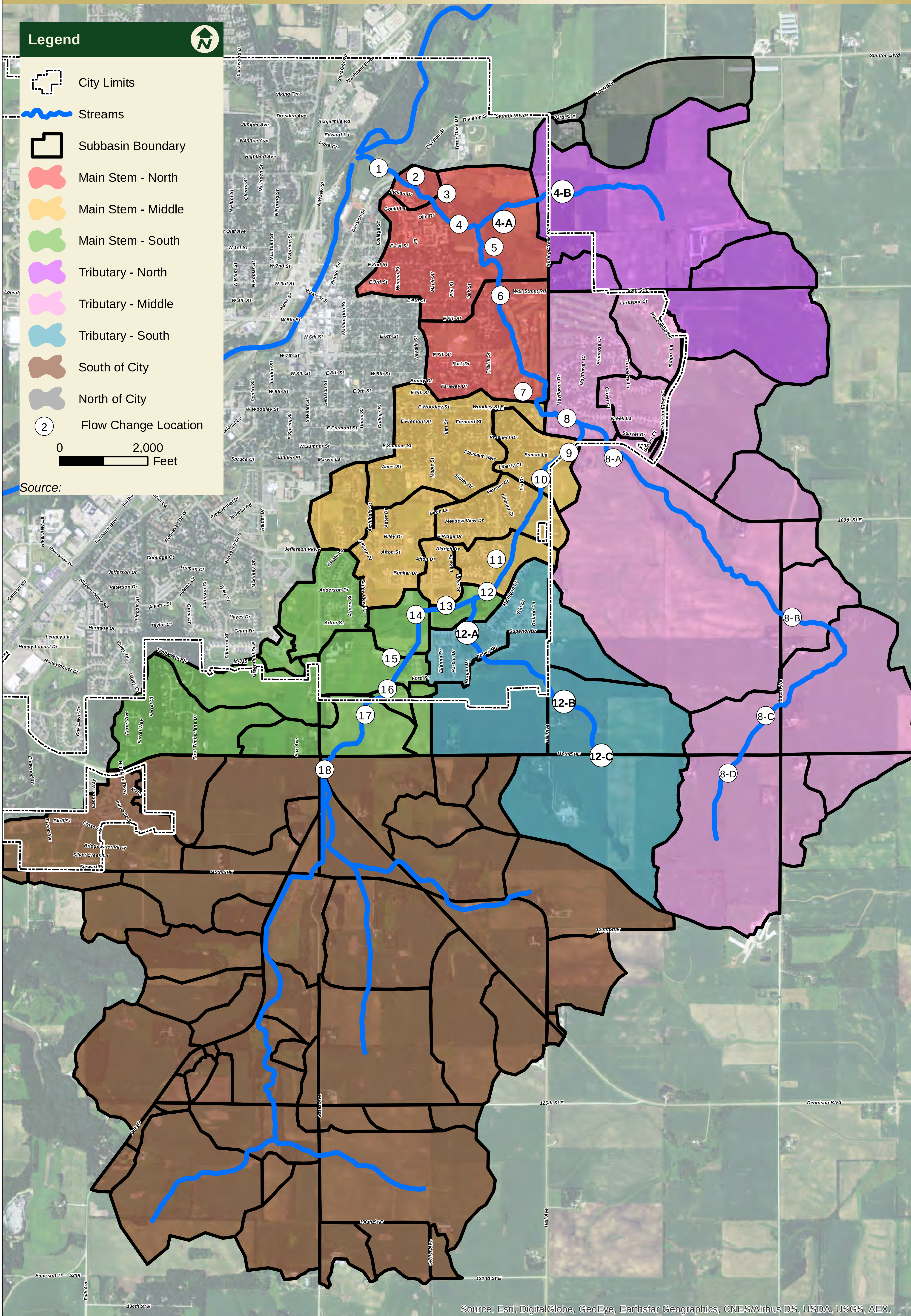
*Note: Potential flood reductions listed in this table are cumulative and include the combined benefits of Bridgewater Township Improvements and Expansion Area Future Conditions.

SOUTH EXPANSION AREA HYDROLOGIC STUDY

NORTHFIELD, MN

FIGURE 1 - WATERSHED MAP

September, 2015



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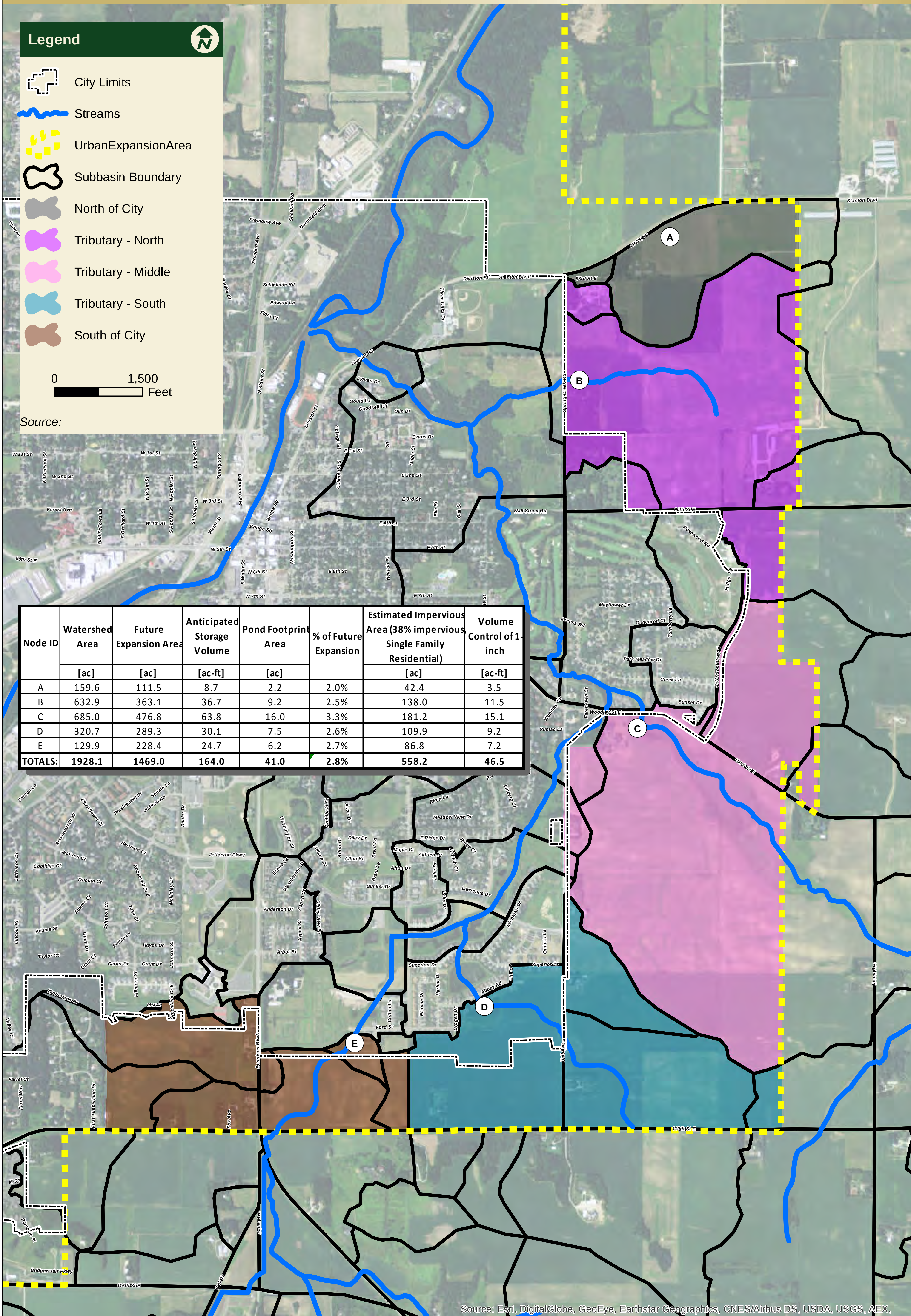
SOUTH EXPANSION AREA HYDROLOGIC STUDY

NORTHFIELD, MN

FIGURE 2 - LOCATION MAP

September, 2015



Node ID	Watershed Area	Future Expansion Area	Anticipated Storage Volume	Pond Footprint Area	% of Future Expansion	Estimated Impervious Area (38% impervious, Single Family Residential)	Volume Control of 1-inch
	[ac]	[ac]	[ac-ft]	[ac]		[ac]	[ac-ft]
A	159.6	111.5	8.7	2.2	2.0%	42.4	3.5
B	632.9	363.1	36.7	9.2	2.5%	138.0	11.5
C	685.0	476.8	63.8	16.0	3.3%	181.2	15.1
D	320.7	289.3	30.1	7.5	2.6%	109.9	9.2
E	129.9	228.4	24.7	6.2	2.7%	86.8	7.2
TOTALS:	1928.1	1469.0	164.0	41.0	2.8%	558.2	46.5

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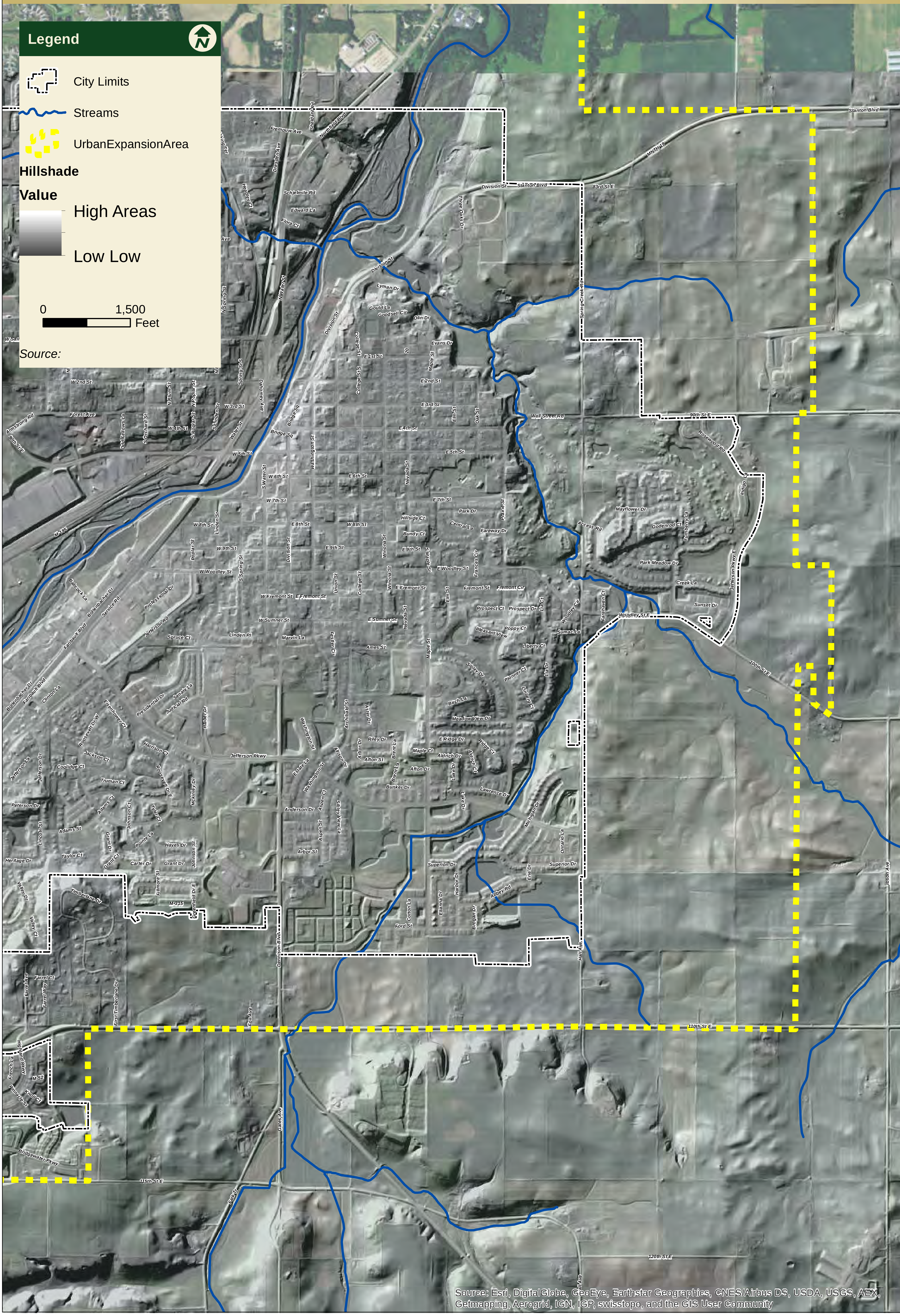
SOUTH EXPANSION AREA HYDROLOGIC STUDY

NORTHFIELD, MN

FIGURE 3 - HILLSHADE MAP

September, 2015



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City Of Northfield Minnesota

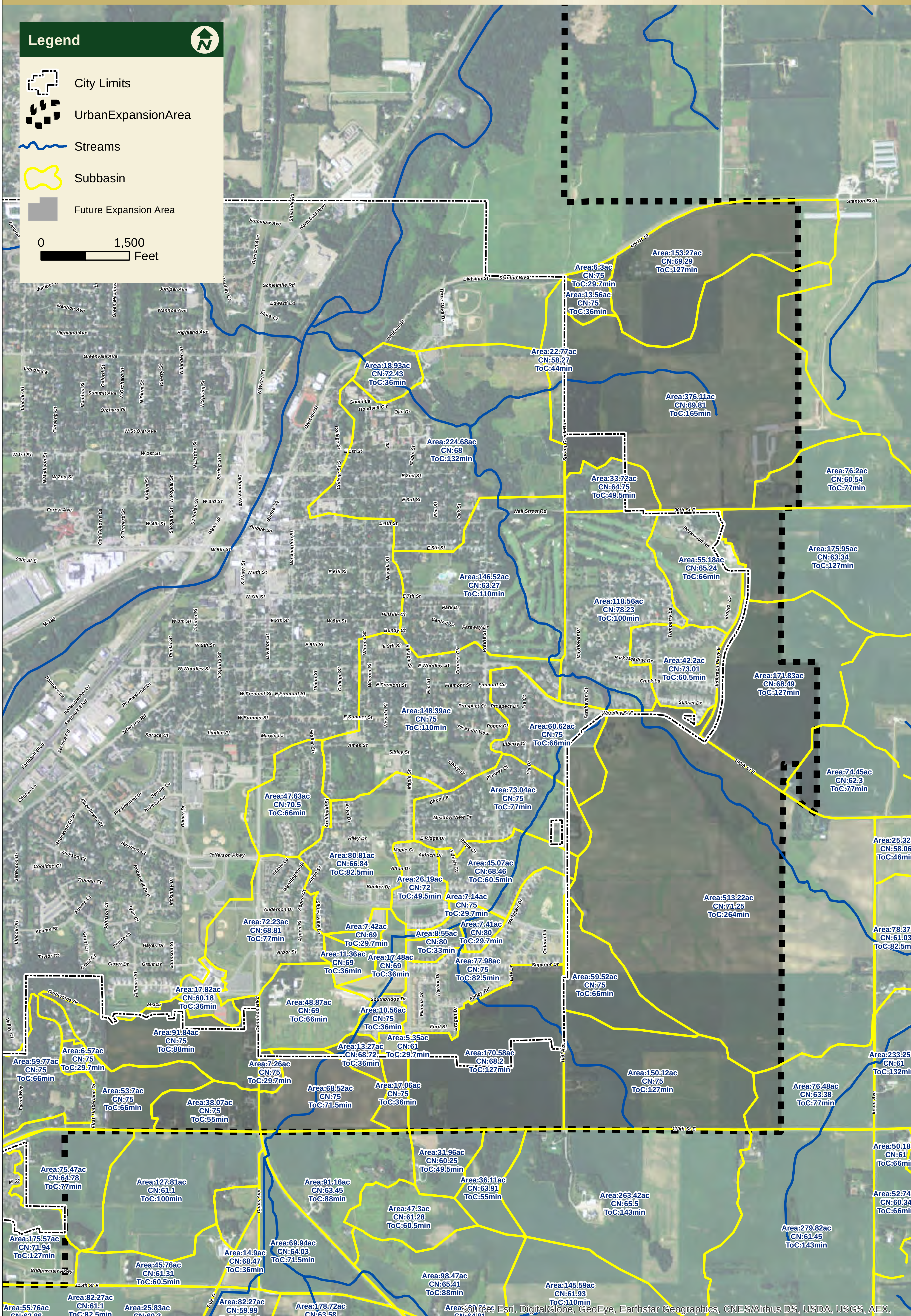
SOUTH EXPANSION AREA HYDROLOGIC STUDY

NORTHFIELD, MN

FIGURE 4 - WATERSHED SUMMARY MAP

September, 2015

BOLTON & MENK Engineers & Surveyors



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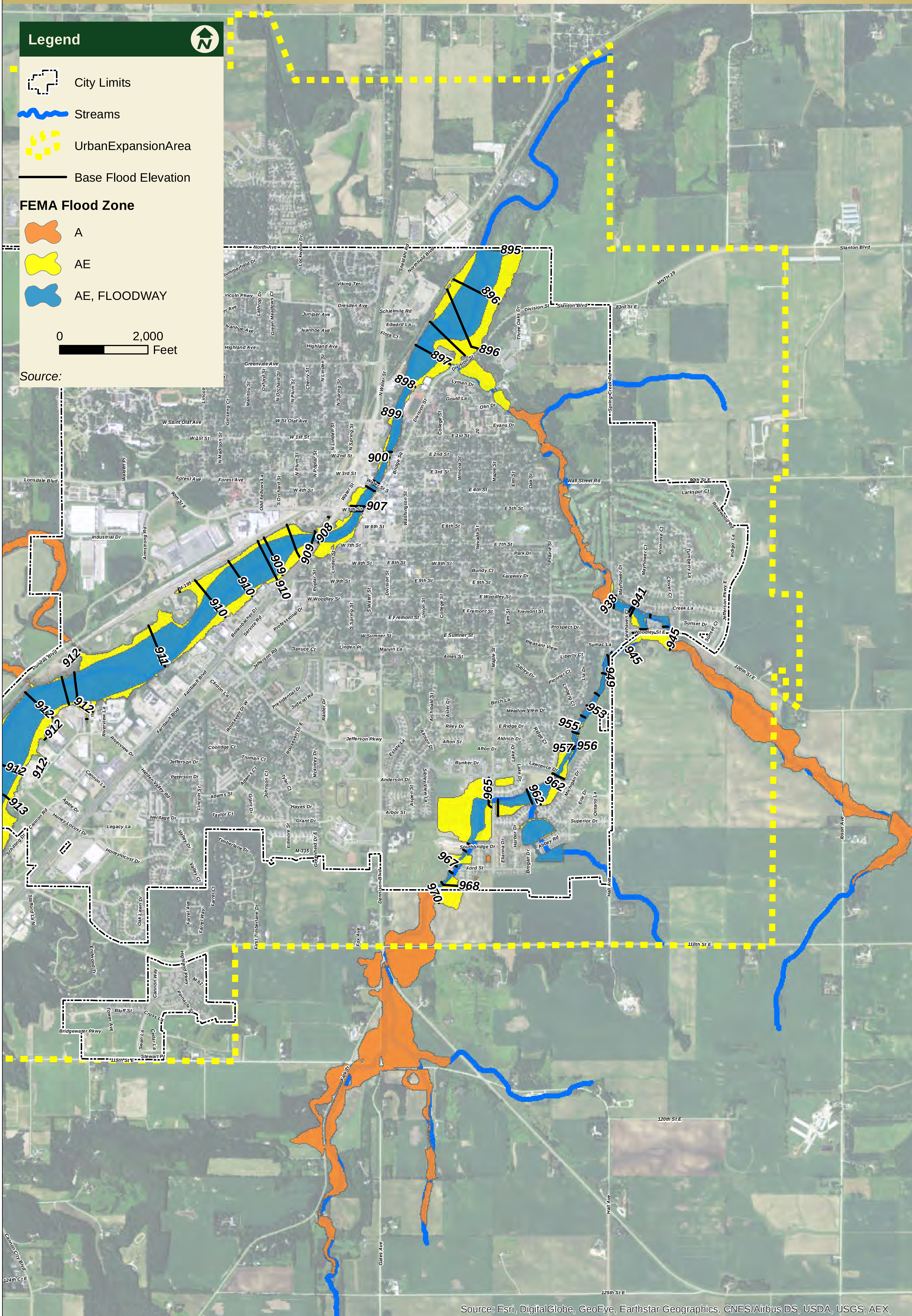
SOUTH EXPANSION AREA HYDROLOGIC STUDY

NORTHFIELD, MN

FIGURE 5 - FEMA DFIRM MAP

September, 2015



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City Of Northfield Minnesota

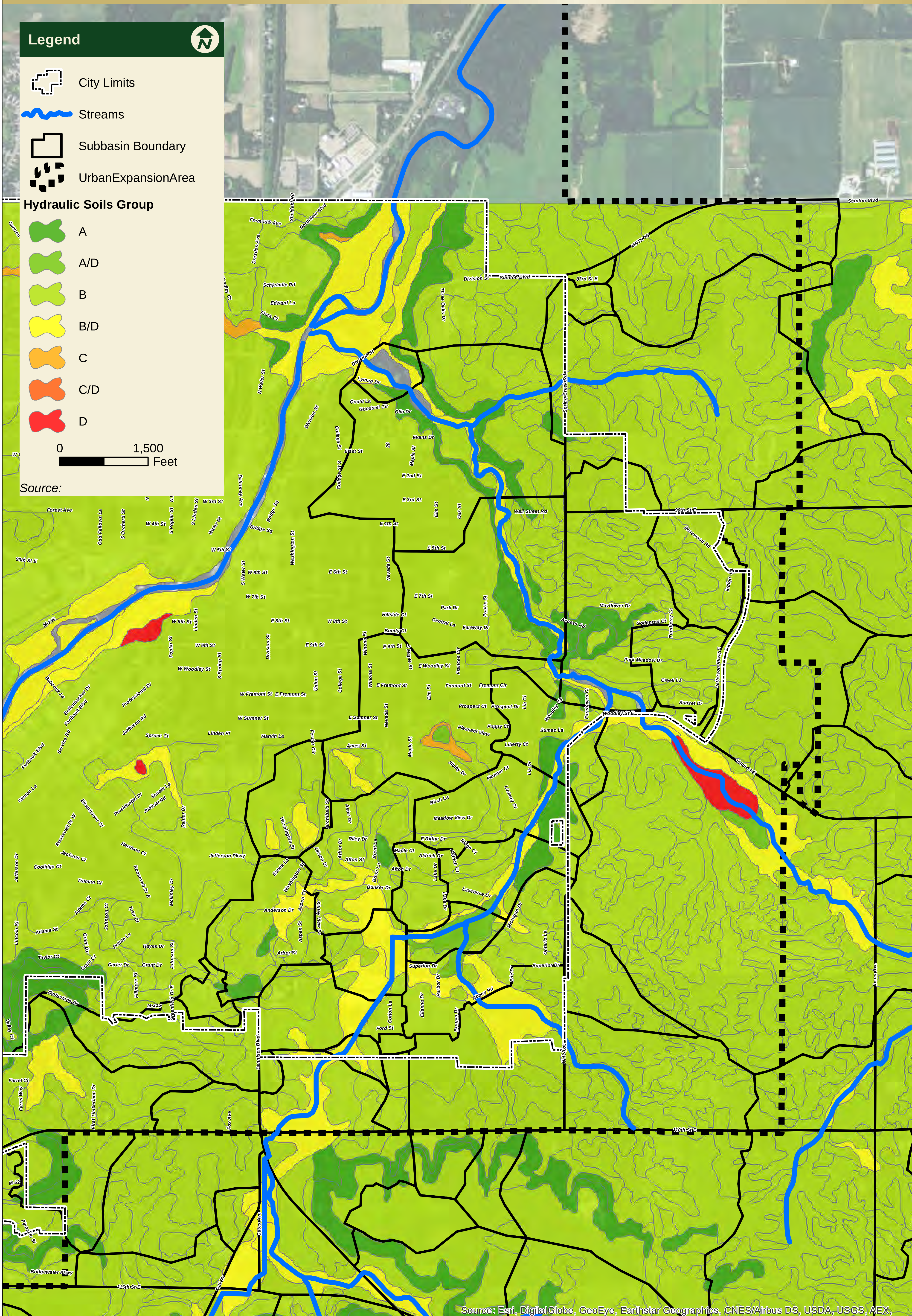
SOUTH EXPANSION AREA HYDROLOGIC STUDY

NORTHFIELD, MN

FIGURE 6 - SOILS MAP

September, 2015

BOLTON & MENK Engineers & Surveyors



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City Of Northfield Minnesota

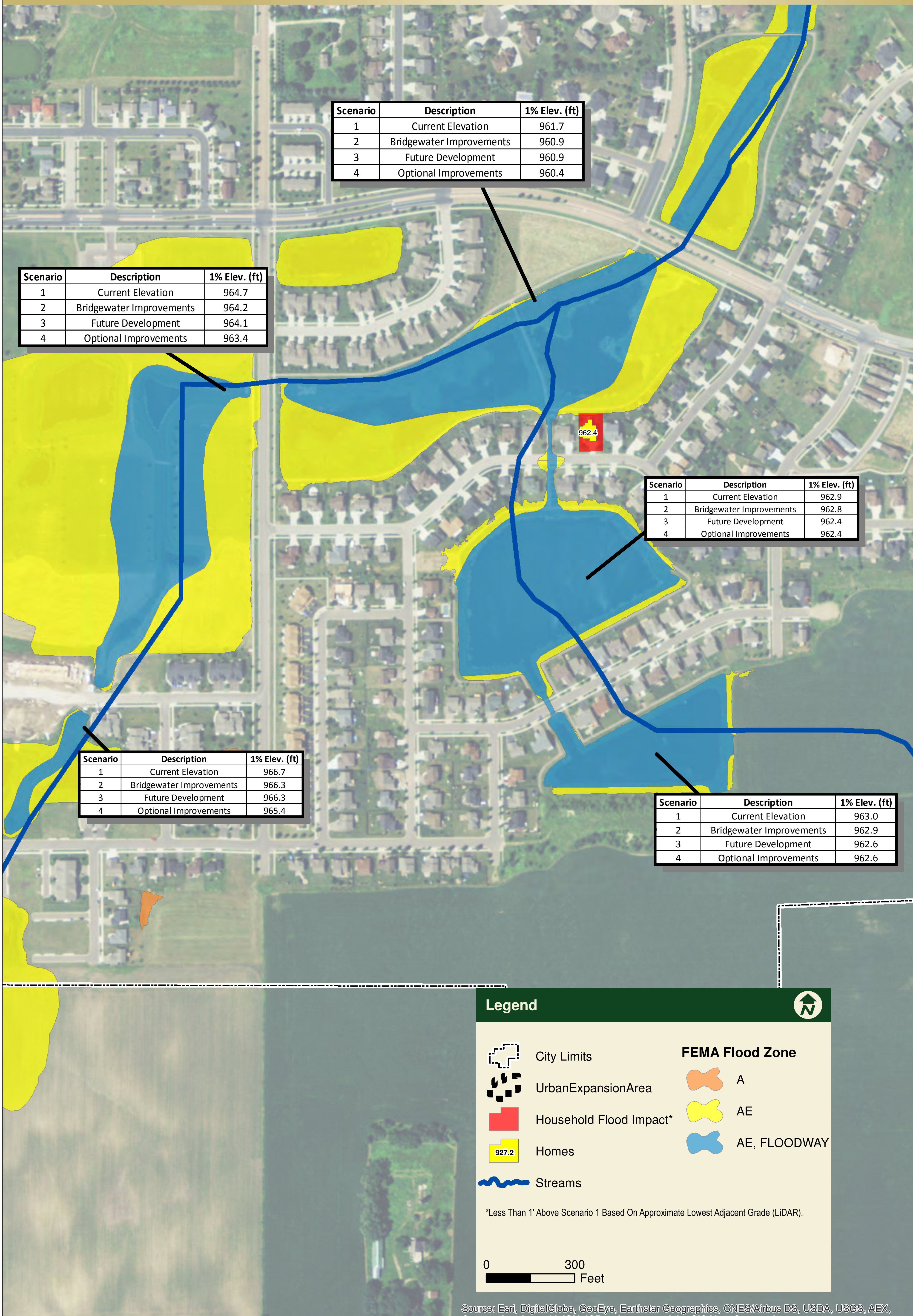
SOUTH EXPANSION AREA HYDROLOGIC STUDY

NORTHFIELD, MN

FIGURE 7 - FLOOD IMPACT MAP

October, 2015

BOLTON & MENK Engineers & Surveyors



Scenario	Description	1% Elev. (ft)
1	Current Elevation	961.7
2	Bridgewater Improvements	960.9
3	Future Development	960.9
4	Optional Improvements	960.4

Scenario	Description	1% Elev. (ft)
1	Current Elevation	964.7
2	Bridgewater Improvements	964.2
3	Future Development	964.1
4	Optional Improvements	963.4

Scenario	Description	1% Elev. (ft)
1	Current Elevation	962.9
2	Bridgewater Improvements	962.8
3	Future Development	962.4
4	Optional Improvements	962.4

Scenario	Description	1% Elev. (ft)
1	Current Elevation	966.7
2	Bridgewater Improvements	966.3
3	Future Development	966.3
4	Optional Improvements	965.4

Scenario	Description	1% Elev. (ft)
1	Current Elevation	963.0
2	Bridgewater Improvements	962.9
3	Future Development	962.6
4	Optional Improvements	962.6

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City Of Northfield Minnesota

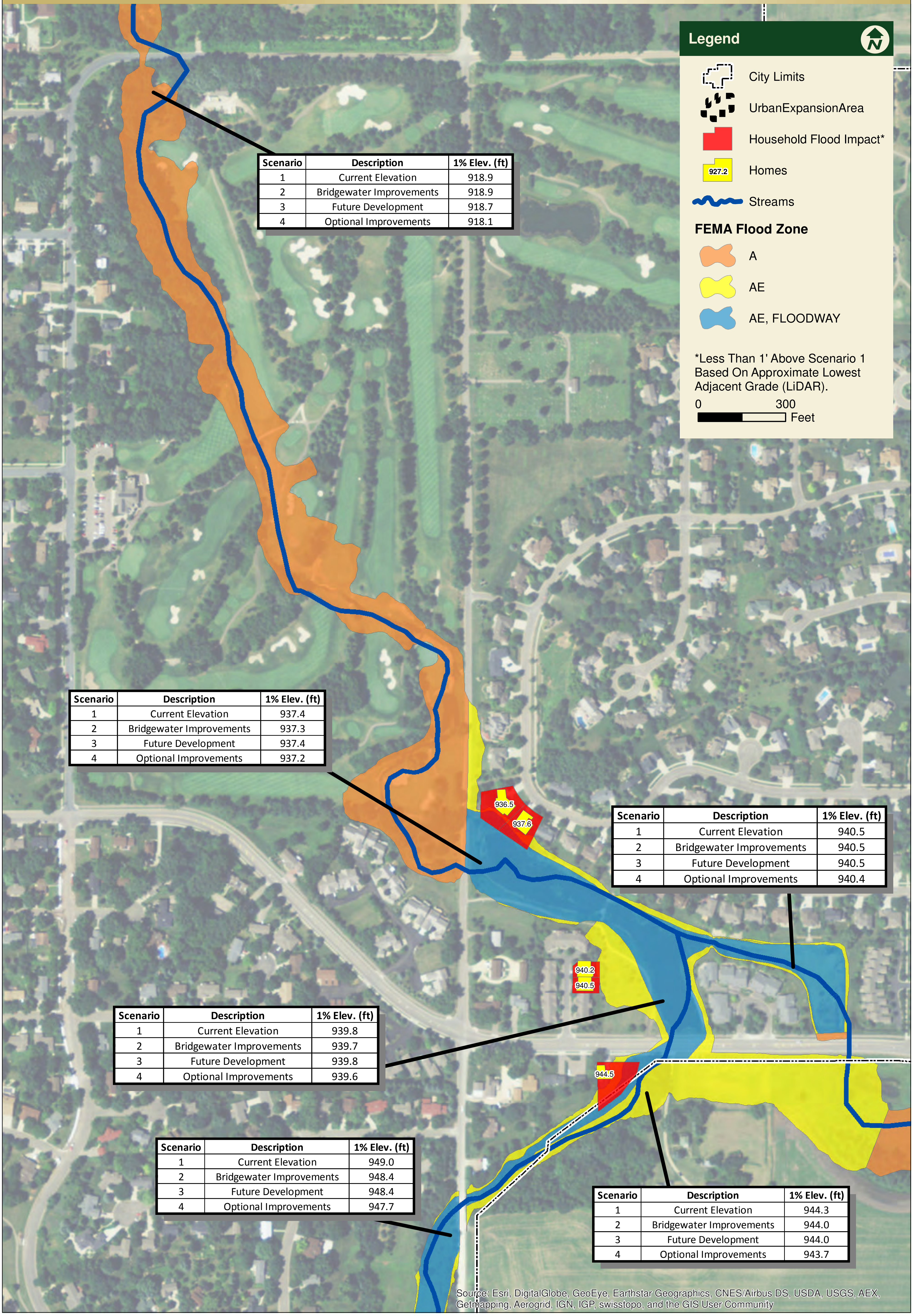
SOUTH EXPANSION AREA HYDROLOGIC STUDY

NORTHFIELD, MN

FIGURE 8 - FLOOD IMPACT MAP

October, 2015

BOLTON & MENK Engineers & Surveyors



Scenario	Description	1% Elev. (ft)
1	Current Elevation	918.9
2	Bridgewater Improvements	918.9
3	Future Development	918.7
4	Optional Improvements	918.1

Scenario	Description	1% Elev. (ft)
1	Current Elevation	937.4
2	Bridgewater Improvements	937.3
3	Future Development	937.4
4	Optional Improvements	937.2

Scenario	Description	1% Elev. (ft)
1	Current Elevation	940.5
2	Bridgewater Improvements	940.5
3	Future Development	940.5
4	Optional Improvements	940.4

Scenario	Description	1% Elev. (ft)
1	Current Elevation	939.8
2	Bridgewater Improvements	939.7
3	Future Development	939.8
4	Optional Improvements	939.6

Scenario	Description	1% Elev. (ft)
1	Current Elevation	949.0
2	Bridgewater Improvements	948.4
3	Future Development	948.4
4	Optional Improvements	947.7

Scenario	Description	1% Elev. (ft)
1	Current Elevation	944.3
2	Bridgewater Improvements	944.0
3	Future Development	944.0
4	Optional Improvements	943.7

Map Document: H:\NOFD\N14110280\GIS\ESRI\Figure 8 - Flooding Impact Map_10_02_2015.mxd
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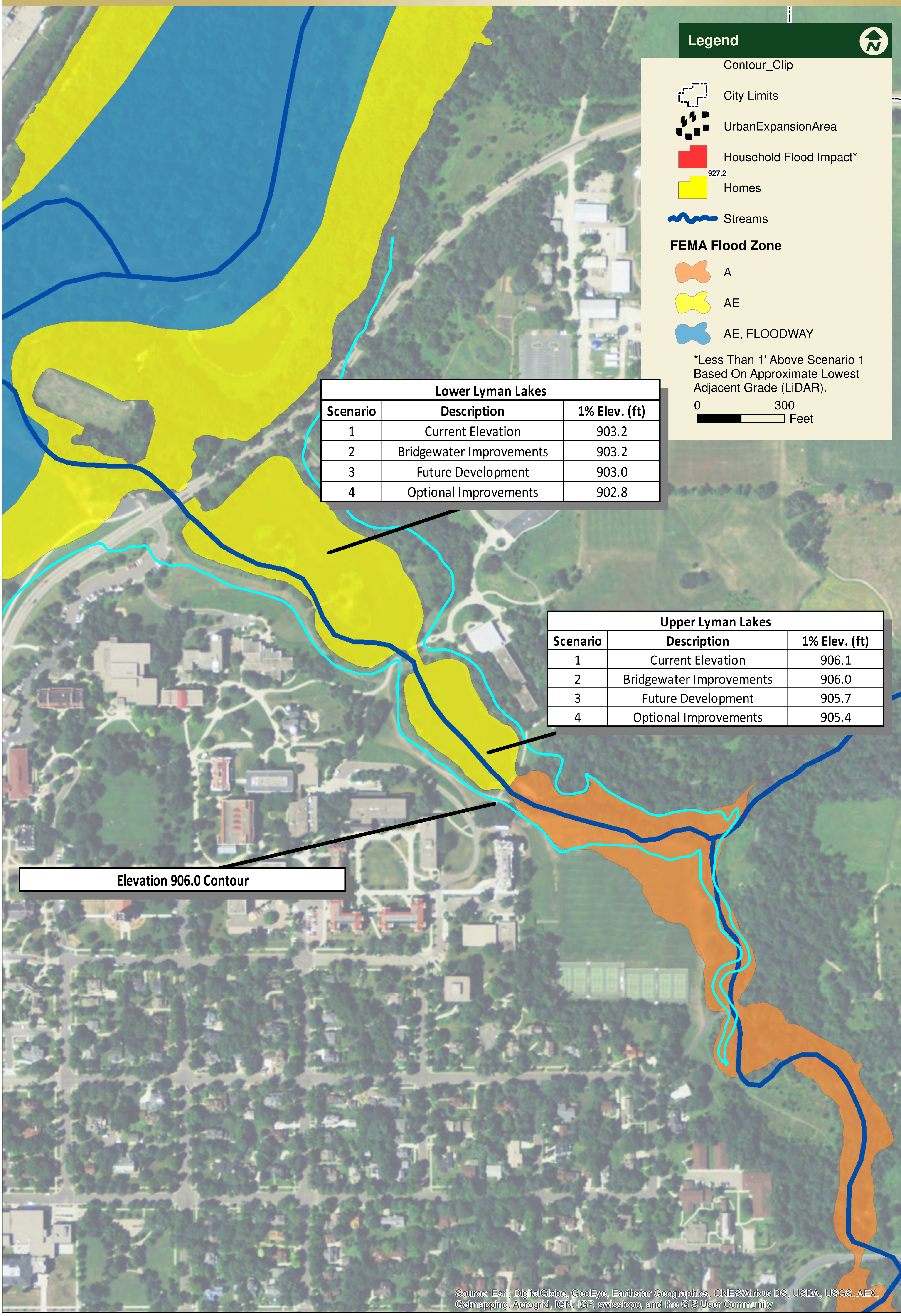
SOUTH EXPANSION AREA HYDROLOGIC STUDY

NORTHFIELD, MN

FIGURE 9 - FLOOD IMPACT MAP

October, 2015



Lower Lyman Lakes

Scenario	Description	1% Elev. (ft)
1	Current Elevation	903.2
2	Bridgewater Improvements	903.2
3	Future Development	903.0
4	Optional Improvements	902.8

Upper Lyman Lakes

Scenario	Description	1% Elev. (ft)
1	Current Elevation	906.1
2	Bridgewater Improvements	906.0
3	Future Development	905.7
4	Optional Improvements	905.4

Map Document: H:\NOFD\N14110280\GIS\ESRI\Figure 9 - Flooding Impact Map_10_02_2015.mxd
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City Of Northfield Minnesota

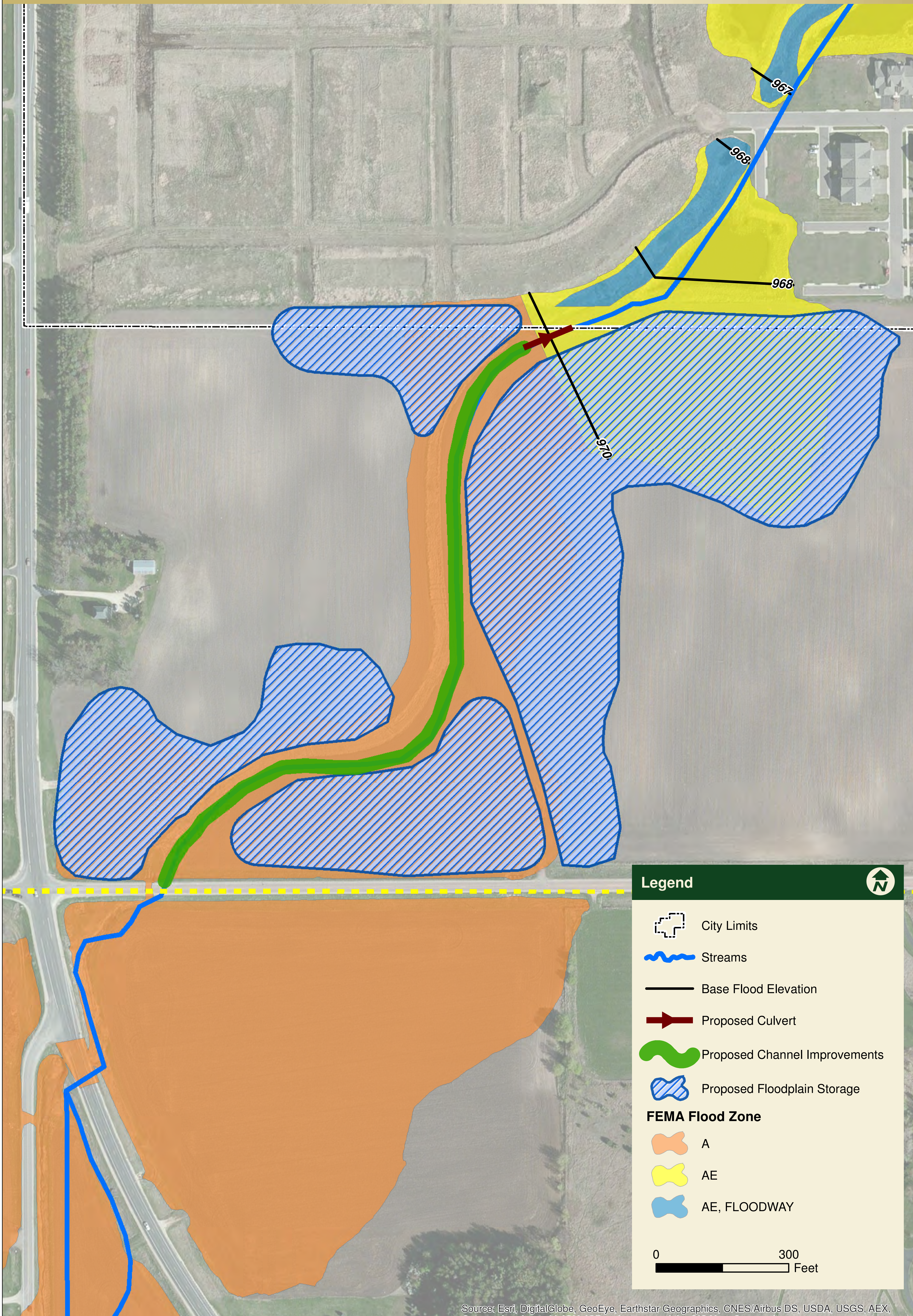
SOUTH EXPANSION AREA HYDROLOGIC STUDY

FIGURE 10 - OPTIONAL FLOOD CONTROL

NORTHFIELD, MN

October, 2015

BOLTON & MENK Engineers & Surveyors



Map Document: H:\NOFD\N14110280\GIS\ESRI\Figure 10 - Additional Improvements.mxd
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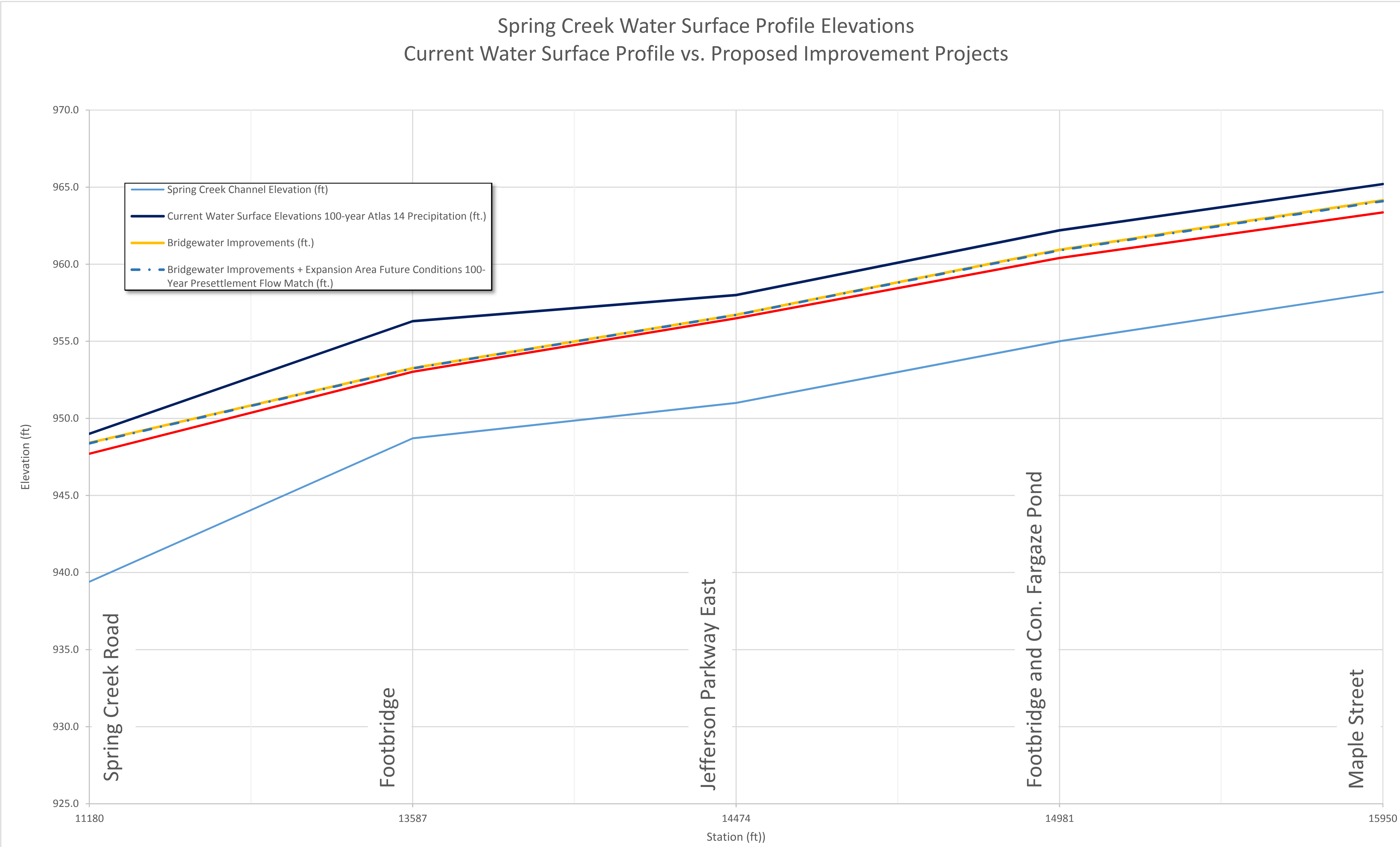
Spring Creek Water Surface Profile Elevations
Current Water Surface Profile vs. Proposed Improvement Projects
Spring Creek Channel Elevation (ft)
Current Water Surface Elevations 100-year Atlas 14 Precipitation (ft.)
Bridgewater Improvements (ft.)
Bridgewater Improvements + Expansion Area Future Conditions 100-Year Presettlement Flow Match (ft.)
970.0
965.0
960.0
955.0
950.0
945.0
940.0
935.0
930.0
925.0
Elevation (ft)
Spring Creek Road
Footbridge
Jefferson Parkway East
Footbridge and Con. Fargaze Pond
Maple Street
11180
13587
14474
14981
15950
Station (ft))